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Portland District

Columbia River Channel Improvement Project

Final Supplemental Integrated Feasibility Report and Environmental Impact Statement

Volume 2

Exhibits
1 of 2

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Preface for Exhibits

The following exhibits required no updating for the Final Supplemental IFR/EIS (see the Final IFR/EIS, August 1999):

Exhibit A – Correspondence
Exhibit B – Scoping Documentation
Exhibit C – Fish and Wildlife Coordination Act Report
Exhibit D – Section 103 Evaluation
Exhibit G – Biological Assessment for Wildlife and Plants

Exhibit H required no updating and is available on the Corps web page under consultation

The following exhibits ***have been revised or are new*** for the Final Supplemental IFR/EIS:

Exhibit E - Section 404(B)(1) Evaluation (Revised)
Exhibit F - Coastal Zone Management Act Consistency Determination (Revised)
Exhibit I - Essential Fish Habitat Assessment (Revised)
Exhibit J - Columbia River Sediment Impacts Analysis (Revised)
Exhibit K
- K-1, Evaluation Report White And Green Sturgeon (Revised)
- K-2, Evaluation Report Smelt (Revised)
- K-3, Evaluation Report Fish Stranding (Revised)
- K-4, Evaluation Report Dungeness Crab (Revised)
- K-5, Wildlife And Wetland Mitigation (Revised)
- K-6, Royalty Fees For State-Owned Dredged Material (Revised)
- K-7, Evaluation Report Floodplains (Revised)
- K-8, Part I - Consistency With Critical Areas Ordinances Including Wetland Mitigation Plan (Revised)
  Part II - Wetland Mitigation Plan
- K-9, Consistency With Washington Local Shoreline Master Programs (Revised)

Exhibit L - Cost Estimate Summary (Revised)
Exhibit M - Economic Analysis (Revised)
Exhibit N - Physical and Biological Studies of the Deep and Shallow Water Sites

List of Exhibits

Volume 2

EXHIBIT E
SECTION 404(B)(1) EVALUATION
(REVISED)

Table of Contents
Exhibit E
Section 404(B)(1) Evaluation (Revised)
Columbia River Channel Improvement Project

SECTION 404(b)(1) EVALUATION (Revised)
COLUMBIA RIVER CHANNEL IMPROVEMENT PROJECT

I. Introduction

Section 404 of the Clean Water Act (CWA) of 1977, as amended, requires that all projects involving the discharge of dredged or fill material into waters of the United States be evaluated for water quality and other effects prior to making the discharge. All disposal of dredged or fill materials associated with the Columbia River channel improvement project are activities undertaken by or at the direction of the Corps of Engineers. Federal regulations, at 33 CFR 336.1, provide that a Section 404 permit will not be issued for such discharges of dredged material by the Corps; however, the Corps shall apply the Section 404(b)(1) guidelines to the project. This evaluation assesses the effects of the discharge, as described below, for the Columbia River channel improvement project, utilizing guidelines established by the U.S. Environmental Protection Agency (USEPA) in conjunction with the Secretary of the Army under the authority of Section 404(b)(1) of the Act. This revised evaluation reflects currently available information and analysis, and supercedes all earlier 404(b)(1) evaluations, including Exhibit E to the Final *Integrated Feasibility Report for Channel Improvements and Environmental Impact Statement*, dated August 1999 (Final IFR/EIS).

II. Description of Proposed Action

<u>Proposed Action</u>

The proposed action is to deepen the Columbia River portion of the Columbia and lower Willamette Rivers federal navigation channel from its current authorized 40- feet depth with advanced maintenance to 45-feet, to an authorized depth of 43-feet with advanced maintenance to 48- feet based on the recommendations in the Final *Integrated Feasibility Report for Channel Improvements and Environmental Impact Statement*, dated August 1999 (Final IFR/EIS). Actions to deepen the Willamette River portion of the federal navigation channel have been deferred until completion of Superfund cleanup efforts and will be subject to a separate 404(b)(1) evaluation. Additional information and analysis of the project as currently proposed is provided in the Draft Supplemental *Integrated Feasibility Report for Channel Improvements and Environmental Impact Statement*, dated July 2002 (Draft Supplemental IFR/EIS). The Final SEIS is expected to be released to the public in December 2002 with the issuance of a record of decision in February 2003. The actions to be specifically addressed under the guidelines include the following.

(1) Potential wetland fills at two sites totaling 16.1 acres. Both sites are located in Washington: 10.7 acres at Mt. Solo (W-62.0) and 5.4 acres at Puget Island (W-44.0).

(2) In-water (flowlane) disposal for the 43-foot channel alternative includes 3 million cubic yards (mcy) for construction and 24 mcy of maintenance material during the first 20 years. Flowlane disposal sites are in or adjacent to the Columbia River federal navigation

channel in both Oregon and Washington at depths generally ranging from 50 to 65 feet. New flowlane disposal areas will be used at depths below 65 feet and above 35 feet at locations described in Section II(c) below.

(3) Placement of material at 3 beach nourishment sites: Sand Island, Oregon, Skamokawa Beach, Washington, and Miller Sands Spit, Oregon. Sump locations at Columbia River Mile (CRM) 21 (Harrington Sump) and at CRM 18-20 (Tongue Point, Oregon) would also be used for placement of dredged material.

(4) In-water placement of dredged material for restoration of intertidal emergent marsh habitat at Martin Island embayment, Washington.

(5) In-water placement of dredged material for restoration of tidal marsh-intertidal flat habitat at Lois Island embayment, Oregon, and at Miller/Pillar between Pillar Rock and Miller Sands Islands, Oregon.

(6) Two restoration measures (interim and long-term) are being considered at Tenasillahe Island, Oregon. The interim actions would be directed at improving connectivity and water exchange between sloughs/backwater channels interior to the levees at the Julia Butler Hansen National Wildlife Refuge and the Columbia River. The interim measure includes construction of two temporary cofferdams at existing tidegates to allow installation of improved outlet structures in a “dry” environment. These improved outlet structures would improve fisheries access and egress. Inlet improvements, channels, and water control structures would be constructed at three locations to direct Columbia River waters into the interior sloughs to improve fisheries access and improve water quality and circulation in the interior sloughs.

(7) The long-term measure at Tenasillahe Island involves breaching the flood control levee surrounding Tenasillahe Island at five locations. These breach locations include the two existing tidegates and the three proposed inlet sites for the interim restoration measures. This action will improve conductivity of interior channels and restore tidal circulation to approximately 1,778 acres of estuarine habitat; a substantial gain in salmonid habitat is envisioned.

(8) Tidegate retrofits for salmonid passage at Burris Creek in Woodland Bottoms, Washington.

(9) The Shillapoo Lake, Washington, ecosystem restoration feature creates waterfowl and wildlife habitats on 470 to 839 acres. The concept for the restoration feature would be to create cells hydraulically separated by levees, but interconnected by water control channels and structures. This will require modifications to the outlet structure involving excavation and/or fill and emplacement of a porous rock levee to block carp access to the wetland management cells comprising the project feature.

(10) Development of managed wetland habitat at the Webb and Woodland Bottoms mitigation sites.

Purpose and Need

As originally stated in the Final IFR/EIS, the purpose of the proposed project is to improve the deep-draft transport of goods on the Columbia and lower Willamette Rivers navigation channel, and to provide ecosystem restoration for fish and wildlife habitats. As noted above, actions to deepen the Willamette River portion of the federal navigation channel have been deferred until completion of Superfund cleanup efforts. The planning period for the project is 50 years. For purposes of Section 404(b)(1) analysis, deepening of the authorized navigation channel is a water dependent activity.

The need for navigation improvements has been driven by the steady growth in-waterborne commerce on the Columbia River and the use of larger and more efficient vessels to transport bulk commodities, which comprise the majority of export tonnage shipped. With the increased use of deep-draft vessels for transport, limitations posed by the existing channel dimensions now occur with greater frequency. Ships with design drafts near the 40-foot depth constraint cannot fully utilize their carrying capacity. Also, water depth availability problems cause vessel delays. By improving navigation, the opportunity to realize greater National Economic Development (NED) benefits (limited to a maximum authorized depth of 43 feet) would result from reducing transportation costs by allowing deep-draft vessels to carry more tonnage, and by reducing vessel delays.

The ecosystem restoration component covered by this evaluation was scoped and coordinated with state and federal agencies in accordance with Corps Engineers' Circular 1105-2-210, dated June 1, 1995, *Ecosystem Restoration in the Civil Works Program*.

Additional ecosystem restoration features and research and monitoring actions resulting from consultation of the project under Section 7 of the Endangered Species Act (ESA) have been incorporated into the project since publication of the Final IFR/EIS. The additional ecosystem restoration features and research and monitoring actions are based on opportunities identified to enhance juvenile salmonid feeding and rearing habitat for listed salmonid species. The primary purpose of these ecosystem restoration features is to restore habitat conditions for salmonids and other listed species, which would contribute to the recovery and long-term viability of the listed species. These features also would provide benefits to many other species of fish and wildlife.

General Description of Dredged or Fill Material

The material to be dredged and disposed as part of the Columbia River channel deepening and maintenance is predominately medium grain sand with some fine and coarse grain sand. The proposed 43-foot deepening alternative would result in flowlane disposal of an estimated 3 mcy during construction and an estimated 24 mcy over the first 20-years of maintenance. This maintenance quantity is estimated to be 20-30 mcy less than if current dredging and disposal practices were continued.

As described in Section 5.1.7 of the Final IFR/EIS, since the 1930s, the Corps has collected sediment data on the Columbia and Willamette Rivers. A comprehensive Sediment Quality Evaluation was prepared for the study (See Appendix B of the Final IFR/EIS). Since issuance of the Final IFR/EIS, the Corps has reviewed the analysis of thousands of collected samples from within and outside the channel. The likelihood of contaminants in the Columbia River portion of the federal navigation channel is low based upon all of the past testing and evaluation discussed in the Final and Supplemental IFR/EIS. All material dredged will be evaluated under joint USEPA and Corps Dredged Material Evaluation Guidelines prior to disposal. The Sediment Quality Evaluation and compliance with USEPA/Corps Guidelines prior to dredging meet the evaluation and testing requirements of 40 CFR Part 230 Subpart G.

Ecosystem restoration activities at Tenasillahe Island, Shillapoo Lake, and the tidegate retrofit at Burris Creek will include the construction of cofferdams and levees. The fill material used for these activities will consist of clean sand and/or insitu material. A porous rock dam will also be constructed at Shillapoo Lake.

Mitigation at Webb and Woodland Bottoms will include construction of levees with insitu material.

Description of the Proposed Discharge Sites

Flowlane sites are in or adjacent to the Columbia River federal navigation channel at depths generally from 50 to 65 feet. However, there would be exceptions to the general depth criteria for the channel improvement project. The actual disposal sites cannot be designated beyond the general description in the first sentence of this section. They vary from year to year depending on the condition of the channel. Flowlane disposal could occur at depths of 35 to 65 feet between CRMs 64 and 68 and CRMs 90 and 101. Flowlane disposal could occur in areas over 65 feet deep in four specific areas: downstream of CRM 5; CRMs 29 to 40; CRMs 54 to 56.3 on the Oregon side of the channel; and CRMs 72.2 to 73.2 on the Washington side. The substrate at these locations is predominately medium grain sand with some fine and coarse grain sand.

The two wetland discharge sites total approximately 16.1 acres. Both sites are located in Washington [10.7 acres at Mt. Solo (W-62.0) and 5.4 acres at Puget Island (W-44.0)]. These sites lie behind flood control levees, and are drained and used for a variety of agricultural purposes.

Harrington Sump is a deepwater (~-40 feet CRD) site located between RM 20-22 in Oregon waters that historically and currently is used for placement of dredged material by hopper dredges. The sandy substrate at this location is comparable to the dredged material placed there. The sump is typically filled over a 2-3 year period, to approximately 35 ft CRD and then dredged to approximately 45 foot CRD with material disposed on Rice Island.

The temporary (2-year) sump to be used near Tongue Point (CRM 18-20), on the Oregon side, and immediately adjacent to the navigation channel, occurs in-water 38 to 60+ feet deep. The sandy substrate at this location is comparable to the dredged material to be placed there from the adjacent navigation channel.

The three sites selected for beach nourishment Sand Island, Oregon, Skamokawa Beach, Washington, and Miller Sands Spit, Oregon. are non-vegetated erosive shoreline areas with sandy substrate.

The Lois Island embayment totals 357 acres, and was dredged as a mooring basin for decommissioned WWII ships. This restoration action would restore approximately 190 acres of the embayment to marsh habitat. The existing substrate averages about -18 feet CRD and consists of predominately medium grain sand with some fine and coarse grain sand. The Miller/Pillar restoration feature between Pillar Rock and Miller Sands Islands is approximately 230 acres. The existing substrate averages about -25 feet CRD and consists of predominately medium grain sand with some fine and coarse grain sand. Since the site is naturally erosive, a pile dike field would be constructed to stabilize the site and maintain bathymetry comparable to pre-erosion conditions. A stable bathymetry at historic depths is anticipated to improve benthic invertebrate productivity and fisheries resource use.

The Martin Island embayment is an approximately 34-acre area formed via excavation of material to provide fill for an adjacent portion of Interstate 5, and was subsequently used for log moorage and recreational boating, including moorage. The average depth of the embayment is approximately -20 feet CRD. Silt that settled in this quiet backwater and bark debris from log storage activities likely make up the bottom substrate.

The Tenasillahe Island (interim) sites affected by temporary cofferdam construction are silty to fine sand substrates at 2 to 4 foot depths. The inlet structures would principally entail construction through the flood control levee with minor construction activities in adjacent intertidal lands with a silt substrate. Long-term activities at Tenasillahe Island would include breeching the levees to restore full tidal circulation.

Tidegate retrofits proposed at the five primary locations would primarily entail construction work in levee material with a minor construction element potentially in the adjacent intertidal zone comprised primarily of silts.

Construction actions associated with the Shillapoo Lake ecosystem restoration feature would primarily occur interior to the main flood control levee on agricultural lands. Some construction work would occur in levee material with a minor construction element potentially in the adjacent intertidal zone comprised primarily of silts. Sediment discharge to adjacent waters would be minimal. Rock fill would occur in the existing discharge channel from the pump station to serve as a carp access barrier to the interior managed wetlands.

The Webb and Woodland Bottoms mitigation sites will be developed for wetland and riparian habitat by constructing low levees inside the main flood control dike and constructing gradual sloping banklines within the mitigation sites.

III. Alternatives

The project alternatives were described and analyzed in Chapter 4 of the Final IFR/EIS and draft Supplemental IFR/EIS [no action, non-structural, and structural (channel deepening at 41, 42, and 43 feet), and disposal alternatives]. Alternatives other than the 43' deepening alternative were screened out on a number of grounds. The 41 and 42-foot alternatives were eliminated because they failed to maximize NED benefits. The regional port alternatives were eliminated because of higher anticipated construction, transportation or environmental costs. The non-structural / LoadMax alternative has been fully developed and implemented.

As required by the 404(b)(1) guidelines, a detailed evaluation of disposal alternatives, including upland and flowlane disposal and shoreline disposal, was performed in conjunction with preparation of the Final IFR/EIS. All practicable alternatives to the proposed disposal sites were studied with the coordination and cooperation of Federal and state resource agencies. Refinements to the disposal plan have been made since issuance of the Final IFR/EIS to further reduce impacts to wetlands. As discussed in the Final and Draft Supplemental IFR/EIS and below, practicable alternatives to the proposed in-water disposal areas and the two affected wetland sites do not exist.

The Supplemental IFR/EIS describes ecosystem restoration features in addition to those proposed in the Final IFR/EIS (Tidegate Retrofits, Improved Embayment Circulation [Walker/Lord Islands and Fisher/Hump Islands], and Shillapoo Lake). The additional restoration features include Lois Island Embayment, Miller/Pillar, Tenasillahe Island (interim and long-term features), Purple Loosestrife Control Program, Cottonwood/Howard Island Columbian White-tailed Deer Reintroduction, and Bachelor Slough Aquatic Restoration. The additional ecosystem restoration features were developed through the ESA consultation process with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) for ESA-listed salmon and other species as well as generally restoring fish and wildlife habitat.

a. Upland Disposal Sites (Includes two Wetland Sites)

The process used for screening upland disposal sites is described in Section 4.4.3.4 of the Final IFR/EIS. Over 157 sites were reviewed. Multiple environmental and engineering criteria were applied to screen the sites and select those proposed for disposal of project dredged materials.

One of the environmental criteria applied was avoidance of wetlands to the extent practicable. As a result of the screening process, comments on the draft EIS, and subsequent adjustments in disposal site boundaries, the total area of wetland fill was reduced from 30 acres for the plan evaluated in the draft EIS to 16.1 acres in the current recommended plan.

The two areas of wetland fill, 10.7 acres at Mt. Solo and 5.4 acres at Puget Island, are in river areas where the in-water disposal capacity is insufficient to handle the amount of material to be dredged. No other practicable means exists for disposing of dredged material without impacting a comparable or greater amount of wetland habitat. Other upland or in-water sites are not available in the vicinity or are already being used to capacity. The disposal sites containing wetland habitat lie behind flood control dikes, are actively drained and are used for agricultural purposes. These wetlands provide limited wildlife habitat value. The Puget Island and Mt. Solo disposal sites lie behind flood control dikes and are outside the Federal Emergency Management Agency 100-year floodplain.

b. In-water Disposal

Flowlane disposal is used in areas where no other disposal alternatives exist or where the quantity of material to be dredged is too small to warrant use of a pipeline dredges that would be necessary for upland disposal. Flowlane disposal is not expected to have a significant impact on aquatic resources. Benthic invertebrate productivity is generally low in the deeper channel areas and impacting these areas would not affect the overall productivity of the Columbia River.

Shoreline disposal locations were selected because of beneficial use that they provide. Sand Island protects a county/public park and riparian habitat. Skamokawa beach provides the resale of material and protects the public beach. Miller Sands protects an important aquatic habitat.

The Harrington Sump is necessary in the estuary in order to eventually place material upland on Rice Island. The Rice Island upland disposal site is located within the estuary adjacent to Harrington Sump. Material is temporarily placed in the sump when river conditions or equipment availability does not allow direct placement of material on Rice Island. Pipeline dredges later remove the material from Harrington Sump and place it upland for permanent disposal. The sump has been used for decades and is a disturbed area with low productivity. Use of Harrington Sump reduces the need for flowlane disposal elsewhere in the estuary. The Tongue Point Sump is to be used during construction to temporarily store disposal material that will ultimately be placed on the Lois Island ecosystem restoration site by a pipeline dredge.

Two ecosystem restoration sites will be constructed utilizing dredge material in the estuary to help restore valuable habitat. The Lois Island embayment will be filled with material to an elevation approx 7 feet mllw in order to develop tidal marsh habitat. This action would occur during the two-year construction period. The Miller Pillar ecosystem restoration feature will restore subtital and/or intertidal habitat in a naturally erosive area. Both of these restoration sites have been identified through the ESA consultation as beneficial to listed salmonid stocks.

The mitigation habitat development at the Martin Island embayment will also utilize dredged material to accomplish the habitat objective. Project mitigation, including mitigation for wetland impacts such as the proposed creation of intertidal emergent marsh at Martin Island, was developed through an interagency team approach. The mitigation team included representatives from the Corps, Washington Departments of Ecology and Fish and Wildlife, US Fish and Wildlife Service, and Oregon Department of Fish and Wildlife.

c. Other Restoration

The ecosystem restoration features described in the Final IFR/EIS that involve discharges of dredged or fill material into the waters of the U.S. include Tenasillahe Island and Shillapoo Lake. The purpose of these restoration features is to benefit listed ESA species, including salmonid ESUs and also to improve fish and wildlife habitat conditions. The Shillapoo Lake restoration feature and the Burris Creek tidegate retrofit feature were formulated as the result of a series of workshops with federal and state resource agencies. Tenasillahe Island restoration was a result of the ESA consultation process between the Corps, NMFS and USFWS. The discharges that are a part of these features are necessary in order to realize the purpose of the features. There are no practicable alternatives to these discharges.

d. Other Wildlife Mitigation

The wildlife habitat mitigation described in the Final IFR/EIS that involve discharges into the waters of the U.S. includes Martin Island (Martin Island embayment was addressed in paragraph b above), Woodland Bottoms, and Webb mitigation sites. The purpose of these wildlife mitigation actions is to offset project-related wildlife habitat losses for riparian, wetland and agricultural lands. These mitigation actions were developed through an interagency process (WDFW, ODFW, USFWS, WDOE and COE) utilizing the USFWS's Habitat Evaluation Procedures to assess project related losses and net gains in habitat units at potential mitigation sites. The selected mitigation sites produced the best net gain in habitat units at the least cost. The discharges that are a part of these mitigation actions are necessary in order to attain the wildlife habitat improvements. There are no practicable alternatives to these discharges.

IV. Factual Determinations (40 CFR § 230.11)

Physical Substrate Determinations

Sediments in the mainstem Columbia River typically are composed of fine to course sand with less than 1% in the silt to clay size classification and less than 1% volatile solids. The dredging sites within the navigation channel, access channels, and all flowlane disposal sites and sumps are located within the mainstem of the Columbia River. Flowlane disposal sites are typically located near associated dredging sites and are subject to similar hydraulic forces. The riverbed generally consists of sand waves that have minimal compaction or consolidation. Therefore, the materials in the extraction sites and the substrate of the in-river discharge sites are similar in particle size, shape and compaction.

The disposal of dredged material would alter the depth and/or gradient of the flowlane disposal sites and sumps via raising the bottom elevation. As previously noted, the disposal location and depth of flowlane sites cannot be determined until shortly before the time of discharge due to the dynamic nature of the river bottom. However, rise in bottom elevation is expected to range from two to six feet depending on individual flowlane sites. This range of rise is not expected to cause significant changes in-water circulation, current pattern, water fluctuation and water temperature. The elevation rise in the disposal sites may affect the contours of the surrounding substrate; however, any such affect is expected to be insignificant. The physical characteristics of bottom sediments would not change significantly as the dredged material is essentially the same composition as material found at the discharge site.

The substrate of both disposal sites containing wetland habitat is primarily silty clay loam. Placement of dredged material at the sites would change the physical composition to primarily sand. The top one foot of topsoil would be removed at the Puget Island disposal site would be removed and stockpiled prior to deposition and then replaced on the surface as each of the three disposal cells at the location are filled. All wetland function and value will be lost at these locations; therefore, these wetland discharges will not be addressed any further under these factual determinations.

The sandy substrate of the three-shoreline disposal sites is the same as the material that will be placed there. Disposal will raise the riverbed of shallow water areas along the beach. Some areas could change from shallow water to beaches. Disposal would erode away in three to four years. All of these sites have been used in the past to maintain the Columbia River. These sites tend to be non-vegetated erosive sites with low benthic productivity. There are no expected impacts to downstream habitat as a result of these sites.

The substrate of the two ecosystem restoration sites and one wildlife mitigation site utilizing dredged material for fill ranges from coarse sand to silt. Placement of dredged material at Miller/Pillar would raise the bottom elevations from 6 to 24 feet with predominately medium grain sand with some fine and coarse grain sand. For Lois Island embayment, the elevation increase would range from 1 to 32 feet and average about 24 feet. The bottom elevation of Martin Island embayment would rise approximately 20 feet to an intertidal level post-construction.

Implementation of the interim measure at Tenasillahe Island would result in a temporary modification to the physical substrate associated with placement of cofferdams established to allow construction in the dry. These structures would be removed once the outlets are modified. The improved outlets are not anticipated to modify the physical substrate at the outlets beyond existing condition. Some modification to the substrate will occur at the three inlet works to be established. These may include excavation of entrance and exit channels either mechanically or in combination with hydraulic forces associated with the initiation of flows at these locations.

The long-term restoration measure at Tenasillahe Island will entail breaching (excavation) the flood control levee at the two existing outlets and three proposed inlet locations associated with the interim measure. The restoration of tidal flows to the interior of Tenasillahe Island may result in the natural development of channels and/or modification to the existing drainage channels and substrate from the reintroduction of hydraulic forces. Disposal of excavated material from the breaches will be atop the remaining levee section to the extent practicable but deposition on interior lands that are currently pastures (drained wetlands) may occur, subject to further evaluations, for development of riparian forest habitat.

Tidegate retrofits at Burris Creek would have minimal impacts to the existing substrate. Typically, construction earthwork would be limited to the flood control levee if it proceeded beyond a simple replacement or modification of the tidegate at the end of the culvert. No change in the existing condition of the surrounding substrate due to changes in flow is anticipated with these modifications.

The Shillapoo Lake ecosystem restoration feature will entail construction of water control levees interior to the main flood control levee and modifications to the outlet works. The interior levees are per the Washington Department of Fish and Wildlife's management desires for the presently agricultural and Shillapoo Wildlife Management Area lands comprising the restoration feature. Structural modifications to the present outlet works will primarily encompass the flood control levee with minor disturbance to the outlet channel to Lake River. Another project feature entails placement of a porous rock fill (levee) across the outlet channel to block carp access to the interior managed wetlands. The substrate of the area is composed of silty clay loam. The levees will be constructed from these native soils.

The discharges at the Webb and Woodlands Bottoms mitigation sites will use clean sand and insitu materials, and will not adversely impact the existing substrate.

The cumulative impacts of other ongoing and currently authorized activities involving discharges of dredged or fill material that potentially affect physical substrate (e.g., existing filling and diking, ongoing maintenance dredging, maintenance of the mouth of the Columbia River, operation of the Federal Columbia River power system, and existing development along the Columbia River) are reflected in the current substrate conditions found at the sites discussed above. Future activities, including potential future upland development, are not anticipated to affect physical substrate except in the immediate vicinity of such projects. While future cleanup of the Willamette River under the federal superfund program could potentially affect substrate in a limited area downstream of the Willamette's confluence with the Columbia, the cleanup plan has not been developed yet and therefore the potential effect of the cleanup cannot be predicted at this time.

Water Circulation, Fluctuation and Salinity Determinations

The proposed in-water disposal, including flowlane, two sumps, and shoreline disposal, would affect minor changes in hydrologic features such as circulation patterns, downstream flows, or normal water level fluctuations. Discharges at shoreline disposal sites are intended to offset shoreline erosion. However, the minor changes in hydraulic features are not expected to otherwise result in any significant impacts to aquatic communities, shoreline and substrate erosion and deposition rates, the deposition of suspended particulates, the rate and extent of dissolved and suspended components of the water body. Water quality characteristics such as water chemistry, clarity, color, odor, taste, dissolved gas levels, temperature, or nutrients would not be affected to any measurable degree. As discussed in Sections 6.2.2.2 and 6.2.2.3 of the Final and Supplemental IFR/EIS and Appendix F of the Final IFR/EIS, channel deepening and related disposal could cause a minor increase in salinity in the main channel in the lower part of the estuary. The hydraulic analysis of water surface elevations and salinity concentrations support the expectations of minor changes. Since the water surface profiles and thus the energy gradients are essentially unchanged, the flow in side channels and shallows would also be unchanged. The results of salinity intrusion modeling show insignificant changes in salinity concentrations outside the main channel. This result indicates that there would be very little hydraulic change away from the main channel. Based on the results of sediment analysis [see subpart (d) below], and that dredged material would originate from nearby in-water locations, physical or chemical characteristics of the receiving water would not be adversely affected. Additional analysis of salinity and hydraulic effects, including potential minor changes in the location of the Estuarine Turbidity Maximum (ETM) associated with deepening (as opposed to disposal of dredged or fill material), is included in the Supplemental IFR/EIS.

The proposed restoration actions at Tenasillahe Island, and the tidegate retrofits at Burris Creek are intended to improve water circulation within these sloughs, backwaters and embayments. The creation of tidal marsh habitat within the Lois Island embayment is not anticipated to alter flow or water circulation patterns in the adjacent area. The placement of a pile dike field and subsequent fill between the pile dikes at Miller/Pillar to restore subtidal and or intertidal elevations would have a negligible impact to flows into lower Cathlamet Bay. The porous rock levee across the outlet/inlet for the Shillapoo Lake restoration effort is intended to maintain flow through the existing tidegate and pumping station at this location but preclude the passage of carp to the interior managed waters.

The creation of the intertidal habitat in the Martin Island embayment is in a protected area and is therefore not expected to alter circulation patterns adjacent to this site. The discharges at the Webb and Woodlands Bottoms mitigation will occur behind the main flood control dikes and will have no effect on water circulation, fluctuation and salinity.

The cumulative impacts of other ongoing and currently authorized activities involving discharges of dredged or fill material that potentially affects water circulation, fluctuation and salinity are reflected in the current conditions described in the Final and Supplemental IFR/EIS. Future activities, including potential future upland development, are not anticipated to affect water circulation, fluctuation or salinity except in the immediate vicinity of such projects. While future cleanup of the Willamette River under the federal superfund program could potentially affect water circulation, fluctuation and salinity in a limited downstream area, the cleanup plan has not been developed yet and therefore the potential effect of the cleanup cannot be predicted at this time.

Suspended Particulate/Turbidity Determination

Hopper dredges discharge through doors in the bottom of the hull while under power and traveling at slow speeds, generally around 1 or 2 knots. Hopper dredges typically discharge their load in a 5-20 minute period. A hopper dredge may make 6-15 disposal cycles per day. Loaded draft depths for hopper vessels vary with their capacity but will typically fall in the 15-30 foot depth range which is essentially the range for load discharge. The hopper dredges generates a turbidity plume that is limited in extent to the area below the discharge depth and immediately along the vessel path for the 5-20 minute disposal effort. The discharged sand settles quickly to the river bottom. The sediment concentrations in the plume are limited because of the small amount of fines in the disposal material. River currents will carry the plume a short distance before it mixes with the river.

For pipeline dredges, dredged material is continuously pumped through a discharge diffuser that is located 20 feet below the water surface. The discharged sand settles rapidly to the bottom and a plume of fine grained sediments is carried away by the river currents. The downstream extent of the plume will depend on the river velocities and channel geometry at each discharge site.

Short-term minor increase in turbidity would occur in the mixing zones of Project in-water disposal sites and in-water work areas associated with mitigation and ecosystem restoration features. This condition would temporarily inhibit light penetration through the water column for a short period of time (hours) and would not significantly affect aquatic organisms. The dredging and disposal activity in the Project will involve the same type of sandy material, and will be performed with the same type of equipment and the same method of operations, as existing maintenance dredging of the 40-foot channel. Both states have previously issued state water quality certifications that have included approved mixing zones. With the issuance of state water quality certifications containing approved mixing zones and/or short-term modifications as appropriate, the expected increase in turbidity levels would not violate state water quality standards. Best management practices (BMP) would be utilized for the dredge and fill actions associated with the deepening and all in-water disposal, as well as the Lois Island embayment, Miller/Pillar ecosystem restoration features and Martin Island embayment development for wildlife mitigation. Best management practices would also be implemented for other ecosystem restoration features entailing work in-water, including construction of temporary cofferdams to contain and allow settling time for suspended sediments at Tenasillahe Island, and potentially for the Burris Creek tidegate retrofits. The BMP's are described in the BA and BO. See further discussion in Chapters 4 and 6 of the Final and Supplemental IFR/EIS.

All other discharges will occur in wetland areas. These discharges are not expected to involve flowing or standing water where turbidity would be an issue.

The cumulative impacts of other ongoing and currently authorized activities involving discharges of dredged or fill material that potentially affect suspended particulates and turbidity are reflected in the current conditions described in the Final and Supplemental IFR/EIS. Future activities, including potential future upland development, are not anticipated to affect suspended particulates or turbidity except in the immediate vicinity of such projects. While future cleanup of the Willamette River under the federal superfund program could potentially affect suspended particulates and turbidity in a limited downstream area, the cleanup plan has not been developed yet and therefore the potential effect of the cleanup cannot be predicted at this time.

Contaminant Determinations

With the exception of some discharge of materials associated with the mitigation sites and several of the ecosystem restoration features (Tenasillahe Island, Burris Creek tidegate retrofit, Shillapoo Lake), all of the material proposed to be discharged pursuant to this 404(b) evaluation is dredged material from the navigation channel and from existing access channels between the navigation channel and shoreside berths at three grain facilities, one gypsum plant and one container terminal. Actual deepening of these berths will require separate Section 404 permitting and review.

The discharges into the mitigation sites and several ecosystem restoration sites that do not involve material dredged from the navigation channel will be either insitu material or clean sand or rock from non-contaminated sources. Currently available information indicates no reason to suspect contaminants in the insitu material.

Sediments in the mainstem Columbia River typically are composed of sand with less than 1% in the silt to clay size classification and less than 1% volatile solids. The material present in the mainstem Columbia River meets exclusionary criteria as defined under the Marine Protection, Research, and Sanctuaries Act (MPRSA) and the CWA and, therefore, would not be subject to further testing under these two environmental laws. However, this material has been subjected to both physical and chemical testing as part of this project. The mainstem sediment has been determined, in accordance with the 1998 Dredged Material Evaluation Framework (DMEF), Lower Columbia River Management Area (USEPA/COE 1998), to be suitable for unconfined in-water disposal by the USEPA, Corps, and the States of Oregon and Washington.

Sediment testing still will be required for material dredged from the turning basin at Astoria. The evaluation would be conducted by and coordinated with the appropriate agencies prior to any dredging and disposal action.

Material from the areas dredged in the Columbia River has been collected and analyzed since dredging first began in the early 1900s. Prior to the passage of the MPRSA and CWA physical analyses was conducted to determine dredging capability and to estimate production. After passage of these two environmental laws, analyses were expanded to include chemical and biological analyses as well as the traditional physical analyses. Physical analyses are also conducted as a regular parameter evaluated during benthic infauna studies conducted in the river. Many of these infauna studies have been conducted along the slopes and outside of the navigational channel during dredged material disposal site evaluation studies. The Corps has identified and is entering into a SEDQUAL database over 100 separate studies that have been conducted on the Columbia River by the Corps since 1980. This includes sampling of over 3,100 stations for a total of over 4,100 samples.

While the nature of the mainstem material meets the exclusion from testing as provided in the regulations and evaluation guidelines, the Corps and USEPA decided to conduct confirmatory testing for the entire project. Sixty-seven separate shoal areas were identified for sampling through assessment of the of the 1994 navigation channel bathymetry. In June 1997, 89 surface grab samples were collected from the 67 shoals in the Columbia River project area (CRMs 3.0 to 106.2). In addition to physical analysis, 23 were further analyzed for chemical contaminants.

As in accordance with the DMEF, chemical tests were performed including; inorganic total metals (9), polynuclear aromatic hydrocarbons (PAHs), total organic carbon (TOC), total volatile solids (TVS), acid volatile sulfide (AVS), pesticides and polychlorobiphenyls (PCBs), pore water tributyltin (TBT), and P450 reporter gene system (RGS), a dioxin/furan screen. Information regarding the sediment testing and results can be found in Appendix B of the Final IFR/EIS, *Columbia and Willamette River Sediment Quality Evaluation*. The dredged material was determined to be suitable for unconfined in-water disposal.

Additional evaluation of materials proposed for dredging was conducted as part of the ESA re-consultation and can be found in Appendix B of the Biological Assessment and in the Biological Assessment amendment letter (both found at Exhibit H of the Supplemental IFR/EIS). The additional evaluation confirmed the earlier conclusion that the primarily sandy dredged material does not contain unacceptable concentrations of contaminants and is suitable for unconfined in-water disposal. No additional testing is necessary.

The cumulative impacts of other ongoing and currently authorized activities involving discharges of dredged or fill material that potentially affect contaminants are reflected in the current conditions described in the Final and Supplemental IFR/EIS. Future activities, including potential future upland development, are not anticipated to affect contaminants except in the immediate vicinity of such projects. While future cleanup of the Willamette River under the federal superfund program could potentially affect contaminants in a limited downstream area, the cleanup plan has not been developed yet and therefore the potential effect of the cleanup can not be predicted at this time. Further, because the purpose of the cleanup is to effectively control contaminants and protect human health and the environment, it is likely that a major focus of cleanup design will be on avoiding and eliminating any off-site contaminant impacts.

Aquatic Ecosystem and Organism Determinations

Impacts to the aquatic ecosystem associated with discharge of dredged material will occur. Impacts associated with flowlane discharge of dredged material are expected to be minimal since the substrate of the main navigation channel consists primarily of sand naturally formed into sand waves by river currents. These sand waves are constantly eroding and reforming and do not provide the stable habitat needed for productive benthic communities. Sampling in the channel areas has confirmed their low productivity for benthic invertebrates. Additionally, those portions of the sand waves in the dredging prism are disturbed by annual dredging operations that typically occur from May through September for the navigation channel.

In-water disposal operations consist of flowlane disposal, use of two sumps and three shoreline disposal sites. Flowlane disposal is done in or adjacent to the channel margins typically at depths from 50-65 feet. These areas are generally similar to the channel areas and are not considered very productive for benthic communities. Static benthic communities would be covered and would not likely recover because of the continuous use of the sites. However, populations of these organisms are not considered to be very high because of the dynamic nature of the flowlane habitat.

Mobile organisms present in flowlane disposal areas, such as smelt, sturgeon and crab, are adapted to the dynamic nature of the habitat arising from continuous movement of sand via river currents. They are mobile organisms and generally should be physically capable of avoiding the disposal in most instances. Sturgeon occur in the flow lane disposal sites as both adults and juveniles. The behavioral research by the USGS, funded by the Corps, will be used to manage the dredging and disposal operations to minimize impacts to sturgeon populations. Dungeness crabs are located primarily in the lower reaches of the estuary but can occur as far upriver as mile 15 when river flow is low and up river salinity is high. Crabs could be present in Harrington Sump as well as the flowlane site at RM 5. Studies have shown that crab are able to dig out of disposal materials, although some individual crab do not dig out and are smothered. The number of crabs impacted will depend upon how many are in the disposal site, which is dependent upon river and tide conditions. A study to develop a model of crab abundance versus salinity is being developed by Battelle NW Labs for the Portland District. This model will be used to schedule dredging and disposal to avoid periods of high crab abundance to the extent practicable in order to minimize impacts.

Studies have shown that smelt spawning is not successful in the high-energy areas like those used for flowlane disposal. Larval smelt move up into the water column after hatching; consequently, it is likely that smelt larvae would not be affected by aquatic disposal operations. Based on the above, it is likely that smelt populations would not be affected by flowlane disposal.

Shoreline disposal sites are located in areas that are highly erosive and do not provide much, if any, habitat for benthic communities. Consequently, use of these sites is not expected to have a significant impact on the benthic productivity of the area. Through consultation with the NMFS, only three shoreline disposal sites (Sand Island and Miller Sands Spit, Oregon and Skamokawa, Washington) are cleared for disposal operations.

Proposed wildlife mitigation actions would restore wetland functions of high value on approximately 210 acres over the three wildlife mitigation areas. Wetland habitat development would occur in the context of a larger, diverse, natural area, with a substantial riparian forest component, at each mitigation site. Riparian habitat restoration would restore approximately 228 acres of this habitat feature compared to the approximately 50 acres impacted by disposal. Fill activities associated with the Martin Island embayment mitigation site will convert the aquatic ecosystem at the site to intertidal emergent marsh.

Proposed ecosystem restoration features at Lois Island embayment and Miller/Pillar would restore approximately 590 acres of low to moderately productive subtidal habitat to highly productive shallow subtidal and tidal marsh habitat. Tidegate improvements at Burris Creek and inlet structures (interim action) at Tenasillahe Island would improve water quality and salmon habitat in several sloughs within the island complex. Implementation of the long-term feature at Tenasillahe Island, breaching the flood control dikes, would restore approximately 1,778 acres of habitat to tidal influence in the future. The Shillapoo restoration feature creates waterfowl and wildlife habitat on 470 to 839 acres (dependent upon planned acquisition).

The USFWS and the NMFS have both determined that the proposed action, including ecosystem restoration features, is not likely to jeopardize the continued existence of threatened or endangered species under their purview. The NMFS believes that the most predictable impacts from the proposed action to ESA-listed salmonids and their habitats in the lower Columbia River, estuary, and river mouth are short-term, physical changes during the construction and subsequent maintenance period of the project. Expected impacts to key physical processes will be limited and short-term in nature during construction and maintenance. Further discussions of aquatic impacts are included in the Final IFR/EIS, Supplemental IFR/EIS and Biological Assessments prepared by Portland District for this action and in the biological opinions prepared by the USFWS and NMFS.

The cumulative impacts of other ongoing and currently authorized activities involving discharges of dredged or fill material that potentially affect the aquatic ecosystem and organisms are reflected in the current conditions described in the Final and Supplemental IFR/EIS. Future activities, including potential future upland development, are not anticipated to affect the aquatic ecosystem and organisms except in the immediate vicinity of such projects. Further, any such projects that may affect the aquatic ecosystem and organisms are likely to require independent evaluation under the Endangered Species Act and NEPA. While future cleanup of the Willamette River under the federal superfund program could potentially affect the aquatic ecosystem and organisms in a limited downstream area, the cleanup plan has not been developed yet and therefore the potential effect of the cleanup cannot be predicted at this time.

Proposed Disposal Site Determinations

In-water disposal, flowlane and sump disposal, may be conducted by either hopper or pipeline dredges. The aerial extent of the mixing zone for in-water disposal is influenced by river conditions, material type, and dredge equipment. These factors are discussed in detail in the BA, SEIS, and the FEIS.

Flowlane disposal sites are located in or adjacent to the Columbia River federal navigation channel from RM 3 to RM 106, at depths generally from 50 to 65 feet. However, there would be exceptions to the general depth criteria for the channel improvement project. The actual disposal sites cannot be designated beyond the general description in the first sentence of this section. They vary from year to year depending on the condition of the channel. Flowlane disposal could occur at depths of 35 to 65 feet between CRMs 64 and 68 and CRMs 90 and 101. Flowlane disposal could occur in areas over 65 feet deep in four specific areas: downstream of CRM 5; CRMs 29 to 40; CRMs 54 to 56.3 on the Oregon side of the channel; and CRMs 72.2 to 73.2 on the Washington side. The sump sites are located near RM's 18-20 and 20-22. River currents along the river are influenced by upstream discharges and ocean tides and typically vary from –1 fps to +3 fps. The Columbia River is generally not stratified except in the estuary where salinity intrusion causes stratification. The stratification is not expected to significantly influence mixing of the disposal plume.

The substrates at the flowlane and sump locations are predominately medium grain sand with some fine and coarse grain sand with less than 1 percent silt or clay. Columbia River suspended sediment concentrations vary seasonally, but are generally between 10-20 mg/l during the dredging season.

Hopper dredges discharge through doors in the bottom of the hull while under power and traveling at slow speeds, generally around 1 or 2 knots. Hopper dredges typically discharge their load in a 5-20 minute period. A hopper dredge may make 6-15 disposal cycles per day. Loaded draft depths for hopper vessels vary with their capacity but will typically fall in the 15-30 foot depth range which is essentially the range for load discharge. The hopper dredges generates a turbidity plume that is limited in extent to the area below the discharge depth and immediately along the vessel path for the 5-20 minute disposal effort. The discharged sand settles quickly to the river bottom. The sediment concentrations in the plume are limited because of the small amount of fines in the disposal material. River currents will carry the plume a short distance before it mixes with the river.

For pipeline dredges, dredged material is continuously pumped through a discharge diffuser that is located 20 feet below the water surface. The discharged sand settles rapidly to the bottom and a plume of fine grained sediments is carried away by the river currents. The downstream extent of the plume will depend on the river velocities and channel geometry at each discharge site.

For flowlane and sump disposal the river current would carry away fine sediment but since the disposal material would be mostly sand, the extent and duration of the plume would be minor. No mud flats and vegetated shallows would be affected by disposal in these areas as it occurs in and adjacent to the navigation channel which is generally distant from these habitat types The material would not introduce toxic substances (see above discussion of contaminant determinations) into the surrounding waters.

Shoreline disposal can generate elevated suspended sediment concentrations near the shoreline at the three shoreline disposal sites. The suspended sediment concentrations decrease rapidly as the disposal water mixes with the river discharges.

The Lois Island and Miller-Pillar restoration sites will be filled by pipeline dredge. The disposal operation will be similar to a shoreline disposal. The suspended sediment plume will also be similar to that caused by shoreline disposal. The currents at the Lois Island site are generally lower than those in the main river channel and the plume will move away more slowly than at the shoreline disposal sites. The Miller-Pillar site will have reduced current velocities within the pile dike field, but the plume will rapidly mix with the river currents outside of the dike field.

The Martin Island mitigation site will be filled by pipeline dredge. The disposal operation will be similar to a shoreline disposal. The suspended sediment plume will also be similar to that caused by shoreline disposal. The currents at the Martin Island site are generally lower than those in the main river channel and the plume will move away more slowly than at the shoreline disposal sites.

Potential Effects on Human Use Characteristics.

Municipal and Private Water Supplies: There are no municipal or private water supply intakes in the vicinity of the disposal areas.

Recreational and Commercial Fisheries: Impacts to recreational and commercial fisheries will occur. Fill at Lois Island embayment will restrict the area available for recreational fishermen, principally for sturgeon, and commercial fisherman who utilize this area as part of the Select Area Fishery established in the lower Columbia River. The Miller/Pillar location would impact a portion of the Miller Sands gill net drift rendering it unsuitable for commercial fishing use. As indicated by the evaluation of contaminates above, the commercial and recreational fisheries are not anticipated to be impacted by contaminants. Disposal operations are not expected to disrupt migration and spawning areas. Dredging impacts to crab, including flowlane discharge of dredged material, are anticipated to impact a small fraction of the crab population in the estuary. The crab population in the estuary is only part of the total crab population in the area. Therefore, the project is not anticipated to adversely affect the crab fishery.

Water-related recreation: Water related recreation in the project area consist of: pleasure craft, jet skies, water skiing, wind surfing, canoeing, and kayaking . Impact to water related recreation is expected to be minor in areas where disposal will occur. Dredges will be operating in localized areas within the project area for short periods of time. Although there may be some disturbances to individual recreators, these disturbances will be minimal.

Disposal within the Martin Island embayment to create emergent marsh habitat will prevent the recreational boaters' use of that area.

Aesthetics: No impacts to aesthetics are anticipated.

Parks, etc: There are two public beaches that are also shoreline disposal locations. While material is being disposed of at this location, there will be minor disturbances to shoreline use by individuals using the beach. The periodic placement of material at these locations enables continued public use of these areas. There are no national and historical monuments, national seashores, wilderness areas, and research sites within the discharge areas.

Determination of Cumulative Effects on the Aquatic Ecosystem

The proposed discharge of dredged material is not expected to have any significant adverse cumulative effects on the aquatic ecosystem.

The wetlands proposed for dredged material disposal do not contribute much value to the aquatic ecosystem in their current state as they lie behind flood control dikes, are subject to drainage, and are impacted by current agricultural activities. Proposed enhancement and development of wetlands through implementation of the wildlife mitigation plan, and shallow water, riparian, slough and tidal marsh habitat improvements through restoration, would add cumulative resource value to the lower Columbia River ecosystem.

Other discharges of dredged material associated with the project are not predicted to have significant adverse effects either alone or in combination with other existing or reasonably predicted discharges of dredged or fill material. As discussed above, the cumulative effects of other ongoing and currently authorized activities involving discharges of dredged or fill material (e.g., existing filling and diking, ongoing maintenance dredging, maintenance of the mouth of the Columbia River, operation of the Federal Columbia River power system, and existing development along the Columbia River) are reflected in the current conditions described in the Final and Supplemental IFR/EIS.

While not caused by or connected to channel improvement, some future development of port, marine, and industrial facilities is reasonably foreseeable within the project area. Similarly, continued urban and industrial development in the project area is reasonably foreseeable in response to regional and national economic trends.

Future urban, industrial and port development as it is implemented, would likely include some discharge of dredged or fill material which would in turn result in localized impacts to aquatic ecosystems (e.g., wetlands, riparian and shallow water habitat, and water quality). The NMFS and USFWS May 2002 Biological Opinions discuss such potential development and its potential impacts (e.g. increased localized demand for electricity, water and buildable land with indirect effects to water quality; and, the increased need for transportation, communication and other infrastructure;) on listed species, as well as state, local, tribal and private actions to benefit listed species.

Given the large geographic area involved and the uncertainties associated with state, local, tribal and private actions, the precise nature and timing of future development, and its environmental impact, are extremely difficult to predict. However, given the minimal adverse effects to aquatic ecosystems (if any) anticipated for the discharge of dredged materials associated with the entire Columbia River channel improvement project (including the ecosystem restoration features and mitigation measures), the discharges under the proposed project are not anticipated to contribute significantly to any adverse cumulative effects resulting from unrelated development projects. Further, all significant future development, including future discharge of dredged or fill material, will likely be subject to additional independent environmental reviews by state and federal agencies under the NEPA, CWA, ESA, and similar state programs.

Cleanup of the lower Willamette River under the federal Superfund program is also reasonably foreseeable and may directly affect the Columbia River and its aquatic ecosystem. At this time, the remedial investigation and feasibility study have not yet been completed and a cleanup plan has not been selected. Therefore, it is not possible at this time to determine the nature or magnitude of any short-term or long-term impacts of the cleanup action on the aquatic ecosystem or whether such impacts would be cumulative to any impacts (positive or negative) of the channel improvement project.

Determination of Secondary Effects on the Aquatic Ecosystem

The proposed action would not result in fluctuating river levels. Surface runoff from disposal sites would be negligible as precipitation is expected to readily percolate into the sand. The rehandling (sale) of sand from upland disposal and shoreline disposal sites would not affect the aquatic ecosystem as the activity would occur behind containment dikes and/or above the high tide line. No other secondary effects resulting from the discharge of dredge material are anticipated.

IV. Findings of Compliance (40 CFR § 230.12)

a. No significant adaptations of the guidelines were made regarding this evaluation.

b. Alternatives. Alternatives to the proposed action were considered, including the no-action alternative. Upland disposal of all Columbia River dredged material is not practicable from a physical or economic standpoint and would affect substantially more wetlands and wildlife habitat if it were implemented. All alternative disposal actions have been evaluated for engineering and environmental suitability using an array of screening criteria. Avoidance of wetlands, critical (ESA) riparian habitat and habitat important to threatened and endangered species are among the screening criteria considered in the analysis. Any remaining wetlands or riparian areas affected by disposal were considered unavoidable in achieving a practicable disposal plan. A wildlife mitigation plan addressing impacts to agricultural, wetland and riparian habitats has been developed in cooperation with federal and state resource agencies. Ecosystem restoration features were formulated as the result of a series of workshops with federal and state resource agencies and the public, and through the ESA reconsultation process between the Corps, NMFS and USFWS, and was based on review of potential alternative actions that would benefit listed ESA species, including salmonid ESUs and Columbian white-tailed deer, and also improve fish and wildlife habitat conditions generally.

c. Water Quality Standards [40 CFR § 230.10(b)(1)]. The project complies with state water quality standards. The Corps has applied to the States of Oregon and Washington for water quality certifications under Section 401 of the Clean Water Act for all discharges of dredged material into waters of the United States associated with the project. Issuance of these certifications will reflect the states' reasonable assurance of compliance with state water quality standards.

d. Toxic Effluent Standards [40 CFR § 230.10(b)(2)]. The USEPA has designed 65 substances and compounds as toxic pollutants under section 307 (see 40 CFR § 401.15), but it has adopted effluent standards under this subsection only for manufacturers and formulators of aldrin, dieldrin, DDT, DDD, DDE, endrin, toxaphene, benzidene, and polychlorinated biphenyls (PCBs; see 40 CFR part 129). The disposal of dredged material associated with this project would not violate toxic effluent standards of Section 307 of the CWA.

e. Endangered Species [40 CFR § 230.10(b)(3)]. The proposed action has been evaluated under the ESA through formal consultation with the USFWS and the NMFS. Biological Assessments prepared by the Corps for species under the jurisdiction of the USFWS principally concluded that the proposed action would have no affect on nine listed species and determined that certain actions may affect Columbian white-tailed deer, bald eagles and peregrine falcons. Subsequently, Aleutian Canada goose and peregrine falcon were delisted. Further, the Corps concluded that the project had a limited potential to adversely affect bull trout and coastal cutthroat trout (USFWS jurisdiction) and listed Columbia River salmonid ESUs (NMFS jurisdiction) and formal consultation was entered into with the USFWS and NMFS to address affects to these species. The Biological Opinion prepared by the NMFS concluded that the proposed action is not likely to jeopardize the continued existence of all listed Columbia River salmonid ESUs under their jurisdiction. NMFS also concluded that the project would not result in the destruction or adverse modification of then-designated critical habitat for salmonids.[1] The USFWS concluded that the proposed action is not likely to jeopardize the continued existence of bull trout, coastal cutthroat trout (subsequently not listed), bald eagles, or Columbian white-tailed deer. They concurred with the Corps' determination on the other listed species under their jurisdiction. The Corps will comply with numerous terms and conditions listed in the Biological Opinions prepared by the Services in order to implement the 'reasonable and prudent measures' identified. Corps

[1] Although the Biological Assessment and Biological Opinion addressed potential effects on salmonid critical habitat, NMFS has since withdrawn the designation of such habitat.

actions will address dredging impact minimization measures, best management practices, monitoring activities, ecosystem restoration features, and ecosystem research actions.

f. Marine Sanctuaries [40 CFR § 230.10(b)(4)]. No marine sanctuary designated under Title III of the Marine Protection, Research, and Sanctuaries Act of 1972 will be affected by the proposed action.

g. No Significant Degradation [40 CFR § 230.10(c)].

As discussed in the Final and Supplemental IFR/EIS and in the factual determinations above:

(1) The proposed action, including wildlife mitigation actions and ecosystem restoration features, would not result in significant adverse effects on human health or welfare, including municipal water supplies, plankton, fish, shellfish, or wildlife.

(2) Significant adverse effects on life stages of aquatic life and other wildlife dependent on the aquatic ecosystem, on ecosystem diversity, productivity, or stability, or on recreational, esthetic, or economic values would not occur.

(3) No significant adverse effects on aquatic ecosystem diversity, productivity and stability are expected due to avoidance, impact minimization, mitigation of impacts, and implementation of best management practices, monitoring actions, and research actions to assess project-related impacts throughout the project life.

(4) No significant adverse effects of the discharges are expected on recreational, aesthetic and economic values.

h. Minimization of Impacts [40 CFR § 230.10(d)]. Initial efforts focused on avoiding or minimizing impacts to the extent practicable during selection of disposal sites. Avoidance was accomplished by focusing disposal at existing and previously used disposal sites. Sites with wetland and riparian habitat were avoided to the extent practicable. The two wetland sites that will be filled are of low quality, function and value. Adjustment of disposal site boundaries to avoid riparian and wetland habitat where possible, based on site visits and aerial photography, has also continued throughout the process. Additional appropriate steps to minimize potential adverse impacts, in accordance with the BMP's that resulted from the ESA consultaion, would be specified in the dredging contracts for new construction efforts and/or dredging orders for O&M dredging actions. With the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem, the proposed discharge is specified as complying with the requirements of Section 404(b)(1) guidelines.

V. Conclusions

The factual determinations and findings in this evaluation summarize and incorporate information on and analysis of related issues contained in the Final and Supplemental IFR/EIS.

On the basis of the factual determinations and findings made above, I conclude that the proposed disposal sites for discharge of dredged materials as outlined in the *Integrated Feasibility Report for Channel Improvements and Environmental Impact Statement* and the *Supplemental Integrated Feasibility Report and Environmental Impact Statement* comply with the Guidelines at 40 CFR Part 230 and with the requirements of Executive Order 11,990 (Protection of Wetlands).

I further conclude, based on the factual determinations and findings made above, in combination with the Final and Supplemental IFR/EIS' analysis of other potential environmental impacts of the project as well as the projected contribution to National Economic Development, that the proposed discharge of dredged material associated with the project is in the overall public interest.

Date: ____________________

Richard W. Hobernicht
Colonel, EN
Commanding

EXHIBIT F
COASTAL ZONE MANAGEMENT ACT CONSISTENCY DETERMINATION (REVISED)

Table of Contents
Exhibit F
Coastal Zone Management Act Consistency Determination (Revised)
Columbia River Navigation Channel Improvement Study
Oregon And Washington

COASTAL ZONE MANAGEMENT ACT CONSISTENCY DETERMINATION (Revised)
COLUMBIA RIVER NAVIGATION CHANNEL IMPROVEMENT STUDY
OREGON AND WASHINGTON

Introduction

The proposed federal actions addressed in this consistency determination are described in the Final *Integrated Feasibility Report and Environmental Impact Statement* (IFR/EIS) dated August 1999 and Supplemental IFR/EIS. These actions include deepening the authorized 40- feet depth channel, with advanced maintenance to 45-feet, to an authorized depth of 43-feet with advanced maintenance to 48- feet; and disposal of the dredged material at Miller Sands and Skamokawa beach nourishment sites, disposal of dredged material at several upland sites, in-water estuarine (flowlane) disposal, disposal of dredged material in the Deep Water ocean disposal site, restoration via beneficial use of dredged material of tidal marsh habitat at Lois Island embayment and tidal marsh/intertidal flat habitat at the Miller-Pillar location, and restoration of tidal connection and intertidal habitat within Tenasillahe Island based on the recommendations in the Final *Integrated Feasibility Report for Channel Improvements and Environmental Impact Statement*, dated August 1999 (Final IFR/EIS) and the Supplemental IFR/EIS. The Final SEIS is expected to be released to the public no later than January 30, 2003.

The Supplemental IFR/EIS updates information, environmental analyses, and project modifications resulting from consultation of the Columbia River Channel Improvement Project under Section 7 of the Endangered Species Act (ESA). Additional ecosystem restoration features also have been incorporated into the Project. These features would be constructed using several different means. The Lois Island Embayment and Miller-Pillar habitat restoration efforts would be constructed via placement of dredged material to attain target depths at each location. Miller-Pillar would also require construction of a pile dike field (five pile dikes) to hold the dredged material in place.

This determination of consistency with the Coastal Zone Management Program is based on review of applicable Oregon Statewide Planning Goals and Guidelines, Washington Coastal Zone Management Program and policies and standards of the Clatsop County Comprehensive Plan and Pacific and Wahkiakum County (Washington) Shoreline Management Programs. Additional discussion of consistency with the Pacific and Wahkiakum County Shoreline Management Program is contained in the Technical Memorandum prepared under the Washington State Environmental Policy Act and is incorporated by this reference.

Proposed Actions

<u>Dredging</u>

Dredging would be accomplished by both hopper and pipeline dredge within the coastal zone. Bathymetric changes will include up to 3 feet of deepening in areas of the navigation channel that are currently shallower than -43 feet CRD, with an additional 5-feet of advance maintenance. The exact amount of riverbed lowering and the final dredging locations will depend on river bathymetry just prior to construction. There will be no changes in bathymetry in the approximately 55% of the navigation channel in this reach that will not require dredging. There is a potential for 0-3 feet of deepening along the side-slopes adjacent to the dredge cuts in the 5-10 years following construction. The estimated total quantity of construction dredging (new work and 40-foot maintenance) in the estuary is 11 million cubic yards (mcy). The estimated maintenance quantities over the 20 years following deepening are estimated at 53 mcy.

Disposal

Proposed disposal within the area defined by the coastal zone boundaries of Oregon and Washington include:

Oregon
James River (upland)
Tenasillahe Island (upland)
Welch Island (upland)
Pillar Rock Island (upland)
Miller Sands Spit (shoreline)
Miller-Pillar Ecosystem Restoration Feature
Lois Island Ecosystem Restoration Feature

Washington
Brown Island (upland)
Puget Island (upland)
Skamokawa (shoreline)

Rice Island in both States (upland)
Flowlane Disposal in both States

This consistency determination will focus on the proposed new disposal sites at Puget Island, new flowlane disposal locations at CRM 5 and CRM 29-40, and disposal on Welch Island and an expanded area for Miller Sands Spit. The other sites within the coastal zone are designated disposal sites previously used for maintenance of the 40-foot channel. These sites have been reviewed and determined consistent with State and local plans for dredged material disposal. Use of all existing and proposed new sites will conform to the estuary standards described herein.

Disposal within the flowlane would raise the riverbed intermittently along the channel throughout the life of the Project. Flowlane disposal will generally be in portions of the river in or near the navigation channel between elevations -50 and -65 feet CRD. Two proposed flowlane locations (in the vicinity of CRM 5 and at various locations between CRM 29-40) are at elevations greater than -65 feet CRD. The sand will be spread out during disposal by keeping hopper dredges moving as they dump and by frequently moving the discharge pipe from a pipeline dredge. The disposal material will then be incorporated into the riverbed, forming sand waves and gradually moving downstream, mainly as bedload transport. Flowlane disposal in the estuarine reach is expected to be about 2 mcy during construction and about 24 mcy over the first 20 years of maintenance.

Both Welch Island and Miller Sands Spit would be used for maintenance disposal only. Disposal at Miller Sands Spit is estimated at 7 mcy over a 20-year period. Disposal at this location utilizes only a fraction of the total site area in any given year. Use of the entire 151-acre site would likely occur over a several year timeframe. Disposal at the 42 acre Welch Island site is estimated at about 450,000 cy over a 5 year period. Use of this site would be for channel maintenance only.

The Draft SEIS describes two ecosystem restoration features, including restoration of tidal marsh and/or shallow water habitat at Miller-Pillar and Lois Island embayment. Construction of the Millar-Pillar and Lois Island embayment features would use dredged materials from construction and maintenance that otherwise would have been taken to the ocean. With the implementation of these two ecosystem restoration sites, the placement of dredge material in the ocean should not be necessary. In the event dredge material from the channel did go to the ocean it would be discharged into a site designated under Section 102 of the Ocean Dumping Act. Such discharge would be in accordance with the management and monitoring plan as require by the Ocean Dumping Act. At this point in time, we fully anticipate that the Deep Water Site would be the site designated under Section 102. A complete set of project documents, including project maps have been provided to WDOE staff.

Ecosystem Restoration Features

Lois Island Embayment

The area for the restoration is approximately 190 acres. It would occupy the northeastern portion of the embayment along Lois Island.

Restoration of the Lois Island Embayment would require about 6 mcy of material from initial construction. The initial construction material would originate from the navigation channel between CRM 3-30. Material dredged from the navigation channel would be transported via hopper dredge and temporarily placed in the flowlane (CRM 18-20) near the entrance of the Tongue Point channel. No deep draft vessels currently call at Tongue Point because industrial facilities requiring their service have not been developed. Consequently, placement of dredged material in the channel entrance would not compromise vessel traffic. After placement of dredged material in the temporary flowlane location, a pipeline dredge would be used to transfer the material into the embayment to the target elevations. These target elevations would be predicated on surveyed elevations for existing tidal marsh habitat at this location.

Miller-Pillar

This ecosystem restoration feature is located between Miller Sands and Pillar Rock Islands in the Columbia River estuary (CRM 25-26). Natural processes are currently eroding material south of the navigation channel and redepositing the material in the navigation channel. This erosive action has been occurring since 1958 at an average annual rate of approximately 70,000 cubic yards. The erosion is affecting productive, shallow water and flats habitat (0-6 feet CRD) and converting the area to less productive, deep subtidal habitat (a minimum depth of 25 feet). Restoration of the erosive area to tidal marsh and intertidal flats habitat can be accomplished by placement of dredged material at the location to mimic the existing elevation of the tidal marsh/intertidal flat complex at the upstream end of Miller Sands Island. Approximately 6 mcy of material would be required to develop the targeted habitats. Dredged material placed at this location would be comparable to *in situ* materials. Dredged material retention will require the construction of pile dikes to reduce water velocities and maintain the desired substrate elevations. Three pile dikes would be constructed during the construction phase of the project to create suitable conditions for retention of dredged material placed at this location and establishment of tidal marsh and intertidal flat habitat. This ecosystem restoration feature will be monitored post-construction to assure that productive tidal marsh and intertidal flat habitat has developed. Upon that determination, additional tidal marsh and intertidal flat habitat would be developed at this location, to include the construction of two additional pile dikes.

The dredged material would be obtained from the deepened navigation channel during subsequent maintenance dredging operations. This restoration feature will be phased during O&M, with dredged material placed to the target elevation, beginning at the downstream border and moving upstream. This would create tidal marsh and intertidal flat habitat to benefit salmonids. The time frame to accomplish this restoration depends on the volume of maintenance dredging material that accumulates in the navigation channel. Pipeline dredges would supply the material from adjacent bars, as the area is too shallow for placement via hopper dredge. Barging of material to the location for placement is physically feasible, although unlikely from a cost standpoint.

Tenasillahe Island

Two restoration actions are anticipated for this location. The interim action would be directed at improving connectivity and water exchange between sloughs/backwater channels interior to the levees and the Columbia River. This would be accomplished through interim and long-term improvements to tidegates and provision of controlled inlets to improve water movement and accessibility for juvenile salmonids. Implementation of the interim action is contingent on hydraulic engineering analyses to ensure that any improvement will not compromise habitat integrity for Columbia white-tailed deer that inhabit Tenasillahe Island.

For the long-term action, the levees would be breached to restore full tidal circulation to approximately 1,778 acres of former intertidal marsh/mudflat and forested swamp habitat. The long-term action is contingent on delisting of the Columbia white-tailed deer and determination that such actions are compatible with the purposes and goals of the refuge, to include restoration of intertidal marsh/mudflat and forested swamp habitat for ESA Critical Habitat for salmonids.

Consistency Review

Oregon State-wide Planning Goals and Guidelines

Goal 16 - Estuarine Resources. The Columbia River estuary is classified as a "Development Estuary." This classification allows for uses such as navigation development and dredged material disposal in development management units. Implementation of estuary plans is the responsibility of local jurisdictions. Proposed new actions affecting the estuary will be reviewed by the state and local agencies having coastal zone jurisdiction. Actions occurring outside the coastal zone, including channel deepening may have an effect on resources utilizing the Columbia River estuary such as marine mammals and anadromous fish. The EIS prepared for this action addresses direct, indirect and cumulative effects on these species and concludes that no significant impact would result from this action. See additional discussion regarding consistency with local plans.

Goal 19-Ocean Resources. This goal requires that agencies determine the impact of proposed projects or actions. Paragraph 1(c) of Goal 19 states that "agencies ... shall 1. protect and encourage the beneficial uses of ocean resources such as navigation ... provided that such activities do not adversely affect the resources protected in subsection 1., avoid, to the extent possible, adverse effects on or operational conflicts with other ocean uses and activities; and 2. comply with applicable requirements of the Oregon Territorial Sea Plan." According to the provisions of Goal 19 and the Oregon Territorial Sea Plan, decisions to take such an action, such as using an ocean disposal site, are to be preceded by "inventory information necessary to understand potential impacts and relationship of the proposed activity to the continental shelf and near shore ocean resources." In addition, there should be a contingency plan and emergency procedures to be followed in the event that the operation results in conditions that threaten to damage the environment.

Guidelines for ocean disposal of dredged material are specified by the U.S. Environmental Protection Agency (USEPA) in 40 CFR Part 227 (Ocean Dumping Regulations). Specification of suitable dredged material is based on evaluation of the potential impacts. An evaluation of suitable ocean disposal sites, demonstrating compliance with parts 227 and 228, is included as Appendix H and in the Section 103 Evaluation in Exhibit D of the IFR/EIS. The new site(s) will be selected upon completion of the EPA site designation process. Under the preferred option presented in the Supplemental IFR/EIS, construction of the Millar Pillar and Lois Mott ecosystem restoration features would use dredged materials from construction and maintenance that otherwise would have been taken to ocean disposal. With the use and implementation of the two estuarine restoration sites, the ocean disposal should not be necessary. In the event dredge material from the channel did go to the ocean, it would go to a site designated for ocean disposal under Section 102 of the Ocean Dumping Act. At this point in time, we fully anticipate that the site designated under the ODA for potential use on this Project will be the Deep Water Site. Compliance with Goal 19 and the Oregon Territorial Sea Plan, Part II Resource Inventory and Effects Evaluation, will be met once the requirements and criteria contained in parts 227 and 228 are completed. Remaining actions to be completed include a biological baseline study and further analysis of potential Dungeness crab impacts. Additional discussion of effects on ocean resources and activities is included in the following.

Other Oregon Revised Statutes Applicable to the Oregon Coastal Management Program

ORS Chapter 274 - Submersible and Submerged Lands. This statute applies to disposal of dredged material below ordinary high water of the Columbia River. The environmental impact evaluation and public review process provided by the Supplemental IFR/EIS, and the evaluation under Section 404 (b)(1) Evaluation satisfy the substantive federal requirements of this statute. ORS 274.550(1) specifically authorizes the "removal of material from submersible lands of any navigable stream . . . when the material is removed for channel or harbor improvement." Any conflicts with existing state leases or uses will be resolved prior to in-water disposal.

ORS Chapter 496 - Wildlife Laws. The wildlife inventory and impact analysis contained in the Supplemental IFR/EIS, including analysis under the Endangered Species Act, addresses the requirements of this statute. All proposed actions have been or currently are coordinated with Oregon Department of Fish and Wildlife.

In addition to the species listed under the Endangered Species Act that were the subject of consultation with US Fish and Wildlife Service and NOAA Fisheries, the State of Oregon has requested that the Corps include Lower Columbia River native coho salmon listed as endangered under the State's ESA. Coho spawn in small, relatively low gradient tributaries in the lower Columbia River. Juveniles rearing in these tributaries for two years before migrating to the ocean. Adult coho return to spawn as three year olds. Lower Columbia River Coho are predominately of hatchery origin, with only the Clackamas and Sandy Rivers still having wild runs. Most of the coho juveniles in the Channel Improvement project area are of hatchery origin and are released from mainstream and tributary hatcheries as smolts. Coho juveniles are considered stream type since most of their rearing occurs in the tributary areas. Consequently, the analysis of the impacts to federally listed stocks with stream type juveniles by the Channel Improvement Project consultation would apply for coho as well. In additional all the monitoring and restoration actions proposed for the federally listed stocks would be beneficial for juvenile coho as well. Adult coho return in the same time frame as federally listed stocks of adult Fall chinook and would use the same habitat. Consequently, the assessment done for adult Fall chinook would be applicable for coho. As a result, the Biological Assessment and Biological Opinion prepared for the Channel Improvement Project for the Federally listed stocks in the Columbia River is considered adequate for the assessment of impacts to Lower Columbia River coho.

In that assessment the Corps and Services developed a conceptual model of the Lower Columbia River ecosystem relationships that are significant for salmonids. This model also applies to Lower Columbia River coho. Because the habitat requirements of adult salmonids are limited in the lower Columbia River, the model focuses on juvenile salmonids. The conceptual model incorporates the best available science for adult and juvenile salmonids. The basic habitat-forming processes-physical forces of the ocean and river-create the conditions that define habitats. The habitat types, in turn, provide an opportunity for the primary plant production that gives rise to complicated food webs. All of these pathways combine to influence the growth and survival and, ultimately, the production and ocean entry of juvenile salmonids moving through the lower Columbia River.

The conceptual model also demonstrates that the Project complies with the Survival Guidelines in ORC 635-100-135. Specifically, the analysis demonstrates that the Project should not degrade water quality, reduce stream flows, affect gravel in spawning areas, or adversely affect riparian habitat.

Although none of the changes identified in the conceptual model from the Channel Improvement Project are believed to have a measurable effect on existing habitat types, the Corps is proposing to implement compliance measures to ensure effects will be minimized and will also monitor to confirm this conclusion. In addition, proposed ecosystem restoration and research actions will benefit Lower Columbia River coho. Based on the above, the project will not have a significant effect on native Lower Columbia River coho.

<u>ORS Chapter 506 - Commercial Fishing and Fisheries</u>. Although this statute does not apply directly to the proposed action, the proposed action may affect commercial fishing in the estuary and ocean. The Supplemental IFR/EIS describes the potential impact to these fisheries and means to avoid or minimize these impacts.

<u>ORS Chapter 509 - General Protective Regulations</u>. The Supplemental IFR/EIS describes minimizing or mitigating for habitat losses from the deepening Project.

<u>ORS Chapter 468A - Air Quality</u>. The Supplemental IFR/EIS addresses potential air quality impacts from the deepening Project. Essentially, all air quality standards would be met.

<u>ORS Chapter 468B - Water Quality</u>. The Supplemental IFR/EIS and Section 404 (b)(1) Evaluation prepared for this action address all water quality evaluations required by this statute.

Clatsop County Comprehensive Plan
Columbia River Estuary Land and Water Use Plan

Section P20, Estuary Shoreland and Aquatic Regional Policies

<u>P20.5, Dredging and Dredged Material Disposal</u>. As described in the report documents and elsewhere in the consistency determination, the proposed action complies with applicable policies with the possible exception of proposed disposal at Welch Island and expanded Miller Sands site and flowlane disposal at depths below 65 feet MLLW. See Standards, S4.232 below.

P20.6, Estuarine Construction. Proposed pile dike construction between Miller Sands and Pillar Rock Islands and installation of inlet structures at Tenasillahe Island apply under this policy. These actions are addressed under the estuary standards, S4.208 in compliance with this policy.

P20.8, Fish and Wildlife Habitat. The proposed action, as coordinated with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service, complies with this policy regarding protection of endangered or threatened species habitat and protecting nesting, roosting, feeding and resting areas used by resident and migratory bird populations. See Standards, S4.239. No major marshes, significant wildlife habitat, coastal headlands or exceptional aesthetic resources would be adversely affected by the proposed action.

P20.12, Mitigation. The proposed flowlane disposal at depths greater than 65 feet MLLW has been identified as an activity that may cause a loss of aquatic resources. Coordination with state and federal resource agencies resulted in an agreement to conduct sturgeon, smelt and benthic invertebrate sampling to determine if significant numbers of these species occur in these areas. The results of these studies indicate minimal impact to smelt or benthic invertebrates from dredging or disposal. Behavioral research by the USGS, funded by the Corps, will be used to manage the dredging and disposal operations to minimize impacts to sturgeon populations. See further discussion under *Columbia River Aquatic Use and Activity Standards* and the Supplemental IFR/EIS, Chapter 6.

P20.19, Water Quality Maintenance. This policy does not address water quality effects from dredging and dredged material disposal activities. The proposed dredging and disposal actions, however, would not degrade estuarine water quality. See further discussion under standards Section 4.242.

P21.5, State and Federal Consistency. The proposed navigation channel deepening action is being reviewed for consistency with the regional policies, development standards and land and water use designations in the comprehensive plan.

Section P30, Estuary Subarea Plans

P30.3, Estuary Channels (deep water estuary from Columbia river miles 3.0 to 22.5). The navigation channel and adjacent flowlane area are designated Aquatic Development, which allows for dredging and dredged material disposal.

P30.5, River Channels (Harrington Point to western end of Puget Island). The main navigation channel and adjacent flowlane disposal areas are designated Aquatic Development.

Section P40, Columbia River Estuary Dredged Material Management Plan

P40.1, Purpose and Content. Describes the *Dredged Material Management Plan* prepared by CREST in 1979 and revised in 1986. The plan serves as a guide to dredging Projects sponsors and regulatory agencies. The plan lists some possible disposal sites; however, the plan explicitly notes that it "is not intended to be an exhaustive list of all possible disposal sites and it in no way restricts the disposal of dredged materials to designated sites only." The plan is incorporated by reference via Section P60, Appendices, to the County Comprehensive Plan and applicable plan policies have been fully incorporated into comprehensive plan policy 20.5, Clatsop County development standard S4.232 and other Clatsop County provisions addressed in this consistency determination. For the reasons discussed under these provisions, with the possible exception of the proposed actions described below, the proposal is consistent with the existing dredged material disposal plan.

The plan identifies a smaller site than is identified at Miller Sands and does not identify Welch Island as a disposal site (although it has been used since the 1970s). As noted above, the plan notes that it "no way restricts the disposal of dredged materials" to these sites. The plan also establishes the depth for flow lane disposal between 20 and 65 feet below MLLW. The CREST is currently updating the Dredged Material Management Plan. The updated plan recognizes that the Welch Island disposal site has been used for disposal since the 1970's, was inadvertently not included in the original plan, and should reasonably continue to be used as a disposal site. The updated plan also recognizes that expanding the existing 98 acre Miller Sands beach nourishment site to 151 acres is warranted compared to other potential disposal alternatives, would not unreasonably degrade estuarine resources or uses and should be included in the revised plan. With the inclusion of these sites in the revised plan, the proposed disposal actions would be consistent with this policy.

The plan also identifies flowlane disposal at depths up to a maximum of 65 feet. The proposed disposal would extend beyond that depth at river mile 5 and between river miles 29 and 40. A plan exception under the procedures outlined in OAR 660-004-0020 is proposed for flowlane disposal at these greater depths. The request for a plan exception will be based on a "reasons" exception under OAR 660-004-0020(1). The exception will evaluate the reasons for the exception, consistent with OAR 660-004-0022(7), the lack of availability of exception areas to reasonably accommodate the material to disposed of through flow-lane disposal below 65 feet, the long-term environmental, economic, social and energy consequences resulting from the exception, and how the flow lane disposal will be rendered compatible with adjacent uses. The need for disposal at these locations is discussed in the IFR/EIS and demonstrates that other reasonable alternatives are not available. The resource analysis discussed in the Supplemental IFR/EIS includes studies conducted to determine potential impacts to smelt, sturgeon and benthic invertebrates. The studies have been completed for smelt and benthic invertebrates and have concluded that the flowlane disposal would not result in unacceptable or appreciable impacts to these species. Behavioral research by the USGS, funded by the Corps, will be used to manage the dredging and disposal operations to minimize impacts to sturgeon populations. Recent analysis also demonstrates that the disposal material would remain in the active sand transport zone and would migrate downstream as bedload material.

Columbia River Estuary Shoreland and Aquatic Zones

Section 3.740, Aquatic Development Zone. In-water disposal sites within or adjacent to the navigation channel are within the Aquatic Development Zone, which permits dredged material disposal in conjunction with navigation at designated sites. See additional discussion of flowlane disposal modification under Columbia River Estuary Aquatic Use and Activity Standards and Columbia River Estuary Land and Water Use Plan.

Section 3.760, Aquatic Conservation Two Zone. The ecosystem restoration feature at Lois Island embayment lies within an Aquatic Conservation Zone and is an approved use. The proposed restoration feature at Miller-Pillar also occurs within this zone and is therefore an approved use. Restoration is a permitted activity in this zone provided all standards for estuary work are met. The proposed ecosystem restoration features would comply with all applicable standards (See standards discussion below).

Section 5.125, Consistency Review Procedure for Federal Activities and Development Projects. This Coastal Zone Management Act consistency determination has been prepared for review by the States of Oregon and Washington.

Sections 5.810-5.840, Impact Assessment. Development activities that could potentially alter the estuarine ecosystem (i.e., dredged material disposal, riprap, fill, in-water structures, etc.) require an impact assessment. An EIS and SEIS that discuss the effects of the proposed actions on the existing resources of the Columbia River has been prepared. The EIS and Supplemental EIS fulfill the requirement of a separate impact assessment. The results of the EIS and Supplement indicate that the proposed activities do not represent a potential degradation or reduction of significant fish and wildlife habitat and essential properties of the estuarine resource.

Columbia River Estuary Shoreland and Aquatic Use and Activity Standards

S4.208, Estuarine Construction. Applies to in-water structures including pile dikes; may be allowed only if the following criteria are met:

a. If a need (i.e., a substantial public benefit) is demonstrated; and
b. The proposed use does not unreasonably interfere with public trust rights; and
c. Feasible alternative upland locations do not exist; and
d. Potential adverse impacts, as identified in the impact assessment, are minimized.

Construction of pile dikes is proposed in conjunction with the proposed ecosystem restoration feature at Miller-Pillar.

The standards require that structural shoreline stabilization measures be coordinated with state and federal agencies to minimize adverse effects on aquatic and shoreline resources and habitats. Comments were received from agencies in the Draft and Final IFR/EIS review. Concerns were raised regarding the potential for increased predation of juvenile salmonids by piscivorous birds. Pile dikes have been used as perches by these birds, particularly cormorants. NOAA Fisheries recommended further studies to evaluate the effects of pile dikes on salmonid predation. These studies have been completed and concluded that the use of bird excluders on pile dike structures all but eliminated predator bird perching on the pile dikes. Any new pile dike construction would include installation and maintenance of bird excluders.

The proposed tidegate and circulation improvements at Tenasillahe Island also apply to this standard. These are minor construction activities that would benefit juvenile salmon feeding and rearing area within the estuary. This action has been coordinated with state and federal resource agencies. The construction would conform to all regulatory requirements to minimize impacts on aquatic resources.

S4.209, Deep-Water Navigation, Port and Industrial Development. The proposal is consistent with this standard for the reasons set forth in the discussion of S4.232, Dredging and Dredged Material Disposal, and in the 1999 IFR/EIS and SIFR/EIS.

S4.218, Mitigation and Restoration. The proposal is consistent with this standard for the reasons discussed above under Clatsop County Comprehensive Plan Policy 20.12, Mitigation.

S4.230, Bankline and Streambed Alteration. The proposal is consistent with this standard. Stream surface area will be maintained, existing deepwater channels will be used, undesirable hydraulic conditions will not be created, and adverse effects on estuarine resources, if any will be minimized as discussed under Clatsop County Comprehensive Plan Policy P20.12 and Clatsop County Standard S4.232.

S4.232, Dredging and Dredged Material Disposal. Dredging is conducted for navigational purposes as allowed by the plan. Dredging, disposal site selection and the material to be disposed comply to the maximum extent practicable with appropriate sections of S4.232. The need for channel deepening is identified in Chapter 3 of the EIS, as well as receiving the support of the sponsoring lower Columbia River Port Districts.

Undesirable erosion, sedimentation, increased flood hazard and circulation changes are not expected based on the results of the hydraulic done as part of the salinity intrusion analysis conducted for this study. See Appendix F of the Final IFR/EIS and Draft Supplemental IFR/EIS, Chapters 4, 5, and 6. This analysis essentially concluded changes in flow patterns from a 3-foot channel deepening would be imperceptible.

Based on the conclusions described in Chapters 2 and 6 of the IFR/EIS, short-term dredging and disposal effects are expected to be minor within the estuary reach when compared to existing 40-foot channel dredging and disposal. Most of the work occurs in areas currently disturbed on an annual basis. Dredging and disposal would occur in deeper areas that are lower in benthic productivity. Some destabilization of near channel side slopes would occur for 5-10 years following initial deepening.

All relevant state and federal water quality standards will be met and sediments evaluated in accordance with the Regional Testing Manual. All Columbia River sediments from navigation channel dredging are suitable for unconfined in-water disposal.

Alternatives to reduce disposal in the estuary have been evaluated. Existing upland and any proposed new upland sites available within the estuary would be used to their capacity. Disposal area capacity has been determined to be adequate for initial dredging and at least 20 years of maintenance dredging for the Project.

Flowlane disposal would occur primarily in areas at depths greater than 50 feet. Chapters 4, 5 and 6 of the IFR/EIS describe these areas and identify resources that may be present at these locations. Disposal is proposed for depths greater than 65 feet downstream of CRM 5 and at various locations between CRM 29-40.

Disposal within these areas is expected to slightly change bottom elevations. This material would reform as sand waves and gradually move downstream with the river bedload. The actual change in bed elevations that would occur would depend on factors such as the total area used for disposal, the volumes disposed and the amount of material transported away from the sites. About 2 mcy of this material disposed within the estuary reach would be from construction of a deeper channel. Maintenance dredging material (estimated 24 mcy over 20 years) would increase slightly over existing 40-foot channel maintenance quantities. Estimated quantities proposed for disposal at locations below 65 feet are 8 mcy of maintenance material over 20 years in the vicinity of CRM 5, and 2 mcy construction material and 12 mcy 20-year maintenance material between CRM 29-40.

Resource agencies have expressed concern over potential impacts to juvenile sturgeon, smelt larvae and benthic invertebrates within areas proposed for flowlane disposal. Biological sampling has been conducted to determine the location and extent of these resources. The sampling results indicate that disposal at these locations would have minimal impact to smelt and benthic invertebrate populations. The sampling data indicates that there could be potential impacts to sturgeon from disposal within the sites. If ongoing baseline studies or monitoring indicate unacceptable impacts to sturgeon or sturgeon habitat, alternative disposal methods, disposal timing or other means to avoid or minimize impacts will be implemented. Overall sturgeon habitat or populations would not be significantly affected. See the Supplemental IFR/EIS, Chapter 6 for further discussion.

Concerns over continued disposal at Rice Island and its attraction to Caspian terns for nesting and feeding on juvenile salmon have also been raised. Recent actions by the Corps to discourage nesting on Rice Island have been successful and juvenile salmon predation has been significantly reduced. These current actions will continue. Long term Caspian tern management actions to address estuarine population levels and distribution of terns in the western U.S. are in progress by the U.S. Fish and Wildlife Service, Corps, NOAA Fisheries and other State and Federal resource agencies.

The Deep Water disposal site proposed for designation is beyond the limits of the Territorial Sea and is not within Clatsop County jurisdiction. Since this action may affect the resources of the states of Oregon, it would be applicable to Oregon Statewide Goal 19. Designation and use of that site is addressed in the IFR/EIS, Appendix H and the Section 103 Evaluation (Exhibit D). The current preferred alternative would utilize the Lois Island embayment and Miller-Pillar ecosystem restoration features for disposal of channel material, plus flowlane and existing disposal sites. This should eliminate the need for ocean disposal.

S4.235, Filling of Aquatic Areas and Non-Tidal Wetlands. The proposed actions affected by this standard is "flowlane disposal" in the vicinity of river mile 5 and between river miles 29 and 40 and implementation of ecosystem restoration features at Lois Island embayment and Miller-Pillar. Flowlane disposal at the proposed quantities and rates would slightly raise bottom elevations at these locations. Although this action is technically considered fill, it is not converting aquatic area into uplands as implied in this standard. Dredged material placed at flowlane locations would continue to slowly move downstream as bedload material. As previously stated, biological sampling has been conducted to identify areas where significant resources can be avoided or impacts minimized.

The two restoration areas are subtidal aquatic areas considered to have low biological productivity. Creating tidal marsh and intertidal flats habitat would increase biological productivity and would particularly enhance feeding and resting area for juvenile salmon. The proposed restoration features could potentially disrupt commercial salmon harvest at these locations. As discussed in the SEIS, about 19% of available area for gillnet fishing in the Tongue Point select area fishery would be displaced by the Lois Island embayment fill. A drift net fishery encompasses the Miller-Pillar ecosystem feature. The phased implementation of this feature will delay the level of impact to commercial fishing interests. We project at full development of this feature that 14% of the Miller Sands Drift would be impacted to the extent that drift fishing would be precluded.

S4.237, Riparian Vegetation Protection. The proposed dredging or disposal work would disturb no riparian vegetation.

S4.239, Fish and Wildlife Habitat. The proposed action is being coordinated with state and federal resource agencies. Comments and recommendations from those agencies have been and will continue to be considered in the development of the plan. Measures to avoid or minimize impacts to aquatic resources, such as timing, in-water disposal site depths and dredging methods would be incorporated into the proposed action. As noted in our response to S4.232 and S4.235, biological sampling has been conducted to determine presence of significant resources in this area. The data will be used to identify the preferred mitigation measures of avoiding or minimizing impacts to significant resources.

S4.241, Significant Areas. No significant areas as defined by this standard would be affected by the proposed action.

S4.242, Water Quality Maintenance. The potential adverse water quality effects have been addressed in the FEIS and SEIS prepared for this action. Dredging and disposal of Columbia River navigation channel sediments would not contribute to unacceptable levels of turbidity, dissolved oxygen, biochemical oxygen demand or contaminants. Salinity intrusion from deepening has been analyzed and determined to have no significant change. The proposed action has no effect on water temperature. Sediment distribution has been analyzed and would not significantly change from present conditions.

Washington Coastal Zone Management Program

Shoreline Management Act, chapter 90.58 RCW

The Shoreline Management Act ("SMA"), chapter RCW 90.58 RCW is the core authority of Washington's Coastal Zone Management Program.

State Policy

RCW 90.58.020 enunciates the following state policy:

- To provide for the management of the shorelines of the state by planning for and fostering all reasonable and appropriate uses..
- To insure the development of shorelines in manner that promotes and enhances the public interest while allowing only limited reduction of rights of the public in the navigable waters.
- To protect against adverse effects to the public health, the land and its vegetation and wildlife, and the waters of the state and their aquatic life, while protecting generally public rights of navigation and corollary rights.

The Project is consistent with this broad statement of policy. As discussed in detail under the discussion of Shorelines of Statewide Significance, the Project improves the federal navigation channel enhancing the navigability of this water body and restores a number of areas. The navigation and restoration components promote the public interest in having an efficient means of transporting goods in the navigation channel and to have areas along the Columbia River restored. The Project employs many measures, to protect against or mitigate adverse effects.

Shorelines of Statewide Significance.

The SMA establishes use preferences for shorelines of state-wide significance. The Project is consistent with the criteria for activities within shorelines of statewide significance as follows:

1. Recognize and protect the statewide interest over local interest.

The Project furthers the interests of Oregon and Washington and recognizes the statewide, regional, and national interests in interstate commerce over local interests. The primary purposes of the Project are to improve the deep-draft transport of goods on the authorized

40-foot deep Columbia River navigation channel, and to provide ecosystem restoration for fish and wildlife habitats. The Project will enhance the efficiency of navigation on the Columbia River and improve navigational access for goods throughout Oregon, Washington and the region Navigation is one of the principal public uses recognized and protected under the public trust doctrine and the Washington Shoreline Management Act. (Johnson, The Public Trust Doctrine and Coastal Zone Management in Washington State, Washington Law Review July 1992). The Columbia River is an international gateway for waterborne cargo for the Pacific northwest region and the United States. More than 35 million tons of cargo are shipped annually on approximately 2,000 ocean-going vessels via the ports of Kalama, Longview and Vancouver in Washington, and Portland and St. Helens in Oregon. In 2000, cargo valued at $14 billion was shipped via lower Columbia River ports. The Columbia River corridor serves as a funnel for cargo moving from more than 40 states, which is then shipped from Columbia River ports.

Since the last improvement to the Columbia River navigation channel, authorized in 1962, the volume of cargo carried by deep-draft vessels to and from Columbia River ports has tripled. During the same period, the average tonnage per vessel has also tripled, while the number of deep-draft vessels calling at Columbia River ports declined slightly. Over the past 20 years, an increasing share of the Columbia River cargo tonnage has been carried on vessels that are Panamax class (the largest size vessels that can transit the Panama Canal) or larger. These larger vessels have design drafts that, after allowing for underkeel clearance requirements, exceed the depth allowed by the 40-foor channel; consequently, these ships must often come into the Columbia River ports “light loaded” (i.e., only partially loaded). Currently, more than 70 percent of the vessels deployed in the transpacific container trade are constrained by the 40-foot channel depth. This amount would be reduced to 39 percent with a 43-foot channel. By deepening the navigation channel, the Project will continue to support these water-dependent uses that are vital to the economies of Oregon and Washington.

Ecosystem restoration also recognizes the statewide interest. Proposed restoration focuses on habitat types that have been determined to be important to species listed under the Endangered Species Act, including Columbian white-tailed deer, bald eagles, and salmonids. This habitat will also benefit a variety of non-listed species.

2. Preserve the natural character of the shoreline and minimize man-made intrusions on shorelines.

The Project includes restoration features to help restore the natural function of shoreline ecosystems and minimize intrusions on shoreline areas. The Project’s restoration components responds to a well-demonstrated need for ecosystem restoration and incorporates many restoration actions.

The Project uses dredging and disposal methods similar to those used for maintenance dredging that are designed to minimize man-made intrusions on shorelines. Dredging and flowlane disposal will occur at depths to minimize impacts. Dredging will use hopper and pipeline dredges to minimize turbidity. Flowlane disposal uses a “down pipe” with a diffuser plate at its end. The down pipe extends 20 feet below the water surface to avoid impacts to migrating juvenile salmonids. The diffuser and movement of the pipe help prevent mounds from forming on the river bottom. Upland disposal will use temporary pipelines extending from dredges. These temporary pipelines will be removed after dredged material disposal occurs for each event. The Project uses shoreline sites for upland disposal that have been previously used for this purpose. The new sites in Washington State are located at least 300 feet from the Columbia River to minimize intrusion on the shoreline.

3. Plan for long term over short term benefit.

The Project plans for the long-term benefits of enhanced navigational access. Over the past 20 years, an increasing share of the Columbia River cargo tonnage has been carried by Panamax class vessels or larger. These larger vessels have design drafts that, after allowing for underkeel clearance requirements, exceed the depth allowed by the 40-foot channel; consequently, these ships must often come into the Columbia River ports “light loaded” (i.e., only partially loaded). Currently, more than 70 percent of the vessels deployed in the transpacific container trade are constrained by the 40-foot channel depth. This amount would be reduced to 39 percent with a 43-foot channel. By deepening to 43 feet, the Project will be able to improve navigation infrastructure and maximize the efficiency of the vessels and waterborne cargo shipments for years to come.

The Project’s restoration features also are intended to provide a long term benefit to the Columbia River. These features include tidal marsh and intertidal flats habitat important to salmonids including ESA stocks. Columbian White tailed deer will benefit from re-introduction on Howard and Cotton wood Islands. Waterfowl raptors and many other species will benefit from these restoration features.

4. Protect the resource and ecology of the shoreline.

Modeling of the Project has shown that it should have only minor, if any effects, on physical parameters such as salinity, stream flows, erosion and accretions. Habitat forming processes and food chain effects have also been determined to be minimal. The Project uses dredging and disposal methods designed to protect the resources and ecology of the shorelines.

The Project will not reduce the available sand supply and the expected hydraulic changes are too small to measurably alter sand transport or erosion/accretion in the river of estuary. There will be no measurable change in hydraulic conditions or sedimentation processes at the Mouth of the Columbia River. There will continue to the transport of sand both landward and seaward at the mouth, with a small net discharge of sand from the estuary to the Mouth of the Columbia River. Large freshet will continue to have the potential to discharge larger volumes of sand from the estuary to the MCR, however flow regulation has made such freshets less likely to occur. The proposed deepening is not expected to impact the littoral sand budgets north or south of the MCR.

Dredging will be done at depths of more than 40 feet, while salmonids generally migrate at depths of less than 20 feet. The primary hopper and pipeline dredges generally do not produce large amounts of turbidity during dredging because of the suction action of the dredge pump and the fact that the drag arm or cutter head is buried in the sediment. Turbidity produced by clamshell dredges is minimal

Flowlane disposal generally will also be in depths ranging from 50 to 65 feet. The benthic invertebrates that provide a major food source for some fish are found at depths of less than 20 feet. Therefore, restricting the disposal of dredged materials to depths greater than 20 feet will minimize potential impacts from this activity. To avoid mounding during hopper-dredge disposal, material will be released while the dredge is in motion to disperse material over the flowlane disposal area. During disposal or placement of dredged material by pipeline dredge, the diffuser and movement of the pipe help prevent mounds from forming on the river bottom.

Upland disposal along the Columbia River channel has been reviewed by the National Marine Fisheries Service and Fish and Wildlife Service to avoid adverse impacts on listed fish species or proposed critical habitat. Upland disposal activities will employ measures to minimize potential impacts.

Sand will be placed at upland disposal sites with a temporary pipeline. The pipeline will be removed after the sand is in place, in order to minimize any interference with recreational boating and commercial fishing. Upland disposal sites are designed to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle. Water is allowed to settle and clear through the retention pond drainage system before it runs back into the river. Weirs are used to regulate the return of water to the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance.

Upland sites that have been used for past dredged material disposal are being used again. New upland disposal sites have been located 300 feet beyond ordinary high water. All proposed sites have been located to avoid wetlands to the extent practicable. Impacted wetlands will be mitigated as prescribed in the Mitigation Plan in the 1999 FIR/EIS, Appendix G.

5. Increase public access to publicly owned areas of the shorelines.

The beach nourishment at Skamokawa Beach helps to maintain a popular public park. A number of the sites are being acquired for restoration or mitigation and are currently planned to focus on their potential to enhance natural resources and help to recover fish and wildlife species, rather than significantly increase public access. Public access often can adversely affect natural resources in a manner that would be inconsistent with the basin wide priority for natural resource restoration.

6. Increase recreational opportunities for the public on the shorelines.

The Project will enhance recreational opportunity on the shorelines by restoring the erosive beach at Skamokawa beach. The ecosystem restoration features within the coastal zone of the Project will enhance passive recreational opportunities for studying and viewing wildlife on the shorelines. These Project features are located in Washington and Oregon and include tide gates retrofitted for salmonid passage at selected locations along the lower Columbia River; the Lois Island Embayment Habitat Restoration (Oregon); the Purple Loosetrife Control Program (Oregon and Washington), Miller/Pillar Habitat Restoration (Oregon); and the Tenasillahe Island Tidegate/Inlet Improvements and Dike Breach (long term).

General Use Preferences

RCW 90.58.020 also states that alterations of the natural condition of the shorelines of the state, in those limited instances when authorized, shall be given priority for single family residences and their appurtenant structures, port, shoreline recreations uses, and other improvement facilitating public access to shorelines of the state, industrial and commercial developments which are particularly dependent on their location on or use of the shorelines of the state.

The Project is consistent with this general use preference. The Project's navigation and restoration components are generally occurring in areas that have been previously altered. The dredging activity is occurring in the location of the existing channel. In-water disposal is likewise occurring adjacent to the channel in areas generally used for this purpose previously. Upland disposal is occurring primarily in sites that have been previously used for this purpose. The one new disposal site within the areas covered by the Coastal Zone Management Program is located more than 300 feet from the river, beyond the jurisdiction of the Shoreline Management Act.

<u>Ocean Resources Management Act, chapter 43.143, WAC 173-16-064</u>.

Under the preferred option presented in the Supplemental IFR/EIS, construction of the Millar Pillar and Lois Mott ecosystem restoration features would use dredged materials from construction and maintenance that otherwise would have been taken to ocean disposal. With the use and implementation of the two estuarine restoration sites, the ocean disposal should not be necessary. In the event dredge material from the channel did go to the ocean, it would go to a site designated for ocean disposal under Section 102 of the Ocean Dumping Act. At this point in time, we fully anticipate that the site designated under the ODA for potential use on this Project will be the Deep Water Site.

The Ocean Resources Management Act (ORMA), chapter 43.143 RCW establishes guidelines for the exercise of state and local management authority over Washington's coastal waters, seabed, and shorelines. RCW 43.143.020 defines "coastal waters" as "the waters of the Pacific Ocean seaward from Cape Flattery *south to Cape Disappointment*, from mean high tide seaward two hundred miles." (emphasis added). WAC 173-16-

064(2), which implements the Ocean Resources Management Act, specifies that "[t]he guidelines apply to Washington's *coastal waters from Cape Disappointment* at the mouth of the Columbia River north one hundred sixty miles to Cape Flattery . . . including the offshore ocean area, the near shore area under state ownership, shorelines of the state, and their adjacent uplands." This section further states that "[t]he guidelines address uses occurring in Washington's coastal waters, *but not impacts generated from activities offshore of Oregon*, Alaska, California, or British Columbia or impacts from Washington's offshore on the Strait of Juan de Fuca or other inland marine waters." (emphasis added).

The Deep Water Disposal Site, which is the only ocean disposal site being considered for potential use under this Project, is located south of Cape Disappointment and in an area offshore of Oregon. Therefore, in accordance with the express language of the Ocean Resources Management Act and implementing administrative code, the ORMA does not apply to the Project.

Washington State Water Quality Requirements

The Corps has submitted an application for water quality certification.

Washington Air Quality Requirements

The Project does not require an Air Quality Permit.

Pacific County Shoreline Master Program

The Federal Coastal Zone Management Act requires Federal activities that may affect coastal resources or uses be evaluated for consistency with the applicable provisions of state Coastal Management Programs, including relevant local Shoreline Master Programs. As discussed below, the Pacific County Shoreline Master Program does not include policies that are applicable to this Project.

The Pacific County Shoreline Master Program includes a number of provisions that implement the Washington Ocean Resources Management Act. As discussed above, the Ocean Resources Management Act does not apply to the Project because the Deepwater Ocean Disposal Site is off the coast of Oregon and outside of the area explicitly regulated by the Act. The Pacific County SMP provisions regarding ocean resources are reviewed below.

Section 2. Definitions. The Pacific County SMP defines "coastal waters" as "waters of the Pacific Ocean seaward from Cape Flattery south to Cape Disappointment, from mean high tide seaward two hundred miles. For Pacific County, coastal waters include from mean high tide seaward three miles." This definition is similar to the definition in the ORMA, except that it limits Pacific County's definition of coastal waters to within three miles. The Pacific County SMP defines "ocean uses" as "activities or development involving renewable and/or nonrenewable resources that occur on Washington's coastal waters."

As discussed under the section on the ORMA, the proposed ocean disposal site is located below Cape Disappointment and is, therefore, not within the "coastal waters" covered by Pacific County's SMP.

Section 23. COLUMBIA RIVER SEGMENT

Section 23 of the Pacific County SMP applies to the area defined by the Columbia River Segment of the Pacific County's Shoreline Master Program. Appendix 5 of the SMP defines a part of the Columbia River Segment as including a specific area around Cape Disappointment. Subsection D of Section 23 identifies use and activity regulations for the Columbia River Segment. Subsection D provides tables identifying permitted uses and activities in seven management designations created by Subsection 25.B.1. through Subsection 25.B.8 of this Master Program. None of Subsections 25.B.1-8, cover the ocean. Subsection 25.B.9 designates an "Ocean Environment" and defines it as "waters of the Pacific Ocean from Cape Disappointment north to the border between Pacific County and Grays Harbor County; and from mean high tide, seaward three miles.

Section 23.D. provides use standards for activities in the environments of the Columbia River Segment defined in Subsections 25.B.1-8. As noted above, the Project has no activities in any of these environments. Therefore, the use standards in Subsection D do not apply to this Project.

Paragraph 23 of Section 23.D provides the use standards for dredge disposal in the Columbia River Segment. As discussed above, these standards only apply to specific environments that do not include the ocean. In addition, the Ocean Environment as defined by the SMP does not include the Ocean Disposal Site. Therefore, the standards in Section 23 do not apply.

S25.05.21, Dredged Material Disposal (DMD) Policies. No estuary sites are proposed within the jurisdiction of Pacific County. Therefore, this section does not apply to the Project.

S25.08.01, Permitted Development, Uses and Activities. The proposed action does not include disposing at any site within the jurisdiction of Pacific County. Therefore, this section does not apply to the Project.

Section 27 OCEAN RESOURCES, Subsection E. Ocean Environment

Section 27 of the Pacific County SMP applies specifically to the "Ocean Environment." As discussed above, Section 25 defines the Ocean Environment as being the area north of Cape Disappointment out to 3 miles. Therefore, Section 27 does not apply to the Deepwater Disposal site.

Wahkiakum County, Washington, Shoreline Management Master Program

Policies - Dredging. This policy refers to deepening of a navigation channel or use of bottom material for a landfill.

Standards - Dredge and Fill. Permitted Use Standards for Conservancy, Rural and Urban Environments.

Dredging: (1) Dredging in aquatic areas shall be permitted only for navigation or navigational access, and (2) dredging shall be the minimum necessary to accomplish the proposed use. The proposed action conforms to these applicable standards.

Fill: Fill in aquatic areas shall be permitted only in conjunction with a permitted or conditionally permitted water-dependent use for which there is a demonstrated public need and for which no feasible upland sites exist. The proposed action is water-dependent. There is, based on the economic analysis prepared for this action, a demonstrated public need for deepening and subsequent maintenance of the navigation channel. Upland sites including Puget Island, Browns Island and a small portion of Rice Island have been identified as available upland sites within the Wahkiakum County estuarine reach.

Dredged Material Disposal (the Deposition of Dredged Material in Aquatic Areas or Shorelands): The Corps complies with the Permitted Use Standards for Conservancy, Rural and Urban Environments (1-9, as applicable) to the maximum extent practicable. All estuarine disposal sites (flowlane and Skamokawa Beach) are in accord with the currently approved Dredged Material Disposal Plan. Browns Island is an existing upland disposal site within the county shorelands. Disposal at this location would conform to all shoreland use requirements. The Puget Island site is outside the 200-foot shorelands zone. Use of this site including placement of pipeline within the shorelands zone would conform to state and county requirements. Best Management Practices will be applied as follows for each type of disposal practice:

General Provisions for all Disposal – The contractor, where possible, will use or propose for use materials that may be considered environmentally friendly in that waste from such materials is not regulated as a hazardous waste or is not considered harmful to the environment. If hazardous wastes are generated, disposal of this material shall be done in accordance with 40 CFR parts 260-272 and 49 CFR parts 100-177. If material is released, it shall be immediately removed and the area restored to a condition approximating the adjacent undisturbed area. Contaminated ground shall be excavated and removed and the area restored as directed. Any in-water discharge shall be immediately reported to the nearest U.S. Coast Guard Unit for appropriate response.

Flowlane Disposal – The discharge pipe of the pipeline dredge will be maintained at or below 20 feet of water depth during disposal. This measure reduces the impact of disposal and increased suspended sediment and turbidity on migrating juvenile salmonids, since they are believed to migrate principally in the upper 20 feet of the water column. Disposal of material will be conducted in a manner that prevents mounding of the material. The material will be spread, reducing the depth of the material on the bottom, which will reduce the impacts to fish and invertebrate populations. These actions will continue over the life of the contract or action and be maintained until new information becomes available that would warrant a change.

Upland Disposal - Upland disposal sites will be bermed, and settling ponds will incorporated, to maximize the settling of fines in the runoff water. This action reduces the potential for increasing suspended sediments and turbidity in the runoff water. A 300-foot habitat buffer will be maintained preserving important habitat functions. These activities will be continuous during disposal operations or over the life of the contract and be maintained until new information becomes available that would warrant a change.

Shoreline Disposal – There are no timing restrictions associated with shoreline disposal as consulted with NOAA Fisheries and US Fish and Wildlife Service. Ungraded slopes can provide conditions on the beach that will create small pools or flat slopes that can strand juveniles washed up by wave action. The disposal site will be graded to a slope of 10 to 15 percent, with no swales, to reduce the possibility of stranding of juvenile salmonids. These activities will be continuous during dredging and disposal operations and be maintained until new information becomes available that would warrant a change.

Suspended Particulate/Turbidity Determination - Short-term minor increase in turbidity would occur in the immediate vicinity of in-water disposal sites and in water work areas. This condition would temporarily inhibit light penetration through the water column and thereby affect aquatic organisms. Since the dredged material is primarily sand, the expected short-term increase in turbidity levels would not violate state water quality standards. Best management practices would be utilized for the dredge and fill actions associated within the permitted areas.

Impact Assessment

In addition to the impact assessments provided herein, the Final and Supplemental IFR/EIS along with the Ocean Disposal Site Evaluation Study (Appendix H) have been prepared in compliance with impact assessment procedures. The Washington Port Sponsors are participating with the Corps of Engineers in preparing a Supplemental Integrated Feasibility Report/Environmental Impact Statement. The Corps and Ports issued a draft Supplemental IFR/EIS on July 12, 2002. A final Supplemental IFR/EIS is scheduled for release in December 2002. These documents are prepared to comply with the National Environmental Policy Act (NEPA) and the State Environmental Policy Act (SEPA).

Statement of Consistency

Based on the above evaluation, we have determined that the actions proposed in the *Columbia River Navigation Channel Improvement Study* and *Supplement 1* are, with the approval of the updated CREST Dredged Material Management Plan including Welch Island and expanded Miller Sands site, and, with the Clatsop County approval of flowlane disposal below 65 feet at two locations under the plan exceptions process, consistent with the enforceable policies of the approved coastal zone management programs of Oregon and Washington, including the enforceable policies as specified in the local planning documents for Clatsop County, Oregon, and Pacific and Wahkiakum Counties, Washington that are incorporated in the approved programs. Restoration of shallow water habitat at Lois Island embayment would require Type II review procedure if it is determined that the affected area lies within an Aquatic Development zone. If it is within an Aquatic Conservation Two zone, it is a permitted activity without further review.

EXHIBIT I

ESSENTIAL FISH HABITAT ASSESSMENT (REVISED)

Table of Contents
Exhibit I
Essential Fish Habitat Assessment For Columbia River Channel Improvement Project And Ocean Disposal Site Designation Action

Essential Fish Habitat Assessment For Columbia River Channel Improvement Project And Ocean Disposal Site Designation Action

Action Agency

US Army Corps of Engineers, Portland District.

Location

Channel Improvement Project- Columbia River from RM 3 to 106.5 and Willamette River from RM 0 to 11. Ocean Disposal Site- Pacific Ocean off the Mouth of the Columbia River.

Project Name

Columbia River Channel Improvement Project and Ocean Dredged Material Disposal Site Designation Document.

Project Description

The integrated feasibility report and Environmental Impact Statement (IFR/EIS) documents the results of a feasibility study for proposed improvements to the authorized Columbia and lower Willamette River navigation channel in Oregon and Washington. The channel is currently authorized at a 40-foot depth and generally a 600-foot width. The project area for improvements covers 11.6 miles of the Willamette River below Portland, Oregon and 103.5 miles of the Columbia River, from river mile 3 to 106.5, below Vancouver, Washington. The Willamette portion has been deferred until the completion of the remediation investigation and remediation decisions related to contaminated sediments in the Portland Harbor. The impact area for project extends upriver to Bonneville Dam on the Columbia and to Willamette Falls on the Willamette.

The study was authorized by a resolution of the U.S. House of Representatives, Committee on Public Works and Transport, adopted August 3, 1989. The feasibility study was initiated in 1994 and is co-sponsored by the U.S. Army Corps of Engineers and six lower Columbia River ports: St. Helens, and Portland in Oregon and Longview, Kalama, Woodland and Vancouver in Washington. The Port of Portland serves as the overall coordinator for the sponsoring ports. The U.S. Environmental Protection Agency (EPA), Region 10 in Seattle, Washington, is a cooperating agency for this report. NOAA Fisheries staff participated throughout the study and in the EIS, SEIS and the Endangered Species Act (ESA) consultation. The selection of the Deep Water ocean disposal site was done by a multi- agency/ stakeholder taskforce. The process is described in Appendix H Vol. 1&2 of the 1999 Final IFR/EIS.

The purpose of the deepening project is to improve the deep-draft transport of goods on the authorized navigational channel and to provide ecosystem restoration for fish and wildlife habitats. The need for navigation improvements has been driven by the steady growth in waterborne commerce and the use of larger, more efficient vessels to transport bulk commodities. With the increase of deep-draft vessels, limitations posed by the existing channel dimensions now occur with greater frequency. By improving navigation, the opportunity to realize greater benefits would result from reducing transportation costs by allowing deep-draft vessels to carry more tonnage, and by reducing vessel delays.

Channel improvement alternatives were limited to a maximum of 3 feet of deepening by the study's authorizing legislation. The study authorization also directed that the Dredged Material Management Plan (Portland District, Corps of Engineers, 1998) would serve as the no action alternative for the study. This plan evaluated the most efficient way to maintain the currently authorized 40-foot navigation channel in the future.

The report also includes documentation in support of EPA designation of a new Deep Water ocean disposal site. Though the site will be used primarily for maintenance material from the Mouth of the Columbia River project, it may also be used for maintenance material in later years for the Channel Improvement Project. The new site is needed because existing ocean disposal sites were not as dispersive as originally thought and consequently have reached their capacities. The Deep Water Site has been sized to accommodate both projects for a 50 year time period. The current preferred plan for the Channel Improvement Project which is addressed in the Final SEIS now includes ecosystem restoration features at Lois/Mott Islands and the area between Millar Sands and Pillar Rock Islands. If these two features are constructed then ocean disposal should not be necessary for the project.

Essential Fish Habitat Designations

Pursuant to the Magnuson-Stevens Fishery Conservation and Management Act and the 1996 Sustainable Fisheries Act an Essential Fish Habitat (EFH) consultation is necessary for the channel improvement project as well as the designation of the new site. Essential fish habitat is defined by the Act in Section 3 (104-297) as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The Columbia River estuary and the Pacific Ocean off the mouth of the Columbia River are designated as EFH for various groundfish, coastal pelagic and salmon species. EFH for groundfish, and coastal pelagic species and their life history stages that would be affected by the two actions are listed in Table 1 below. An X in the table below indicates the presence of designated EFH in the Columbia River estuary or the Pacific Ocean off the mouth of the Columbia River.

Table 1 Designated EFH in the Columbia River estuary or the Pacific Ocean off the mouth of the Columbia River

Groundfish Species	Egg	Larvae	Young Juvenile	Juvenile	Adult	Spawning
Spiny Dogfish			X	X	X	
Ratfish				X	X	
Lingcod		X		X	X	X
Cabezon		X				
Kelp Greenling		X				
Pacific Cod		X	X	X	X	X
Pacific Whiting (Hake)			X	X	X	
Sablefish		X	X	X	X	X
Jack Mackerel					X	
Darkblotched Rockfish				X	X	
Greenstriped Rockfish				X	X	
Thornyheads		X				
Pacific Ocean Perch				X	X	
Widow Rockfish			X	X		
Misc. Rockfish				X	X	
Arrowtooth Flounder				X	X	
Butter Sole	X	X				
Curlfin Sole	X					
Dover Sole	X			X	X	
English Sole	X	X	X	X	X	X
Flathead Sole		X		X	X	X
Pacific Sanddab				X	X	
Petrale Sole			X	X	X	
Rex Sole	X	X		X	X	
Sand Sole	X	X				
Starry Flounder	X	X	X			X
Coastal Pelagic Species	**Egg**	**Larvae**	**Young Juvenile**	**Juvenile**	**Adult**	**Spawning**
Northern Anchovy	X	X		X	X	
Pacific Sardine	X	X		X	X	
Pacific Mackerel	X	X		X	X	
Jack Mackerel					X	
Market Squid	?	?	?		X	?

A detailed discussion of EFH for groundfish is provided in the Final Environmental Assessment/Regulatory Impact Review for Amendment 11 to The Pacific Coast Groundfish Fishery Management Plan [Pacific Fisheries Management Council (PFMC) 1998] and the NMFS (June 15, 1998) Essential Fish Habitat for West Coast Groundfish Appendix. A detailed discussion of EFH for Coastal Pelagic species is provided in Amendment 8 to the Coastal Pelagic Species Fishery Management Plan (PFMC 1998).

Assessments of the impacts to these species' EFH from the channel improvement project and the designation of the new ocean disposal site is discussed below. EFH consultation for salmonid species for the channel improvement project, including the Deep Water site, was completed simultaneously with the 2002 ESA consultation with NOAA Fisheries. See NOAA Fisheries 2002 BO at Ch. 13. EFH consultation for a shallow-water ocean disposal site (Site E) is being conducted as part of the EFH review for the Mouth of the Columbia navigation project.

Potential Effects of Dredging and Dredged Material Disposal on EFH

The Channel Improvement Project would affect EFH for groundfish and coastal pelagic species by altering channel and bottom habitat by dredging and disposal. Dredging and disposal would affect EFH in the following ways: changing bottom topography, removal or covering of benthic populations, creating a temporary increase in turbidity and reducing migratory habitat by disturbance. Alteration of bottom habitat is likely to effect habitat for populations of managed species by reducing food sources through the reduction in benthic invertebrate populations. Reduced food sources and increased turbidities may reduce feeding success and consequently the overall value of the habitat to the managed species.

In general dredging and disposal impacts to managed species are expected to be minimal. The navigation channel bottom is not considered highly productive habitat because it is disturbed on a regular basis from dredging and ship traffic. The deeper channel is below the photic zone, which is considered the more productive zone in the river because of increased light penetration. In addition, the amount of habitat impacted in the channel areas is small compared to the total amount available for the managed species. Loss of migratory habitat will occur primarily as a result of disturbance created by dredging operations. This impact is not expected to be large since the dredge is only operating in a small portion of the total width of the river. In addition, hopper dredges only operate intermittently since once they are full they have to go to the disposal area to empty the hopper. During this time period disturbance would not be occurring from the dredge operations and any impact to fish migration that may be occurring would be minimal.

Several ecosystem restoration projects are proposed with the project. Two of them, Miller/Pillar and Lois/Mott Islands embayment involve filling of estuarine subtidal areas to bring them up to a depth suitable for the creation of marsh habitat as well as a small amount of sand flat habitat. These projects are being designed to provide juvenile salmon rearing habitat, but many also provide habitat for juvenile sole and flounders when salinity levels are adequate. It is likely that these areas may currently provide some habitat for flounders, particularly starry flounder who can tolerate a wider range of salinities then most flounders. It is unlikely, however, that these areas provide a great deal of habitat, or any unique habitat that is not currently available in large quantity in the estuary and river. The developed of the marsh/sandflat areas will likely replace any habitat that is lost and may in fact improve it by increasing the food supply available from the more productive marshes.

Use of the Deep Water ocean disposal site will involve covering of existing benthic populations and the loss of them as a food supply to the managed species. In addition, the bottom topography and sediment type may be changed such that recovery after disposal events may be to a different benthic community than what was there prior to disposal. This in turn may change the value of the habitat to the managed species. This is dependent upon where the disposal site is located and whether the type of material disposed of is similar to the natural sediment at the site.

The new ocean disposal site has been selected and sized so that it will not be necessary to find a new site and create further impacts to the EFH and the ocean environment. The site has also been sized so that it can be managed to minimize impacts. Consequently, designating this site will reduce further cumulative impacts to the area offshore of the mouth of the Columbia River. Mitigation for the deep water ocean disposal site was done by avoiding unique areas of greater biological productivity and thereby minimizing impacts to the bottom habitat. A buffer zone was also established to prevent disposal of material from occurring outside the site. Selection of the site was done through an extensive coordination process with both federal and state agencies and private interest groups. In addition, both pre and post studies will be done to further characterize the site and help in the management of the site.

Mitigation for dredging and disposal impacts are provided by the following measures that were incorporated into the project design to reduce impacts:

Dredging

1. Dredging will be done only in channel areas that are dredged on a regular basis and generally have a lower biological productivity than undisturbed areas.

2. Dredging in shallow areas will be done during recommended in-water work periods to minimize impacts to managed species habitat.

3. Dredging will be done principally with hydraulic dredges to reduce turbidity levels in the water column.

Disposal

1. Sediments have been tested and determined to be non-contaminated and suitable for in-water disposal.
2. Disposal at the ocean disposal site will be managed in a manner to reduce impacts and allow disturbed areas a chance to recover.
3. Several ecosystem restoration projects have also been proposed in connection with the project. These projects will provide additional areas of EFH for salmon as well as potential for some groundfish species. The ecosystem restoration projects are described in Chapter 4 in the Final SEIS and in Chapter 8 of the 2001 BA.

EFH Assessment: Channel Improvement Project

The Columbia River main navigation channel consists primarily of medium grain sand with some fine and course grain sand. The bottom is relatively unstable consisting primarily of large sand waves that build and then collapse at irregular intervals as part of the sediment transport process. A detailed description of the physical properties of the navigation channel is given in Chapter 5, Section 5.1 of the Main Report of the EIS for the Channel Deepening Project (1999 Final IFR/EIS).

Biological productivity of the channel is low because of low light penetration at depth and an unstable bottom. Benthic sampling taken in the channel areas have shown benthic invertebrate densities a third less than in the areas less than 20-feet deep which are the more productive areas of the Columbia River. A detailed discussion of the biological productivity of the channel areas is given in Chapter 5, Section 5.2.4 of the main report of the EIS for the Channel Improvement Project (1999 Final IFR/EIS).

Groundfish EFH

The Columbia River navigation channel in the estuary is designated EFH for several species of flounder, the majority being starry flounder and English sole. Most occur primarily as different age juveniles that may use the channel as a migratory corridor to rearing areas in the bays and intertidal areas which have large concentrations of food organisms such as the amphipod *Corophium salmonis*. Less than one-year-old juveniles occur throughout the estuary but are more concentrated in the freshwater and low salinity areas. They are generally not as abundant in the estuary as the older age classes. Age one to two year old juveniles occur throughout the estuary but are abundant year around in the side channels and bays and also in the main navigation channel. Two-year-old juveniles are less widespread and occur mostly in the portions of the estuary with higher salinity.

The Columbia River estuary provides EFH for less than one, one and one plus year old juvenile English sole. They use the estuary primarily as a feeding and nursery area occurring in the lower part of the estuary where salinity is high. Less than one year old juveniles occur mostly in the side channels and bays and are most abundant in the spring and summer when salinity is higher in these areas. One plus year old juveniles occur only in the lowest portion of the estuary where salinity is greatest. Juvenile English sole are primarily benthic feeders and occur principally in side channels and bays where benthic productivity is high.

Deepening the Columbia River navigation channel by dredging will have a minimal adverse effect on EFH for the above groundfish species, since the main navigation channel and limited adjacent areas to be used for flowlane disposal are the least productive of the designated estuarine EFH complex and do not provide critical feeding or rearing areas for juveniles or adults. Alteration of physical dynamics of the estuary by deepening is only expected to have a small impact and will not effect groundfish species' use of the area.

The ecosystem restoration projects, though initially impacting some limited amount of groundfish habitat, may actually improve the habitat available through the development of the marsh. It is likely that the habitat lost will be replaced by the marsh development and may in fact be of higher quality because of the increased the food supply available from the higher productive marshes.

Coastal Pelagic EFH

The water column of the Columbia River navigation channel is designated EFH for the northern anchovy. Anchovies that occur in the estuary are an extension of the coastal population and occur primarily in the lower estuary where salinity is high. They spawn in the ocean, but all life history stages can occur in the estuary with the eggs and larvae apparently swept into the estuary by flood tides. Individuals less than one year old, however, are not abundant in the estuary while anchovy one year or older can be abundant particularly during low river flow periods when salinity is higher. Anchovies are pelagic feeders feeding primarily on copepods. Deepening the Columbia River by dredging is expected to have minimal impact on turbidity levels in the water column or coastal pelagic EFH.

EFH Assessment: Ocean Disposal Site Use

The physical characteristics of the Deep Water site are described and detailed in Appendix H, Volume 1 and 2 of the Final EIS for the Channel Improvement Project (1999 Final IFR/EIS). The site is located about 4.5 miles west of the entrance to the Columbia River and extends westerly to about 7 miles. The site varies in depth from 200-300 feet with a bottom topography that is featureless and gently slopes away from shore. Overall site dimensions including a 3000 feet buffer zone, are 17,000 x 23,000 feet. Disposal will occur only in the inner 11,000 x 17,000 rectangle and not in the buffer area. Sediment type is very fine-grained sand and the bottom is generally very stable except under extreme wave conditions.

Benthic populations have been sampled in the Deep Water site and the area is considered to be moderate to highly productive averaging between 8,000 to 10,000 organisms per meter squared in Oct/Nov 1995 and from 5,000 to 8,000 in June of 1996. A detailed discussion of the benthic productivity of this site is given in Appendix H, Volume 1, Exhibit A. Benthic and fish populations were sampled in the Deep Water Site in July and September, 2002. Results of the study are still being analyzed but preliminary results have indicated that species present are similar in type and number to other coastal areas of similar depth and habitat and substantiate the species discussion below.

Groundfish EFH

The Deep Water site is designated EFH for the groundfish species listed in Table 1. It provides EFH for most of the groundfish listed.

Spiny Dogfish- EFH for young juvenile, juvenile and adult spiny dogfish has the potential to be impacted disposal at the Deep Water site. Spiny dogfish are inner shelf-mesobenthal species that occur at depths from 0-900m, but most occur in depths less than 350m. Adult females move inshore to shallow waters in the spring to release their young. Young juveniles are neritic while juveniles and adults are sublittorial bathyal. Juveniles occur principally on mud bottoms when not in the water column while adults can occur from the intertidal to great depths. Based on the above description of habitat requirements for spiny dogfish, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Ratfish- EFH for juvenile and adult ratfish has the potential to be impacted by disposal at the Deep Water site. Ratfish are a middle shelf mesobenthal species that occur in depths from 0 to 913m. They are most abundant, however in depths from 100-150m. They also occur in the estuarine EFH complex during the winter and early spring to feed and mate. Ratfish are, however, generally a deep water species that prefer low relief rocky bottoms or exposed gravel or cobble. They are not common over sand or boulders. Based on the above description of Ratfish habitat requirements the Deep Water site does not provide any unique habitat that is not available elsewhere and it is only a small proportion of the total areal extent of the EFH for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Lingcod- EFH for spawning, larval, juvenile and adult lingcod has the potential to be impacted by disposal at the Deep Water site. Lingcod are an estuarine-mesobenthal species that occurs in depths from 0 to 475m. Spawning occurs in 3-10m below mean lower low water over rocky reefs in areas of swift currents. Larvae occur in nearshore areas from winter to late spring. Larger larvae are epipelagic primarily found in the upper three meters of the water column. Juveniles settle in estuaries and shallow waters along the coast while older juveniles move offshore as they grow but are most common in waters greater than 150m. Adults prefer slopes of submerged banks 10-70m below the surface with sea weeds, kelp and eelgrass beds that form feeding grounds for small prey fish. They also prefer channels in rocky intertidal areas with swift currents that concentrate plankton and plankton feeding fish. Based on the habitat requirements for Lingcod, the Deep Water site does not provide any unique habitat that is not available elsewhere and in only a small proportion of the total areal extent of the EFH for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Cabezon and Kelp Greenling- EFH for larval cabezon and kelp greenling has the potential to be impacted by disposal at the Deep Water Site. Both species are abundant all year in estuarine and subtidal areas. Larval and young juvenile cabezon and kelp greenling are pelagic and have been found offshore as far as 322 km. Juveniles settle to the bottom and are found primarily in the shallow water bays and estuaries. The disposal site provides minimal habitat for larval stage cabezon and kelp greenling. Impacts to these species from using the site is expected to be minimal.

Pacific Cod- EFH for larval, young juvenile, juvenile, adult and spawning of Pacific cod has the potential to be impacted by disposal at the Deep Water Site. Pacific cod are a member of the inner shelf-mesobenthal community. The majority of Pacific cod are found at depths between 50-300m with spawning occurring at depths from 40-265m. The eggs are demersal, adhesive and are found sublittorally. Larvae and small juveniles are pelagic, with the highest abundance in the upper 15 to 30m of the water column. Larvae are found over the continental shelf from winter through summer. Small juveniles occur from 60 –150m gradually moving to deeper water with increased age. Larger juveniles and adults are parademersal occurring over mud, sand and clay and occasionally coarse sand and gravel bottoms. Based on the above habitat descriptions for Pacific cod, it is possible that disposal at the Deeper Water site could have an impact on habitat used by some life stages of Pacific cod. Based on the habitat requirements described above for Pacific cod, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Pacific Whiting (Hake)- EFH for young juvenile, juvenile and adult Pacific whiting has the potential to be impacted by disposal at the Deep Water site. Pacific hake is a migratory species that inhabits the continental slope and shelf from Baja California to British Columbia. Juvenile hake usually reside in shallow coastal waters, bays and estuaries with adults occurring further offshore, usually between depths of 50- 500m. Along the Pacific Coast from British Columbia to California adults use a narrow band of feeding habitat near the shelf break for 6-8 months per year. Based on the habitat requirements described above for Pacific whiting, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Sablefish- EFH for larval, young juvenile, juvenile, adult and spawning of sablefish has the potential to be impacted by disposal at the Deep Water site. Sablefish are an inner shelf-bathybenthal species that occurs in deep water. Sablefish are most abundant from 200-1000m but have been reported to depths of 1900m. Spawning occurs at depths greater than 300m. Larvae and young juveniles are pelagic and may move inshore and remain there for up to four years to rear. Older juveniles and adults inhabit progressively deeper water and are benthopelagic on soft bottoms. Based on the habitat requirements described above for sablefish, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Jack mackerel- EFH for adult jack mackerel has been identified as having the potential to be impacted by disposal at the Deep Water site. Adults occur in neritic and oceanic areas to depths as great as 402m. They are relatively uncommon below 75m. Since jack mackerel are pelagic and show no affinity to any type of bottom substrate, it is not expected that disposal at the deep water site would have any affect on jack mackerel EFH.

Rockfish species, Darkblotched, Greenstriped and Misc. Rockfish- EFH for juveniles and adults of these species have the potential to be impacted by disposal at the Deep Water site. These species are primarily mid- to deep water species. The inshore depth range of adults and juveniles of these species overlaps, to some extent, the depth of the Deep Water disposal site. Based on the habitat requirements described above for rockfish species, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Thornyheads- EFH of larvae of the thornyhead has the potential to be effected by disposal in the Deep Water site. Thornyheads are deep water species occurring in depths from 400-1400m. Larvae and small juveniles are pelagic for 18-20 months before settling to the bottom. During this time they may occur at the outer edge of the deep water site. Based on the habitat requirements described above for thornyhead, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Pacific Ocean Perch- Pacific Ocean Perch is a deep water species that does not occur to any extent in the area of the Deep Water Disposal site. Therefore there will be no impact to their habitat from the use of the Deep Water site.

Widow Rockfish- EFH of young juvenile and juvenile widow rock fish has the potential to be impacted by disposal in the Deep Water site. Both juvenile stages are pelagic. Young juveniles occur from near surface to 20m deep from the inshore out to 300km offshore. Juveniles occur near bottom inshore at depths of 9-37 meters. Off Oregon, widow rockfish are most abundant on the continental shelf. All life histories stages are associated with some type of bottom structure such as seamounts, rocks, and ridges near canyons and headlands. Based on the above habitat requirements for widow rockfish, and because the disposal site is featureless it does not provide the preferred habitat complexity, no adverse impacts on widow rockfish EFH are anticipated.

Arrowtooth flounder- EFH for juvenile and adult arrowtooth flounder habitat has the potential to be impacted by disposal at the Deep Water site. Juveniles and adults are sublittorial-bathyal and occur from depths of 18-900m. They prefer sand or sandy gravel bottoms. Arrowtooth flounder migrate from shallow water feeding areas in the summer to offshore spawning areas in the winter. Based on the habitat requirements described above for arrowtooth flounder, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Butter Sole- EFH for eggs and larvae of the butter sole has the potential to be impacted by disposal at the Deep Water site. Spawning takes place in coastal areas, within 18 km of the shore. They utilize the shallow waters to rear and then move offshore, as they grow larger. Based on the habitat requirements described above for butter sole, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Curlfin Sole- EFH for eggs of the curlfin sole has the potential to be impacted by disposal at the Deep Water site. Curlfin sole are an inshore coastal species that occur on soft bottom. Little information is available on their habitat requirements but it is possible that their eggs could occur in the area of the disposal site. Any adverse impact to the EFH for eggs will be minimal considering the eggs are pelagic.

Dover Sole- EFH for egg, juvenile and adults of the Dover sole has the potential to be impacted by disposal at the Deep Water site. Dover sole are a dominant meso-benthal species in the North Pacific. They occur primarily in off shore waters at depths less than 500m. Eggs are epi-pelagic and may occur in the water column over the Deep Water site. Juvenile and adults are demersal and may occur in the disposal site during summer when they are inshore feeding. Based on the habitat requirements described above for Dover sole, the Deep Water site does not provide any unique feeding habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

English Sole- EFH for all life history stages of the English sole has the potential to be impacted by disposal at the Deep Water site. English sole are an inner shelf-mesobenthal species that occurs to depth of 55m. Adults spawn in inshore waters and the eggs and larvae are pelagic settling to the bottom as young juveniles. Juveniles rear in the inshore areas and in the bays and estuaries. As they grow older they move offshore. English sole are distributed throughout the inshore area on soft bottom habitat. Based on the habitat requirements described above for English sole, the Deep Water site does not provide habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Flathead Sole- EFH for spawning, larval, juvenile and adult flathead sole has the potential to be impacted by disposal at the Deep Water site. Flathead sole are mesobenthic, occurring on the continental shelf to depths of 550m, but usually less than 366m. Spawning occurs at depths of 80 –140m. Eggs and larvae are generally buoyant in seawater. The juveniles settle to the bottom and rear in the inshore areas and bays and estuaries. Larger juveniles and adults are usually found further offshore on soft, silty or mud bottoms. Based on the habitat requirements described above for flathead sole, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Pacific Sanddab- EFH for juvenile and adult pacific sanddab has the potential to be impacted by ocean disposal at the Deep Water site. Pacific sanddab is an inshore sublittorial species that occurs between 0 and 306m, but are most abundant off Oregon from 37- 90m. Juvenile pacific sanddab occur in shallow water coastal areas, bays and estuaries on silty sand bottoms. Adults are found further offshore on coarser sandy areas. Based on the habitat requirements described above for Pacific sanddab, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Petrale Sole- EFH for young juvenile, juvenile and adult Petrale sole has the potential to be impacted by disposal at the Deep Water site. Petrale sole is an inner shelf-mesobenthal species that occurs at depths up to 460m. Juveniles and adults are demersal with young juveniles found at depths of 18-82m and larger juveniles at depths of 25-145m. Adults occur from the surf line to 550m but are most abundant at depths less than 300m on sand and sandy mud bottoms. Adults migrate seasonally from winter spawning grounds in deep water to summer feeding areas in shallow water. Based on the habitat requirements described above for Petrale sole, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Rex Sole- EFH for egg, larvae, juvenile and adult for Rex sole have the potential to be impacted by disposal at the Deep Water site. Rex sole is a middle shelf-mesobenthal species occurring at depths from 0 to 850m. It is one of the mostly widely distributed sole on the shelf and upper slope, occurring in a variety of depths and sediment types. Spawning occurs at depths from 100-300m. Larvae are pelagic and are widely distributed offshore with a peak of abundance at about 46km offshore. Rex sole settle to the bottom at the outer continental shelf and rear in the outer continental shelf. Intermediate sized Rex sole move inshore to depths of 55-150m. Adults are distributed throughout the depth range but are more abundant inshore in the summer when they are feeding. Based on the habitat requirements described above for Rex sole, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Sand sole-EFH for egg and larvae of the sand sole will not be affected by ocean disposal at the Deep Water site. Sand sole eggs and larvae are pelagic and are generally found in the upper 10m of the water column at water depths greater than 200m which is deeper than the deep water site.

Starry Flounder- EFH of egg, larvae and young juvenile starry flounder have the potential to be impacted by dredged material disposal at the Deep Water site. Eggs and larvae are epipelagic and occur near the surface over water 20-70m deep. Juveniles are demersal and occur in the estuaries or in the lower reaches of the major coastal rivers. Juveniles prefer sandy to muddy substrates and are found at depths less than 375m. Eggs and larvae may occur in the water column over the disposal site and could be adversely impacted. Juveniles may occur on the bottom in the disposal areas and could also be adversely impacted. Based on the habitat requirements described above for starry flounder, the Deep Water site does not provide any unique habitat that is not available elsewhere and is only a small proportion of the total areal extent of the EFH described for this species. Therefore, impact to the total EFH for this species is anticipated to be minimal.

Coastal Pelagic EFH

EFH for the all the coastal pelagic species life history stages is the water column except for the market squid, which spawns in specific spawning grounds on the bottom. Squid spawn year around at various locations. Eggs are fertilized as the females extrude them into egg capsules. The female then attaches the egg capsules to the bottom substrate. As spawning continues, mounds of capsules can cover an area of 100 square meters.

Some individuals may be present in the water column during disposal and there would be a potential for some impact from disposal material. Since the dredged material settles rapidly, however, it is unlikely the impact would be very significant. Disposal on squid spawning EFH could have a major effect on the reproductive success of the squid population, since it is unlikely that the eggs would survive. However, while squid spawning areas have been identified off the Oregon coast, none have been found in the vicinity of the disposal site. Accordingly, use of the Deep Water site is not expected to have any adverse effect on squid EFH.

Conclusions

The following conclusions can be drawn from the above EFH assessment:

1. Deepening of the Columbia River navigational channel by dredging will have a minimal adverse effect on EFH for groundfish, and coastal pelagic species since the main navigation channel is the least productive of the designated estuarine EFH areas and does not provide critical feeding or rearing areas for juveniles or adults. Alteration of the hydrologic regime by deepening the channel is also expected to be small and not effect its use as EFH.

2. The ecosystem restoration projects, though initially impacting some limited amount of groundfish habitat, may actually improve the habitat available through the development of the marsh. It is likely that the habitat lost will be replaced by the marsh development and may in fact be of higher quality because of the increased the food supply available from the more productive marshes.

3. As indicated above, there is a potential to impact EFH, as defined by NMFS, for some of the groundfish, and coastal pelagic species by use of the Deep Water ocean disposal site. The amount of the habitat impacted, however, is very small compared to the total EFH habitat identified for any of the species evaluated. In no case does the habitat in the disposal site represent any unique habitat that is not available elsewhere. Because of the minimal impact to the total EFH available for a given species, it is unlikely that use of the ocean site will reduce the total designated EFH to the point that the population levels for any species

evaluated will be adversely affected if at all.

EXHIBIT J

COLUMBIA RIVER SEDIMENTATION IMPACTS ANALYSIS (REVISED)

Table of Contents
Exhibit J
Columbia River
43-Ft Navigation Channel Improvement
Sedimentation Impacts Analysis (Revised)

COLUMBIA RIVER
43-FT NAVIGATION CHANNEL IMPROVEMENT
SEDIMENTATION IMPACTS ANALYSIS (Revised)

Prepared by:
U.S. Army Corps of Engineers
Portland District

January 2003

COLUMBIA RIVER
43-FT NAVIGATION CHANNEL IMPROVEMENT
SEDIMENTATION IMPACTS ANALYSIS

EXECUTIVE SUMMARY

This sedimentation impact assessment evaluates the potential changes in sedimentation that might occur with the proposed 43-ft navigation channel. The historical sediment budgets for the lower Columbia River, estuary, and littoral cell are examined to identify system responses to past natural and human activities. The main focuses were on changes to the lower river's sand transport, estuarine sand accretion, and the movement of sand between the estuary and the mouth of the Columbia River (MCR). It is concluded that there have been declines in all three of those processes due to changes in the river flows and the changes in entrance conditions that followed the construction of the MCR jetties. Development of the Columbia River navigation channel upstream of river mile 3 has not and will not have a significant impact on those processes.

The Columbia River's average annual sand transport has declined considerably from the late 1800's to present. The declines are related to global climate variations and upstream flow regulation that have reduced the river's peak streamflows and sediment transport capacity. The reduced sand inflow from the river has contributed to the reduction in sand accretion in the estuary. The MCR jetties reduced the sand transport from the MCR into Baker Bay and across Clatsop Spit into the south channel caused by ocean waves. However, the jetties caused a large discharge of sand from the MCR and vicinity, to the ocean. The sand eroded from the inlet and south flank of the inlet following jetty construction has deposited in the outer delta, on Peacock Spit, and the shorelines along Long Beach, Washington, and Clatsop Plains, Oregon.

Over the last 120 years, navigation channel development has noticeably altered the Columbia River's channel configuration in the river, estuary, and the MCR. However, past dredging and channel modifications upstream of RM 40 have not measurably altered the available sand supply or sand transport in the river. Excluding the effects of the MCR jetties, past navigation channel development also has not altered the estuary's overall erosion/accretion or bedload transport patterns. The reduction in the Columbia River's net sand discharge to the MCR since the early 1900's is related to lower Columbia River flood discharges and not the navigation channel or the MCR jetties.

The potential channel modifications in the Columbia River and estuary from the proposed 43-ft navigation channel are similar to, but much smaller than, those caused by navigation development over the past 100 years. There will be increases in riverbed depths and slight changes in river hydraulics. Deepening will not reduce the available sand supply and the expected hydraulic changes are too small to measurably alter sand transport or erosion/accretion in the river or estuary. Sediment transport and the sediment budget at the MCR are not likely to change by the proposed 43-ft navigation channel.

COLUMBIA RIVER SEDIMENTATION IMPACTS

INTRODUCTION

The Corps' Integrated Feasibility Report for Channel Improvement and Environmental Impact Statement (FEIS) (USACE, 1999) stated that the sedimentation impacts from the proposed 43-ft deepening would be limited to increases in riverbed depths and localized increases in suspended sediment and turbidity at dredging and disposal sites during dredging operations. Since completion of that report, questions have been raised about the potential for sedimentation impacts to salmon and their habitat, adequacy of the Corps' dredging forecast, and potential changes to the river's sediment budget. All of these questions were addressed, descriptions of potential impacts refined, and concerns alleviated during preparation of the Corps' Biological Assessment (BA) completed in consultation with the NOAA Fisheries and U.S. Fish and Wildlife Service on potential impacts to threatened and endangered species (USACE, 2001, and SEI workshops, 2001).

However, questions still persist about a potential impact of the deepening on the sediment budget of the Columbia River. Those questions are largely based on the presumption that past navigation developments (dredging, disposal, pile dikes, and jetties) have already altered the river's sediment budget and those of the estuary and coast; and that further deepening will cause additional impacts to those sediment budgets. Appendix A uses the available sediment information on the river, estuary, and coast to define the system's sedimentation processes and its sediment budget since 1868. It also examines the system's response to the last 120 years of human development of the river and the entrance. The history of navigation developments in the study area is described in the FEIS (1999).

This sedimentation impact assessment supplements those in the FEIS and BA by utilizing the historic sedimentation processes and system responses described in Appendix A to predict the sedimentation responses to the proposed 43-ft channel project. This assessment relies on existing information, including new information that has become available since publication of the Corps' FEIS (1999). The impact assessment area, as shown in Figure 1, includes the Columbia River downstream of the Portland/Vancouver area, the estuary, and the mouth of the Columbia River (MCR) plus those portions of the Columbia River littoral cell (CRLC) within approximately 12 miles, north and south, of the (MCR). The Corps' 1999 study area (USACE, 1999) has been expanded to include the MCR and portions of the littoral cell to cover potential coastal impacts.

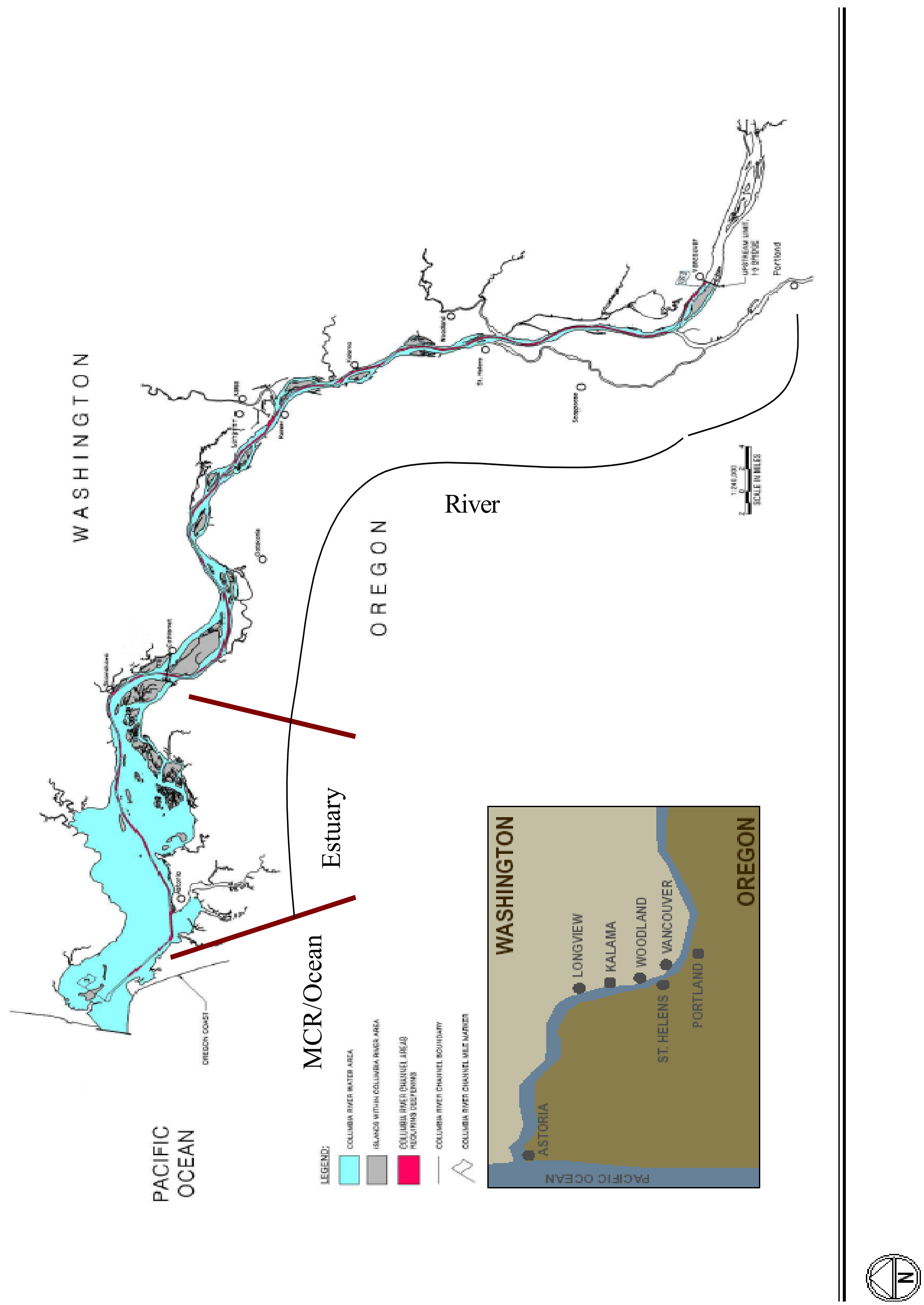

Figure 1. STUDY AREA MAP.

HISTORIC SEDIMENTATION PROCESSES

This section summarizes the significant findings from the sediment budgets and historical sedimentation processes analyses that are presented in Appendix A.

I. COLUMBIA RIVER (RM 40-106)

A. Sand Transport

The Columbia River's average annual sand transport has declined considerably, from the 6-mcy/yr in 1868-1926, to 3.6 mcy/yr for 1926-58, to 2.7 mcy/yr in 1959-72, and to 1.3 mcy/yr for 1973-99. Global scale climate variations that reduced streamflows were the primary cause of the decline in sand transport between the 1800's and 1972. Prior to 1972 the effects of flow regulation by upstream reservoirs and water diversions in the Columbia basin had caused relatively small reductions in sand transport. Since 1973, flow regulation has significantly reduced spring freshet discharges and consequently the average annual sand transport.

The relationship between river discharge and sand transport in the Columbia River has not changed since 1868. There is also no discernable change in that relationship through the river reach from RM 106 to RM 48.

B. Navigation Development Impacts

Navigation development began to noticeably alter the width and depth of the Columbia River streambed in the 1920's with the construction of the 30-ft channel and the development of pile dike fields to control flow. The riverbed continued to deepen as the navigation channel was deepened to 35-ft in 1935 and to 40-ft by 1976. Between 1900 and 1999, dredging to deepen and maintain the navigation channel between RM 40 and 106 totaled 450 mcy. Dredge material disposal utilized upland, shoreline, and in-water sites. Dredging, pile dike fields and shoreline disposal have combined to increase the depth and reduce the width of the riverbed, especially in those reaches that were naturally broad and shallow. Navigation development has not measurably altered Columbia River sand transport.

II. ESTUARY (RM 6-40)

A. Sedimentation Patterns

The 1868-1958 sediment accretion rates were comparable to those of the past 7,000 years. The average annual estuary accretion rate did decline from 5.0 mcy/yr in 1878-1926 to 3.7 mcy/yr for 1927-1958. That decline appears to be related to lower streamflows and the associated reduction in sand inflow from the river, and reduced sand inflow from the MCR. At the observed 1868-1958 accumulation rates, the estuary will not fill with sediment for 800-7,700 years.

River sand has accumulated in bays and shallows upstream of RM 15, including Cathlamet and Grays Bays, and in the south channel. There is bedload movement seaward across the central flats toward Desdemona Sands and landward transport in the north channel from the MCR to Desdemona Sands. This convergence of transport paths indicates that Desdemona Sands is an accretion zones for sand from both the estuary and the MCR. These accretions and bedload transport patterns have remained essentially unchanged since the 1930's.

B. Navigation Development Impacts

Navigation dredging had little impact on channel depths until the construction of the 30-ft channel. Depths in much of the south channel (RM 6-31) have increased as the navigation channel was deepened to 35-ft and then 40-ft. Navigation dredging totaled 230 mcy between 1900-99. In-water disposal has been by far the dominant disposal method downstream of RM 40. In-water disposal has redistributed the dredged sand along the south channel, keeping it in the active sand transport system. The exceptions to that have been the transfer of 20 mcy of sand from the south channel and the MCR to the north channel near RM 6 between 1957-87, and the placement of about 22 mcy on the Rice, Miller Sands, and Pillar Rock islands.

III. The MCR (RM 0-6)

A. Sand Transport

There was net sand discharge from the estuary to the MCR of 138 mcy in 1868-1926 and 17 mcy in 1927-1958. During both periods there was probably also sand inflow from the MCR, perhaps as much as 60 mcy in the earlier period and 5 mcy in the later period. The MCR jetties and the resulting inlet bathymetry changes reduced the sand transport into the estuary caused by ocean waves. Since the 1930's, sand entering the estuary from the MCR has been primarily transported by tidal currents through the north channel. It appears that sand discharged from the estuary to the MCR is primarily transported through the south channel during high river discharges.

B. Navigation Development Impacts

Construction of the MCR jetties changed the inlet hydraulics and sand transport. Nearly 800 mcy of sand eroded from the inlet and south flank and deposited along the coast following jetty construction. Over 100 mcy of dredged sand has been disposed of on the outer delta and over 100 mcy more has been placed near the west end of the north jetty. The jetties reduced the sand transport into Baker Bay and across Clatsop Spit into the south channel caused by ocean waves.

IV. COASTAL EROSION/ACCRETION

Since 1868, there has been erosion at the MCR inlet and south flank, and offshore along the Oregon portion of the littoral cell. The sand from the MCR area has deposited in the outer delta, on Peacock Spit, and the shorelines for approximately 12 miles north along Long Beach, Washington, and 12 miles south along Clatsop Plains, Oregon. Sand accretion along both the south and north shorelines has continued up to the present time.

43-FT CHANNEL IMPROVEMENT SEDIMENTATION IMPACTS

There has been concern about what impact the proposed 3-ft deepening of the Columbia River deep-draft navigation channel might have on the sediment budgets of the river and littoral systems. This impact assessment re-examines those issues based on the system's sedimentation processes and its response to the last 120 years of human development of the river and coast. That information is presented in Appendix A and was used to predict the sedimentation responses to the proposed 43-ft channel project that are described below. This assessment relies on existing information and incorporates new information that has become available since publication of the Corps' FEIS (USACE, 1999).

Construction and 20 years of maintenance of the proposed 43-ft navigation channel will likely remove around 70 mcy of sand from the Columbia River and place it in upland disposal sites. Approximately 40 mcy of dredged sand would be disposed of back in-water along the navigation channel or in ecosystem restoration sites in the estuary. This will cause increased riverbed depths and slight changes in river hydraulics (USACE, 1999 and 2001).

The proposed deepening would lower about 45-percent of the navigation channel in the estuary (RM 3-40) and 60-percent of the navigation channel in the river (RM 40-106) by up to 3 ft. Dredging would directly impact about 1- and 10-percent of the entire riverbed between RM 3-40 and RM 40-106, respectively. After the initial deepening the riverbed would begin to adjust to the new channel depth. Riverbeds adjacent to the deeper dredge cuts will degrade as bedload is deflected down the cut slope and into the navigation channel. This process may continue for 5-10 years before the side-slopes reach equilibrium with the channel hydraulics (USACE, 1999 and 2001). The Columbia's riverbed is underlain by thick deposits of alluvial sand that vary in thickness from 400 ft in the estuary to 100 ft near Vancouver (Gates, 1994). The volume of sand removed by dredging and side-slope adjustment will not reduce the available sand supply in the riverbed.

The depth of bed degradation would be nearly equal to the depth of the dredge cut at the edge of the cut and reduce steadily to near zero some distance away from the cut. Side-slope adjustments may extend to the shoreline around RM's 22, 42-46, 72, 76, 86, and 99. The resulting depth increases are expected to be less than one foot near the shore. These locations are all past shoreline disposal sites and the sandy beaches may experience 10-50 ft of lateral erosion (USACE, 2001). Sand eroded from these sites will become part of the active bedload transport on the riverbed.

The hydraulic impacts of a 3-ft channel deepening were examined in the Corps' FEIS and BA (USACE, 1999 and 2001). The deepening would not change water surface profiles between RM 3-70. Upstream of RM 70 there is a progressive reduction in water surface elevations up to RM 106. The maximum reductions ranged from 0.12 to 0.18 ft. The water surface reductions extended upstream to Bonneville Dam at RM 146.

Flow velocities in the Columbia River change continuously due to the influence of the ocean tides. The river's cross-sectional flow area varies, but is generally around 100,000 sq ft. For most non-flood discharges, river velocities will fluctuate between 0-ft/sec and about 3-ft/sec over the course of a day. Given the general size of the river's cross-sectional flow area upstream of the project (RM 106-146), water surface reductions of 0.12-0.18 ft would cause velocity increases of about 0.1 ft/sec, or less, for any river discharge.

Downstream of RM 106, changes in velocities are similarly small, but more complex. Between RM 70-106, the changes in flow areas due to reductions in water surface elevation may be more than offset by the deepening of the riverbed in dredging areas, but not in non-dredging area. Velocity changes in this reach could range from minus 0.2 ft/sec in areas to be deepened, to plus 0.1 ft/sec, in non-dredged reaches. In the dredging reaches downstream of RM 70, velocities would tend to decrease by 0.2 ft/sec or less, but would be unchanged where there would be no dredging. The Corps' three-dimensional hydraulic modeling of the estuary (RM 0-48) indicates velocities, for a 70,000 cfs river discharge, would be unchanged over most of that reach (USACE, 2001). That modeling also showed that the bottom velocities only changed in the navigation channel and that the changes ranged from minus 0.2 ft/sec to plus 0.2 ft/sec.

To alter the Columbia River's sediment budget and/or sand discharge to the Pacific Ocean, the proposed deepening would have to reduce the sand available for transport or alter the transport capacity of the system. The project will not alter the sand inflows from the main stem upstream of the project or from tributaries. The project also will not reduce the abundant sand supply available in the riverbed within the project area. The expected hydraulic changes are very small and fluctuate between changes that would increase, decrease, and not change sand transport in the river. For these reasons, there is not likely to be a detectable change in the sediment budget or sand transport within the Columbia River.

In the estuary, the slight changes in the hydraulic conditions would be restricted to the deeper navigation channel. Hydraulic conditions in the north channel and the estuary's bays and flats would be unchanged. The estuary-wide erosion/accretion patterns also would not change. Desdemona Sands and Cathlamet Bay should remain the two areas most rapidly accumulating sand. Estuarine ecosystem features and flowlane disposal will be used for most of the sand dredged from the channel downstream of RM 40. This disposal practice will minimize changes to the estuary's sand transport and sediment accommodation space. Large floods will continue to have the potential to discharge large volumes of sand to the MCR and ocean, but flow regulation has made such floods less likely to occur. The proposed 43-ft navigation channel should cause no appreciable change in the estuary's sediment budget, sand transport, or the estimated 800-7,700 years before the estuary fills with sediment.

The 43-ft channel project does not include modification of the MCR navigation channel. The Corps' hydraulic modeling showed the deepening would not change the hydraulic conditions in the MCR (USACE, 2001). Therefore, sedimentation processes in the MCR are not likely to change and there will continue to be the transport of sand both landward and seaward at the MCR. Deepening the navigation channel in the river and estuary will not alter the sand transport through the MCR nor the sediment budget of the littoral cell.

Over the last 120 years, navigation channel development has noticeably altered the Columbia River's channel configuration in the river, estuary, and the MCR. However, past dredging and channel modifications have not measurably altered the available sand supply or sand transport in the river. Excluding the effects of the MCR jetties, past navigation channel development also has not altered the estuary's overall erosion/accretion and bedload transport patterns. The reduction in the Columbia River's net sand discharge to the MCR since the early 1900's is related to lower Columbia River flood discharges and not the navigation channel or the MCR jetties. The potential channel modifications in the Columbia River and estuary from the proposed 43-ft navigation channel are similar to, but much smaller than, those caused by navigation development over the past 100 years. The impacts to the sediment budget and sand discharge to the ocean caused by the proposed 43-ft navigation channel are thus expected to likewise be imperceptibly small.

CONCLUSIONS

Construction and 20 years of maintenance of the proposed 43-ft navigation channel will likely remove around 70 mcy of sand from the Columbia River. Another 40 mcy of dredged sand would be disposed of back in-water, mostly in the estuary. This will cause increased riverbed depths and slight changes in river hydraulics between RM 3-106. Deepening will not reduce the available sand supply and the expected hydraulic changes are too small to measurably alter sand transport or erosion/accretion in the river or estuary. There will be no measurable change in hydraulic conditions or sedimentation processes at the MCR. There will continue to be the transport of sand both landward and seaward at the MCR. Large freshets will continue to have the potential to discharge larger volumes of sand from the estuary to the MCR, however flow regulation has made such freshets less likely to occur. The proposed deepening is not expected to impact the littoral sand budgets north or south of the MCR.

Over the last 120 years, navigation channel development has noticeably altered the Columbia River's channel configuration in the river, estuary and the MCR. However, past dredging and channel modifications have not measurably altered sand supply or sand transport in the river or estuary. Excluding the effects of the MCR jetties, past navigation channel development also has not altered the estuary's overall erosion/accretion and bedload transport patterns. The reductions in the Columbia River's net sand discharge to the MCR since the early 1900's are related to lower Columbia River discharges caused by natural climate variations and upstream flow regulation. The potential channel modifications in the Columbia River and estuary from the proposed 43-ft navigation channel are similar to, but much smaller than, those caused by navigation development over the past 100 years. The sedimentation impacts from the proposed 43-ft navigation channel are thus expected to likewise be indiscernibly small.

APPENDIX A

COLUMBIA RIVER SEDIMENTATION PROCESSES; THE LOWER RIVER TO THE COAST

Prepared by:
U.S. Army Corps of Engineers
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January 2003

COLUMBIA RIVER SEDIMENTATION PROCESSES; THE LOWER RIVER TO THE COAST

For thousands of years, sediment carried downstream by the Columbia River has helped shape the estuary and nearby coast. Human activities have altered the river's sediment budget and those of the estuary and coast. There has been concern about what additional impact the proposed 3-ft deepening of the Columbia River deep-draft navigation channel might have on those sediment budgets.

This report examines the available sediment information in the river, estuary, and coast to define the system's sedimentation processes and its response to the last 120 years of human development of the river and coast. This report relies on existing information and incorporates new information that has become available since publication of the Corps' Integrated Feasibility Report for Channel Improvement and Environmental Impact Statement (FEIS) (USACE, 1999). The historic sedimentation processes present here provides additional background for predicting the sedimentation responses to the proposed 43-ft channel project.

STUDY AREA

The study area, as shown in Figure 1, extends from the Columbia River downstream of Bonneville Dam, to the Columbia River littoral cell (CRLC), which extends north and south of the mouth of the Columbia River (MCR). The Corps' 1999 study area (USACE, 1999) has been expanded to include the littoral cell to cover potential coastal impacts. The study area is broken into three reaches, river, estuary, and the MCR, including the adjacent coast. These divisions are based on the dominant hydraulic forces that drive the sediment transport in each reach. The history of navigation developments in the study area is described in the FEIS (USACE, 1999).

RIVER

The river reach extends from downstream of Bonneville Dam (River Mile 145) to the downstream end of Puget Island near River Mile (RM) 40. Through this reach the river occupies a single main channel with occasional small side channels around islands. Sediment transport in this reach is controlled by the river discharges, primarily those of the Columbia upstream of Bonneville and the Willamette River. Ocean tides influence water surface elevations and can create slack water conditions, but flow reversals are negligible to nonexistent.

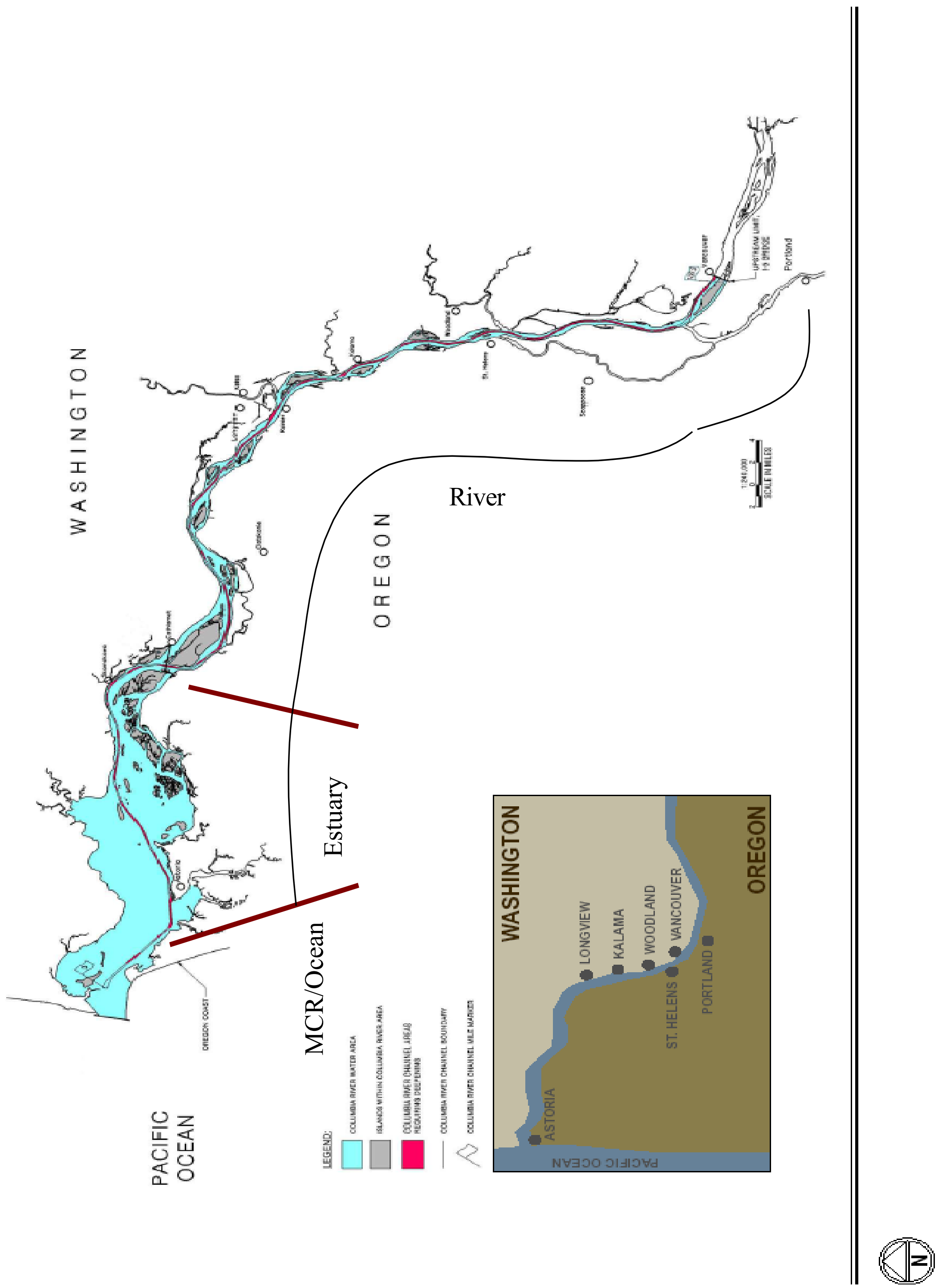


Figure 1. STUDY AREA MAP.

ESTUARY

The estuary reach extends from RM 40 to near the MCR. The Columbia River estuary is 4 to 5 miles wide and contains two main channels, the north and south channels. This reach has very complex hydraulic conditions because of the combined effects of river discharges, ocean tides and waves, and multiple side channels and flats. The main channel transitions from river dominated at the upstream end to tidally dominated near the MCR. Water and sediment are dispersed from the main channel to the estuary's side channels, bays and flats, beginning at RM 40 with flow into Cathlamet Bay.

MOUTH OF THE COLUMBIA RIVER

The MCR reach extends several miles on either side of the entrance to include Long Beach in Washington and Clatsop Plains in Oregon. The Columbia's littoral cell (CRLC) stretches from Tillamook Head on the south to Point Grenville on the north. However, the northern and southern ends of the littoral cell are not included in this report because of the lack of volume change data. The MCR is a high-energy area that extends from RM 6, excluding Baker Bay to the ebb tidal delta. Tidal flows are the dominant factor in sediment transport between the jetties; shoaling wind waves and swell, shodf-modified tidal currents, estuaring-induced currents, and wind-driven currents are the influencing morphologic changes factors along the surrounding coastline and over the ebb tidal delta. The longshore currents vary seasonally along this coast, flowing to the south in the summer and to the north the remainder of the year. Large winter storm waves come in primarily from the southwest, while summer waves come from the northwest (USACE 1999).

STUDY TIME FRAME

This report generally covers the last 130 years, but breaks those into three significant periods, 1868-1926, 1926-1958 and 1958 to present. These time periods are dictated by the time periods of the bathymetric change analysis done for the MCR and coast by Gelfenbaum, et al (2001). The 1868-1926 period includes the relatively natural conditions prior to 1885 and the initial navigation development period from 1885 to 1926. Between 1885 and 1926 the jetties at the MCR were constructed and deepening of the navigation channel began, but river discharges remained unregulated. During the 1926-58 time period, navigation channel development continued and development of the upstream reservoir system was underway, but flow regulation was still minimal. Since 1958 the MCR and river channels have been deepening and river flows have become highly regulated by the upstream reservoirs.

SEDIMENTATION PROCESSES

This study will address natural sedimentation processes and human actions in the study area that have a significant influence on the behavior of the system. Natural processes will include hydrology, transport mechanisms, sediment sources, and deposition. Human actions include dredging, disposal, flow control structures and flow regulation by upstream reservoirs. The timing of major sediment movements is important to their interaction, and is also addressed in this study.

While the sedimentation processes in the study area involve sand, silt, and clay, the emphasis of this report will be on the movement of sand. Sand is the primary material in the riverbed, ocean beaches and dredging operations, and is essential to the morphology of the study area. The natural system works to maintain a balance between transport potential and sand load such that if the transport potential is less than the incoming sand load, deposition will occur. Conversely, if transport potential exceeds the incoming sand load and there is an available source, erosion will occur (ASCE, 1977). However, transport potential varies in time and space, causing natural alluvial channels to shift and evolve. These basic processes are introduced in this section and then the specifics for the Columbia River are covered in more detail later in this report.

HYDROLOGY

The Columbia River drains 259,000 square miles, originating in Canada's Columbia Lake and flowing 1,214 miles to the Pacific Ocean. Flow from the upper basin is dominated by snowmelt, resulting in low winter discharges and large spring freshets. Heavy winter rainfall in the lower basin can cause high discharges in the study area. Since 1878, the average annual discharge at The Dalles has been 192,000 cubic feet per second (cfs). However, there has been a reduction in average annual discharge since the 1800's due to global scale climate variations, and upstream diversions and flow regulation (Jay and Naik, 2000). The 1878-1900 average annual discharge at The Dalles, was just over 220,000 cfs. For the time period before completion of any large reservoirs (1878-1935), the average annual discharge was 200,000 cfs. The period-of-record average annual discharge continued to fall until it reached approximately its current value around 1945.

Reservoirs upstream of the study area store water during the spring snowmelt and release it during the fall and winter to increase hydroelectric power generation. After completion of the large Canadian storage reservoirs in the early 1970s, the 2-year flood peak at the Dalles, Oregon, was reduced from 580,000 cfs to 360,000 cfs with regulation (USACE, 1987). Low flows, typically in the 100,000 cfs range, occur in September and October after the snowmelt runoff but before the winter rains. Flows in the study area are slightly higher due to local inflows, especially from the Willamette and Cowlitz rivers. The average annual discharge in the Willamette River at Portland is 33,000 cfs.

TRANSPORT MECHANICS

The two basic types of sediment transport of concern in this report are suspended and bedload. These two transport mechanisms occur in all three reaches of the study area; however, the hydraulic forces that drive sediment transport differ significantly between the river and the ocean. For that reason the important components of riverine and ocean transport are described separately in the following text.

Riverine Suspended Sediment

Suspended sediment is sand, silt, and clay transported within the water column. Buoyancy and turbulence within the water column support the sediment particles. Particles are carried at near the velocity of the river current and can therefore move long distances before depositing. Suspended sediment can be divided into "wash load" and "bed sediment load" (ASCE, 1977). Wash load is composed of fine sediment found in very small quantities in the bed, while the bed sediment load is composed of the larger particle sizes which are common in the bed sediments. The summation of the wash load and bed sediment load is referred to as the total suspended sediment load.

The wash load comes from outside sources, such as tributaries and local runoff, and can stay in suspension for extended periods of time. Wash load transport tends to rise and fall with river discharge but, because it is independent of the channel's bed and hydraulic conditions, it does not necessarily have a consistent relationship to discharge. The Columbia River wash load is composed of silts and clay.

Suspended bed sediment load is generally the sand portion of the suspended sediment load. Suspended sand transport is the result of the integration of the transport potential (energy) of the water, the settling properties of the sand particles, and the available sand supply. The suspended bed sediment load may originate from outside sources, but there are also erosion/deposition interactions with the riverbed that maintain the balance between suspended bed sediment load and transport potential. Because of these interactions, sand transport is dependent on both material and hydraulic properties. Important material properties include, available supply, and grain size and shape. A variety of hydraulic parameters influence transport potential, such as discharge, depth, velocity, slope, and density (ASCE, 1977).

In rivers with alluvial beds there is usually a relationship between water discharge (Q) and suspended sand discharge (Q_{ssand}). This relationship is referred to as a sediment rating curve and generally takes the form of $Q_{ssand}=aQ^b$, where a and b are variables dependent on local river conditions. Suspended sand discharge increases very rapidly with increasing water discharge because of this exponential relationship. A sediment rating curve can be combined with streamflow data, or a flood-duration curve, to estimate sand discharges for time periods without transport measurements (USACE, 1989).

The suspended sediment concentrations in the Columbia River are quite low. Measurements taken during the spring freshet in 1922, before any large dams were built, found an average suspended sediment concentration of 130 parts per million (ppm) downstream of the Willamette River (Hickson, 1961). Measurements taken in 1959 and 1960 (USACE Portland, 1961) and in the 1980's (USGS, 1980-2000) show similar suspended sediment concentration verses river discharge relationships for the two time periods. Based on observed concentrations and appropriate flow-duration curves, the Corps estimated that the average annual suspended sediment yield at Vancouver, WA, has been reduced from 12 mcy/yr pre-regulation to only 2 mcy/yr post-regulation (USACE, 1999).

Not all size classes of suspended sediment in the Columbia River are important components of the shoaling and sediment accumulation in the study area. USGS sediment data indicates around 70-90 percent of the suspended sediment is silt or clay, materials not found in significant quantities in the riverbed, estuary, or ocean beaches. Sand is generally less than 15 percent of the suspended load, increasing to over 30 percent when the discharge exceeds 400,000 cfs, but makes up about 95 percent of all the bed material in the study area. The Corps (USACE, 1999) estimated the current average suspended bed material (sand) transport into the Columbia River is only between 0.2 and 0.6 mcy/yr.

Riverine Bedload

Bedload is the movement of sand, or larger grains rolling and bouncing along the surface of the riverbed. The current velocity near the bed is slower than that of the rest of the water column, causing the bedload particles to move slower than suspended particles. Bedload particles move intermittently and when in motion tend to cover only short distances before returning to rest. This transport behavior results in bedload rates that are generally much lower than the suspended transport rates in the same stream.

In sandy riverbeds, like the Columbia's, the bedload transport shapes the bed into a series of sand waves. These waves move downstream as sediment erodes from the upstream face, deposits in the downstream trough and is then buried by additional material eroded from the upstream face. This movement occurs in a layer only a few sand grains thick. Through this mechanism, all the individual grains in a sand wave are exposed to flow, eroded, transported, deposited, buried, and then eventually exposed again as the sand wave migrates downstream.

Bedload transport varies with discharge, but is not in general directly related to discharge. Bedload movement depends on the forces exerted on the sand particles by the flowing water to cause motion. This force can be represented by the boundary shear stress (τ_b) which is a function of the density of the water (γ), the depth of flow (d), and the energy slope (S) such that $\tau_b=\lambda dS$. Bedload occurs when τ exceeds the critical shear stress (τ_c) for the bed material and the rate increases as τ increases above that value (ASCE, 1977). The actual bedload movement within a stream varies greatly because of variations in both τ_b and τ_c, and due to the effects of turbulence along the bed.

No attempt has been made to directly measure the bedload transport of the Columbia River. However, bedload estimates have been made using two independent methods (Eriksen and Gray, 1991). An empirical equation developed by the USGS was used to estimate unmeasured load for pre- and post-regulation conditions. That equation is based on the modified Einstein equation and relates unmeasured load to river discharge (USACE Portland, 1986). Applying this equation to the pre- and post-regulation flow-duration curves resulted in bedload estimates of 1.5 mcy/yr pre-regulation and 0.2 mcy/yr post-regulation.

The second estimate was made by equating bedload transport to the movement of the sand waves present on the bed. Sequential surveys were made of two sets of sand waves, one during high flow conditions and the second during average discharge conditions. The analyses of those surveys and flow conditions resulted in bedload estimates ranging from 0.1 mcy/yr to 0.4 mcy/yr. The analysis also found that large sand waves only moved several hundred feet a year.

Ocean Transport Processes

Waves and currents are the necessary elements in transporting sediment through the entrance channel as well as north and south along the coastline. Tides cause a short-term change in the direction of sediment transport, as can be seen by the flood- and ebb-tidal shoals. As waves approach a coastline, the dissipation of the wave energy causes sediment movement. The wave direction and angle determines the direction and amount of sediment transport. A wave that approaches shore-normal will tend to cause more cross-shore transport, where an oblique wave results in a majority of alongshore transport. A more long-term sediment transport pattern is seen in a seasonal timeframe, with the dominant wave direction varying. In Moritz, et al (1999) the net littoral transport is described as to the north with significant periods toward the south, because the circulation of the inner shelf region is greatly influenced by a seasonal variation. The circulation in this region is also greatly influenced by a change in wind conditions in the alongshore direction (USACE 1999). This effect is greatly decreased as the distance offshore is increased. Moritz, et al (1999) also concluded that the response of the seabed was affected primarily by wave processes and secondarily by bottom current processes.

There are three cross-shore regions for sediment transport along the Oregon-Washington continental shelf as defined by USACE 1999. The first is the outer shelf, defined as the area in depths greater than 300 ft, that is characterized by shoaling internal waves and seasonally-modified regional currents that affect the movement of bottom sediments. The next area is the mid-shelf region, in the 120 ft to 300 ft depth range, where wind-driven waves are the most important factor for sediment transport. The area in depths less than 120 ft is called the inner shelf. Wind-driven currents, estuaring-induced currents, shelf-modified tidal currents, and shoaling wind waves and swell dominate sediment transport of bottom sediment in this area. A more detailed explanation of the sediment transport processes can be found in USACE 1999.

Ocean Currents

The continental shelf of Washington and Oregon is characterized by three seasonal current regimes, fall-winter, spring, and summer (USACE 1999). The fall-winter season, which runs from November to March, marks the onset of the Davidson Current, a northward flowing current. The Davidson current develops off the Oregon and Washington coastline in the fall due to southerly winds and becomes established in January. The spring represents the transition time between the northward flowing Davidson Current integrating into the southward flowing California current by May. The California current dominates the flow offshore of the continental shelf break, more than 20 miles offshore, to a depth of 500 ft during the summer regime. The current obtains maximum strength in the summer when winds are consistently from the north-northwest. The subsurface portion of the Davidson current is believed to flow to the north throughout the year, resulting in a net flow along the bottom towards the north. A more detailed account of the ocean currents in this region is available in USACE 1999.

SEDIMENT SOURCES

Whetten et al. (1969) characterized the Columbia River as having two principal sediment sources: the upper watershed (above the Columbia/Snake confluence) that produces fine grained sediments from surfacial deposits, and the Cascades that produce sand from the erosion of volcanic material. They concluded that under average conditions, it was likely that sediments from the two sources were transported and deposited independently, the upstream sediment as suspended load and the coarser downstream sediment as bedload. Whetten et al (1969) found that sediment was not generally accumulating in the main stem Columbia River reservoirs because sediment was being scoured from those reservoirs during high flows. The Columbia River's main stem sediment discharge into the study area would thus be composed of material from both these sources.

Potential sources of coarse-grained Cascade sediments also occur throughout the study area. Tributaries such as the Sandy and Cowlitz rivers discharge volcanic sand into the Columbia River. The Willamette River was probably a sand source in historic times, but flow regulation and channel modifications have substantially reduced its sand transport. The river, estuary, and MCR beds are large potential sand sources, especially for bedload. The coastal beaches and ocean floor are also composed of sands that are potential sources for sediment transport.

The construction of the MCR jetties caused a large amount of sediment to accrete in the littoral zone north and south of the entrance. This “wave of sand” continues to travel away from the entrance, causing accretion along the littoral cells north and south of the entrance. Approximately 67% of the suspended sediment discharged from MCR is transported to the continental shelf off Washington; about 17% of this sediment is lost to the littoral system to submarine canyons. (USACE 1999)

DEPOSITION

Sediment deposition in the study area occurs in many different forms and has a wide range of time scales. In a geologic sense, the entire study area is a deposition zone responding to thousands of years of sea level rise (Gates, 1994). But on a more immediate time scale, the most important deposition conditions include annual shoaling in the navigation channel, and deposition and accumulation of sand in the estuary and along the coast.

Shoaling in the navigation channel through the river and estuary is primarily the result of convergence of bedload transport paths and sand wave development (USACE, 1999). This process goes on continuously, but occurs more rapidly during river discharges over 300,000 cfs. This shoaling is more a redistribution of bed sediment, rather than accumulation of sediment, since it does not change the volume of material in a river reach.

Sediment deposition and accumulation has been occurring in the Columbia estuary over the past 130 years (Sherwood et al., 1984). The bays and shallow areas accumulated most of the sediment over that time. Bed material sampling done in the early 1960's (Hubbell and Glenn, 1973) indicates that sand comprised over 80 percent of the accumulated sediment. There was a higher percentage of silt in the estuary bays, but sand was still the dominant material.

Moritz, et al (1999) and USACE (1999) both describe the deposition characterization of sediments found in the vicinity of the MCR.

HUMAN ACTIONS

Dredging and Disposal

Dredging removes material from the riverbed and disposes of it somewhere else. This discussion will summarize the dredging and disposal methods used for navigation in the study area. A detailed discussion of these methods is provided in the Columbia River Channel Improvement Project Biological Assessment (USACE, 2001).

Pipeline and hopper dredges are commonly used by the Corps in the Columbia River. A pipeline dredge uses a revolving cutter head on the end of an arm that is buried 3-6 feet deep in the riverbed. Dredged material is pumped through a pipe to the disposal site. Hopper dredges pull dragheads along the riverbed and suck sediment through the draghead and into the hold of the dredge. Large pipeline or hopper dredges have the ability to move tens of thousands of cubic yards of sediment per day.

Dredged sediments can be disposed of at upland sites, along the shoreline, in-water in deeper parts of the river channel and at ocean sites. Upland disposal sites are used by pipeline dredges and can range from a few acres to over a hundred acres in size. Upland sites generally have containment dikes and holding ponds to retain the sediments. Sediment placed in upland sites may be permanently stored at the site, or it may be removed and put to beneficial use.

Shoreline disposal along the river is done by pumping sediment directly onto a beach. The sand quickly deposits on the beach, and the water and fine sediments are allowed to return to the river. Bulldozers are then used to distribute the material along the beach, typically building river beaches out 100-150 feet. In the past, this method of disposal has been used to fill within pile dike fields. "Beach nourishment" is the use of shoreline disposal to replace beach material eroded by the currents and/or waves, and is the only type of shoreline disposal remaining in use on the Columbia River.

In-water disposal is the placement of material back into the river. In the Columbia River the most common practice is flowlane disposal. Flowlane disposal is in-water disposal within or adjacent to the navigation channel. For the 40-ft channel, flowlane disposal sites may be at depths between 35 and 65 feet deep, but are typically greater than 50 feet deep and downstream of the dredging site. Occasionally disposal depths exceed 65 feet, but only in previously agreed upon locations. Flowlane disposal is distributed along the riverbed to avoid creating mounds. These flowlane disposal practices minimize the amount of material that can return to the dredging area and also minimize the disruption to the natural downstream movement of sand.

<u>Flow Control Structures</u>

Pile dike fields, dredged material disposal, and stone jetties have been used in the past to construct flow control structures to improve navigation and manage sedimentation in the study area. Pile dikes and disposal have been used along the river and estuary reaches. Stone jetties were built at the MCR.

Pile dikes are rows of wooden piling constructed out into the river. There are 256 pile dikes in the study area. Pile dikes were usually built in "fields", a series of dikes spaced 1,200-1,500 feet apart, which run along the shoreline for up to four miles. When built, the two main purposes for the pile dike fields were; 1) to concentrate flow in the main channel to cause scour, and 2) to stabilize the channel and banks (Hickson, 1961 and USACE, 1987).

Flow velocities are reduced at and downstream of the pile dikes, causing more flow in the center of the channel. This reduces the sediment transport potential along the shore and increases it in the channel. Dredged material has been placed within many of the dike fields, completely eliminating the flow area and further increasing the flow in the channel. Most of the disposal material placed within pile dike fields remains in place today. Pile dikes and disposal have also been used to reduce flow into side channels and alter the alignment of the river channel.

Flow is restricted to the channel between the stone jetties at the MCR. This has caused scour in the entrance and stabilized the location of the entrance channel. The jetties also protect the entrance channel and lower estuary from large storm waves.

Flow Regulation

Many reservoirs have been built on the Columbia River and its tributaries upstream of the study area. These reservoirs provide flood control, hydropower, navigation, and irrigation water. River and sediment discharges in the study area have been permanently altered by flow regulation from those upstream reservoirs. Reservoirs upstream of the study area store water during the spring snowmelt, reducing the freshet discharges. The reduced discharges have caused large reductions in sediment transport during the spring freshet (USACE, 1999). The stored water is released during the fall and winter to increase hydroelectric power generation. Those releases cause little increase in sediment transport because the river discharges remain below critical levels.

TIMING

The timing of sedimentation processes is an important factor in how the various processes interact. The combined affect of coincident events may be much greater than the sum of the individual affects of independent events. Sedimentation processes in the study area are influenced by both natural events and human actions that range from a few hours in duration up to tens of years. Natural events include spring snowmelt freshets, large winter storms, and ocean tides. Human actions involve flow regulation, jetties, dredging and disposal, and pile dike fields.

Sedimentation in the study area is largely driven by the Columbia's hydrologic cycle. The majority of the river's sediment transport typically occurs in May and June, during the spring freshet. Infrequent (on average, less than once every ten years) winter floods can also transport high concentrations of sediment, however their sediment volumes are smaller because the flood duration may be only a few days. The Columbia's hydrology is affected by global climate events, such as El Nino/La Nina events (NOAA, 2002) and the Pacific Decadal Oscillation (Joint Institute for the Study of the Atmosphere and Ocean (JISAO), 2002), that have durations of a few years and tens of years, respectively. Jay and Naik (2000) explain the interaction between these climate cycles and how they affect sediment transport in the Columbia River.

River and sediment discharges in the study area have been permanently altered by flow regulation from upstream reservoirs. Reservoirs upstream of the study area store water during the spring snowmelt, reducing the freshet discharges. The reduced discharges have caused large reductions in sediment transport during the spring freshet (USACE, 1999). The stored water is released during the fall and winter to increase hydroelectric power generation. Those releases cause little increase in sediment transport because the river discharges remain below critical levels. Hydroelectric power releases also cause relatively minor hourly river discharge fluctuations that do not alter sedimentation.

Dredging to construct the proposed 43-ft channel would occur on a year round schedule for two years. Maintenance dredging would occur annually for the life of the project. Maintenance dredging is typically done in the May through October time period, with most work done during the summer when sediment transport is low. Dredging at any one location might range from a few days at small shoals in the river, up to a month or more at the large river shoals. Due to hazardous conditions, MCR maintenance dredging is performed in the summer.

SEDIMENT BUDGET

A sediment budget provides an accounting of sediment volumes in time and space. It can be used to help define sediment processes, detect sediment trends, identify impacts of individual events, and predict impacts of future events. Sediment budget data for the Columbia River channel, estuary, MCR, and coast were compiled from existing sources are presented in this section. The sediment budget will be used to examine questions such as; what is the net transport of sediment through the MCR, what are the long-term sediment trends, and what was the impact of jetty construction and flow regulation on sediment transport?

The usefulness of any sediment budget depends on the refinement of the available data. In the case of the Columbia River system, the available timeframes and locations for bed volume changes in the river, estuary, and ocean limit the sediment budget. There are bathymetric surveys of the river, estuary, and ocean available from the 1800's to the present (USACE, 2002). In the estuary, bathymetric differences have been mapped for 1868-1935, 1935-1958, and 1958-1982 (CREDDP, 1983), but because of differences in survey coverage, volume differences are only available for the first two time periods (Sherwood, et al, 1984). In the near- and offshore areas, bathymetric differences have been calculated for the periods 1868-1926, 1926-1958, and 1958-1999 (Gelfenbaum 2002). However, there are no bathymetric difference studies for the Columbia River upstream of RM 48. Columbia River suspended sediment loads have been estimated for the period 1878 to 1999 (Sherwood et al, 1990 and Bottom et al, 2001). Detailed records of dredging volumes are available for the MCR and river navigation channels from 1890 to 2001 (USACE, 2002). The Corps also has limited information available on the placement of dredged material disposal.

River flows and sedimentation processes have varied greatly over geologic time due to both long- and short-term events. Long-term events include glaciation, and the subsequent Missoula floods and rising sea levels. Short-term events that intensified sedimentation processes included very large floods, subduction earthquakes, landslides, and volcanic eruptions. These natural events probably had sediment impacts on the order of tens- to hundreds-of-millions of cubic yards, or in the case of the Missoula floods, unimaginable impacts. These catastrophic events are rare and unique, and will not be addressed in this report.

The focus of this report will be the last 130 years and in particular the past 115 years when human activities have had an influence on natural sedimentation processes. Major actions have included; construction of jetties at the mouth of the river, diking and filling of wetlands for urban and agricultural uses, development and maintenance of the deep-draft navigation channel from Portland/Vancouver to the Pacific Ocean, and development of a series of multi-purpose reservoirs that regulate river discharges.

GEOLOGICAL BACKGROUND

Long-term geologic processes have established the foundation for today's Columbia River river-estuary-coastal sediment system. The accumulation rate along the Columbia River Valley has decreased from 11 mcy/yr prior to 7,000 years ago, to about 5 mcy/yr, in the last 7,000 years. This indicates the total sediment accumulation volume in the lower Columbia River valley during the last 10,000 years is around 66,000 mcy (Gelfenbaum and Kaminsky, 2000).

The long-term accumulation rate for the past 10,000 years on the ocean shelf is 8.5 mcy/year. An additional 49,000 mcy of Columbia River sediment that has accumulated on the continental slopes, canyons, and fans off Washington and Oregon in the last 5,000 years (9.7 mcy/yr) (Gelfenbaum and Kaminsky, 2000). Grays Harbor and Willapa Bay have also been sinks for Columbia River sediment. Grays Harbor's accumulation rate has decreased from 0.8 mcy/yr 7,000 years ago to 0.26 mcy/yr in the last 5,000 years for a total volume of 5,800 mcy. The volume of sediment accumulation in Willapa Bay has not yet been calculated, however, the basin is about half the size of Grays Harbor, so the estimated accumulated volume is about 2,900 mcy. Accumulation rates for littoral sub-cells north and south of MCR are: Long Beach = 0.51 mcy/yr and Clatsop = 0.43 mcy/yr. The similarities between the accumulation rates north and south of MCR suggest that the net sediment transport direction is not an easy question to answer. The total accumulation of Columbia River sand for all the coastal sub-cells adjacent to MCR for the past 10,000 years is 5,300 mcy.

RIVER AND ESTUARY SEDIMENT BUDGET

A complete, indisputable sediment budget for the Columbia River and estuary is unattainable, but most of the important components can be delineated. The annual sediment transport rates and dredging volumes are the two components that can be best defined. The fate of dredged material is less well defined because of incomplete disposal records. Dredging, disposal, and natural processes have altered the river and estuary bathymetry, but only in the estuary have those changes been documented and quantified.

Sediment transport measurements have only been taken sporadically in the Columbia River. Sherwood et al. (1990) cited U.S. Geological Survey (USGS) work done in 1910-12 and 1964-70. The Corps collected a few samples in 1922 (Hickson, 1930) and conducted a field study in 1959-60 (USACE, 1961). In recent years the USGS has collected occasional measurements at Warrendale (RM 140) and Beaver (RM 55), Oregon (USGS, 1980-2000). Sherwood et al (1990) used 1964-70 USGS suspended sediment data collected at Vancouver, Washington (RM 106), USGS streamflow measurements at The Dalles (1878-1985), and empirical equations to hindcast annual total sediment and total (suspended plus bedload) sand transport for the period 1878 to 1985. Bottom et al. (2001) extended the annual total sediment discharge estimate to 1999. Unless otherwise noted, the sediment transport volumes used in this report have been derived from those two studies. (A correlation of sand/total sediment volumes from

Sherwood et al. (1990) was used to estimate sand transport from the total sediment reported by Bottom et al. (2001).) Figure 2 shows the resulting annual Columbia River sand transport hindcast for 1878-1999.

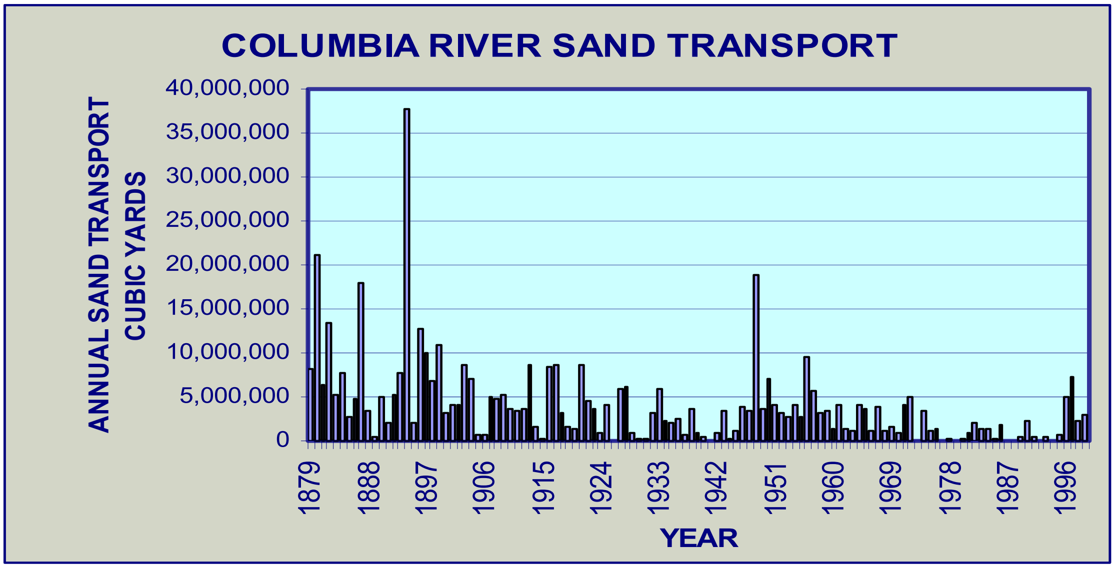


Figure 2. Columbia River total sand transport at Vancouver, Washington, upstream of the Willamette River. Derived from Sherwood et al. (1990) and Bottom et al. (2001).

While the exactness of this sand transport hindcast is limited by the available water and sediment discharge data, Bottom et al. (2001) indicate that the sand transport is nearly as accurate as the water discharge data. This is because the Columbia River has an abundant sand supply in the riverbed and sand transport is only limited by the river's transport capacity. The affects of extended periods of high river discharges on sand transport can be seen in the high transport rates in 1880, 1887, 1894, and 1948. The large winter floods of 1964 and 1996 produced high daily transport rates, but were of limited duration and did not result in high annual sand transport quantities. Sand transport from those floods may be underestimated because much of the 1964 and 1996 flood discharges came from tributary streams not included in the discharge data from The Dalles.

Sediment inflows from tributary streams, such as the Willamette, Sandy, and Cowlitz rivers, are generally unavailable. It is likely that these streams contribute only minor amounts of sand directly to the navigation channel except during very large winter storms and following the eruption of Mount St. Helens (USACE, 1985). The Willamette River's average annual suspended sediment load is estimated to be 1.7 mcy per year. Less than 20 percent, or about 0.3 mcy per year, of that material is sand and the rest is silt or clay.

The eruption of Mount St. Helen's produced extremely high levels of suspended sediment in the Toutle and Cowlitz Rivers between 1980 and 1987. From 1982 through 1987 the Cowlitz River delivered 40 mcy of sand to the Columbia River. Toutle and Cowlitz

Rivers' sediment yield dropped significantly since the completion of the Toutle River Sediment Retention Structure in 1987. The current average sand yield from the Cowlitz River is estimated to be less than one mcy per year.

Navigation channel dredging records are available from 1890 to the present (USACE, 2002). Those records indicate that 680 mcy of sediment has been dredged from the river and estuary (RM 3-106) between 1900 and 1999. Figure 3 compares those annual dredging volumes to the river's annual sand transport volumes. Dredging has exceeded sand transport in all but seven years since 1910, and four of those years were prior to completion of the 35-ft channel.

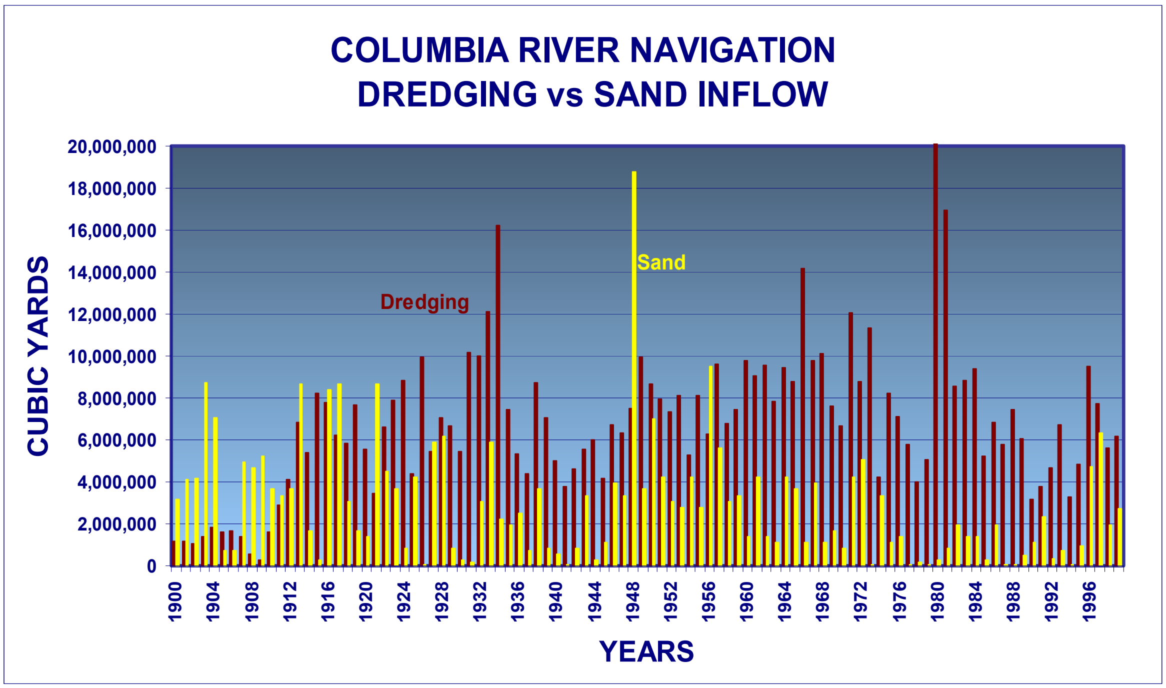


Figure 3. Comparison of dredging and sand transport in the Columbia River.

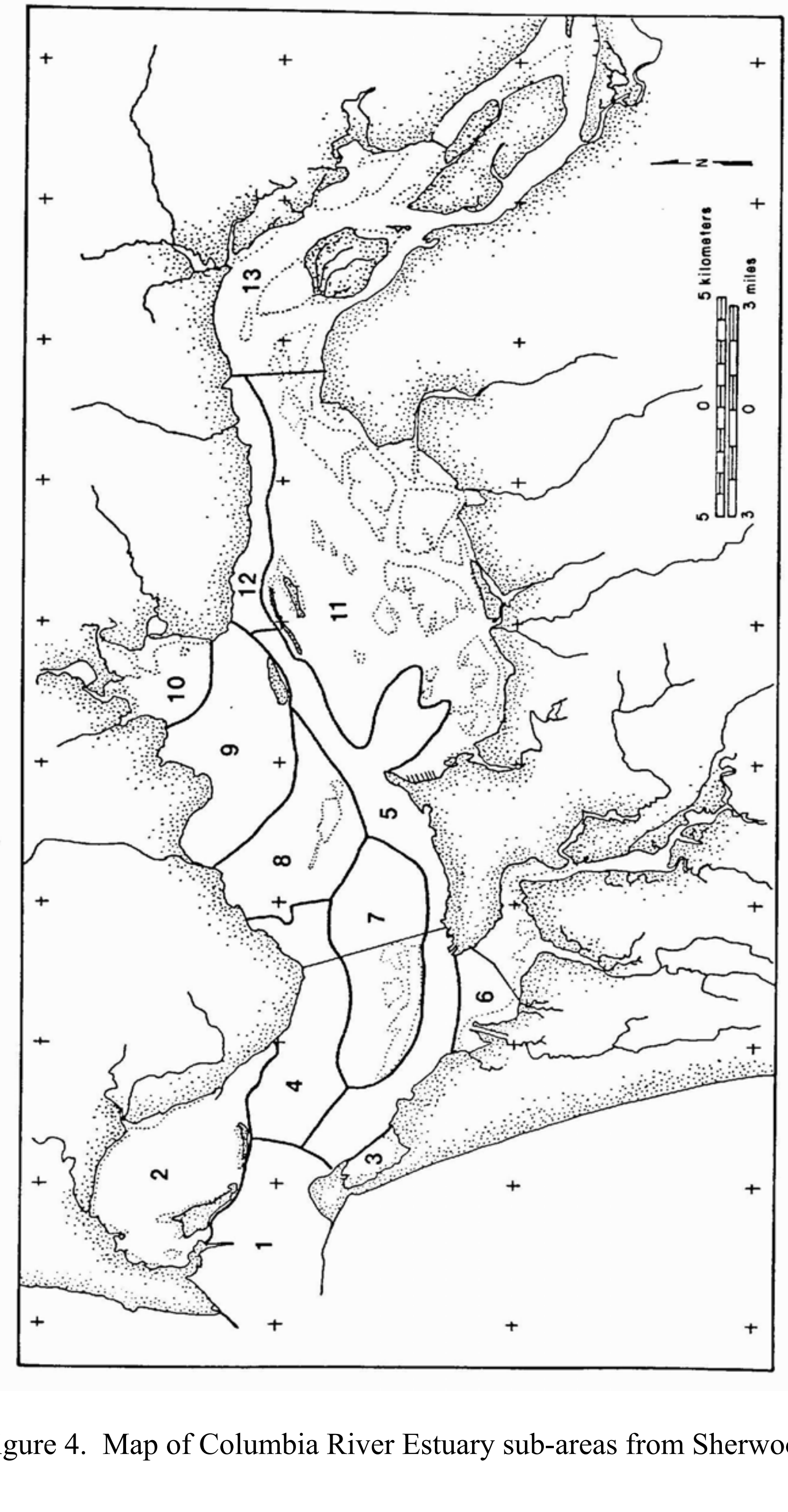
The dredging records identify the location, volume, and type of dredge used for each action. Table 1 summarizes the dredging volumes for four reaches in the river and estuary for the time periods of interest in this report. Unfortunately, the disposal locations were not as carefully recorded and most are not available. It is known that downstream of Puget Island (RM 40), most disposal has been in-water, because most of the dredging has been done by hopper dredges. The only significant removal of sand downstream of RM 40 has been at the Miller Sands-Pillar Rock reach (RM's 21-28) where about 22 mcy of sand has been placed on three islands. About 5 mcy of the island disposal occurred in 1934-35 and the remainder has been since 1970. Dredging upstream of RM 40 has been by a combination of hopper and pipeline dredges, with in-water, shoreline, and upland disposal being used. Shoreline and upland disposal sites can be identified from historical aerial photographs and bathymetric surveys (USACE, 2002). Even in this upstream reach it is likely that more than half of the disposal has been placed directly in-water, or has eroded from shoreline disposal sites and returned to the active river.

Table 1. Columbia River Dredging and Sediment Transport in MCY.

DREDGING REACH	1868-1926	1927-1958	1959-1978	1979-1999	1900-1999
South Channel (RM 6-23)	31	52	41	29	153
Lower River Channel (RM 23-31)	6	19	11	12	48
Upper River Channel (RM 31-48)	12	21	26	32	91
Main River Channel upstream of RM 48	69	143	93	83	388
Total River Dredging	118	235	172	156	680
Sand Transport	355	113	43	30	541
Total Sediment Transport	710	290	130	113	1243

Sand and total sediment transport volumes are based on Sherwood et al. (1990) and Bottom et al. (2001).

Navigation channel construction and maintenance has altered the Columbia's riverbed. The river has been deepened, narrowed, and re-aligned by dredging, disposal, and pile dike fields. The changes have been greatest upstream of Puget Island (RM 40) and smallest in the estuary. These changes can be seen in aerial photographs and bathymetric surveys of the river taken over the past 100 years (USACE, 2002), but the riverbed volume changes have only been documented for the river and estuary downstream of RM 48. Sherwood et al. (1984) calculated volume changes for the time periods 1868-1935, 1935-1958, and 1868-1958, for the estuary and river reaches shown on Figure 4. Table 2 presents their results and shows that the largest volume changes occurred in the estuary's bays and shallow flats. Volume changes in the main channels were relatively small. The 67 years of the first period encompasses a number of important natural and human actions, such as the shift of the north channel out of Baker Bay prior to 1885 (USACE, 1938), construction of the MCR jetties (1885-1917), and construction of the 25-ft (1910-1911), 30-ft (1915-1919) and 35-ft (1934-1935) navigation channels.



Map of the Columbia River Estuary showing 13 subareas used in volume and area calculations: 1) Entrance, 2) Baker Bay, 3) Trestle Bay, 4) North Channel, 5) South Channel, 6) Youngs Bay, 7) Desdemona Sands, 8) Mid-Estuary Shoals, 9) Grays Bay, 10) Brix Bay, 11) Cathlamet Bay, 12) Lower River Channel, 13) Upper River Channel.

Figure 4. Map of Columbia River Estuary sub-areas from Sherwood et al., 1984.

Table 2. Columbia River Estuary Shoaling and Erosion Rates

ESTUARY SUBAREA	1958 Surface Area in Acres	1868-1935 Volume Change in MCY	1935-1958 Volume Change in MCY	1868-1958 Volume Change in MCY
Baker Bay	14,700	119.6	-6.3	113.3
North Channel (RM 6-14)	8,200	-4.5	-7.4	-11.9
Trestle Bay	1,500	11.9	5.2	17.1
Youngs Bay	9,900	41.4	5.1	46.5
Desdemona Sands	8,500	60.4	17.0	77.4
Mid-Estuary Shoals	6,700	1.7	-0.4	1.3
Brix Bay	10,900	8.1	-0.8	7.4
Grays Bay	8,300	30.4	-5.3	25.2
Cathlamet Bay	35,300	64.9	35.3	100.3
South Channel (RM 6-23)	17,100	-13.1	23.2	10.1
Lower River Channel (RM 23-31)	7,300	-9.4	1.2	-8.2
Upper River Channel (RM 31-48)	16,600	25.4	10.8	36.3
ESTUARY TOTALS	145,000	336.9	77.8	414.7

From Sherwood, et al, 1984.

The CREDDP bathymetric maps (1983) show the sediment accumulations in the bays and shallow flats of the estuary that are the net results of processes that include the gradual accumulation of sediments on flats, shifting channels, and the filling and abandonment of large channels. Deposition in the 1868 river channel through Baker Bay accounts for a third of the total estuary sediment accumulation between 1868 and 1935. Baker Bay became a minor source of sand in the 1935-58 time period. Desdemona Sands experienced sand accumulation in both periods, but switched from a pattern of shifting channels prior to 1935, to one of gradual accumulation that continued up to 1982. Cathlamet Bay experienced a steady accumulation of sand, which was the result of continuously shifting of channels and gradual accumulation on the shallow flats. The changes in the main north and south channels are generally the net results of shifting channels with intermittent areas of erosion and deposition. Bed elevation changes of up to plus or minus 30-ft were fairly common in those channels over the 67-year period between 1868 and 1935. Sherwood et al. (1984) estimated that at the observed rates of sediment accumulation, the estuary would fill in 800 years, but that it would take over 7,700 years to fill the estuary and the MCR.

Table 3 presents a summary of the Columbia River and estuary sediment budget. The timeframes and volume changes in the estuary on this table are those of Sherwood et al.

(1990). The table shows that the volume changes in the main channel downstream of RM 31 are much smaller than the corresponding navigation channel dredging volumes. This is a result of using hopper dredges and in-water disposal, as this would just redistribute sand within the river channel and have little impact to the net volume of sediment in a reach. The north channel had a net loss of material during both time periods, even though it likely received a portion of the in-water disposal from dredging downstream of RM 14.

Table 3. Sediment budget summary for the Columbia River and estuary. Positive values indicate accumulation of sediment.

AREA	1868-1935		1935-1958		1868-1958	
	Volume Change in MCY	Dredging Volumes in MCY(1)	Volume Change in MCY	Dredging Volumes in MCY	Volume Change in MCY	Dredging Volumes in MCY
Estuary bays and shallow flats	339	(2)	50	(2)	389	(2)
North Channel (RM 6-14)	-5	0	-7	0	-12	0
South Channel (RM 6-23)	-13	50(3)	23	33(3)	10	83(3)
Lower River Channel (RM 23-31)	-9	17(3)	1	8(3)	-8	25(3)
Upper River Channel (RM 31-48)	25	19(3)	11	14(3)	36	33(3)
River Channel upstream of RM 48	N/A	113	*-140(4)*	99	N/A	212
Total Sand Transport	380		88		468	
Total Sediment Transport	800		200		1,000	

1 Only minor amounts of dredging occurred before 1900 when the 25-ft channel construction began.

2 Insignificant dredging volumes in small side channels.

3 All dredging downstream of Puget Island (RM 40) was done by hopper dredges with in-water disposal except for 5.5 mcy of pipeline dredging at Miller Sands in 1934-35.

4 This is a rough estimate of erosion outside the navigation channel between 1920 and 1960 (Hickson, 1961). It covers the entire study area, including the reach from Vancouver to Bonneville Dam, but it is estimated that most of the change occurred between RM's 48 and 106. It does not account for shoreline fills created with disposal material that would probably offset much of the volume lost.

Sand Discharge to the MCR

The final component of a sediment budget for the river and estuary is the sediment discharge, and more importantly the sand discharge, to the MCR. This has been a critical unknown in the sedimentation analysis of the Columbia River and coastal systems.

Given the available data, the sand discharge to the MCR cannot be calculated with a high degree of certainty, but reasonable estimates of total sand discharge can be made for the 1868-1926 and 1927-58 time periods.

One necessary hypothesis for estimating the sediment discharge to the MCR is the sand behavior in the river upstream of RM 48. This reach could be a sand source, a sink for inflowing sand, or simply a sand transport reach. The detailed data on riverbed volume changes, sand transport rates and disposal placement, necessary to calculate the sand behavior in this reach does not exist. It is therefore necessary to draw conclusions about sediment processes from theory and the limited data that is available.

As Table 3 shows, the only estimate of river channel volume changes is Hickson's (1961) 140-mcy of erosion between Bonneville and the estuary, between 1920 and 1960. Hickson explained this 140-mcy loss (an average of 3.5 mcy per year for 40 years) as erosion caused by the construction of pile dike fields along the navigation channel. He also concluded that because there were no apparent increases in estuary dredging, this material was discharged to the ocean. Hickson's conclusion that the 140 mcy was discharged to the ocean is probably wrong. To transport that volume of sand to the ocean would have required a doubling of the river's sand transport rates and a nearly ten-fold increase in sand discharge from the estuary to the ocean, based on the rates calculated by Sherwood et al. (1990) for this time period. While sand transport rates may have increased locally around the pile dike fields, it is very unlikely that there would have been any overall increase in transport capacity in the relatively unaltered reaches of the lower river or estuary. Also as Tables 3, 4, and 5 show, there was not a large increase in estuary or ocean deposition between 1926-58 as would be expected from such a large inflow of sand. Therefore, it is very unlikely that this sand was actually eroded from the river and transported through the estuary to ocean.

Based on the Corps' latest analysis of navigation channel shoaling processes (USACE, 1999), and an examination of disposal practices and channel changes, it appears that the 140 mcy was dredged from the river and disposed of along the shorelines. The pile dike fields would have cause sand to have been transported into the adjacent navigation channel as bedload, causing shoaling that was then dredged and disposed of along the shoreline within those same pile dike fields. The riverbed's adjustment to the pile dike fields and the progressively deeper navigation channels would have been comparable to the side-slope adjustments expected to follow the proposed 43-ft channel deepening (USACE, 1999 and 2001). The side-slope adjustment occurs because bedload movement, which is generally directed downstream, has a small displacement towards deeper water caused by the side-slopes of the riverbed. The steep side-slopes of the dredge cuts cause bedload to be deflected into the channel, forming new shoals. Over a period of years this action would cause the side-slope adjacent to a dredge cut to degrade until an equilibrium slope is re-established. This side-slope adjustment often produces very flat slopes that extend from the navigation channel to the riverward end of the pile dike fields. The estimated 140-mcy of material removed from the riverbed is compatible with the 205 mcy of dredging that occurred between RM's 40 and 105, during that same time period.

Disposal within the pile dike fields was a common practice during that time. For these reasons, it is concluded that the 140 mcy was not transported to the ocean, but actually migrated into the navigation channel and was then removed by dredging. This indicates that the riverbed upstream of RM 48 was not a net supplier of sand to the estuary or ocean.

While the lower Columbia River has been a sand sink in past geologic times (Gates, 1994), there are no indications that it has been a significant sink during the last 100 years. It would be expected that the natural river would have been at or near a state of dynamic equilibrium (sand inflow equals sand outflow, with a balance between erosion and deposition) until it reached the depositional environment of the estuary. Sherwood et al. (1990), Bottom et al. (2001), Whetten et al. (1969), and Hickson, (1961) use river sand transport and sand delivery to the estuary as interchangeable values. The Corps' shoaling analysis also supports a conclusion of dynamic equilibrium. Navigation channel shoaling was found to be the result of bedload processes that redistribute sand already present in the riverbed and not from deposition of inflowing sand (USACE, 1999). Thus, the river upstream of RM 48 will be treated as a sand transport reach, with no net change in transport volumes.

After setting the sand transport estimates by Sherwood et al. (1990) and Bottom et al. (2001) shown in Figure 2 as the delivery to RM 48, the next step in estimating the sand discharge to the MCR is to determine how much sand was deposited or eroded between RM 48 and the MCR during each time period. The resulting total net sand volume changes would then be combined with the sand inflows from the river to determine the sand discharges to the MCR.

To provide consistent time period comparisons, the estuary sub-area volume changes in Table 2 were adjusted to match time periods used for the MCR and coastal volume changes reported in Gelfenbaum et al. (2002). This adjustment was made for each sub-area by using the average annual volume change for 1935-1958 to calculate a volume change for 1926-35. For each sub-area, the 1926-1935 volume changes were subtracted from the 1868-1935 volume changes to arrive at 1868-1926 volume changes and added to the 1935-58 volume changes to arrive at 1926-58 volume changes. This method was chosen because the 1935-58 river and estuary conditions more closely resemble the 1926-35 conditions than do the 1868-1935 conditions. This is especially true of the pre-1900 conditions, which are remarkably different than the 1926-35 conditions.

The bed material gradations measured by Hubbell and Glenn (1973) were then applied to the appropriate sub-area volume changes to calculate the fine sediment and sand volume changes in each sub-area that are shown in Table 4. The volume changes from all the sub-areas were then totaled for each material size class to arrive at the total net volume change for both fine sediments and sand. The total net volume changes for 1868-1926 and 1926-58 were subtracted from the corresponding sediment inflows to get the sediment discharges to the MCR for both fine sediment and sand. As shown in Table 4, these calculations determined net sand discharges from the estuary into the MCR inlet of 138 mcy for 1868-1926 and 17 mcy for 1926-58.

The average annual rates of sand inflow, accumulation, and discharge all declined from the first to second time period. However, the relative proportion of deposition to river sand entering the estuary was higher in the 1926-58 period, 85% verses 61%. The sand discharges of 138 mcy between 1868 and 1926 and 17 mcy between 1926 and 1958 should not be viewed as uniform average annual sand discharges of about 2- and 0.5-mcy per year, respectively. The sand discharges from the estuary to the MCR are probably driven by high river discharges just like the river's sand transport. Sherwood et al. (1990) suggest that the largest freshets discharged more sand to the MCR than they transported into the estuary from upstream. The sand discharges would thus follow an annual pattern similar to that shown in Figure 2 for the river's sand transport, with most sand discharge to the MCR occurring during just a few high streamflow years.

Table 4. Columbia River Estuary and Lower River Shoaling and Erosion Rates

ESTUARY SUBAREA	Volume Change in MCY					
	1868-1929			1927-1958		
	Total	Fines	Sand	Total	Fines	Sand
Baker Bay	122.2	61.1	61.1	-8.9	-4.4	-4.4
North Channel(RM 6-14	-1.4	0.0	-1.3	-10.5	0.0	-10.3
Youngs Bay	39.2	5.1	34.1	7.2	0.9	6.3
Desdemona Sands	53.4	0.5	52.8	24.1	0.2	23.8
Mid-Estuary Shoals	1.8	0.0	1.8	-0.5	0.0	-0.5
Brix Bay	8.4	0.1	8.4	-1.1	0.0	-1.1
Grays Bay	32.6	0.3	32.3	-7.5	-0.1	-7.4
Cathlemet Bay	50.2	10.5	39.7	50.1	10.5	39.6
South Channel (RM 6-23)	-22.8	-0.2	-22.5	32.9	0.3	32.6
Lower River Channel (RM 23-31)	-9.8	-0.1	-9.7	1.6	0.0	1.6
Upper River Channel (RM 31-48)	20.9	0.2	20.7	15.4	0.2	15.5
Estuary Totals	304.5	77.6	217.2	110.2	7.7	95.7
Sediment Inflow from Upstream in MCY		355	355		177	113
Deposition as a Percent of Sediment Inflow		22%	61%		4%	85%
Sediment discharge to the MCR in MCY		277	138		169	17

The above sand discharges to the MCR are net values. They do not give any indication of the magnitude of the interactions between the river, estuary, and littoral sand systems. It can not be determined if the sand being discharged flowed continuously through the river and estuary, or if it had once deposited and was later scoured from somewhere in the estuary. There probably was sand inflow to the estuary from the MCR during these time periods, especially into Baker Bay prior to jetty construction. However, the volumes of sand inflow from the MCR cannot be specifically determined from the available data. If the volume of sand inflow from the MCR could be defined, the sand discharge to the

MCR would increase by an equal amount to maintain the sediment budget balance and the calculated net sand discharges to the MCR would be unchanged.

MCR SEDIMENT BUDGET

In 1868, prior to jetty construction, at least two channels existed through MCR, with an average depth over the ebb tidal delta about 25 ft (USACE 1999). The location of the channels varied from year to year. As can be seen in Figure 5, Peacock Spit, Clatsop Spit, Sand Island, and what was once called Middle Sands, were very dynamic prior to the construction period. Prior to construction of the jetties, the ebb-tidal delta off MCR was over 6 miles wide located close to MCR in very shallow water. After jetty construction, the ebb-tidal delta moved more than 10,000 ft offshore from MCR into deeper water (USACE 1999). The MCR jetties were built to maintain a single, stable navigation channel. The south jetty was initially built to stabilize Clatsop Spit, but Peacock Spit still meandered into the channel, as can be seen in Figure 6, so the north jetty was authorized. Jetty A, inside the channel was then built to keep the channel from migrating too far to the north.

Prior to jetty construction, there was more accumulation found on the south beaches than the beaches to the north of MCR. After construction, during the 1926-1950s period, Clatsop Spit began to erode, Peacock Spit accreted at a slower rate than immediately post-construction, and the southern portion of the Long Beach sub-cell prograded rapidly. Accretion rates within the entire littoral cell generally slowed after the 1926-1950s period, as did erosion rates in some areas.

Preliminary modeling results indicate that the areas near the jetties have the highest sediment transport rate (Gelfenbaum and Kaminsky, 2000). There is also an indication that some of the sand-sized sediment within the estuary may have been transported through MCR from adjacent nearshore and shelf regions of the Oregon and Washington coasts.

GeoSea Consulting Ltd. performed a Sediment Trend Analysis (STA) and Acoustic Bottom Classification (ABC) (GeoSea 2001) to develop sediment transport patterns related to grain-size distributions. The net transport pathways derived from over 1200 sediment samples can be seen in Figure 7. The flow pattern shows a definite separation between the river sediment transport and the transport within the entrance channel and along the coastline. There is one accretion pattern that shows sediment moving from the estuary towards the north jetty. The rest of the sediment flowing from the estuary appears to flow into Baker Bay and then flow back through a north channel into the estuary.

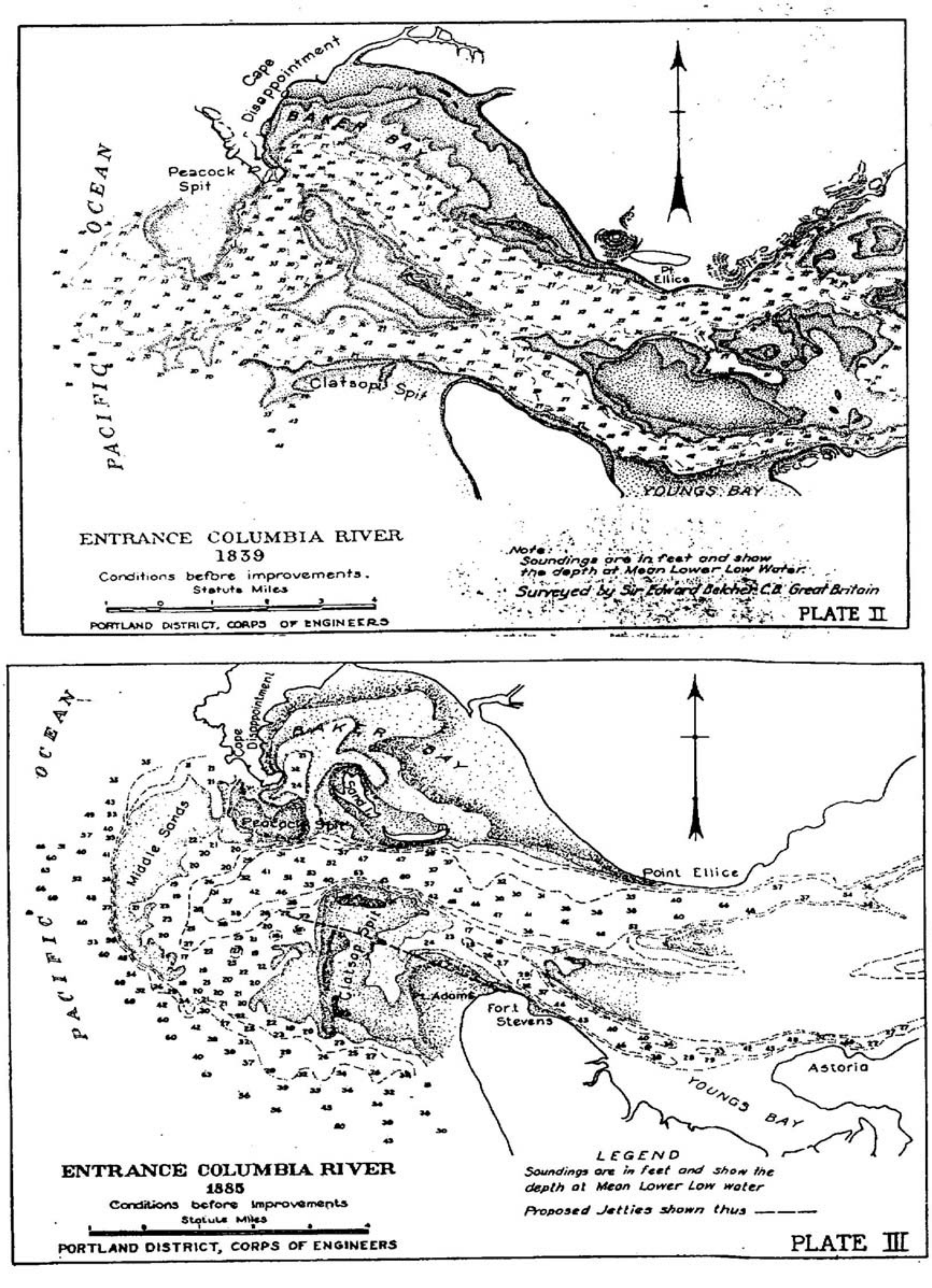


Figure 5. Historical view of MCR prior to jetty construction. MCR was constantly changing prior to improvement. In 1839, a spit, Middle Sands, is present in the middle of the entrance. The south jetty was initially built to stop Clatosop Spit from entering the channel, as seen in 1885.

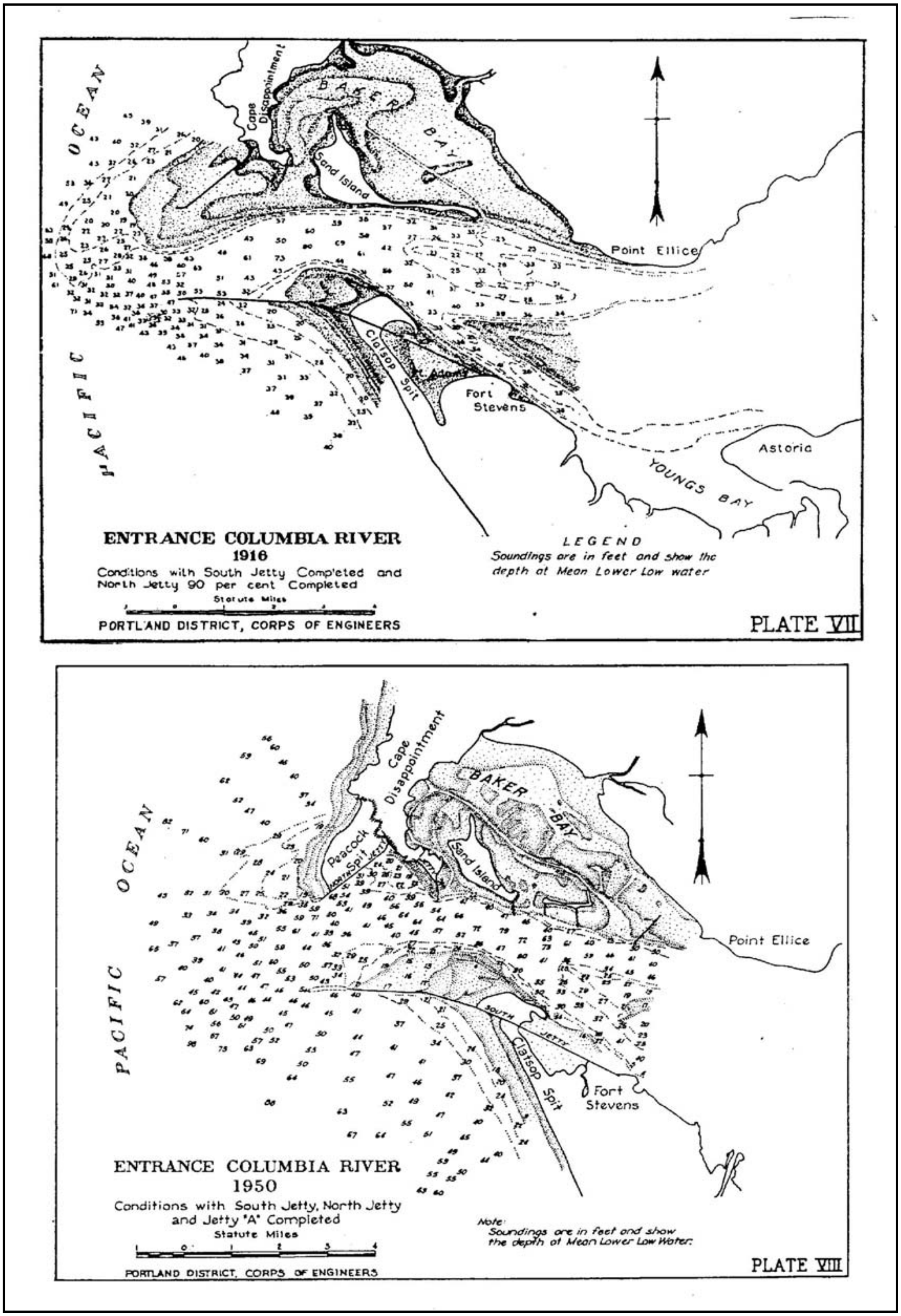


Figure 6. Historical view of MCR after jetty construction. The development of beaches adjacent to both jetties can be seen in 1950.

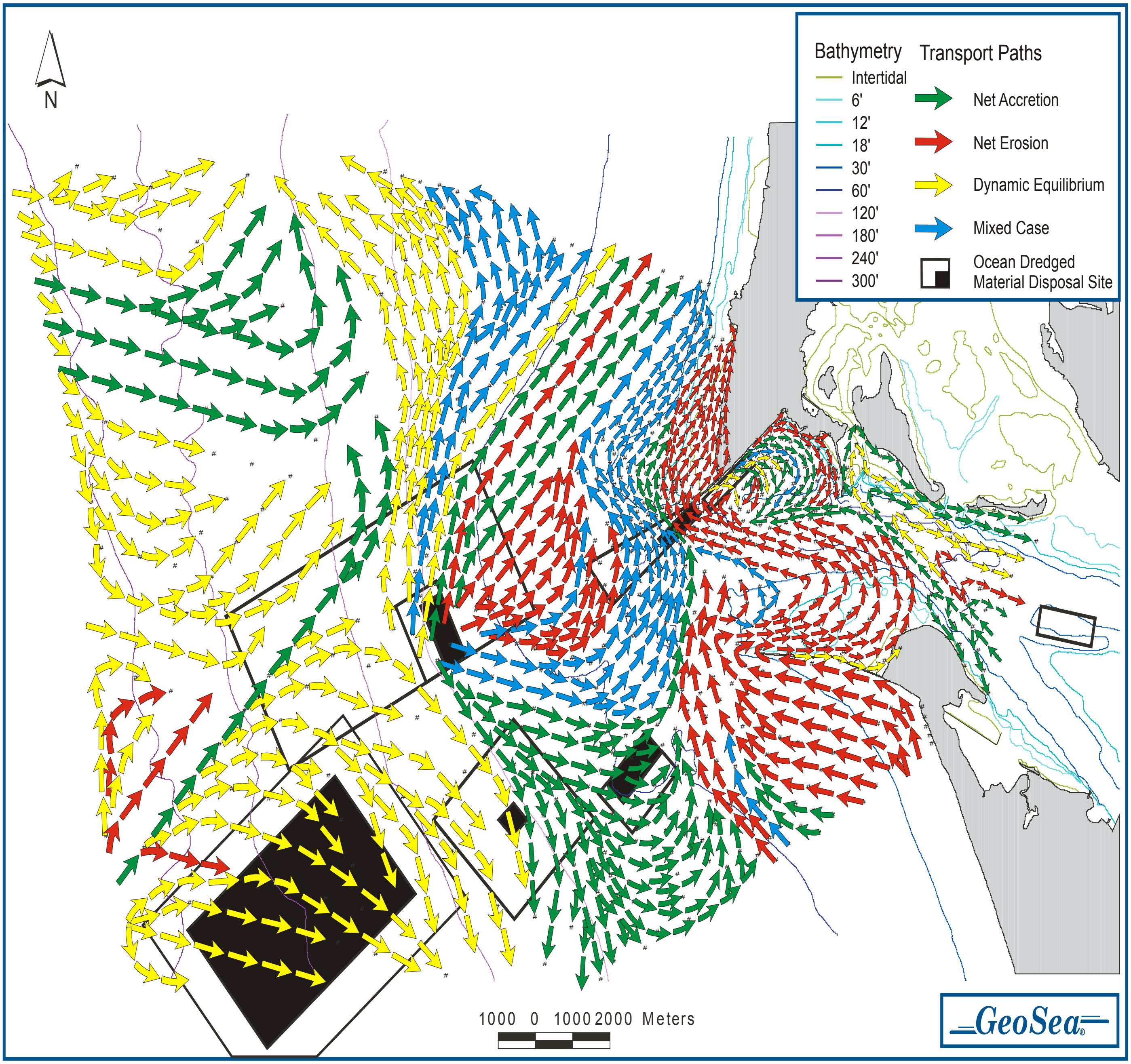


Figure 7 Sediment transport around MCR. From GeoSea, 2001.

Buijsman, et al (2002) made some conclusions based on a study of the volumetric changes within the CRLC (Figure 8). He concluded that sand that eroded from the MCR inlet and inner delta, moved offshore and northward to supply sand to the outer delta and northern beaches. Eroded sand from the south side of the Columbia River delta and shelf along Clatsop Plains was the source of accreted sand to the beach-dune complex of Clatsop Plains and the Columbia River outer delta. Between 1868 and 1928, Long Beach and Clatsop Plains both steepened, due to erosion offshore and accretion in the nearshore. Table 5 shows the overall volume change calculations from Gelfenbaum, et al (2001). There are large uncertainties in the numbers due to vertical datum changes, tide corrections, horizontal errors in historical shoreline positions, and vertical errors in the DEM.

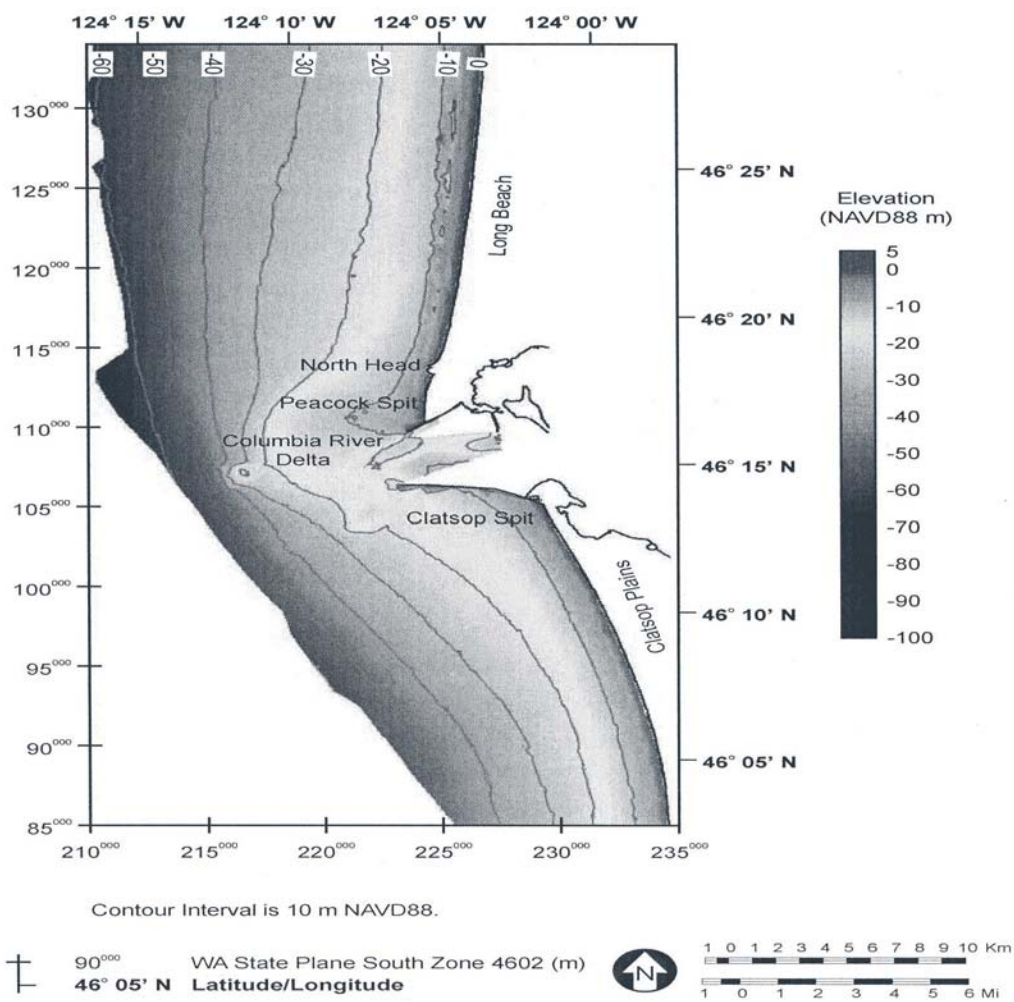


Figure 8 Sub-cells of CRLC adjacent to MCR from Buijsman, et al (2002)

Table 5 Volume Changes (mcy)

	1868-1926	1926-1958	1958-1999
Long Beach and Peacock Spit	66	71	130
Long Beach inner shelf/offshore		48	-1.3
Inlet	-202	-113	-75
Outer Delta	231	140	122
South Flank	-275	-45	-56
Clatsop Plains	102	83	56
Clatsop Plains inner shelf	-31	-34	
Clatsop Plains offshore		-128	-83
Net Volume Change	-109	22	93
Sand Yield from CR	138	17	N/A

Figure 9 (USACE 1999) shows the volume of sediment dredged from MCR. Prior to 1945, dredging was performed intermittently, with an average volume dredged of 0.75 mcy/yr to maintain a 30-foot channel. From 1945 to 1955, regular maintenance

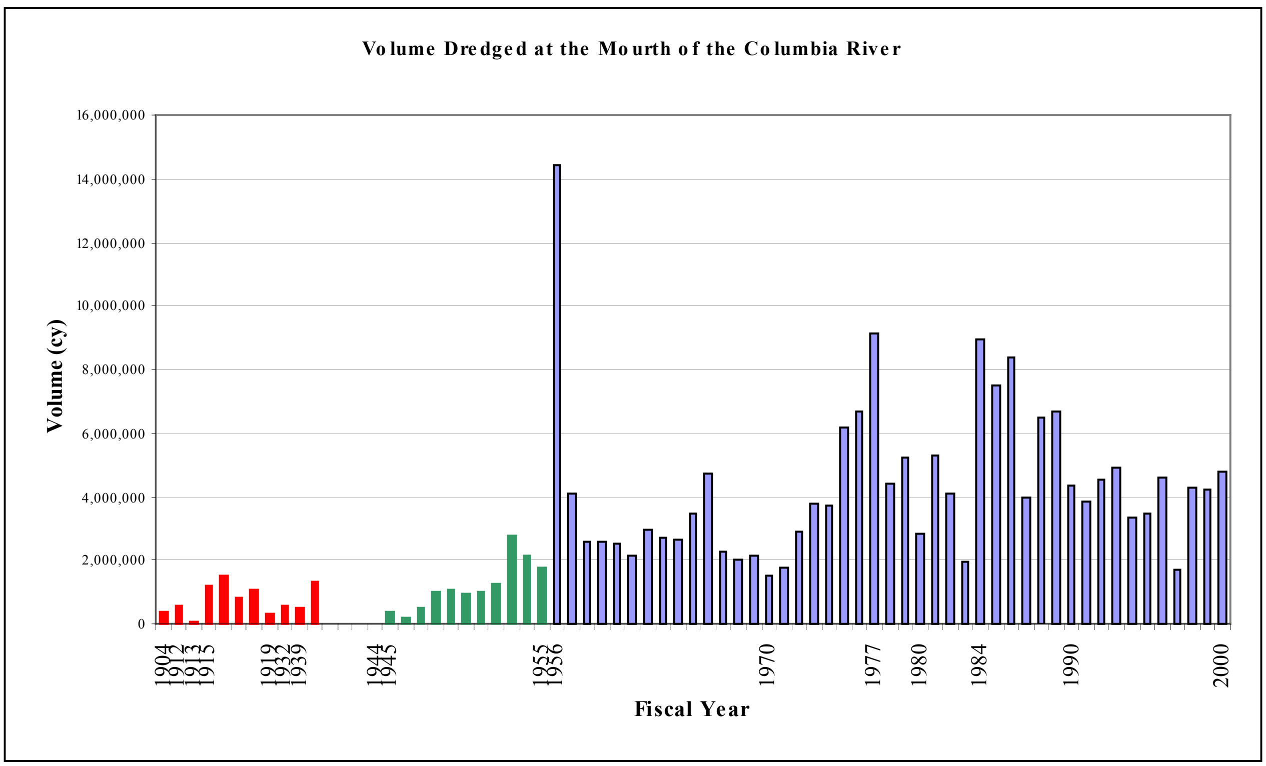


Figure 9 Volume Dredged at MCR

dredging was performed at MCR, with an average volume dredged of 1.2 mcy/yr. As the demand for a deeper and better-defined channel increased due to deeper-draft vessels, the entrance channel was deepened in 1956 to 48 ft. The full authorized channel dimensions and a 5 ft advanced maintenance depth was maintained beginning in 1977. A new authorized depth of 55 ft below MLLW was obtained in 1985. The average volume dredged since the deepening to 48 ft is shown in Table 6.

Table 6 Volume Sediment dredged from MCR

Period	Average Vol. Dredged (cy/yr)
1956-1976	3,696,071
1977-1985	5,478,748
1986-1989	6,375,070
1990-1998	3,887,378

Disposal of material dredged at MCR has been placed in 7 Ocean Dredged Material Disposal Sites (ODMDS) (Figure 10E) since dredging commenced in the late 1800's. Figure 11 shows the volumes placed in each site. "Between 1904 and 1997, approximately 61% of the material dredged from MCR has been placed in the vicinity of ODMDS A and E or estuarine disposal sites" (USACE 1999). The estimated vertical erosion rates at sites A and E is greater than 3 and 4 ft/yr, respectively, with average water depths at these sites of 45 and 55 ft, respectively. In USACE 1999, the maximum water depth for littoral transport to occur at MCR was determined to be about 59 ft. This is an important depth to consider when determining locations for dredge material placement that will be beneficial to the sediment transport within the entire littoral cell; in other words, disposal locations that will keep the sediment moving within the littoral cell.

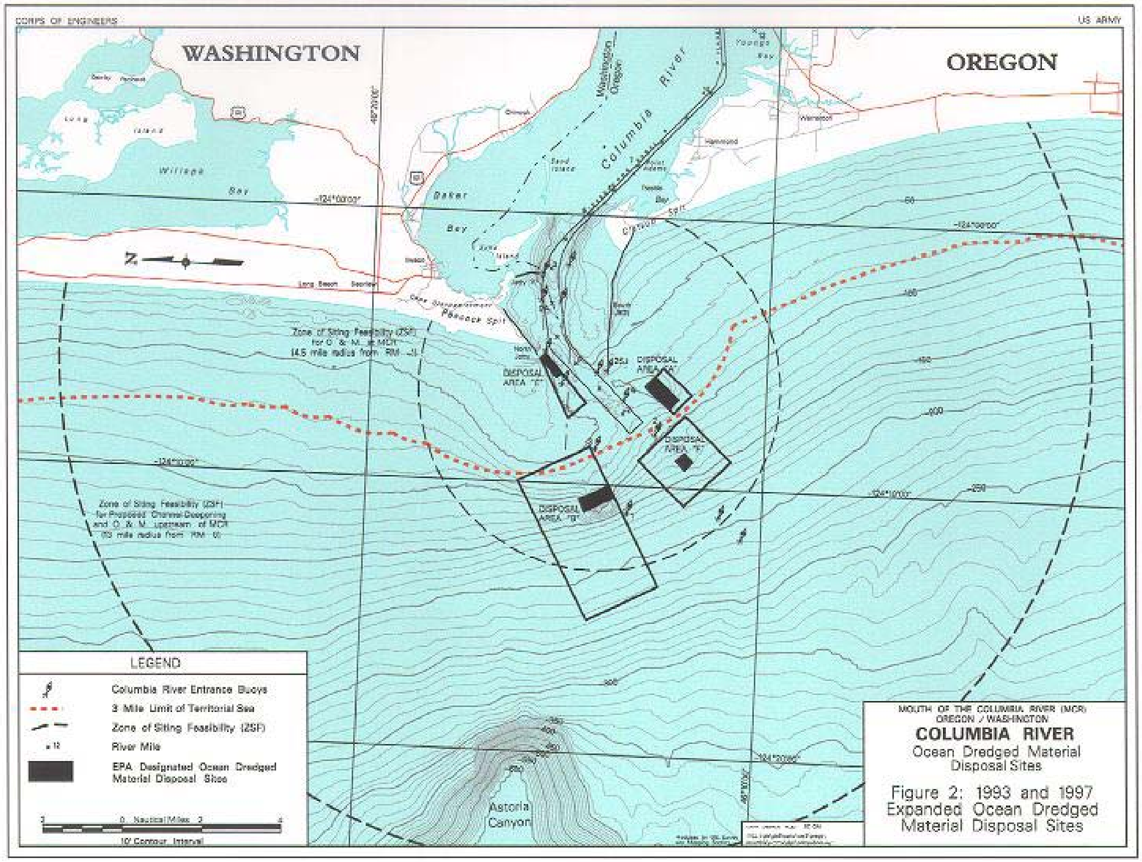


Figure 10 Disposal sites at MCR.

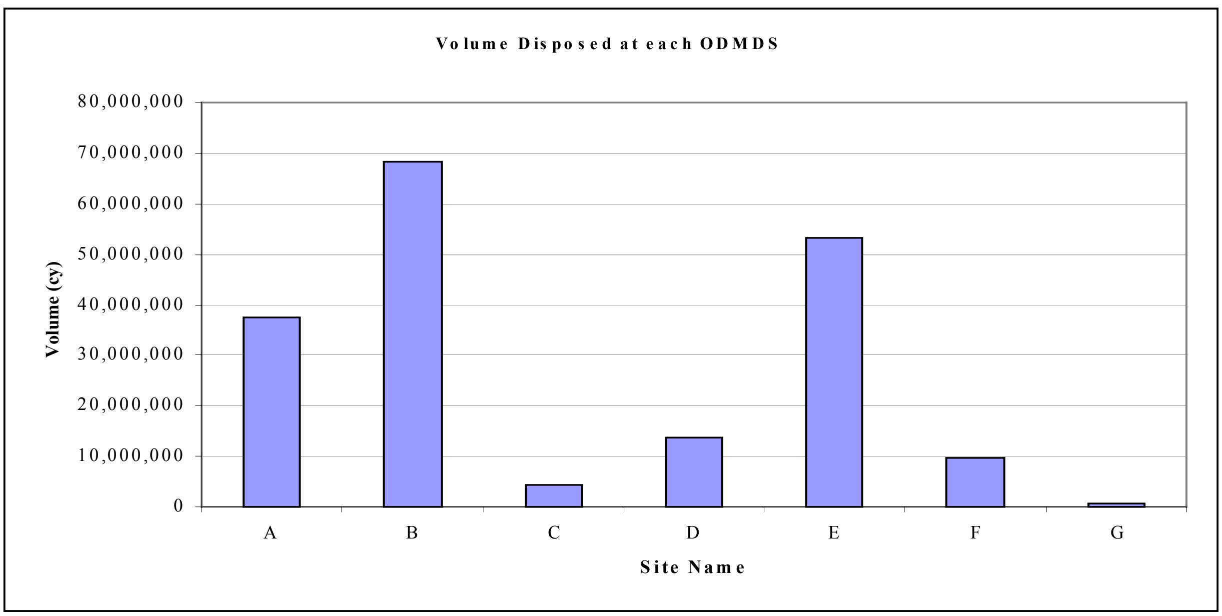


Figure 11 Volume Disposed

1868-1926 SEDIMENTATION

RIVER

Prior to 1926, the Columbia basin was largely undeveloped and there is little specific information on sediment processes. The sediment supply was probably similar to that described by Whetten et al. (1969), with the upper basin producing most of the silt and clay and the Cascades tributaries producing most of the sand. The Columbia River valley was already filled with deep alluvial deposits of sand, with some silt and gravel (Gates, 1994). The bed of the main river channel was composed of deep deposits of mostly fine and medium sand (0.125-0.50 mm). The results of five sediment samples collected between RM's 60-100 indicate very fine sand and finer sediments made up only 0.1-2.3 percent of the bed material in the main river channel (Park, 1924). The natural riverbanks consisted of basalt or erosion resistant sand, silt, and clay deposits. The location of the river channel had been stable for 6,000 years (USACE, 1986).

The natural sand transport in the lower Columbia River was highly variable, mirroring the rise and fall of the river discharges. Available streamflow data allowed Sherwood et al. (1990) to hindcast total sand transport as far back as 1878. The sand transport in Figure 2, shows the annual variability, with annual sand transport ranging from about 0.1 mcy in 1926 to over 37 mcy in 1894. The 1894 spring freshet had an estimated peak discharge of 1,260,000 cfs, with a maximum stage of 33 feet at Portland (Hickson, 1930). The average annual sand transport during this period was near 6 mcy/yr and there were seven years with 10 mcy or more. Bedload transport made up only a fraction of the total sand transport, but was an important factor in navigation channel shoaling. Hickson (1930) explained that shoaling in the navigation channel was the result of transport, or "drift", along the river bottom. He also noted the existence of 8-10 ft high sand waves migrating downstream in the navigation channel. Park (1924) also identified the role of bedload when he reported the downstream movement of a sand bar caused shoaling of the 30-ft navigation channel along Puget Island.

Prior to navigation channel development, much of the main river channel already had natural thalweg (deepest line) depths in the 35- to 45-foot range. However, the controlling depth (minimum depth available anywhere along the navigation channel) was only 12-15 feet (Hickson, 1961). The thalweg of the sandy riverbed repeatedly shifted alignment. Because of the naturally occurring depths, only minor dredging was conducted in the river to maintain the 25-ft channel. As Figure 12 shows, annual dredging increased sharply in 1914, when work began on the 30-ft deep by 300-ft wide navigation channel. An ambitious river control program was implemented between 1912 and 1926 (Park, 1924). Numerous pile dikes and in-water fills were built along the river to constrict the channel, decrease flow into some of the side channels, and to stabilize the navigation channel alignment. Pile dikes were usually built in "fields", a series of dikes spaced 1,200-1,500 feet apart, which run along the shoreline for up to four miles. Those measures combined with dredging began to lower bed elevations in the shallow reaches of the river channel. Figure 13 shows examples of channel constrictions and the resulting channel changes that occurred between 1909 and 1924.

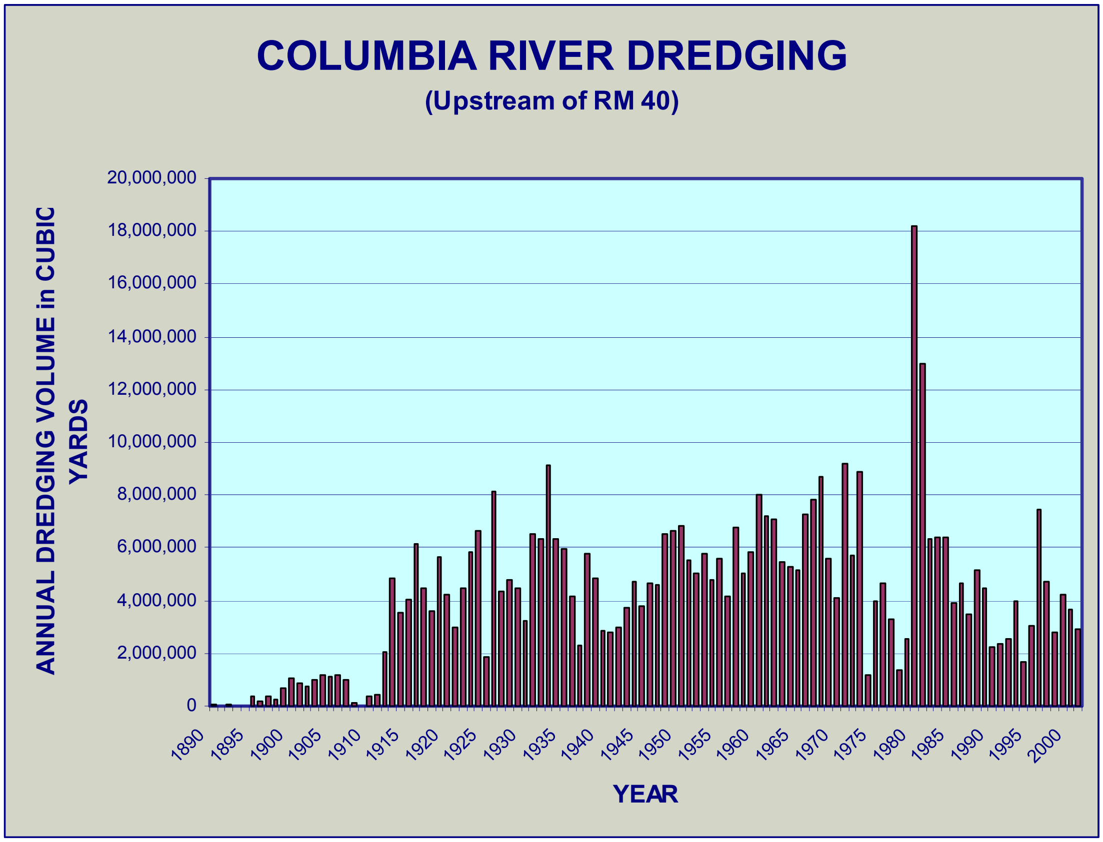
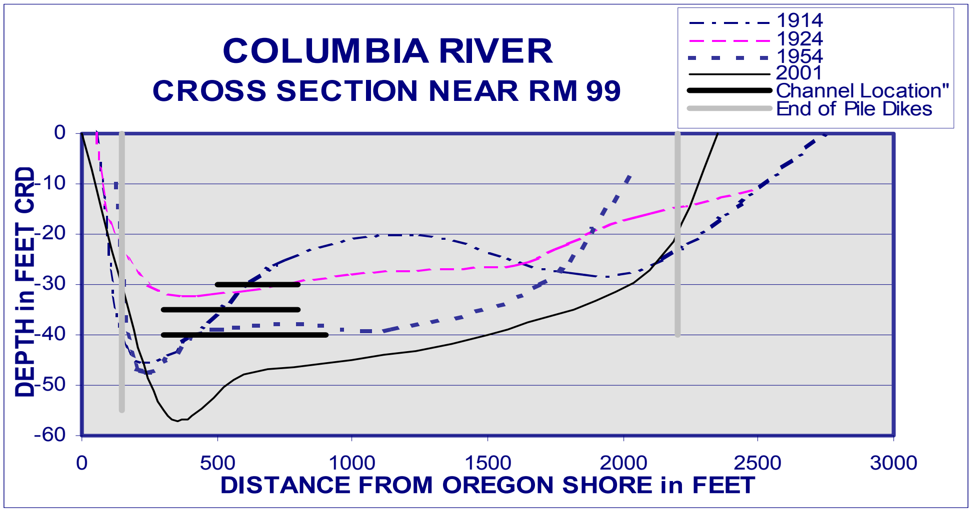
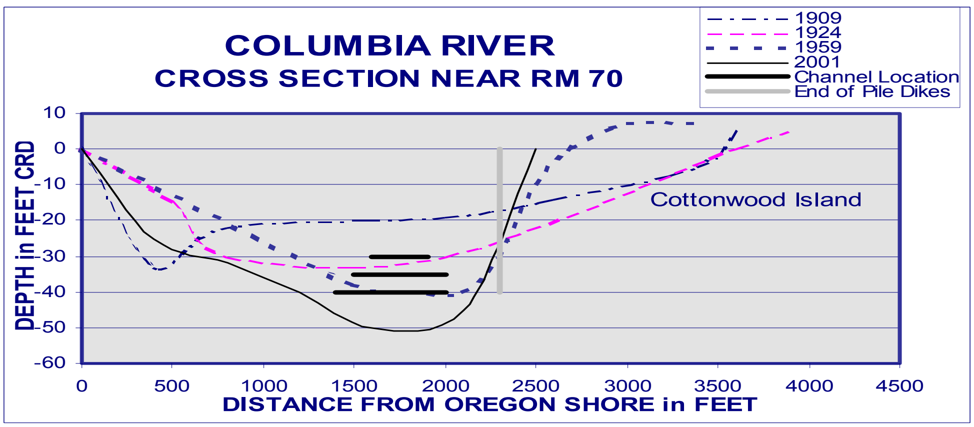


Figure 12. Annual Columbia River dredging between RM 40-106.

The CREDDP atlas (1983) shows large changes in the bathymetry in both channels around Puget Island between 1868 and 1935. Based on the work of Sherwood et al. (1984), about 20 mcy of sediment accumulated between RM's 31-48 (including portions of Cathlamet Bay) between 1868 and 1935. Park (1924) noted local sediment accumulation when he reported that dredging was not required at the upstream end of Puget Island until 1921.





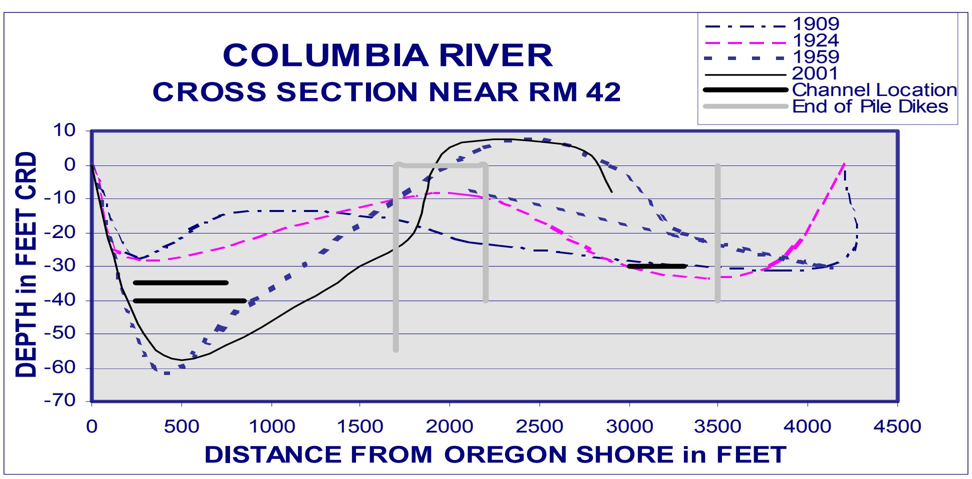


Figure 13. Changes in Columbia River cross-sections at constricted reaches.

ESTUARY

During this 1868-1926 time period, the estuary was a depositional area with several large unstable channels (Sherwood et al, 1984 and CREDDP, 1983). At the beginning of the time period, there was a sizeable channel along the north side of the estuary that flowed from Harrington Point (RM 23) across Grays Bay and through the southern portion of what is now Baker Bay. By 1885, the channel no longer passed through Baker Bay. By then, Sand Island had formed and occupied a portion of the old channel. A University of California (UC-B) report (1936a) also refers to a "Chinook Spit" that migrated from the Sand Island location, east through Baker Bay between 1874 and 1989. Between 1868-89, Baker Bay was just inside the MCR and exposed to ocean waves form the southwest. Ocean waves likely pushed sand into and across Baker Bay. The UC-B study found that after completion of the MCR jetties in 1917, sand movement from the MCR into Baker Bay due to ocean waves was greatly reduced. The pre-1885 changes probably account for most of the 120 mcy of accretion that occurred in Baker Bay between 1868 and 1926. During that time, the river channel downstream of RM 6 shifted south out of Baker Bay. (Sherwood et al. 1984, included the river channels downstream of RM 6 in the entrance sub-area, this report uses those same sub-area delineations as shown in Figure 4.) The north channel (RM 6-14) also experienced large changes in channel geometry. The deep-water channel shifted north, with erosion up to 30 ft deep and accretion of up to 20 ft along the south side of the channel (CREDDP Atlas, 1983). Despite the large geometry changes there was only slightly more than 1 mcy of net erosion during this time period.

The remainder of the estuary bays and shallows were also accumulating sand during this time period. By 1926, Grays Bay (Figure 4) had an estimated 33 mcy of accumulation, much of it in the old north channel which was no longer directly connected to the river channel at Harrington Point. During this period there were three or four distinct, but interconnected, channels that flowed through Cathlamet Bay and joined at Tongue Point. Downstream of Tongue Point, there were two channels, one passed south to north through Desdemona Sands, near RM 15, and the other followed the Oregon shore. The CREDDP atlas (1983) shows all these channels were actively shifting around. Cathlamet Bay and Desdemona Sands both experienced about 50 mcy of deposition during this period.

The south channel eroded around 33 mcy downstream of RM 31. The channel deepened over most of this length. The south channel erosion may have been triggered by flow being concentrated in that channel due to the deposition in Cathlamet Bay, Grays Bay, and Desdemona Sands reducing flow in the channels in those areas. The channel would have eroded until a balance was reached with the increased flow conditions.

The sediment budget indicates 138 mcy of sand were discharged from the estuary to the MCR. This represents an apparent estuary trap efficiency for river sands of 61 percent. However, the trap efficiency for river sands may have been even lower. As noted above, much of the Baker Bay accumulation may have been caused by sediment pushed landward by ocean waves and shifting entrance channels. Sherwood et al. (1984)

concluded that Baker Bay and other areas near the MCR were filled by ocean sediment that accounted for half of the total estuary accumulation since 1868. Crediting just the Baker Bay sand accumulation to ocean sources would increase the discharge of river sands to the MCR to 199 mcy for this time period and lower the estuary's trap efficiency for river sands to 44 percent.

Navigation channel development played a limited role in the estuary changes between 1868 and 1926. The MCR jetties, while causing large bathymetric changes in the entrance and ocean, may actually have reduced some of the sediment instabilities in the lower estuary. The jetties reduced incoming wave energy and cut off the sand supply from Clatsop Spit (UC-B, 1936a). Those changes would help to stabilize the lower estuary by reducing sand transport and supply. Navigation dredging had little impact until construction of the 30-ft channel in 1915-1919. Even then, much of the south channel was naturally over 35 ft deep and only seven miles between RM's 3 and 31 had to be dredged for the 30-ft channel (Park, 1924). Figure 14 shows that only 15 mcy were dredged for navigation from 1893 through 1914 and then 24 mcy were dredged to construct and maintain the 30-ft channel from 1915 through 1926. While this dredging altered channel depths, it did not influence the volume of material in the main channels because hopper dredges did the work. The hopper dredges used in-water disposal, simply moving sand from the navigation channel to other locations within the river channel. Disposal may have transferred some sand between channel reaches, such as from the south channel to the north channel

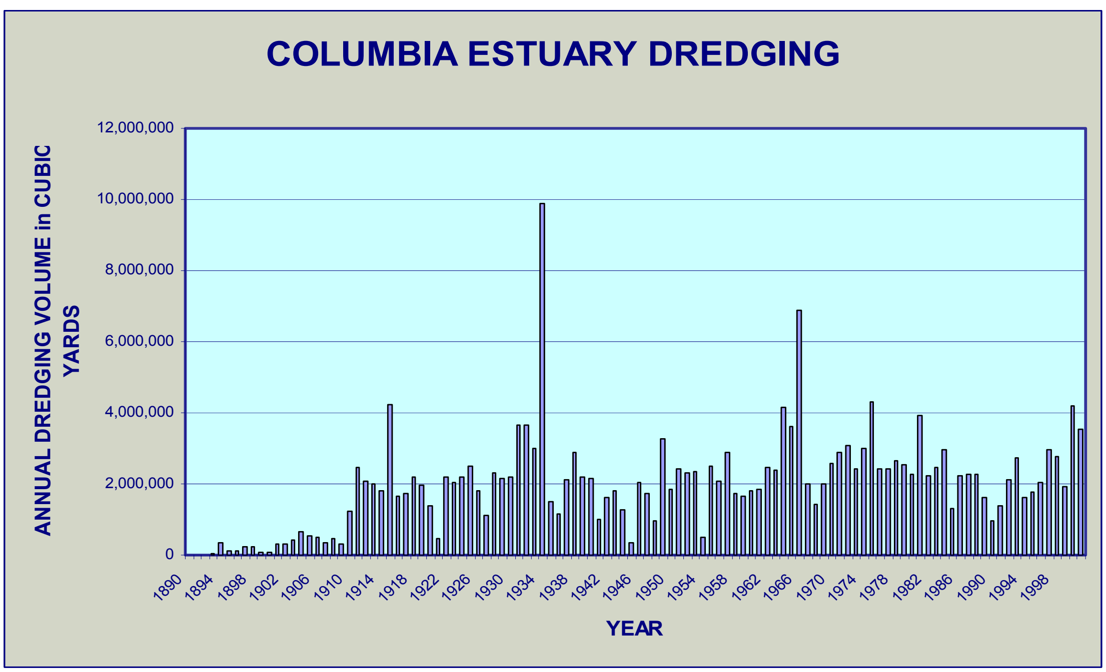


Figure 14. Annual Columbia Estuary (RM 3-40) dredging volumes.

in the vicinity of RM 6. However, the bathymetry of the estuary would not have allowed the hopper dredges to operate outside the boundaries of the main channels. The only notable flow control structure in the estuary prior to 1922 was the Snag Island jetty, built prior to 1871. That jetty was not on the present south channel, but was in Cathlamet Bay, where it directed flow away from Cordell Channel and into Woody Island channel.

<u>MCR: 1868-1926</u>

The Columbia River entrance, prior to jetty construction, consisted of a "broad and shallow ebb-tidal delta complex with up to three dynamic inlet channels, flanked by shallow shoals of Peacock and Clatsop Spit" (Buijsman, et al, 2002). The natural channel had an average depth of 25 ft and shifted on a seasonal and annual basis, as seen in Figure 5. The ebb tidal shoal complex was symmetric on the ocean side of MCR, prior to entrance modifications, which strongly suggests a dynamic equilibrium north and south sediment transport around MCR. After jetty construction, the inlet narrowed, and a single deeper channel with a depth over 33 ft formed. The south jetty was initially built, 1886-1913, to stabilize Clatsop Spit, but Peacock Spit still meandered into the channel, so the north jetty was authorized in 1917. Jetty construction reduced the width of the mouth from 6 to 2 miles.

Work by Gelfenbaum and Kaminsky (2000) and Gelfenbaum, et al (2001), calculated volume changes within different sub-areas around the MCR between 1868 and 1926. During that period, a total of 202 mcy of sand eroded from the entrance channel. This sand migrated to the new ebb-tidal delta, which accreted 231 mcy. The south flank, section 3 in Figure 15, eroded 275 mcy due to the absence of the ebb jet from the entrance traversing this area. The south flank material was transported to the ebb-tidal delta.

Peacock Spit accreted 29 mcy (an area of 960 acres), while the entire Long Beach sub-cell only accreted 37 mcy. This indicates a great imbalance in the areas of accretion on Long Beach, with Peacock Spit receiving a greater portion of sediment than the rest of the cell.

The area south of MCR, Clatsop Spit and Clatsop Plains, also accreted during this period. The shoreline of Clatsop Plains moved seaward, with a rate that increased from 2-3 ft/yr prior to jetty construction, to up to 56 ft/yr after construction (Buijsman 2002). While Clatsop Plains and Clatsop Spit accreted 102 mcy and 34 mcy, respectively, the area offshore of Clatsop Plains eroded 39 mcy.

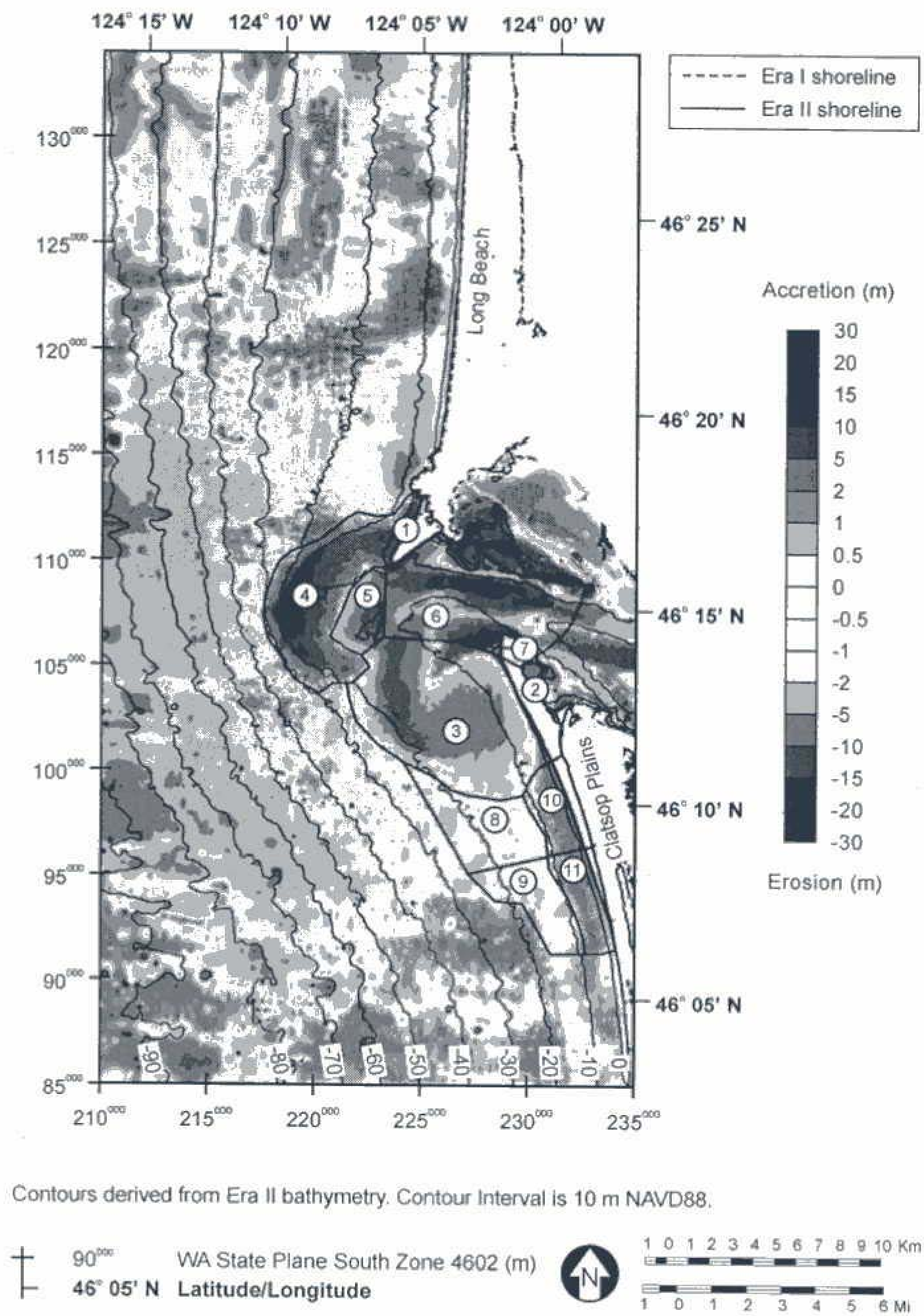


Figure 15. Volume change analysis (Buijsman 2002).

As can be seen in Table 5, there is a large volume imbalance within the MCR area. The total unaccounted for loss of material amounts to 247 mcy, between the amount of sediment being supplied from the Columbia River (138 mcy) and an apparent loss of sediment (-109 mcy) in the areas surrounding MCR. Some of this sediment could be accounted for in the amount of sediment dredged from the entrance channel, but that only amounts to about 6 mcy for the entire period. The material may have moved into areas further north and south along the coast, areas still within the CRLC but that are not accounted for in Table 5. The volume changes further offshore are also difficult to evaluate due to lack of sufficient survey data.

1927-1958 SEDIMENTATION

RIVER

There was a marked decline in annual streamflows during this time period compared with the earlier period. The hydrologic analysis of Bottom et al. (2001) indicates that because of regional climate trends, annual runoff tended to be below normal between 1927 and 1944 and then returned to a more normal pattern for 1945-58. Water resource development was ongoing throughout the Columbia basin during this time period, but only had a small impact on annual streamflows. Bonneville (1937), The Dalles (1957), McNary (1953), Chief Joseph (1955), and Grand Coulee (1941) dams were constructed on the main stem of the Columbia River. These dams have run-of-river reservoirs with little capacity to store water, except Grand Coulee, which is a storage project. Because of the limited storage capacity, these dams had only minor impacts on Columbia River discharges. Upper basin irrigation withdrawals did cause a slightly reduction in streamflows throughout this time period.

Figure 2 shows the reduced sand transport resulting from the decreased streamflows. The average annual sand transport for this period was 3.6 mcy/yr, or 60 percent of the 1878-1926 average of 6 mcy/yr. The occurrence of very high annual sand discharges in the river declined even more, as only one year exceeded 10 mcy, which was 1948 with 19 mcy. Other than the effects due to streamflow changes, the upstream reservoirs did not noticeably affect sand transport or supply. Whetten et al. (1969) found no sand accumulations in the Columbia River reservoirs. They reported that sediment deposited in Columbia River reservoirs during low flows was eroded and transported by subsequent high flows. Sand waves were reported migrating downstream in the Bonneville pool at rates of around 1-2 feet per day during the 1964 spring freshet. They also noted that sand waves covered over 80 percent of the riverbed downstream of the Willamette River. They estimated that downstream of Bonneville, the Columbia River's bedload transport was less than 1 mcy/yr. While those observations were made in the 1960's, they would also be indicative of sand movement in the 1927-58 time period.

Navigation development had a larger impact on the river during this time period. The channel was expanded to 35-ft deep by 500-ft wide and adjustments to channel alignment that brought the channel to approximately its current location. Navigation dredging remained steady, with 158 mcy dredged from upstream of RM 41 during this period. The channel impacts were largest in those naturally shallow reaches where channel constrictions were built. The lowering of the riverbeds and reduction in widths shown in Figure 13 are typical of the riverbed changes in the constricted reaches. The increased depths across the riverbed are due to the deflection of bedload into the deeper navigation channel and the subsequent removal of the resulting shoal by maintenance dredging (Eriksen and Gray, 1991). In these areas, much of the sand was disposed of within the pile dike fields, producing the sediment accumulations shown in Figure 13.

ESTUARY

The estuary continued to accumulate sediment, however there was a clear change in the accumulation pattern. In the earlier period (1868-1926), all parts of the estuary downstream of RM 31 accumulated sediment except for the main channels. During 1926-58, the north side of the estuary lost sediment and the south side, including Desdemona Sands and the south channel, accumulated sediment. The CREDDP atlas shows shifting channels and mixed erosion/deposition over the flats throughout the estuary.

The sediment losses from the north side of the estuary were relatively small, only 28.5 mcy (23 mcy of sand), but losses occurred in all sub-areas, as shown in Table 4. Baker Bay was protected from ocean waves by the MCR jetties and Sand Island. The bay, which had accumulated over 120 mcy in the earlier time period, lost nearly 9 mcy of sediment during this period.

The sediment accumulations on the south side were nearly five times greater than the north side losses. The sand accumulations in Cathlamet Bay and the main south channels totaled 90 mcy, nearly equal to the 113 mcy of sand inflow from the river. Overall, the net sand accumulations in the estuary amounted to 85 percent of the 113 mcy of total Columbia River sand inflow during this period.

In another 1936 report, UC-B (1936b) used a physical model to look at bedload movement in the estuary downstream of RM 30. The study examined bedload transport over the course of a tidal cycle for an "average" river discharge of 196,000 cfs and a "freshet" discharge of 556,000 cfs. The transport rates calculated in that study were very small, but the bedload transport patterns give an indication of the estuary's behavior in the 1930’s.

The UC-B model results for "average" conditions showed the bedload changing direction with the tide as far upstream as Harrington Point (RM 23). The net transport for average flow conditions was downstream everywhere in the estuary, except for the reach downstream of RM 5. Under freshet conditions the model showed net downstream bedload transport throughout the estuary, including downstream of RM 5. The daily transport rates for the freshet condition were 4 to 35 times higher than the daily rates for average conditions at the same locations.

The UC-B model showed that under average flow conditions, the net upstream bedload transport near Sand Island (RM 4-5) resulted from transport in the northern and central portions of the channel. Under freshet conditions the net bedload transport was downstream in this reach. However, over the course of a year, the sum of the average conditions would prevail and there would be net upstream bedload transport in the channel at RM 4-5. It is noteworthy that the model results also showed a very small net bedload discharge from the MCR to the ocean under both average and freshet conditions.

These model results indicate net movement away, in both directions, from the RM 4-5 reach, an area that actually did erode considerably between 1926-58.

Both average and freshet conditions showed sand being transported northwest away from the south channel between Tongue and Harrington Points (RM 17-23) and into Grays Bay and the mid-estuary shoal. The transport paths indicate sand would move seaward through Grays Bay and the mid-estuary shoal, and into the north channel and Desdemona Sands (UC-B, 1936b). These downstream transport paths converge at Desdemona Sands with the upstream paths in the RM 4-5 reach. This would indicate an area of sand accumulation and suggests that much of the sand lost from the north channel, Grays Bay, and the mid-estuary shoal was accumulated on Desdemona Sands.

The UC-B model results for "average" conditions for the south channel showed little or no upstream bedload transport during the flood tide and only low rates of downstream transport during ebb flows. With all the pathways leading away from the south channel in the estuary, the only source for the sand accumulation in the south channel (RM 6-31) and Cathlamet Bay would have been the inflowing sand from the Columbia River.

Lockett (1967), citing another model study and prototype measurements, presented the map of bottom sediment transport shown in Figure 16. The pattern is very similar to the bedload patterns reported by UC-B in 1936. Both studies show sand moving landward in the north channel near Sand Island, sand moving northwest away from the south channel between RM's 17-23, and sand transport following the south channel to the MCR. Locket identifies net transport paths and no transport volumes were reported. Lockett cites observed bed sediment characteristics and sand wave patterns as the prototype information supporting this transport pattern.

The transport patterns presented by UC-B and Lockett, and the lower streamflows and sand inflow from the river during this time period can also be used to explain the changes in estuary sedimentation trends, as described below.

With lower discharges and less sand transport in the river, there would have been less sand diverted from the south channel, between RM 17-23, to the north side of the estuary. The lower supply would reduce deposition in Grays Bay and the mid-estuary shoal. Erosion, being more dependent on tidal currents, would not have been influenced as much by the reduced river flows. The large reduction in deposition, coupled with continued erosion resulted in a shift to net erosion in those areas.

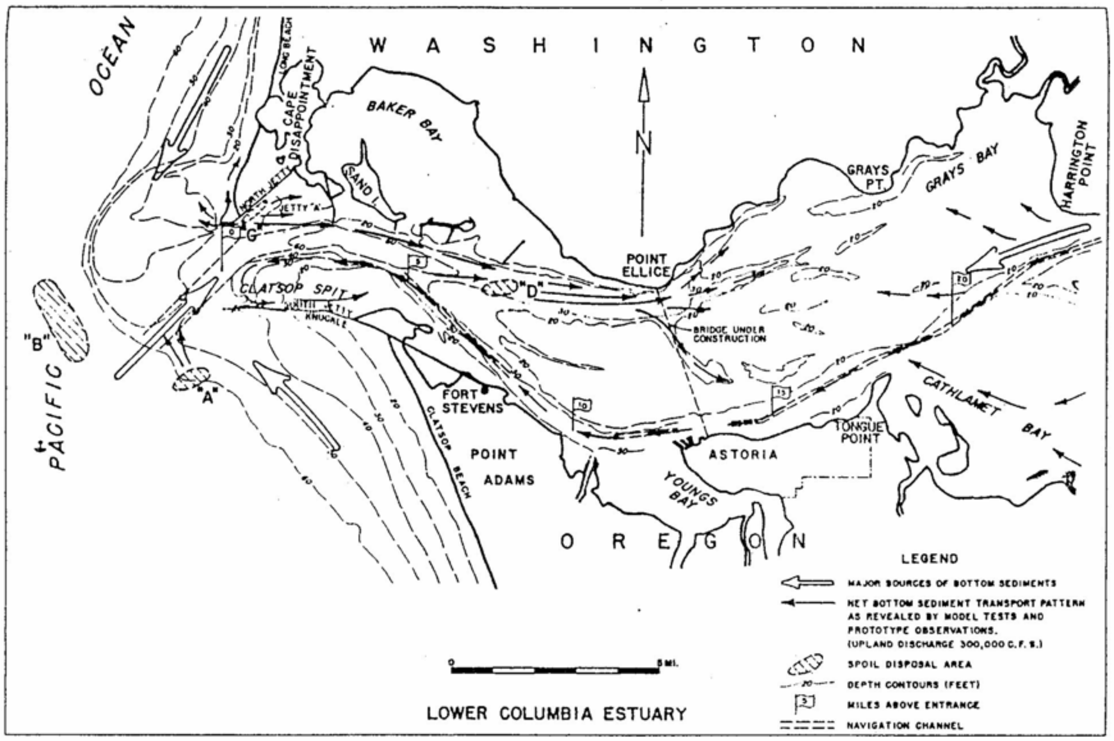


FIG. 1.—LOWER COLUMBIA ESTUARY

Figure 16. Sand transport paths from Lockett, 1967.

The lower streamflows would have had the most impact on sand transport capacity in the main channel and Cathlamet Bay. The smaller freshet flows would have reduced the annual sand transport capacity through the south channel to the MCR. Lower streamflows potentially could allow tides to transport sand upstream from the MCR into the south channel, but the UC-B and Lockett reports both indicate this did not happen and that net transport, though much smaller, remained in the downstream direction to the MCR. The lack of large freshets to carry river sand out of the estuary would explain the increase in the estuary's trap efficiency (based on inflowing river sand) from 61 percent for 1878-1926 to 85 percent for 1927-1958.

Utilizing the theories that converging transport pathways indicate an area of deposition and that of mass balance, the estuary’s transport paths and sediment volume changes can be used to make an estimate of the volume of sand that may have entered the estuary from the ocean. Both UC-B and Locket indicate there is net upstream sand transport in the north channel but not in the south channel in the vicinity of RM 4-5. The reports also show that the landward transport in the north channel converges around Desdemona Sands with downstream transport from the north side of the estuary. Therefore, if there were any inflow of sand from the MCR, it would be part of the 24-mcy accumulation on

Desdemona Sand. As described above, the 19 mcy of sand eroded from the north channel, mid-estuary shoal, Grays Bay, and Brix Bay was the likely source of much of the Desdemona Sands accumulation. The additional 5 mcy of sand accumulated on Desdemona Sand could have come from the river, the MCR, or the ocean. Based on Lockett's conclusions that there was ocean sand moving upstream in the north channel, that additional 5 mcy would have come from the MCR or ocean. This amounts to an average annual sand inflow from the MCR through the north channel of less than 0.2 mcy/yr.

Navigation developments in the estuary included increasing the channel depth to 35 ft, realigning the channel at Miller Sands (RM's 22-25), and construction of pile dikes around Sand Island and at Miller Sands. All the dredging was done by hopper dredges using in-water disposal, except the Miller Sands realignment. As in the earlier period, the in-water disposal would have been along the navigation channel near the dredging sites. The dredging and disposal would not have changed the sediment volumes along the channel, except for some material that may have been transferred from the south channel to north channel near RM 6.

The Miller Sands realignment was constructed in 1934-35 by a pipeline dredge and the 5.5 mcy of disposal created the main island at Miller Sands. Pile dikes were built to reduce flow through the old channel at Miller Sands. This action, combined with the 35-ft channel and deposition in Grays Bay, essentially established the south channel as the dominant estuary channel.

The pile dikes at Sand Island were built in 1933-34 to stop the northward migration of the north channel. The CREDDP bathymetric maps show the pile dikes did stop the migration and some sediment accumulated around the upstream dike near Chinook Point.

MCR: 1927-1958

The erosion/accretion pattern around the MCR was similar to the earlier period. Accretion continued in the outer ebb-tidal delta, and the beach-dune complexes of Long Beach and Clatsop Plains. The area of greatest coastal accumulation shifted away from MCR during this period, as seen in Figure H from Gelfenbaum, et al. (2001). The inner portion of the ebb tidal delta, the inlet, and Clatsop Plains shoreface (Figure I) experienced erosion during this period.

The inlet and inner portion of the ebb-tidal delta eroded 113 mcy. This deepened the channel and the seafloor west of Clatsop Spit, which caused erosion. While the inlet and inner delta eroded, there was 140 mcy of accretion in the deeper water on the eastern edge of the outer delta.

Peacock Spit accumulated 33 mcy of sand, but accumulation was at a slower rate than in the previous time period (Gelfenbaum, et al., 2001). The southern end of Long Beach, including Peacock Spit, accreted 102 mcy, while the northern portion eroded 31 mcy.

Buijsman, et al (2002) suggests that the erosion at the northern end is related to sediment transport processes around Willapa Bay.

The middle of the Clatsop Plains sub-cell began to prograde significantly with the shoreline moving seaward at rates of 23-26 ft/yr and a volume change of +83 mcy. The inner shelf, just offshore of Clatsop Plains, eroded 34 mcy, and may have acted as a sediment source for Clatsop Plains. Further offshore, the area eroded 128 mcy.

Annual maintenance dredging has been performed at the MCR since 1945. Dredging was conducted only intermittently prior to 1945. More than 36 mcy of sediment was dredged from the entrance channel during this time period, with 14 mcy dredged in 1956 for a 48-ft channel-deepening project. Dredging amounts to about a third of the volume loss from the inlet. Disposal was offshore about 1 to 2 miles southwest of the south jetty in water depths of 60 ft (USACE 1999).

1958-1999 SEDIMENTATION

RIVER

This is a long time period, with a substantial change in the Columbia River's annual streamflow pattern and sediment transport occurring in the middle of the period. Additional hydropower and flood control projects were completed in the basin, including the four lower Snake River dams and large storage reservoirs in Canada. Flow regulation of the spring freshet became effective in 1973, reducing the 2-year peak discharge from 560,000 cfs to 360,000 cfs (USACE, 1987). The navigation channel downstream of Portland/Vancouver was deepened to 40-ft between 1968 and 1972.

Because of the exponential relationship between sand transport and river discharge, the annual sand transport declined sharply after flow regulation became fully operational in 1973, as shown in Figure 2. The average annual sand transport for the entire period was 1.8 mcy/yr, half that of the 1926-58 period. However, the pre-regulation period (1959-72) had an average annual sand transport of 2.7 mcy/yr, compared to a post-regulation (1973-99) average of 1.3 mcy/yr. The high streamflow years of 1996 and 1997 accounted for nearly half of the 1973-99 sand transport. Prior to 1996, the post-regulation total sand transport averaged only 0.8 mcy/yr; comfortably within the 0.4-1.0 mcy/yr range of total sand transport used in the Corps' channel improvement FEIS (USACE, 1999a).

While sand transport has declined significantly since the late 1800's, a sand supply has remained readily available in the riverbed from Bonneville Dam to the MCR. A comparison by Jay and Naik (2000) of pre-1970 and post-1990 sediment transport data from the Columbia River at Beaver, Oregon (RM 53) found the best-fit sediment load curves for the two periods were not statistically distinguishable. They concluded that sand is and always has been available in the riverbed and that of the human actions; flow regulation has had the greatest impact on sediment transport. The conclusions of Jay and Naik are consistent with the Corps' conclusions that the reductions in sand transport are the result of flow regulation and that there has been no substantial change in the river's sand supply (USACE, 1999 and 2001).

Navigation development continued to have an impact on main channel depths. The navigation channel was deepened to 40-ft and additional pile dikes were built between 1968 and 1972. By the 1999, thalweg depths had increased to near 50 feet throughout most of the river downstream of Portland/Vancouver. Upstream of Portland/Vancouver the navigation channel is maintained to 17 ft deep and the riverbed has changed relatively little in the last 130 years.

The riverbed's side-slopes have remained flat and depths across the entire channel have increased in response to navigation dredging. Navigation channel shoaling continued to be caused by bedload transport (USACE, 1999), as originally noted by Park in 1924 and Hickson in 1930. The time periods in the sediment transport analysis by Jay and Naik cited above spanned the construction and 20-25 years of maintenance of the 40-ft navigation channel. While they did not specifically comment on the influence of the navigation channel, the lack of change in sediment transport that they identified would indicate that channel related actions also had no detectable impact on sand supply or transport rates in the river.

ESTUARY

Bathymetric difference maps of the estuary were prepared by CREDDP (1983) for the period 1958-82, but limited survey coverage prevented calculation of the volume changes (Sherwood, 1984). The most recent changes around the estuary cannot be identified because there has not been a complete survey of the estuary since 1982. However, the Corps has repetitive surveys along the navigation channel and of the lower 7 miles of the north channel.

The CREDDP atlas shows shifting channels and mixed erosion/accretion over the flats throughout the estuary, very similar to the 1935-58 sedimentation patterns. The south channel appears to have expanded, but shows a mix of erosion and accumulation over the length of its course. The cross estuary channels continued to dwindle in size as sediment accumulated on the south side of the estuary flats. There was erosion along both sides and accumulation in the center of the north channel near Sand Island, RM 5-8. Eriksen (2001) identified continued active sedimentation in the north channel with erosion at RM 5 and sediment accumulation around RM 6-7 between 1980 and 2001.

In addition to the reports by Locket (1959, 1963, and 1967) from the beginning of this time period, there have been two other studies that address estuary sediment transport during this period. Sherwood et al. (1984) conducted an extensive study of sediment processes downstream of RM 48 that is the source of the sediment volume changes used in this analysis. That study also examined suspended and bedload transport in the estuary. The other study, done by McLaren and Hill in 2001, primarily looked at sediment transport patterns in the MCR and ocean, but included the area just inside the MCR at the confluence of the north and south channels.

The Sherwood et al. (1984) study used the CREDDP bathymetric atlas, grain size analysis, suspended sediment measurements, and side-scan sonar to evaluate sediment transport and erosion/accretion patterns in the estuary. Their detailed analysis found much spatial and temporal variation in the sediment processes. They concluded that upstream of Tongue Point the estuary functioned as a fluvial system, with tidal hydraulics and ocean waves becoming more important closer to the MCR.

Sediment processes were found to vary at time scales ranging from the daily tidal cycle to monthly spring/neap cycles, to the seasonal streamflow pattern. Figure 17 is Sherwood et al's summary of estuary sediment transport and deposition that integrates those temporal variations. With only some minor differences, the overall sedimentation patterns shown in Figure 16 (Locket, 1967) and Figure 17 (Sherwood et al., 1984) match closely. The minor differences are in the extent of upstream bedload transport in lower reaches of the south and north channels. The time period between these two studies includes the construction of the 40-ft navigation channel in 1968-72 and the implementation of greater flow regulation by upstream reservoirs in 1973.

In the south channel Locket concluded that net transport was seaward through this entire reach to the MCR. Sherwood et al. found a complex pattern below RM 14, with transport direction changing with location and season. They concluded there was net seaward transport upstream of RM 14 and downstream of RM 8, but net landward transport, mainly on the south side of the channel, at RM 9-10.

In the north channel, Locket extended net landward transport upstream to about RM 16, while Sherwood et al. stopped it at about RM 13. Both studies show transport paths converging in the vicinity of Desdemona Sands, suggesting that sand from the river and the MCR will continue to accumulate there. They also both show sediment moving from the ocean through the MCR and into the north channel.

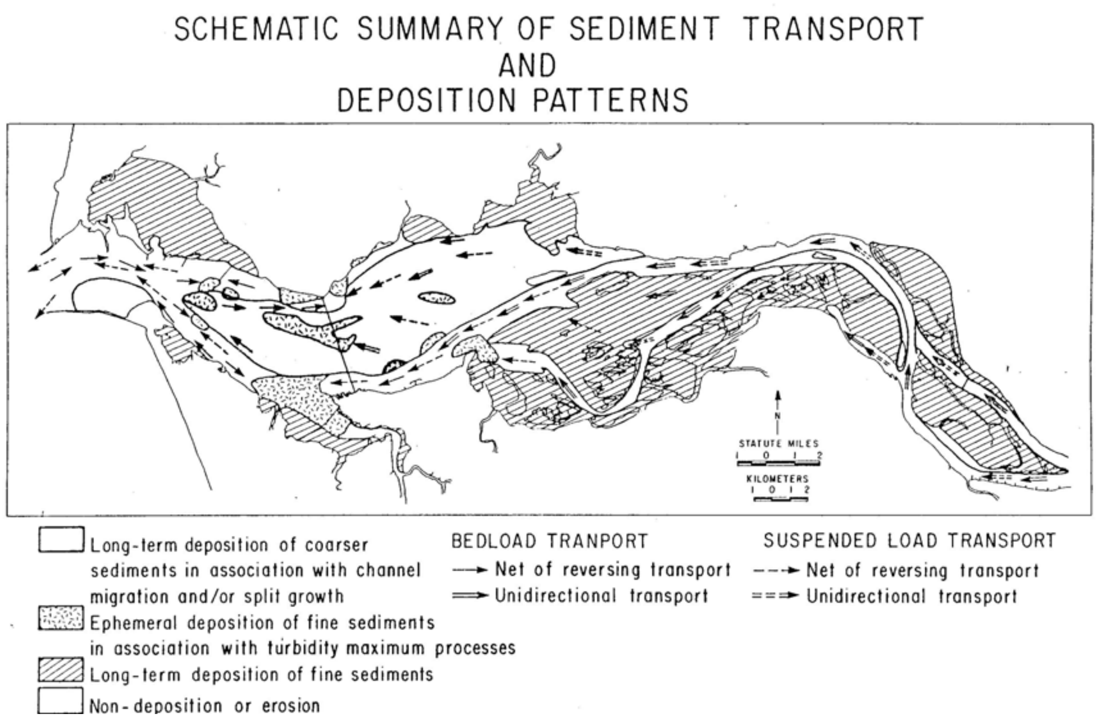


Figure 17. Sediment transport paths from Sherwood et al., 1984.

The minor differences between the two studies are indicative of the complexity of the bedload transport processes in the heavily tidally influenced reach downstream of RM 16.

Sherwood et al. identified that transport varied with changing river flows and the different patterns are likely the result of different flow conditions during the two observation periods.

In the estuary, the 2001 study by GeoSea includes only the confluence of the north and south channels downstream of RM 6 (Figure 7). This study used grain size statistics from bed material samples collected in August and September 2000, to determine sediment transport paths and the trend toward erosion, accumulation, or equilibrium. The results show seaward transport and net accumulation in the south channel between RM 4-6 and then the paths turning landward into the north channel. The results indicate erosion on the south side and deposition on the north side of the north channel. It is notable that this study differs from all the studies discussed above in that it does not indicate a transport path that would move sand from the MCR into the estuary. This study again demonstrates the complexity of bedload transport near the MCR and the differences may also be the result of flow conditions at the time of the study.

Navigation developments in the estuary included increasing the channel depth to 40 ft and construction of pile dikes at Miller Sands and Pillar Rock. Changes in dredging and disposal practices probably contributed to the apparent expansion of the south channel and to sediment accumulation in the north channel near Sand Island.

Hopper dredges using in-water disposal did most of the 113 mcy of estuary dredging during this period. Upstream of RM 15 the in-water disposal would have been along the navigation channel near the dredging sites, as it had been in the past. However, downstream of RM 15 there was a significant change in the in-water disposal practices. It was a common practice between 1957-87 to dispose of sand from the south channel, RM 5-13, at "Area D" in the north channel near RM 6. During that time, over 12 mcy was dredged from the south channel and disposed of in Area D (Beeman and Shapiro, 1987). An additional 8 mcy of sand from the MCR dredging was also disposed at Area D during that time. This disposal could very well have been the cause of the sediment accumulation in the center of the north channel between RM 5-8. The removal of sand from the south channel would have contributed to its enlargement between RM 5-13.

Pipeline dredges were used frequently between RM 19-29 and 37-39. Much of the pipeline disposal was placed along the shorelines and eventually eroded back into the river. There is about 17 mcy of disposal that was placed on Rice Island, Miller Sands Spit, and Pillar Rock Island that remains in place. Perhaps another 1-2 mcy remains at shoreline sites located between RM 29-40. Pile dikes were built to protect the disposal at Rice and Pillar Rock islands.

MCR: 1958-1999

The erosion/accretion pattern for the MCR area for 1959-99 is similar to the earlier two periods, however there are is a large increase in the MCR dredging that may have altered the sediment budget for the inlet sub-area. During 1959-75 annual dredging at the MCR averaged 2-3 mcy/yr and then from 1976 to 1999 it averaged 4-5 mcy/yr. Over 175 mcy of sediment was dredged from the entrance channel during this time period. Of that total, the 69 mcy that was disposed of on the outer ebb-tidal delta and the remainder was placed near the west end of the north jetty. While during the earlier time periods dredging and disposal volumes were small compared the inlet volume losses, during 1959-99 the 69 mcy of dredged sand transferred to the outer ebb-tidal delta is nearly equal to the 75 mcy of sediment lost from the inlet. The 69 mcy also is over half of the 122 mcy accreted on the outer ebb-tidal delta during that time period.

Along Long Beach, north of MCR, the accretion pattern from the previous period continued, with the northern areas accreting faster than previously and the southern portion decreasing its accumulation rate. Peacock Spit, at the extreme southern end of Long Beach, eroded 9 mcy (Gelfenbaum, et al 2001), while the rest of Long Beach continued to accrete at a moderate rate (Figure 18). The sediment supply to Peacock Spit and adjacent nearshore areas was augmented by the Corps' placement of MCR disposal material in Area E at the west end of the north jetty and Site B.

The areas to the south of MCR all experienced decreased accumulation rates, with Clatsop Spit appearing to stabilize. Central Clatsop Plains prograded at a slower rate than the previous time period, with an accretion of 56 mcy, augmented by sediment disposal at Site A.

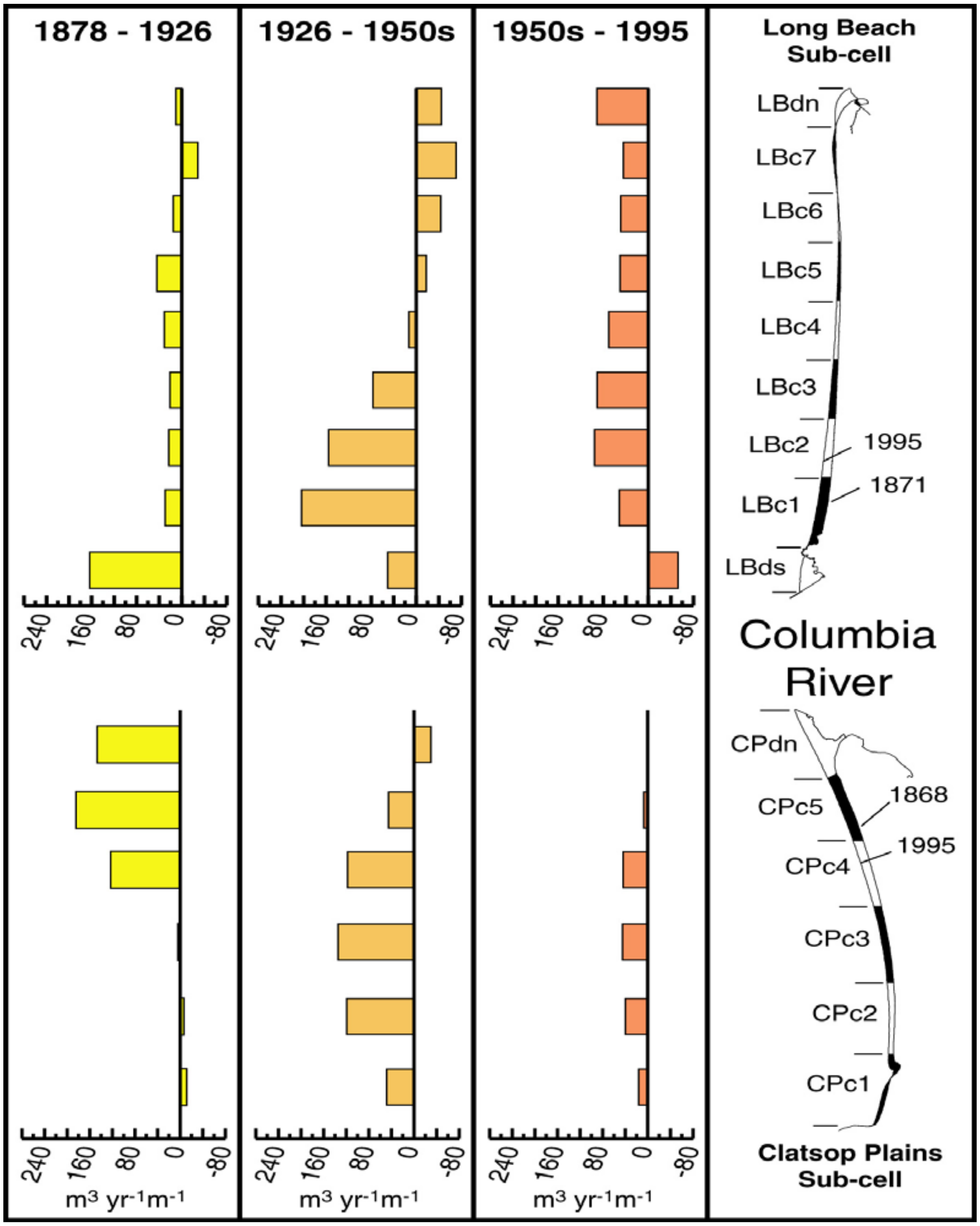


Figure 18 Volume changes along the CRLC (Gelfenbaum and Kaminsky et al, 2000)

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EXHIBIT K-1

EVALUATION REPORT
WHITE AND GREEN STURGEON
(REVISED)

Table of Contents
Exhibit K-1
Evaluation Report
White and Green Sturgeon (Revised)

Evaluation Report
White and Green Sturgeon (Revised)

INTRODUCTION

This memorandum provides supporting information on the effects of dredging and in-water disposal of dredge materials from the Corps of Engineers Channel Improvement Project on white sturgeon (*Acipenser transmontanus*) and green sturgeon (*A. medirostris*) in the lower Columbia River. The following is a summary of the research conducted by Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife on the distribution and abundance of sturgeon at three deep water sites in the project area as well as feeding habits at the site at RM 30. The final report from ODFW/WDW is attached. A progress report on the telemetry work on sturgeon behavior at RM 30 by the U.S. Geological Survey (USGS) is also attached. Although no green sturgeon were caught during the ODFW or USGS studies, green sturgeon have been observed in the study area. Because green sturgeon occupy similar habitat to white sturgeon, and because they are thought to behave similarly, the conclusions of these studies regarding the behavior of and potential effects on white sturgeon should apply equally to green sturgeon.

STUDIES

ODFW / WDFW Report

Introduction
Three sites within the lower Columbia River that are possible flowlane disposal sites were sampled by the ODFW in cooperation with the WDFW for the presence of sturgeon. The sites were sampled during summer, winter, and spring to determine if there are differences in sturgeon seasonal use of these areas. The objectives of this work were to: (1) further describe potential effects of flowlane disposal on sturgeon, and (2) provide, if necessary, recommendations to minimize the effects of flowlane disposal on sturgeon. Specific tasks include: (1) documenting the seasonal presence of sturgeon in the disposal areas, and (2) characterizing the diets of sturgeon collected in the disposal areas as compared to benthic invertebrate data collected.

The benthic invertebrate information was collected in 2001 by Marine Taxonomic Services Ltd. Two surveys of the benthic invertebrate population near the Three Tree Point site (CRM 30) on the lower Columbia River were done. One in the summer and one in the winter.

Results

A total of 1,022 white sturgeon were caught during the four sampling periods. Gill nets caught 410 sturgeon and 612 sturgeon were caught using setline gear. Gill nets were found to be more efficient in catching sturgeon then set line gear during all sampling periods. An examination of 34 white sturgeon stomachs was done.

White sturgeon were present in all three potential flowlane disposal sites sampled. Season appeared to influence the catch at all three sites with summer catches providing the greatest species diversity and winter the least. Diversity and abundance of sturgeon caught differed greatly among sampling periods. It is possible that white sturgeon vulnerability to catch is related to season or water temperature (season or temperature may affect general fish activity levels or feeding activity). This would mean that catch rate does not correlate directly with fish density throughout the year. Regardless of the cause, it seems clear that seasonality does play a role in white sturgeon use of the three sites.

Long-distance seasonal movements of white sturgeon in the Columbia River have been previously documented (Bajkov 1951; Haynes et al. 1978; Haynes and Gray 1981; North et al. 1993). Immature sturgeon were found to undertake an upriver migration in the fall of 1950, leading to a scarcity and even a complete lack of small individuals in drift net catches in the lower part of the river (Bajkov 1951). A corresponding downriver migration occurred during the second part of winter and early spring. Bajkov (1951) reported that these movements may have been feeding migrations. Haynes et al. (1978) recorded an early fall migration in the free-flowing portion of the mid-Columbia River; however, the authors believe that these movements were dependent more on water temperature and size of individuals than on feeding pressures. The belief that sturgeon seasonal movements are linked to water temperature was reiterated in Haynes and Gray (1981).

The Marine Taxonomic Services (2002) data showed that the Three Tree Point site is an area of clean, well-sorted sand with little or no fine sediment and low organic content. This type of dynamic habitat tends not to support quantities of larger benthic fauna. The low numbers of annelid worms found is indicative of a lack of prey items available for both the polychaetes and larger species that would prey on polychaetes. The polychaete, *Nereis vexillosa*, is an omnivore that may prey on Chironomid larvae and on mollusks when they are newly recruited into the habitat. The amphipod, *Corophium*, is probably too mobile to be a common prey item for polychaetes. The mollusk, *Corbicula fluminea*, is a filter feeder and as such tends not to be very mobile. The amphipod and Chironomid populations are significant by comparison to the other fauna and become prey items to juvenile salmonids and other small fish species.

White sturgeon stomach analysis indicated that of the 34 sampled only 4 were empty. It appeared that they were taking the most abundant prey items available *Corophium salmonis* and *Neomysis mercedis*. This contrasts with the results of McCabe et al. (1993) who found that although juvenile white sturgeon were preying heavily on *C. salmonis,* it was not one of the most abundant organisms in samples of benthic invertebrates taken at the same locations. The mollusk *Corbicula fluminea*, the polycheate worm *Nereis vexillosa*, and unidentified Chironomid individuals were all found in the benthos of Three Tree Point yet none of these invertebrates were found in the stomach samples taken from the same area. Without further research it is difficult to determine the cause of these results. McCabe et al. (1993) theorized that juvenile white sturgeon in their study were either (1) feeding on *C. salmonis* that were transported by the current drift, (2) feeding in other areas where *C. salmonis* was more abundant, or (3) feeding very efficiently on *C. salmonis*. The information gather does not conclusively indicate whether sturgeon are feeding in the deep water areas.

References: See attached report.

USGS REPORT

Introduction
Telemetry studies were initiated by USGS under contract to the Portland District to describe how juvenile and adult sturgeon use the aquatic habitat in an in-river flow lane disposal area near Three Tree Point (River Mile 30). The studies are intended to determine if home ranges of juvenile and adult sturgeon are restricted to deepwater areas that may be affected by dredge material disposal. Additionally, the studies were designed to describe juvenile and adult behavior before, during and immediately after dumping material from a hopper dredge.

Methodology
The study is using two types of acoustic telemetry receiver systems to monitor movements of sturgeon. The first includes three moored hydrophones, which monitor fish movements in real time, and provides information on the spatial location and depth of each fish. The second includes seven data-logging receivers surrounding the three moored hydrophones set up to monitor ingress and egress of tagged fish form the primary study area. All movements will be analyzed and displayed within a geographical information system.

Progress to Date
The researchers have secured equipment and supplies and run preliminary tests of the acoustic positioning system. Acoustic telemetry transmitters were surgically implanted in 19 white sturgeon during August 14-22; no green sturgeon were captured. Automated monitoring of sturgeon movements by the system has been ongoing since August 14. Several disruptions were experienced as detailed in the USGS progress report of November 22, 2002.

Findings from USGS Report

The two telemetry systems have enabled us to extensively monitor movements of individual tagged fish. It is not uncommon to obtain several hundred position fixes for an individual fish with the VRAP system on any given day. Precursory examinations of the depth profiles of fish show that the fish are using shallow water habitats as well as the deepest water available. Further analysis will be done to better understand depth use by fish.

Two transmitters (ID 008 and ID 014) have ceased moving within the detection range of the VRAP system, suggesting that the fish expelled the implanted tags or that the fish perished. Another possibility is that fisherman captured the fish and discarded the tags in the study area.

During September 19 to October 2, the Dredge Oregon conducted maintenance dredging adjacent to the VRAP system. This provided an opportunity to monitor sturgeon movements during pipeline dredging operations. The dredge cut began within 100 meters of a VRAP buoy and progressed away from the buoy array. The pipeline was routed between two buoys with the outlet located just upstream of the buoy array. The VRAP system appeared to function well during this activity, alleviating concerns that acoustic noise generated during dredging would hinder detection of the transmitters. During the three days prior to the dredging activity, ten of the tagged fish were using the area. Six of these fish remained in the area throughout the dredging operations. On the day that dredging commenced, two fish left the area and one fish entered the area from upstream. One of the fish that departed on the first day of dredging operations returned 10 days later but again departed within hours. One fish departed on the third day after dredging commenced, returned 5 days later, then departed again the next day. Another fish departed on the 7th day of the dredging operations. When dredging concluded, seven fish were still being monitored within the area.

The track histories of the fish during the dredging operations show that some fish were in close proximity to the Dredge Oregon on several occasions. Further analysis is needed to determine if fish showed altered movement patterns during the dredging operations.

CONCLUSIONS

Further evaluation of this years data and potentially additional research next year are needed to more fully assess potential impacts to sturgeon from dredging and disposal. This information is needed to develop measures to minimize impacts to sturgeon. WDFW has requested that, in order to evaluate the project before this additional information is available, the Corps develop a minimization plan for various outcomes of the research. The table below outlines the Corps' plan for potential outcomes.

Direct Mortality - Immediate mortality of significant numbers of fish due to burial - Delayed mortality of significant numbers of fish due to burial - Fish survive disposal action	• Do not dispose in area or modify / schedule disposal practices to minimize impact • Do not dispose in area or modify / schedule disposal practices to minimize impact • No mitigation action
Disturbance - Significant numbers of fish leave area permanently - Significant numbers of fish leave area temporarily - Fish do not leave area	• Do not use additional sites in the future or modify / schedule disposal practices to minimize impact • Schedule use of site to periods of low abundance • No mitigation action
Feeding - Sturgeon feed in site o Significant, long-term effects o Minor, short-term effects - Sturgeon not feeding in site	• Do not use additional sites in the future • No mitigation action • No mitigation action
Loss of Habitat - Do not use habitat after disposal - Return to area a short time after disposal - Return to area a long time after disposal	• Do not use additional sites in the future or modify / schedule disposal practices to minimize impact • No mitigation action • No mitigation action

SEASONAL PRESENCE AND DIET OF WHITE STURGEON IN THREE PROPOSED IN-RIVER, DEEP-WATER DREDGE SPOIL DISPOSAL SITES IN THE LOWER COLUMBIA RIVER

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Final Report to U. S. Army Corps of Engineers
Contract Number W66QKZ13237211

November 2002

CONTENTS

ABSTRACT

Three proposed in-river, deep-water, dredge spoil disposal sites within the lower Columbia River were sampled to determine the seasonal presence and diet of white sturgeon *Acipenser transmontanus*. Each site was sampled during three seasons (summer, winter, and spring) with gill nets and setlines. Catches of white sturgeon were greatest during summer and least during winter. The diversity of species caught was also greatest during summer and least during winter. Catches of white sturgeon in spring were comparable to the summer for setline sampling and comparable to the winter for gill-net sampling. Gill-net sampling was more productive than setline sampling on a catch per unit effort basis. Setline catches yielded significantly larger fish than gill-net catches. Forty-one stomachs were collected from juvenile sturgeon (23 – 82 cm fork length) and the contents identified to the lowest appropriate taxonomic level. The amphipod *Corophium salmonis* was the most abundant food item identified. It occurred in 32 of the 42 stomachs and accounted for 88% of all prey items.

INTRODUCTION

This project is part of a larger effort to assess the effects of flowlane dredge disposal on white sturgeon *Acipenser transmontanus* that reside in the lower Columbia River. Objectives of the overall effort are to (1) describe potential effects of flowlane dredge disposal on sturgeon, and (2) provide, if necessary, recommendations to minimize the effects of flowlane dredge disposal on sturgeon. Tasks specific to this project include (1) documenting the seasonal presence of sturgeon in disposal areas, and (2) characterizing the diets of sturgeon collected in disposal areas.

The Columbia River is an important shipping channel that provides access to several commercial and recreational port cities, including Longview, Washington and Portland, Oregon. The U. S. Army Corps of Engineers (USACE) has proposed a channel-deepening project in the lower Columbia River to provide access to the commercial ports of Longview and Portland by deeper draft ships than are currently permitted. The proposed channel-deepening project would require the disposal of dredged materials. One possible location for disposal of dredged materials would be in-river, deep-water sites. Past research has shown that juvenile white sturgeon in the Columbia River may prefer deepwater habitats (McCabe and Hinton 1991; McCabe and Tracy 1994).

In documenting the seasonal presence of white sturgeon in proposed disposal areas our objective was to determine if sturgeon use of these areas varies seasonally. This information, along with information from other studies will enable the USACE to determine if seasonal schedules for possible channel-deepening operations are needed and if deep-water disposal of dredge spoil material would adversely affect white sturgeon. Although the results of our study will be useful in documenting seasonal presence or absence of sturgeon in disposal areas, it is not designed to describe the effects of dredge disposal on sturgeon if they are present.

METHODS

Study Area

All work was conducted in the lower Columbia River downstream of the confluence with the Kalama River (Figure 1). Sampling was restricted to three possible in-river, deep-water, dredge spoil disposal sites. The Harrington Sump location extends from river kilometer (RK) 32.8 to RK 34.4, and is located just off Rice Island. The Three Tree Point location extends from RK 47.8 to RK 49.1, and is located to the west of Welch Island and immediately south of Three Tree Point. The Carrolls Channel location extends from RK 114.3 to RK 116.7. This area is located immediately south of Cottonwood Island, northwest of the upriver entrance to Carrolls Channel.

Sampling Gear and Methods

We used setlines and gill nets to sample white sturgeon. Both gears have been used to capture sturgeon in the Columbia River (Elliot and Beamesderfer 1990). For this study 183-m setlines were deployed from a 7.5-m vessel operated by the Washington Department of Fish and Wildlife. Each line contained 40 hooks (sizes 12/0, 14/0 and 16/0) baited with pickled squid. Each line was fished for a minimum of 18.5 h, with an average fishing time of 22.5 h. Gill nets were 45-m long and 2.4-m deep, with 5-cm (stretched measure) monofilament nylon mesh, and were deployed from a contracted commercial fishing boat. Gill nets were fished for a much shorter time than setlines to reduce the incidence of bycatch. Minimum fishing time for gill nets was 0.88 h (50 minutes) and the average fishing time was 1.1 h.

We sampled for white sturgeon during three different seasons throughout the year to assess seasonal use of the study area. The summer 2000 setline sampling period commenced on 15 August and was completed on 17 August. Effort for this period was limited to Harrington Sump only. The summer 2000 gill-net sampling period began on 21 September and was completed on 24 September. Effort for this sampling period was limited to Harrington Sump and Three Tree Point.

The winter setline sampling period began on 2 January 2001. Harrington Sump and Three Tree Point were completed on 5 January 2001. Carrolls Channel was sampled between 30 January and 1 February 2001. The winter gill-net sampling period began on 9 January 2001 and was completed on 19 January 2001. All three sites were sampled.

The spring setline sampling period was conducted from 21 May to 31 May 2001. The spring gill-net sampling period was conducted from 25 April 2001 to 8 May 2001. All three sites were sampled.

We sampled again in summer 2001 to ensure that all three sites were sampled with both gears each season. The summer 2001 sampling period began on 6 August and was completed on 30 August. Setlines were fished at Three Tree Point and Harrington Sump between 6 August and 9 August. Setlines at Carrolls Channel were fished from 28 to 30 August. Gillnetting at Harrington Sump and Carrolls Channel was conducted from 15 to 16 August, and gillnetting was conducted on 27 August at Three Tree Point.

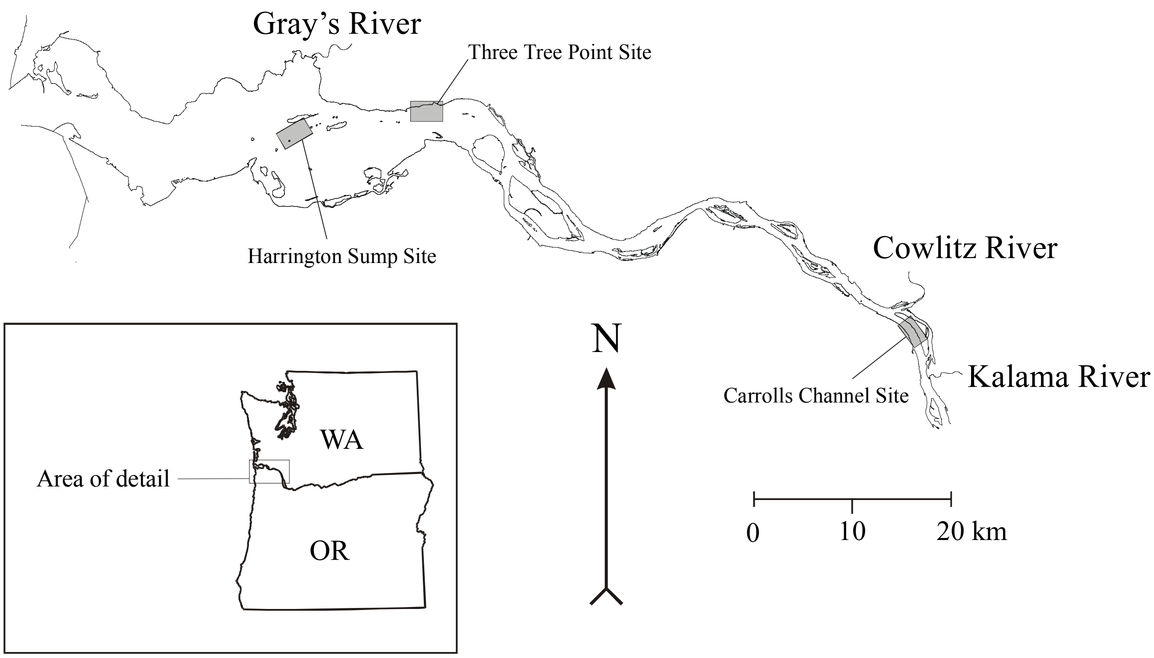


Figure 1. Location of proposed in-river, deep-water, dredge spoil disposal sites in the lower Columbia River that were sampled for white sturgeon.

Diet Analysis

To characterize the diet of white sturgeon inhabiting the study area, we euthanized 71 juvenile (23 – 82 cm fork length) white sturgeon in the field and collected their stomachs for later analysis in the lab. Stomachs were taken from fish caught in gill nets only and from winter, spring, and summer 2001 sampling periods only. All stomachs were preserved in the field in a 10%-formalin solution. Once in the lab, stomachs were emptied of their contents, which were then transferred to an ethyl alcohol solution. All prey items were identified to the most appropriate taxonomic level, counted and weighed (wet mass only).

Data Analysis

We summarized catch of white sturgeon by sampling season for each sampling location and gear. We also summarized catch of other fish species by sampling season for each sampling location and gear.

We used a Kruskal-Wallis one-way Analysis of Variance to compare differences in mean fork length of white sturgeon among sampling sites. If mean fork length differed among sites, we used Dunn's Multiple Comparison Procedure to isolate differences among individual sites. We used combined data from all four sampling periods for each test.
We also compared mean fork lengths between gears. We used a t-test to compare fork length between gears for all sampling periods combined. We also compared mean fork length between gears by sampling period. Results from all tests were considered significant when $P < 0.05$.

We determined the relative contribution of prey taxa to the diet by using a modification of the Index of Relative Importance (IRI; Pinkas et al. 1971; McCabe et al. 1993):

$$IRI = (N + W) \times F$$

Where

N = percent number of a prey item,
W = percent weight of a prey item, and
F = percent frequency of occurrence of a prey item.

We also represent IRI as percent of the summed IRI values for all prey items (%IRI):

RESULTS

Catch Comparisons

We caught 1,022 white sturgeon during the four sampling periods, with 410 white sturgeon caught in gill nets and 612 caught with setlines (Table 1). In general, catch rates were highest during summer. Despite receiving the least amount of total fishing effort, the summer 2000 sampling period was the most productive, with 419 fish caught and a catch per unit effort (CPUE) of 1.49 fish per hour (both gears combined). Catch rates for both gears were lowest in winter, when we failed to catch a white

Table 1. Summary of white sturgeon catch and effort at three proposed in-river, deep-water, dredge disposal sites in the lower Columbia River. Depth = mean depth of sets. HS = Harrington Sump, 3T = Three Tree Point, CC = Carrolls Channel.

	Setline			Gill net		
Season, location	Catch	Effort (h)	Depth (m)	Catch	Effort (h)	Depth (m)
Summer 2000						
HS	70	257.4	10.4	64	11.21	12.5
3T	--	--		285	11.97	23.2
Winter 2001						
HS	0	201.5	13.1	0	7.6	12.6
3T	1	198.3	24.2	8	7.2	22.9
CC	4	202.6	9.7	2	6.7	11.2
Spring 2001						
HS	65	191.6	12.1	3	6.6	13.0
3T	114	192.3	22.1	5	7.0	24.0
CC	92	203.9	9.5	0	7.2	9.8
Summer 2002						
HS	20	213.3	12.2	16	6.0	11.4
3T	82	212.4	17.8	20	6.3	22.7
CC	164	210.8	10.5	7	6.3	11.3

sturgeon with either gear at Harrington Sump. Catches in gill nets remained low in spring (zero at Carrolls Channel), whereas setline catch rates increased considerably. Unlike the other two areas, setline catch rate at Three Tree Point was highest during spring. Setline catch rates remained relatively high in summer 2001, and catch rates in gill nets increased, but not to levels observed in summer 2000.

Throughout the study, setline sampling resulted in very little bycatch. Of 613 fish caught with setlines all but one (a sculpin *Cottus* spp. at Harrington Sump in summer 2000) was a white sturgeon. A much greater variety of species were caught in gill nets. A total of 12 species were caught during the study (see Appendix A for more detail). In general, number of species collected and catch rates of the most abundant species were highest in summer and lowest in winter.

Mean fork length of white sturgeon differed among sampling sites ($P < 0.001$). Fish caught at Harrington Sump were significantly longer that fish caught at Three Tree Point ($P < 0.05$) and Carrolls Channel ($P < 0.005$). Additionally, fish caught at Three Tree Point were significantly longer than fish caught at Carrolls Channel ($P < 0.05$; Figure 2).

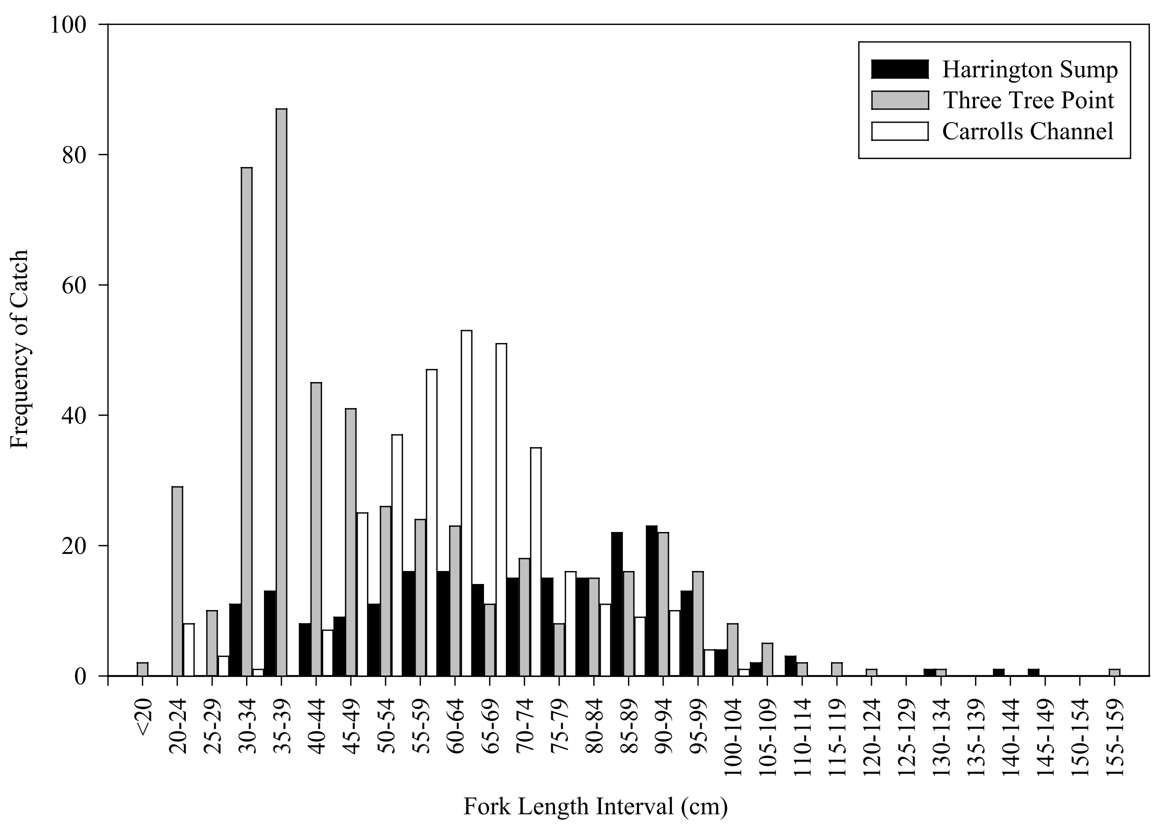


Figure 2. Fork length frequency distribution of white sturgeon caught at three proposed in-river, deep-water, dredge-spoil disposal sites in the lower Columbia River, all four sampling periods combined.

Gear Comparisons

Gill nets were more efficient than setlines in catching white sturgeon throughout the course of the study. We caught 410 white sturgeon with gill nets in 84.1 h of fishing effort for a CPUE of 4.9 white sturgeon/h. In contrast, setlines caught 612 white sturgeon in 2,084.1 h of fishing effort for a CPUE of 0.29 white sturgeon/h.

We caught larger fish ($P < 0.001$) with setlines than with gill nets (Figure 3). The average fork length of white sturgeon caught with setlines was 71.8 cm (± 0.7 SE), whereas average fork length of white sturgeon caught with gill nets was 40.9 cm (± 0.7 SE). Differences in fork length between gears were consistent among seasons (Figures 4-7). Mean fork length of white sturgeon caught with setlines (84.4 cm ± 2.1 SE in summer 2000; 75.4 cm ± 2.7 SE in winter; 69.8 cm ± 1.0 SE in spring; 70.3 cm ± 1.1 SE in summer 2001) was always significantly greater ($P < 0.001$) than mean fork length of fish caught with gill nets (39.0 cm ± 0.6 SE in summer 2001; 26.0 cm ± 1.9 in winter; 45.4 cm ± 7.1 SE in spring; 59.2 ± 2.8 SE in summer 2001).

Diet Analysis

We analyzed 42 stomachs taken from white sturgeon during winter (N = 3), spring (N = 8) and summer 2001 (N = 31). All stomachs were collected from juvenile fish with fork lengths ranging from 22 cm to 82 cm (mean = 48 cm). The most abundant prey item recovered was the amphipod *Corophium salmonis,* which accounted for 3,394 of the 4,095 prey items identified (83%). *C. salmonis* was found in 32 of the 42 stomachs analyzed. *Neomysis mercedis* was the second most abundant prey item (8% of the total), accounting for 348 prey items and occurring in 18 stomach samples. This species is one of the few freshwater examples of the order Mysidacea. The amphipod *Ramellogammarus oregonensis* accounted for 3% of the total number of prey items identified; however, it occurred in only three stomachs (Table 2, Figure 8).

Although *C. salmonis* was the most abundant prey item found in stomach samples it only accounted for approximately 14% of the total wet mass of all prey items. The %IRI for *C. salmonis* in all samples was 88%. Sand, mixed with unidentifiable body parts of invertebrate prey items accounted for about 56% of the total wet mass. Fish accounted for 27% of the total wet mass of all prey items yet 10 other prey items were more abundant. The %IRI for fish in all samples was about 1%. Of the 42 stomachs analyzed only 3 fish were recovered from the samples and only two stomachs contained fish. Although *Neomysis mercedis* was the second most abundant prey item found in stomach samples this species only accounted for 8% of the total wet mass of all stomach contents. The %IRI for *N. mercedis* in all samples was 9%. Four of the stomachs analyzed in the study were completely empty. Two of the three stomachs collected in winter 2001 were empty (67%) the other contained unidentifiable parts. One of the eight stomachs collected in spring 2001 was empty (13%), and two other stomachs collected in the same sampling period contained a single *Corophium salmonis* each. One of the 30 stomachs collected in the summer of 2001 was empty (3%). One other stomach caontained primarily sand.

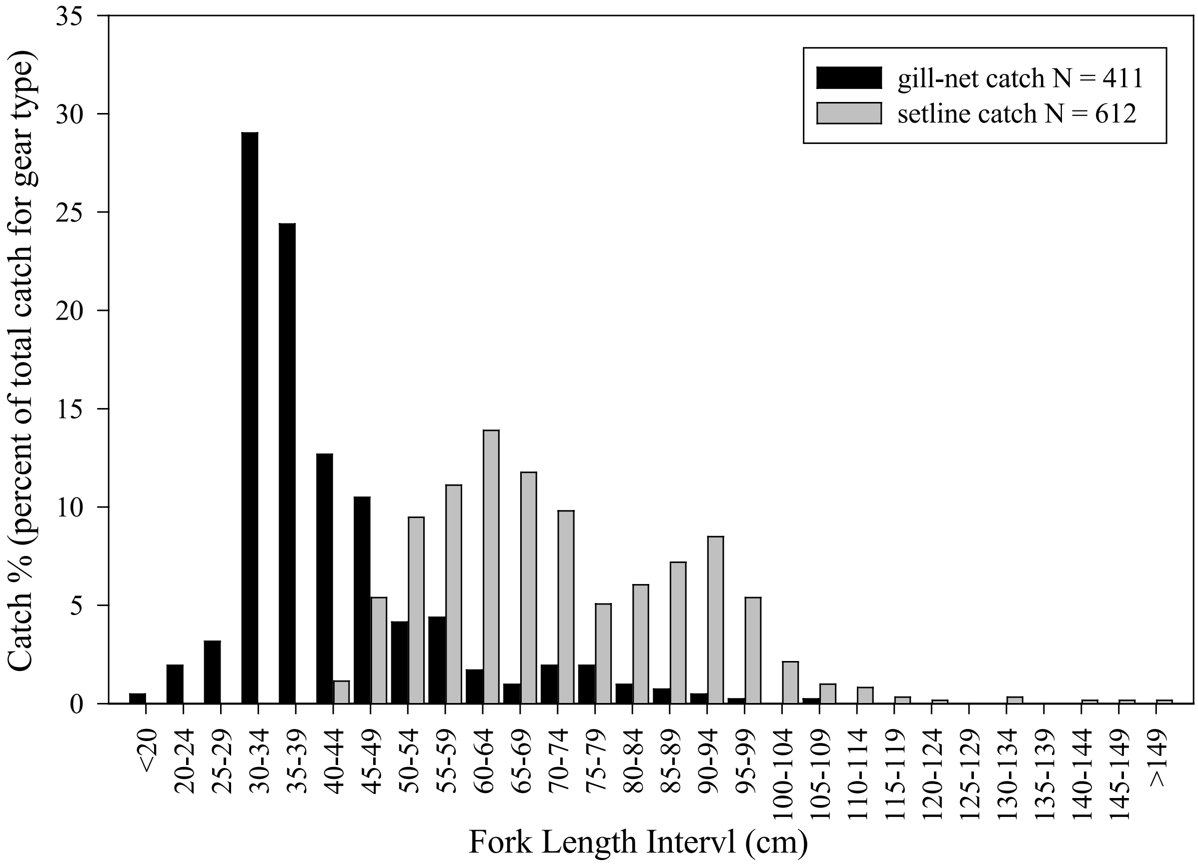


Figure 3. Fork length frequency distribution of white sturgeon as a percent of total catch for each gear type. Data from three proposed in-river, deep water, dredge spoil disposal sites within the lower Columbia River are combined.

DISCUSSION

Catch

White sturgeon were present in all three proposed in-river, deep-water dredge spoil disposal sites that we sampled. Season seemed to influence our catch at all three sites, as diversity and relative abundance of fish differed greatly among sampling periods. Catch and diversity were generally highest in summer, lowest in winter, and intermediate in spring.

Our finding that setlines catch significantly larger white sturgeon than small-meshed gill nets supports previous findings (Elliott and Beamesderfer 1990). A strong setline catch in spring combined with a weak gill-net catch therefore suggests that smaller white sturgeon may be rare in the study sites during spring. It is also possible that white sturgeon vulnerability to catch is related to season or water temperature (season or temperature may affect general fish activity

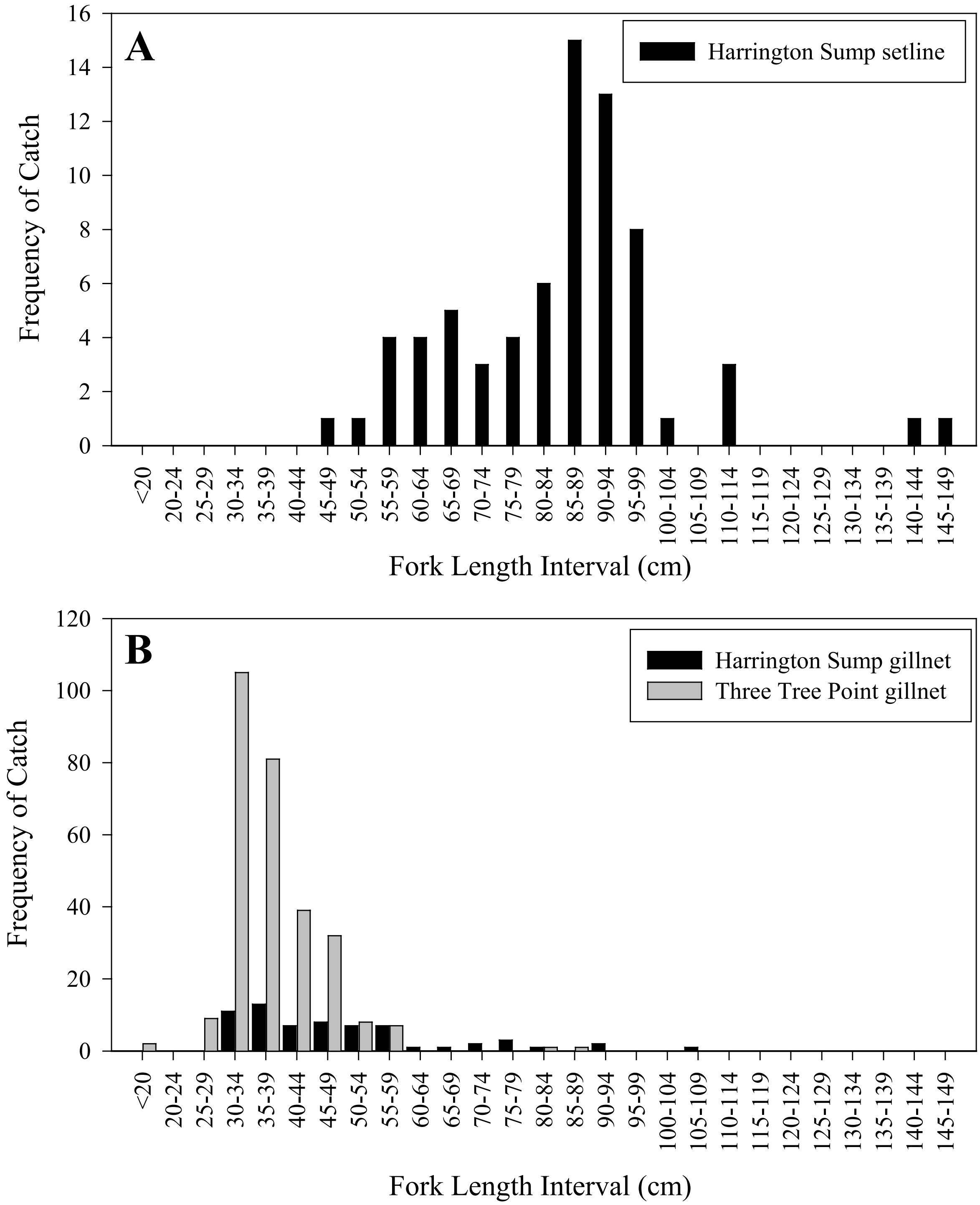
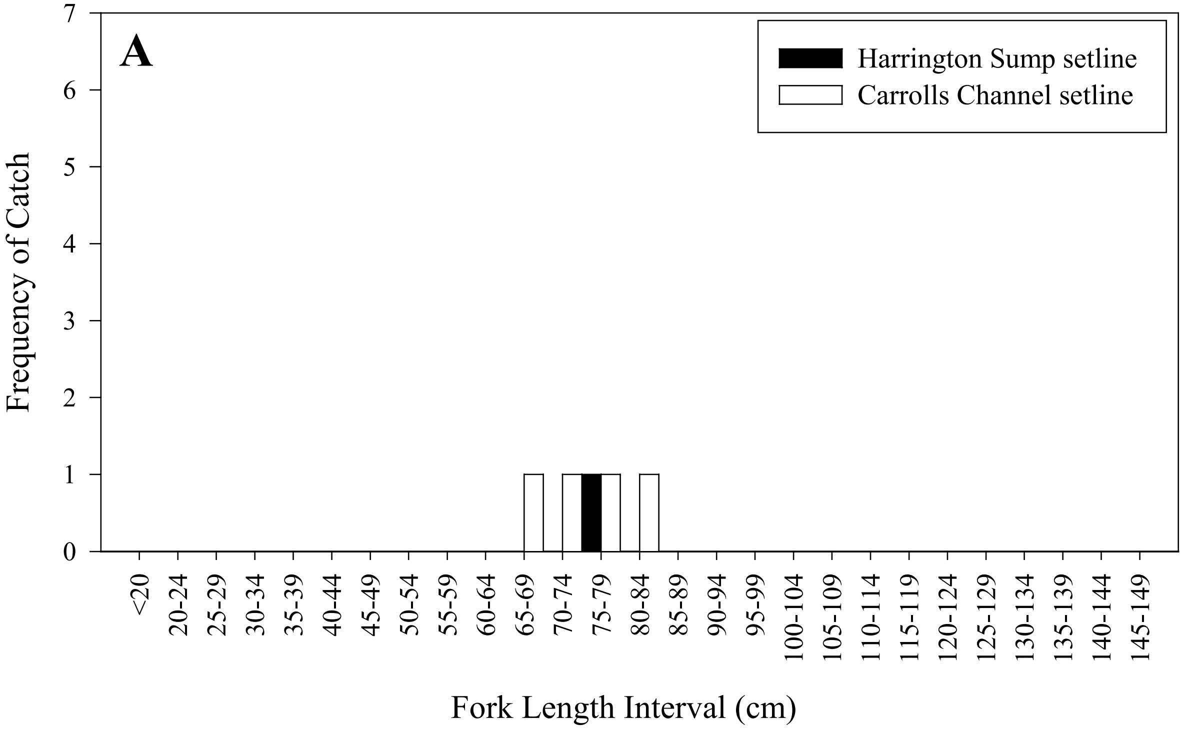


Figure 4. Fork length frequency distribution of white sturgeon caught with (A) setline gear or (B) gill-net gear, at two proposed in-river, deep-water, dredge spoil disposal sites in the lower Columbia River, summer 2000.



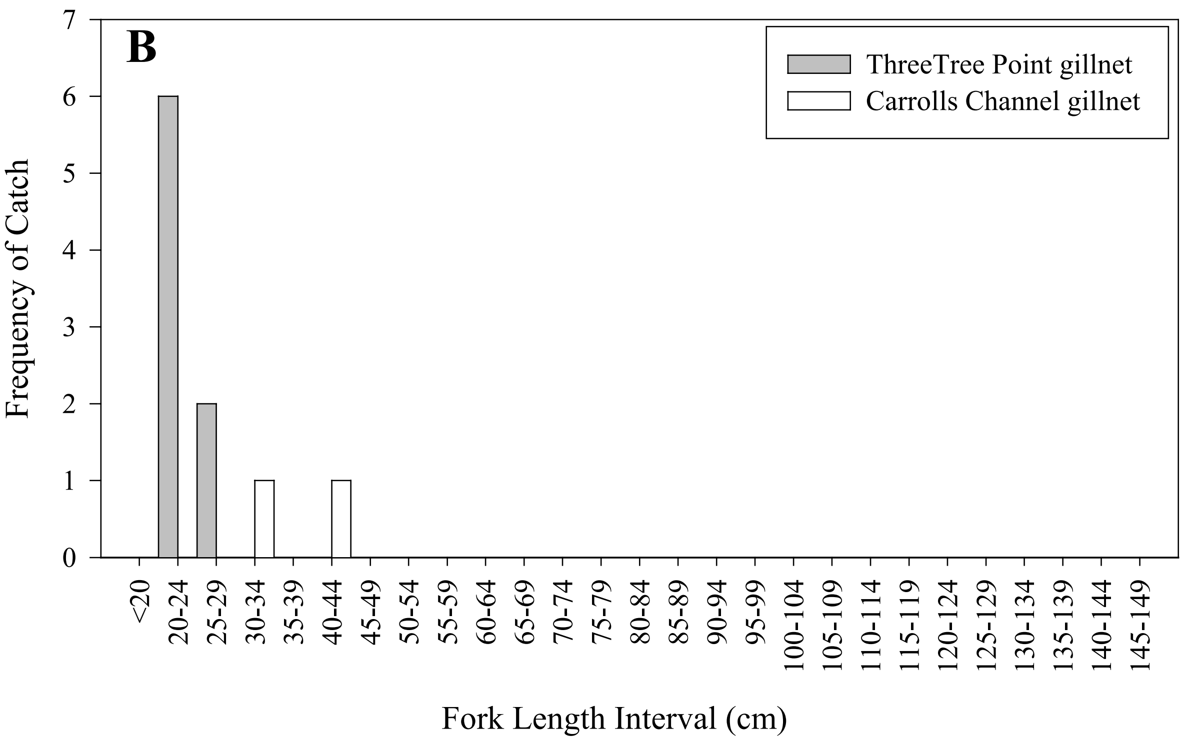


Figure 5. Fork length frequency distribution of white sturgeon caught with (A) setline gear or (B) gill-net gear, at three proposed deep water, in-river dredge spoil disposal sites in the lower Columbia River, winter 2001.

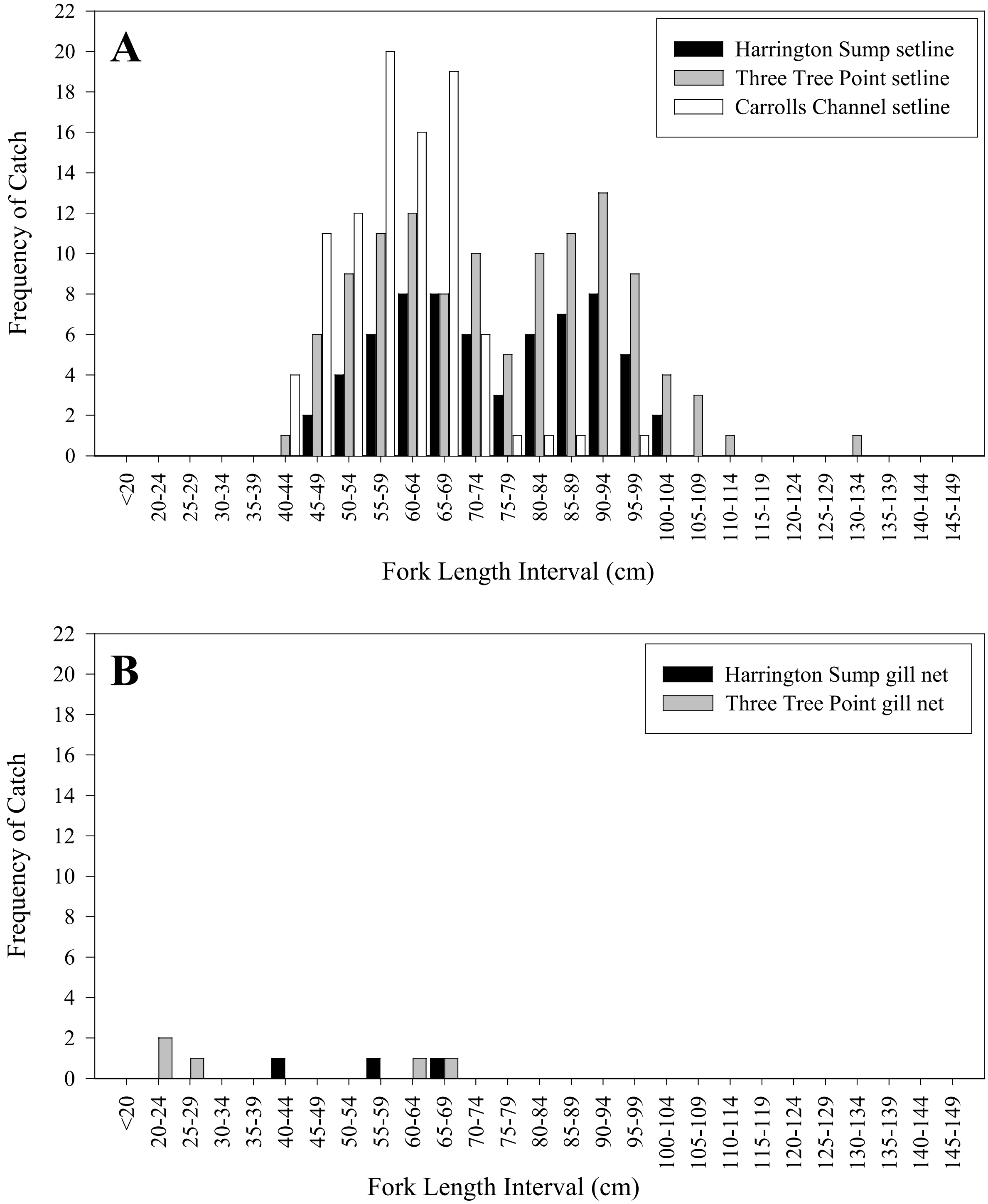


Figure 6. Fork length frequency distribution of white sturgeon caught with (A) setline gear or (B) gill-net gear, at three proposed in-river, deep-water, dredge spoil disposal sites in the lower Columbia River, spring 2001.

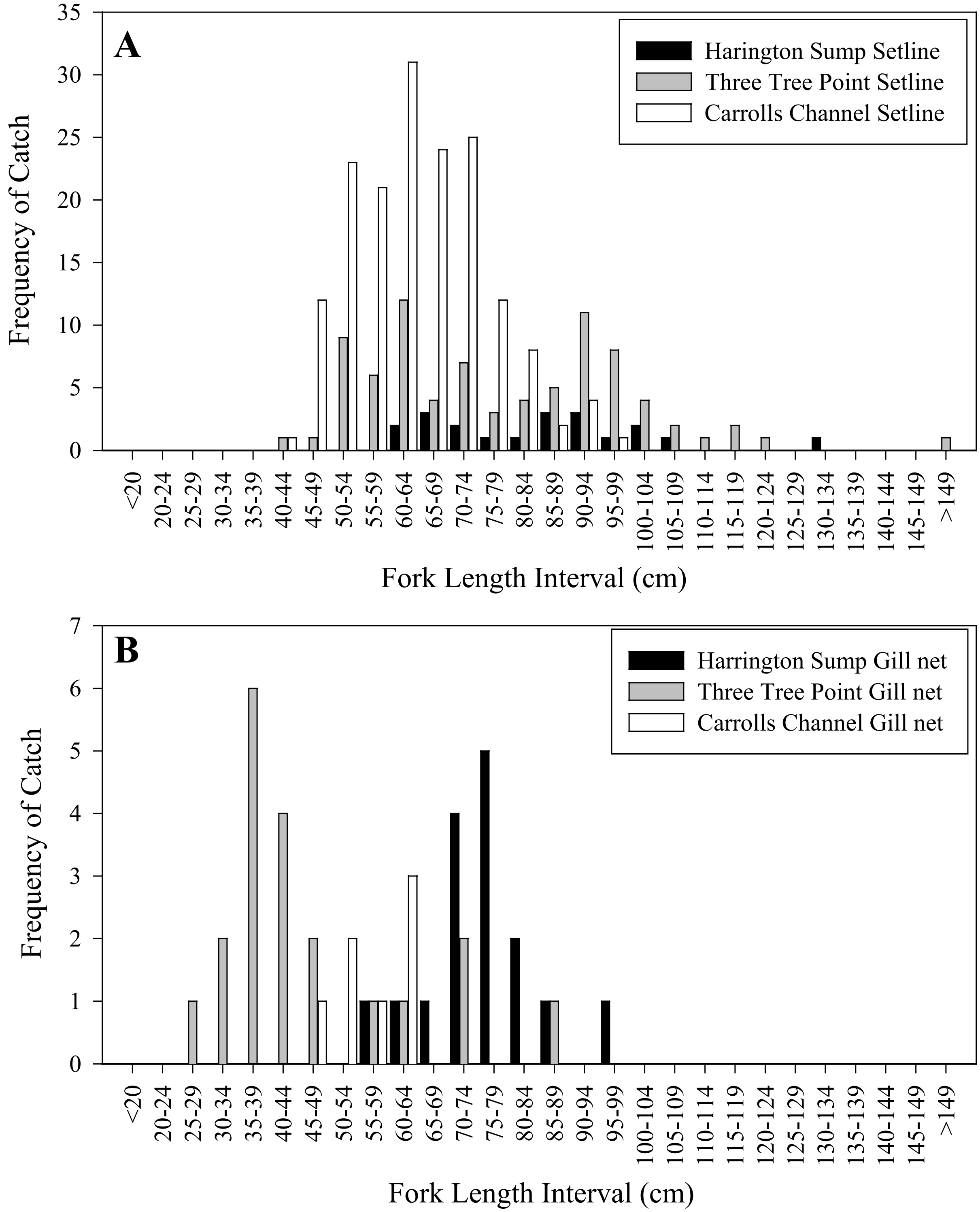


Figure 7. Fork length frequency distribution of white sturgeon caught with (A) setline gear or (B) gill-net gear, at three proposed in-river, deep-water, dredge spoil disposal sites in the lower Columbia River, summer 2001.

Table 2. Occurrence, count, wet weight, and Index of Relative Importance (IRI) for items found in stomachs of white sturgeon sturgeon captured from the Columbia River near Three Tree Point, Washington, August 2000 – January 2001.

	Stomachs		Organisms		Weight (g)		IRI = F*(N+W)	
Organism	Occurrence	Percent (F)	Count	Percent (N)	Sum	Percent (W)	Value	Percent
Turbellaria	2	4.76%	6	0.15%	0.00	0.00%	6.98E-05	0.01%
Nemertea	9	21.43%	57	1.39%	0.00	0.00%	2.98E-03	0.31%
Leech Sp.	2	4.76%	2	0.05%	0.00	0.00%	2.33E-05	0.00%
Gastropoda	1	2.38%	29	0.71%	0.14	0.23%	2.24E-04	0.02%
mollusk (clam)	4	9.52%	7	0.17%	0.00	0.00%	1.63E-04	0.02%
Crangon franciscorum	1	2.38%	31	0.76%	4.24	6.95%	1.84E-03	0.19%
Ceratopogonidae larvae	1	2.38%	1	0.02%	0.00	0.00%	5.82E-06	0.00%
Copepods	1	2.38%	82	2.00%	0.00	0.00%	4.77E-04	0.05%
Neomysis mercedis	18	42.86%	348	8.50%	7.59	12.45%	8.98E-02	9.46%
Shrimp sp.	1	2.38%	1	0.02%	0.00	0.00%	5.82E-06	0.00%
Isopoda	4	9.52%	7	0.17%	4.01	6.57%	6.42E-03	0.68%
Ramellogammarus oregonensis	3	7.14%	119	2.91%	0.80	1.32%	3.02E-03	0.32%
Corophium salmonis	32	76.19%	3,394	82.89%	16.17	26.50%	8.33E-01	87.78%
Northern Anchovy (*Engraulis mordax*)	1	2.38%	1.5	0.04%	14.70	24.11%	5.75E-03	0.61%
Eulachon (*Thaleicthys pacificus*)	1	2.38%	1	0.02%	12.55	20.57%	4.90E-03	0.52%
unidentified 6	1	2.38%	1	0.02%	0.00	0.00%	5.82E-06	0.00%
unidentified 8	1	2.38%	4	0.10%	0.79	1.30%	3.33E-04	0.04%
unidentified 11	1	2.38%	1	0.02%	0.00	0.00%	5.82E-06	0.00%
unidentified 13	1	2.38%	1	0.02%	0.00	0.00%	5.82E-06	0.00%
Parts [a]	34	80.95%	NA	NA	56.17 [a]	47.94% [a]	NA	NA
Empty	4	9.52%	NA	NA	0.00	0.00%	NA	NA
All	42	100%	4,094.5	100%	61.00 [a]	100% [a]	9.49E-01	100%

a. This material included sand and pieces of *Corophium salmonis* and *Neomysis mercedis*. Though "Parts" weighed 56.17 g, they were overwhelmingly comprised of inert material, therefore the weight was not included in totals or estimation of IRI.

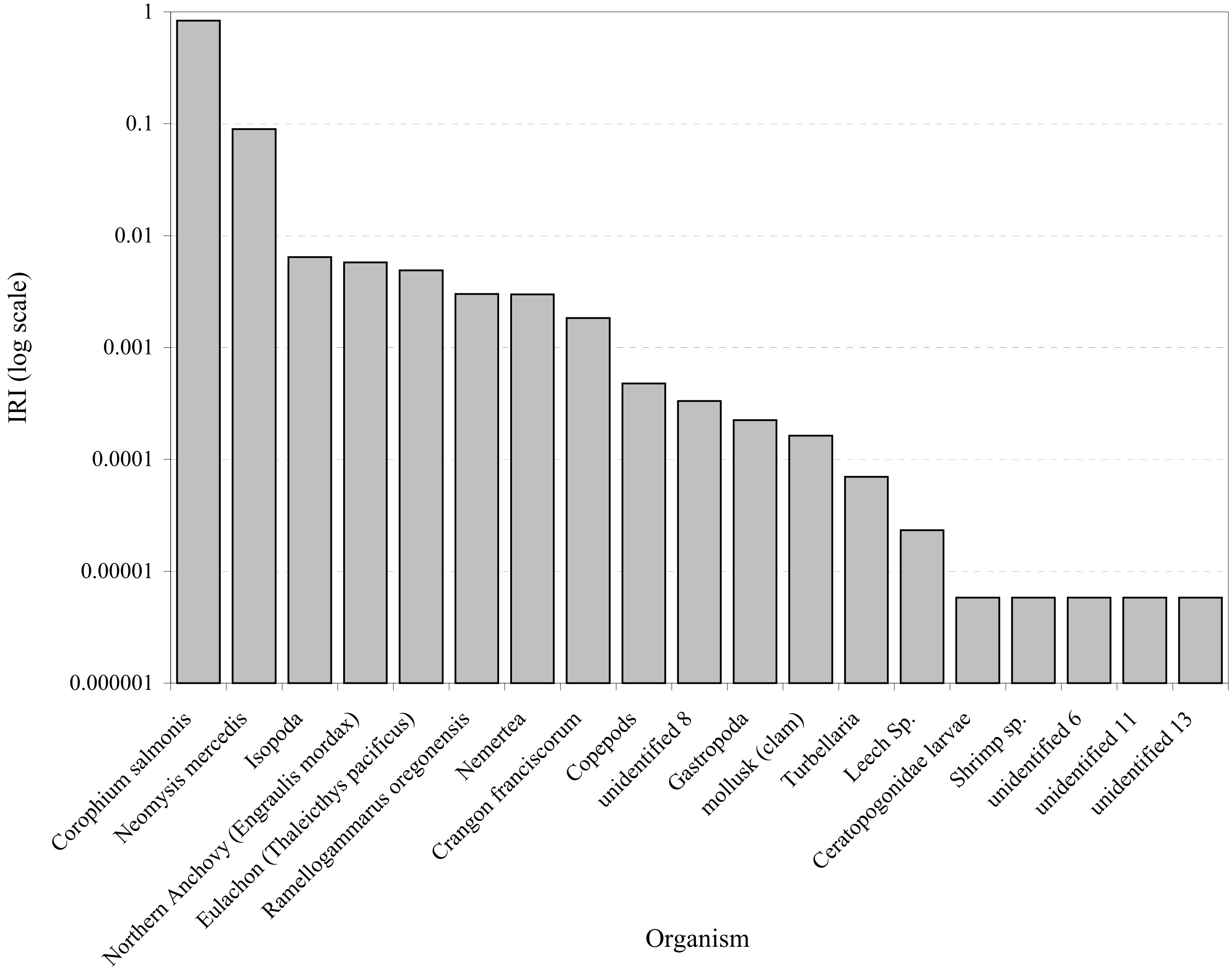


Figure 8. Index of Relative Importance (IRI) for prey items in stomachs of white sturgeon captured from the Columbia River near Three Tree Point,Washington, August 2000 – January 2001.

levels or feeding activity.) This would mean that catch rate does not correlate directly with fish density throughout the year. Regardless of the cause, it seems clear that seasonality does play a role in white sturgeon use of the three study sites

Long-distance seasonal movements of white sturgeon in the Columbia River have been previously documented (Bajkov 1951; Haynes et al. 1978; Haynes and Gray 1981; North et al. 1993). Immature white sturgeon were found to undertake an upriver migration in the fall of 1950, leading to a scarcity and even complete lack of small individuals in drift net catches in the lower part of the river (Bajkov 1951). A corresponding downriver migration occurred during late winter and early spring. Bajkov (1951) reported that these movements might have been feeding migrations. Haynes et al. (1978) also recorded an early fall migration of white sturgeon in the free-flowing portion of the Mid-Columbia River; however, the authors believe that these movements were dependent more on water temperature and size of the individuals than on feeding pressures. Haynes and Gray (1981) reiterated the belief that white sturgeon seasonal movements are linked to water temperature.

We found gill nets had higher average white sturgeon catches per set and per hour than setlines. Elliott and Beamesderfer (1990) had greater catch rates with setlines than with gill nets or angling; however, that study compared catch based on crew hours needed to fish the gear whereas our study based effort on the amount of time each gear type was actively fishing.

We found a great difference in the species caught by the two gears we used. Setlines caught practically all white sturgeon (with the exception of one cottid), whereas gill nets caught several other fish species. Elliott and Beamesderfer (1990) reported similar results. Although they were caught only in gill nets, peamouth chub were the most abundant species of fish caught during the study. This was due primarily to a large catch of 542 peamouth chub during summer 2000 at Three Tree Point. Bycatch of other fish species in gill nets appeared to be affected by season in a pattern similar to the seasonal variation in the catch of white sturgeon. During both summer sampling periods the total abundance and CPUE of peamouth chub and American shad were greater than the spring sampling period, which in turn was greater than the winter sampling period.

Bycatch of salmonids in gill nets was not a substantial problem in this study. The only salmonid caught was a single (presumed) sea-run cutthroat trout *Oncorhynchus clarkii* caught in a gill net at Carrolls Channel during spring. The fish was caught by the mouth only, not the gills, and was released unharmed. This result was encouraging given that Elliott and Beamesderfer (1990) reported substantial bycatch and subsequent mortality of salmonids caught in gill nets in their study. Our use of smaller mesh (5 cm) gill nets is the likely reason for our lack of salmon bycatch.

Diet Analysis

Our study agrees with the findings of both Muir et al. (1988) and McCabe et al. (1993) that *Corophium salmonis* is a common prey of juvenile white sturgeon in the lower Columbia River. Similar to our study, McCabe et al. (1993) also found that *C. salmonis* was the dominant prey in the diet of juvenile white sturgeon over more than one season.

C. salmonis is one of the most abundant invertebrate species at Three Tree Point according to surveys of benthic invertebrates performed by Marine Taxonomic Services Limited (MTS) during July and September 2001 (MTS 2002). Sediment samples in July 2001 contained an average of 452 *C. salmonis* individuals/m^2 sampled. The same samples contained an average of 328 unidentified Chironomid (midge) individuals/m^2 sampled (MTS 2002). Unidentified species of *Corophium* were the most abundant invertebrate in sediment samples collected at Three Tree Point in September 2001, with 873 individuals/m^2 sampled (MTS 2002). *C. salmonis* was also very abundant in September 2001 with 454 individuals/m^2 sampled.

White sturgeon captured in our study appeared to be taking one of the most abundant prey items available. This contrasts the results of McCabe et al. (1993) who found that although juvenile white sturgeon were preying heavily on *C. salmonis,* it was not one of the most abundant organisms in samples of benthic invertebrates taken at the same locations. The mollusk *Corbicula fluminea*, the polycheate worm *Nereis vexillosa*, and unidentified Chironomid individuals were all found in the benthos of Three Tree Point yet none of these invertebrates were found in the stomach samples taken from the same area. Without further research it is difficult to determine the cause of these results. McCabe et al. (1993) theorized that juvenile white sturgeon in their study were either (1) feeding on *C. salmonis* that were transported by the current drift, (2) feeding in other areas where *C. salmonis* was more abundant, or (3) feeding very efficiently on *C. salmonis*.

FUTURE WORK

Although we have established that white sturgeon are present in three potential dredge disposal areas in the lower Columbia River, the response of these fish to disposal activities is not known. We have demonstrated some seasonal variability in catch rates that are strong evidence of variable seasonal use. The short-term response of white sturgeon to dredge disposal activities will be clarified by telemetry work proposed by the U. S. Geological Survey. This added information will provide a more complete assessment of the affects potential loss of habitat (due to dredge-disposal activities) may have on white sturgeon.

ACKOWLEDGMENTS

This project was the result of close collaboration between the Oregon Department of Fish and Wildlife (ODFW) and the Washington Department of Fish and Wildlife (WDFW). All products generated from this research should be considered joint achievements of both agencies. We thank Shane Allen, Peter Barber, Brad Cady, Jody Gabriel, J.T. Hesse, John Hone, Matthew Howell, Chris Kern, Robin Mills, Frank Tarrabochia, and Steve West for assistance in field collection of the data. Susan Hinton (NMFS) assisted with identification of sturgeon stomach contents. Brad James (WDFW) and David Ward (ODFW) helped with initial study conception, design, and analysis of data. The U. S. Army Corps of Engineers funded this work (contracts W66QKZ 10725001 and W66QKZ13237211).

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APPENDIX A

Fish Species Collected During Gill-Net Sampling

Appendix Table A-1. Catch of fish species other than white sturgeon during gill-net sampling at three proposed deep-water, in-river, dredge spoil disposal sites in the lower Columbia River, summer 2000 through summer 2001. HS = Harrington Sump, 3T = Three Tree Point, CC = Carrolls Channel.

		Summer 2000		Winter 2001			Spring 2001			Summer 2001		
Common name	Scientific name	HS	3T	HS	3T	CC	HS	3T	CC	HS	3T	CC
American shad	*Alosa sapidissma*	62	118	0	0	0	1	2	1	19	7	0
Cutthroat trout	*Oncorhynchus clarki*	0	0	0	0	0	0	0	1	0	0	0
Northern anchovy	*Engraulis mordax*	2	0	0	0	0	0	0	0	5	0	0
Eulachon	*Thaleyicthys pacificus*	0	0	0	1	0	0	0	0	0	0	0
Northern pikeminnow	*Ptychochelius oregonensis*	0	14	0	0	0	0	2	0	0	4	1
Peamouth	*Mylocheilus caurinus*	99	542	0	0	0	52	35	107	141	131	32
Largescale sucker	*Catostomus macrochelius*	1	41	0	0	0	0	0	2	0	0	0
Yellow perch	*Perca flavescens*	2	1	0	0	0	0	0	0	1	0	10
Pacific staghorn sculpin	*Leptocottus armatus*	0	0	0	0	0	2	0	0	0	0	0
Sculpin spp.	*Cottus* spp.	7	2	1	1	0	0	0	0	13	0	0
Starry flounder	*Platichthys stellatus*	58	13	4	3	0	18	0	4	21	1	2

EXHIBIT K-2
EVALUATION REPORT
SMELT
(REVISED)

Table of Contents
Exhibit K-2
Evaluation Report
Migration Timing and Distribution of Columbia River Smelt
In The Lower Columbia River (Revised)

Evaluation Report
Migration Timing and Distribution of Columbia River Smelt In The Lower Columbia River (Revised)

The attached report provides a final summary of studies undertaken to characterize the nature and extent of eulachon (smelt) *Thaleichthys pacificus* spawning and larval migration in the lower Columbia River. The overall goal of the study was to use the information colleted to assess the potential effects on eulachon, if any, of the proposed project to deepen the Columbia River shipping channel.

The main objectives of the 2 year study were to (1) determine the presence or absence of egg deposition and larval migrants within and adjacent to specific reaches of the Lower Columbia River navigation channel; (2) use the information acquired to asses the potential effects of dredging; and (3) depending upon the outcome of objective number three, determine if any measures are necessary to minimize the potential effects of dredging to the overall eulachon population.

The findings and recommendations in general were that dredging activities associated with channel deepening are not expected to have a significant impact on migrating eulachon larvae (through entrainment), on eulachon spawning areas, or on eulachon eggs incubating in nearshore areas in the proximity of dredging activities. Impacts to smelt spawning areas from disposal are generally not a concern because most in-water disposal sites are downstream of the lowest major smelt spawning areas, which are at CRM 56-61 and 67-69. While the current construction plan has some limited inwater (flowlane) disposal in CRM 59-62, this disposal is unlikely to directly impact eulachon spawning areas because the dynamic nature of substrates within the flowlane disposal sites (which are in or adjacent to the main channel) do not provide stable surfaces that would allow an adhesive egg to incubate for 30 days. Impacts to migrating larval smelt from disposal are a concern to the agencies and though they are unsure of the level of impact, they have indicated in the attached letter that disposal not occur during the peak of the larval movement downstream. The peak out migration in 2001 was from the 2nd to the 18th of April but can vary. The period of peak larval out-migration will be determined by the agencies prior to construction, but will likely fall within, or near this period. The Corps has agreed to schedule construction dredging and disposal to avoid this period. No additional specific actions (e.g., timing restrictions) are recommended because it is unlikely that dredging associated with channel deepening would have a significant impact on eulachon.

January 9, 2003

Mr. Kim Larson
U. S. Army Corps of Engineers
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Re: Recommendations for potential in-water disposal of dredged materials associated with the Columbia River Channel Improvement Project.

Dear Kim,

In November, 2002, we provided an assessment of the potential impacts of channel deepening activities on eulachon based on study findings in our final report, *Eulachon studies related to lower Columbia River channel deepening operations*, edited by David L. Ward. In our report we stated, "Disposal is generally not a concern because in-water disposal sites are downstream of the lowest major eulachon spawning area." In a recent conversation (January 3, 2002), you explained to me that hopper disposal of dredged materials associated with the Columbia River Channel Improvement Project might occur in the channel within river mile reaches 51-56 and 59-61. You asked that we clarify our recommendations in light of this information.

I have conferred with some of the members of the smelt mitigation workgroup (Dave Ward and Patty Snow with Oregon Department of Fish and Wildlife, and Brad James and Steve Manlow of Washington Department of Fish and Wildlife). What follows is our consensus opinion and recommendations for potential in-water disposal of dredged materials associated with the Columbia River Channel Improvement Project, as it relates to eulachon.

Generally, we do not expect the described disposal will affect eulachon spawning habitat. Further our 2001 study showed that eulachon larvae disperse widely and that the shipping channel was not the primary outmigration corridor. However, larval densities were greater at mid water column and near the river bottom (where dredged materials will be released), and these areas are adjacent to and immediately downstream of one reach identified as an important main stem spawning area (river mile 56 to 61) and a major spawning tributary -- the Cowlitz River. We are concerned that larval eulachon survival may be reduced by an increase in suspended particles, but we do not know a mortality rate or the magnitude of potential losses.

Our recommendations for in-water disposal are intended to protect eulachon larvae during the period of peak outmigration and in areas where they are most abundant. We recognize some losses may occur if disposal happens at anytime during the period of eulachon outmigration

(January through June). However, the eulachon migration is variable, protracted, and sporadic, and larvae disperse widely in the river. Further, we are uncertain of the mechanism or potential magnitude of losses. As such we feel a period of restriction that protects outmigrating larvae during their period of greatest abundance is appropriate.

The following recommendations for in-water disposal are based on findings from our 2001 eulachon study.

1. No in-water disposal should occur in areas shallower than 43 feet along the Washington shore between river mile 35 and 75. Eulachon were found to spawn throughout this area and this restriction will protect spawning habitat.
2. No in-water disposal should occur during the period of peak eulachon outmigration downstream from identified spawning areas (river miles 35-75). Peak eulachon outmigration in 2001 was April 2-18, but this varies in magnitude and duration among years. Since 1988, peak landings of adult eulachon have ranged from the 4^{th} to the 16^{th} week of the year, with most peaks falling between weeks 5 and 11. We would expect peak outmigration to fall about four weeks after peak landings. Further analysis of historic data may better define the peak outmigration period.
3. If in-water disposals are essential during the period of peak outmigration further study is needed to estimate potential eulachon losses.

Thank you for bringing plans for in-water disposal to our attention. I hope that these additional recommendations will be useful in completing an Environmental Impact Statement that will minimize fishery losses that may result from the Columbia River Channel Improvement Project.

Sincerely,

//ss//
Tom Rien
Research Project Leader
Eulachon and Sturgeon Studies

cc: Ward, Snow, Nigro (ODFW)
James, Manlow (WDFW)

EULACHON STUDIES RELATED TO LOWER COLUMBIA RIVER CHANNEL DEEPENING OPERATIONS

Edited by:

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Final Report to U. S. Army Corps of Engineers
Contract Number W66QKZ13237198

November 2002

CONTENTS

REPORT A

PROJECT SUMMARY AND FINAL RECOMMENDATIONS

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CONTENTS

PROJECT SUMMARY

This report provides a final summary of studies undertaken to characterize the nature and extent of eulachon (smelt) *Thaleichthys pacificus* spawning and larval migration in the lower Columbia River. The overall goal of the studies is to use the information collected to assess the potential effects on eulachon, if any, of the proposed project to deepen the Columbia River shipping channel. The study is a cooperative effort by the Oregon Department of Fish and Wildlife, the Washington Department of Fish and Wildlife, and the U. S. Army Corps of Engineers. Field studies were conducted in fiscal years (FY) 2000 and 2001, with FY 2002 dedicated to completing data analyses and preparing reports. Previous progress was summarized in our reports of results for FY 2000 and FY 2001.

The main objectives of the studies were to (1) determine the presence or absence of egg deposition and larval migrants within and adjacent to specific reaches of the Lower Columbia River navigation channel; (2) use the information acquired to assess the potential effects of dredging; and (3) depending upon the outcome of work to address Objective (2), determine if any measures are necessary to minimize the potential effects of dredging to the overall eulachon population. Field activities in FY 2001 were geared toward meeting Objective 1. Information from both years of field work were used to meet Objective 2. This report addresses Objective 3.

Most sampling occurred between Columbia River Mile 30 and 85 (approximately Three Tree Point to the Cowlitz River mouth). In 2000 we focused all sampling within or proximate to areas that have been proposed for channel deepening. In 2001 the study area was expanded somewhat. To evaluate gears we sampled in the Cowlitz River, and we sampled for eulachon larvae upstream of the Cowlitz River mouth when it became apparent that adults had moved upstream. In 2001 sampling was conducted over a broad cross-section of the Columbia River channel to characterize the density of larval migrants relative to that in proposed channel-deepening areas. Also in 2001, sampling for eggs was conducted in relatively nearshore areas to characterize the distribution of spawning in the Columbia River.

Final project findings are detailed three subsequent reports. These reports are:

Report B Migration Timing and Distribution of Larval Eulachon *Thaleichthys pacificus* in the Lower Columbia River, Spring 2001;

Report C Use of an Artificial Substrate to Capture Eulachon *Thaleichthys pacificus* Eggs in the Lower Columbia River; and

Report D Characterization of Development in Columbia River Prolarval Eulachon *Thaleichthys pacificus* Using Selected Morphometric Characters.

Highlights from these reports include:

1. Closeable plankton nets were used to collect larval eulachon at seven transects in the Lower Columbia River from river mile 34 to river mile 100 (Report B).
2. Larval abundance was highly variable through time, by cross-channel location, and with depth. Larvae were present in the Columbia River from January through May 2001. Peak abundance occurred in early/mid-April compared with mid-March in 2000 (Report B).
3. The shipping channel was not observed to be the primary migration corridor. Highest catches of larvae were observed at stations located nearer to the Washington shoreline downstream from major spawning areas (Report B).
4. Although sampling with artificial substrates demonstrated that mainstem spawning occurred throughout the study area, it appears that this input to the larval population is less significant than that from the Cowlitz River. An exception is the Barlow Point locale where larval abundance was observed to be very high (Report B).
5. Larvae were distributed throughout the water column at all sampling locations. At sampling locations situated within the shipping channel larvae were generally more abundant at the bottom and middle of the water column than at the surface (Report B).
6. Artificial substrates were used to collect eulachon eggs in the lower Columbia River. We sampled from river mile 30 to 85, with at least two artificial substrates placed in all but one mile. We did not attempt to standardize or stratify substrate placement among depths or habitat types. Depths of sampling ranged from 3 to 42 feet and distance from the riverbank ranged from 15 ft to over 300 ft. Among 147 sets, eggs were collected in 23, all between river miles 35 and 73. The greatest number of eggs were captured in river miles 56 to 61 and 67 to 69 (Report C).
7. Egg catch per unit effort varied with sampling time and location. In areas that eggs were collected the bottom composition varied, yet was dominated by medium to fine sand. The sample rate was low given the size of the study area, therefore caution was used in applying this finding (Report C).
8. Ripe eulachon were collected from the Cowlitz and Sandy Rivers and artificially spawned in the laboratory at ODFW Clackamas. Eggs were successfully incubated in water filled petrie dishes and hatched 47 days after fertilization, accumulating 752 thermal units – approximately twice that documented by previous workers (Report D).
9. Larvae were allowed to develop in petrie dishes and survived 21 days before total yolk-sac absorption. Larvae were preserved in formalin at various post-hatch ages for subsequent morphometric evaluation (Report D).
10. Trends in larval growth and yolk-sac absorption were observable over time, however, individuals of each age class showed high variability in the chosen morphometric criteria such that development was not statistically identifiable on a time scale of days (Report D).

11. Static environmental conditions in our experiment appear to have retarded larval development. Morphometric analyses of larvae collected in the field from a known spawning area (the Cowlitz River; river mile 68) and the Columbia River mainstem at river mile 34 showed that identifiable development does occur as larvae out-migrate to the estuary and ocean (Report D).

FINAL RECOMMENDATIONS

The following assessments of the potential impacts of channel deepening activities on eulachon are based on report findings. In general, dredging activities associated with channel deepening are not expected to have a significant impact on migrating eulachon larvae (through entrainment), on eulachon spawning areas, or on eulachon eggs incubating in nearshore areas in the proximity of dredging activities. Disposal is generally not a concern because in-water disposal sites are downstream of the lowest major smelt spawning area.

1. Given the large numbers of eulachon larvae and their distribution across the river channel and throughout the water column it is unlikely that dredging associated with channel deepening would have a significant impact (through entrainment) on the migrating larval population.
2. Dredging associated with channel deepening is unlikely to directly impact eulachon spawning areas. Given the dynamic nature of substrates within the reaches proposed for channel deepening, these reaches do not provide stable surfaces that would allow an adhesive egg to incubate for 30 d.
3. Eulachon eggs incubating in near-shore areas in the proximity of dredging activities might be affected if these activities alter flow patterns or increase sedimentation. However, hydraulic models indicate dredging will not significantly alter the river's flow patterns. The average annual bed-load transport in the main river channel to expected to remain the same within the existing range.
4. Artificial spawning substrates may be a useful tool to better characterize the timing and location of eulachon spawning. Although more intensive sampling using egg substrates over multiple years would allow better identification and characterization of long-term spawning sites and relative levels of use among areas, this information is not deemed necessary at this time to assess the potential effects of channel-deepening.
5. As a precautionary measure to minimize any dredging effects on eulachon eggs, channel-deepening operations could be scheduled to avoid certain reaches at times in which the greatest number of eulachon eggs were collected during the peak spawning period. Two reaches identified by this study are river mile 56 to 61 and 67 to 69.

The following recommendations are based on the above assessments:

1. No specific actions are recommended because it is unlikely that dredging activities associated with channel deepening would have a significant impact on eulachon.
2. Dredging activities associated with channel deepening are not scheduled to occur in known areas of high spawning concentration. The most realistic and reliable strategy for reducing impacts from other dredging operations would be to avoid areas of high spawning concentration.

REPORT B

MIGRATION TIMING AND DISTRIBUTION OF LARVAL EULACHON IN THE LOWER COLUMBIA RIVER, SPRING 2001.

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CONTENTS

ABSTRACT

We sampled from 28 January through 1 June 2001 to (1) quantify timing of larval eulachon Thaleichthys pacificus emigration in the Columbia River, (2) determine cross-channel larval distribution during emigration, and (3) determine depth distribution of larvae within the shipping channel during emigration. This study was initiated to evaluate potential effects of proposed channel-deepening operations in the Columbia River on eulachon spawning and emigration. Closeable plankton nets were used to collect larval eulachon at seven transects in the Lower Columbia River from river mile 34 to river mile 100. Larval abundance was highly variable through time, by cross-channel location, and with depth. The shipping channel was not observed to be the primary emigration corridor. Larval densities outside the shipping channel were significantly greater than those inside the channel. Highest catches of larvae were observed at stations located nearer to the Washington shoreline downstream from major spawning areas. We collected larvae throughout the sampling period, but catches peaked between 2 and 18 April. Larvae occurred at all depths sampled, but densities were generally greater near the bottom and in mid-water than near the surface. Although sampling with artificial substrates demonstrated that mainstem spawning occurred throughout the study area, it appears that this input to the larval population is less significant than that from the Cowlitz River. An exception is the Barlow point locale where larval abundance was observed to be very high. Given the variability in distribution and timing of eulachon larval emigration, scheduling of dredging to reduce impacts to emigrating larvae would be confined to the short term. The most realistic and reliable strategy for reducing dredging-related impacts to eulachon would be to avoid dredging in areas of high spawning concentration.

INTRODUCTION

The eulachon *Thaleichthys pacificus*, an anadromous member of the smelt family (Osmeridae), spawns along the Pacific coast of North America, from the Pribilof Islands (Bering Sea) to the Klamath River in California (Wydoski and Whitney 1979). The lower Columbia River Basin supports one of the largest spawning runs of eulachon. In most years many eulachon spawn in the Cowlitz River, with somewhat fewer spawning in the mainstem Columbia River. Smaller, periodic runs occur in other tributaries including the Grays, Skamokawa, Elochoman, Kalama, Lewis, and Sandy rivers. Adult migration in the Columbia River system usually begins in December, peaks in February and continues through May (WDFW 2001).

Spawning eulachon females generally deposit eggs in areas where the substrate consists of coarse sand/fine gravel, and where water flows are "moderate" in velocity (Hart and McHugh 1944; Smith and Saalfeld 1955). Eggs adhere to the surface of the substrate and incubate over a period of about 30-40 days, depending on temperature. Upon hatching the larvae become part of the drift as (presumably) passive plankters and are rapidly transported out to sea (Hart and McHugh 1944; Hart 1973) where they rear in near-shore marine areas at moderate to shallow depths (Barraclough 1964).

Historically, the commercial catch of eulachon in the Columbia River system has generally been strong, yet variable. Recent annual returns, based on commercial landings, were relatively stable until 1994 when a sharp decline occurred. This trend of lower annual returns of spawning adults continued through 1999. Although the 2000 and 2001 spawning runs in the lower Columbia River appear stronger (according to catch data), the relative magnitude is difficult to quantify as restrictive fishery management strategies imposed in response to the recent decline in returns severely reduced commercial effort.

Mechanisms controlling eulachon recruitment and survival are poorly understood. Conditions in the freshwater environment during eulachon spawning may influence productivity. This study was initiated to evaluate the potential effects of proposed channel-deepening operations in the Columbia River (USACE 1999) on eulachon spawning and migration.. Dredging activity has the potential to impact eulachon through entrainment of spawning adults (Larson and Moehl 1990; McGraw and Armstrong 1990) and possible smothering of developing eggs by increased turbidity and suspended sediment in the vicinity of operations (Morton 1977; Prussian et al. 1999). Entrainment of developing eggs and migrating larvae has not been documented but remains a concern. In response to these concerns the U.S. Army Corps of Engineers (USACE) contracted the Oregon Department of Fish and Wildlife (ODFW) and the Washington Department of Fish and Wildlife (WDFW) to identify eulachon spawning sites within proposed channel deepening areas and to characterize the spatial and temporal distribution of eulachon larvae in the mainstem Columbia River during the migration period.

Preliminary results from the first year of the study (Howell and Uusitalo 2001) showed that eulachon larvae were widely distributed throughout the river during migration. Sampling limitations precluded determining the relative importance of the shipping channel as a migration corridor relative to the rest of the river. The objectives for this study in 2001 were to (1) quantify the timing of larval eulachon migration in the Columbia River, (2) determine cross-channel larval distribution during migration, and (3) identify the depth distribution of larvae within the shipping channel during migration.

METHODS

Study Area

Previous studies have documented large spawning concentrations of eulachon in the Cowlitz River, Washington. During field sampling in the spring of 2000 (Howell and Uusitalo 2001) we found the highest densities of migrating larvae in the Columbia River downstream of the confluence with the Cowlitz River at Columbia River kilometer (RK) 110 (Figure 1; all river distances are reported using National Oceanographic and Atmospheric Administration river distances). During 2001 the majority of our effort was therefore concentrated downstream of the Cowlitz River to maximize larval catch rates.

Only one sampling transect was located up river from the confluence of the Cowlitz and Columbia rivers.

Sampling Gear and Methods

We used a plankton net deployed from an anchored vessel to capture eulachon larvae. The net was a typical ring net design comprising a tapered nylon sock (3.35 m length, 300 µm mesh) lashed to a stainless steel circular frame (0.61 m inside diameter).

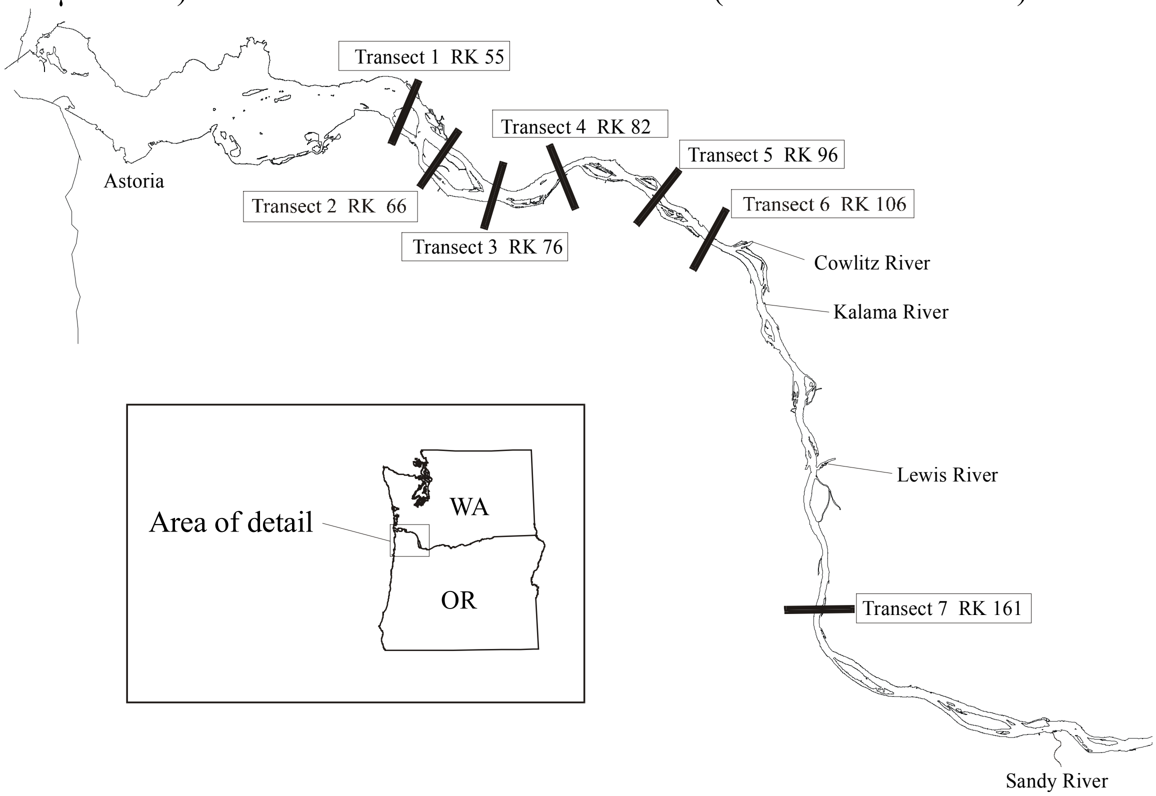

Figure 1. 2001 lower Columbia River, larval eulachon migration study site, showing location of larval eulachon sampling transects, listed by transect name and Columbia River kilometer (RK).

Samples were collected in an 8.9-cm, two-piece polyvinyl chloride (PVC) collection bucket attached to the end of the sock. Spherical lead weights (2.54 kg, 9.07 kg or both) were attached to the frame base. The net was closeable via a row of choke rings placed around the sock approximately 1.3 m behind the mouth. Water flow was measured with a digital flowmeter consisting of a propeller/sensor mounted in the mouth of the net and connected to an onboard digital counter via a cable (Illustrations of net configuration are given in Appendix A).

We sampled during daylight hours on ebb tides. Vessels were anchored and we recorded Differential Global Positioning System (DGPS) co-ordinates, and water

temperature, depth, and turbidity readings. Plankton nets were lowered to the desired depth, allowed to fish for approximately 60 s, closed, and immediately retrieved. The flowmeter was activated when the net reached the desired sampling depth and stopped upon net closure.

Contents of the collection bucket were rinsed into storage jars and fixed with dilute (approximately 70%) ethyl alcohol. We added Rose Bengal stain to aid in laboratory examination.

Sampling Design

We sampled at seven transects in the lower Columbia River to characterize the cross-river distribution of eulachon larvae (Figure 1). Because of a variety of factors transects were not chosen randomly. Transect 1 (RK 55) is an index site for larval eulachon sampling (Price Island Index) that has been monitored by WDFW since 1994 (WDFW 2001). Transect 6 (RK 106) was chosen specifically to characterize the cross-river distribution of larvae in close proximity to a known spawning area (the Cowlitz River). We chose transects 2, 3, 4 and 5 (RK's 64, 75, 82 and 97 respectively) to reflect the heterogeneity in river morphology and relative position of the shipping channel within the study area. Some transects included side channels of the river, some were deeper closer to the Oregon shore, and others were deeper closer to the Washington shore. We sampled transects 1-6 eight times between 28 January and 01 June 2001 (Table 1).

During the 2001 eulachon spawning run a substantial number of adults migrated upriver of the confluence of the Cowlitz and Columbia rivers, some going as far as Bonneville Dam (RK 234). In response to expanded spawning by the strong eulachon run, we added Transect 7 in mid-season at RK 160, upstream of the confluence of Lewis and Columbia rivers (RK 139) but downstream of the confluence of the Sandy and Columbia rivers (RK 194). We sampled Transect 7 on 24 April, 27 April, 07 May, and 10 May 2001.

Each transect line was drawn roughly perpendicular to the river flow, from riverbank to riverbank. Along each transect line we established five sampling stations positioned at intervals across the river (Appendix B). At least one station at each transect was located within the shipping channel. Stations were numbered 1 through 5 across transects from the Washington shore to the Oregon shore. The number of samples collected at a station varied depending on depth. At shallow stations (< 3 m) we took samples from the bottom of the water column only. At stations of intermediate depth (≥ 3 m and ≤ 8 m) we took samples from the bottom and surface of the water column. At the deepest stations (> 8 m) we took samples from the bottom, middle and surface of the water column. For each of these depth strata we took three replicate samples in succession to account for short-term variability in larval density.

Laboratory Methods

Over 1,800 samples were collected and brought to the lab to be analyzed. Many of these samples contained more than 5,000 eulachon larvae and some contained as many as 30,000 larvae. Given the large number of samples taken and limited time

available, we used a representative subsampling method to estimate total larval counts for each sample. Each sample was emptied into an Erlenmeyer flask and total sample volume (wet) was recorded. The flask was swirled to ensure random mixing and approximately 20% of the total sample volume was poured into a graduated cylinder. The subsample was then poured into a Petrie dish and we used a dissecting microscope to count all larvae. Total sample counts were estimated by extrapolation based on subsample volumes.

Table 1. Summary of sampling periods during 2001 larval migration study.

Sampling Period	Dates	Comments
1	30 January – 14 February	Gear testing
2	28 February – 2 March	
3	14 March – 16 March	
4	2 April – 5 April	
5	11 April – 13 April	
6	16 April – 18 April	
7	01 May – 03 May	Transect 1 not sampled
8	11 May – 16 May	Transects 2-4 not sampled

Catch rate for larvae was estimated as catch per cubic meter in each sample.

Data Analysis

We estimated larval eulachon density for each sample based on laboratory count and the estimated volume of water filtered through the plankton net tow using the following digital flowmeter formula:

$$V = R\left(\frac{1}{61} m / revolution\right)A$$

Where

V = volume sampled (m^3),
R = revolution count from flow meter, and
A = area of net opening (m^2).

We examined the catch frequencies of larvae to describe the form of the catch distribution and found that the data possessed a strong negative binomial distribution with several outliers (Figure 2). Attempts to normalize the error terms by transforming data as log (catch rate + 1) failed. Consequently we elected to use non-parametric methods to test for significant differences in larval catch rate among sampling strata. We used the Mann-Whitney rank sum test for paired comparisons and Kruskal-Wallis Analysis of Variance (K-W ANOVA) for multiple comparisons. Following a significant result from the K-W ANOVA a further test was performed to isolate differences among groups (Dunn's Test when group sample size was unequal; Student-Newman-Keuls test when group sample size was equal). All tests were performed at the $\alpha = 0.05$ level of significance.

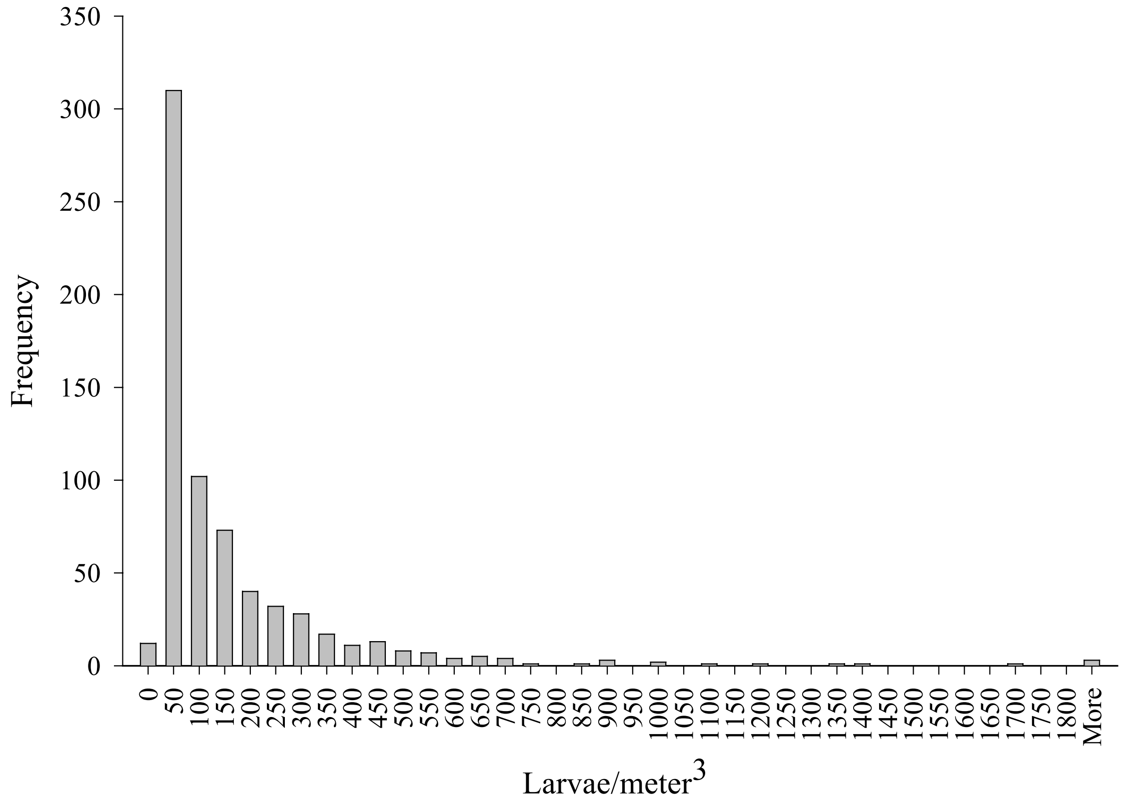

Figure 2. Density frequencies of larval eulachon collected in the Lower Columbia River during the peak of migration, spring 2001. Note negative binomial distribution.

Migration Timing

To quantify timing of larval eulachon migration we pooled data from transects 1-6 and compared larval densities among the eight sampling periods. Contracted sampling precluded using information from Transect 7. Because most larvae were collected in periods 4-6, subsequent analyses for transects 1-6 were limited to data collected during hese peak migration periods. We also compared larval densities among transects to evaluate distribution during peak migration.

Cross-Channel Larval Distribution

We pooled data from transects 1-6 to compare larval eulachon densities within and outside the shipping channel during peak migration. We also compared larval densities within and outside the shipping channel for each transect. To evaluate distribution of larval eulachon across the Columbia River we pooled data from transects 1-6 for each of the five sampling stations and compared larval densities among the pooled stations. We also compared larval densities among stations for each transect.

Similar but separate analyses were conducted for Transect 7. Timing of sampling was different at Transect 7, and Transect 7 was relatively distant from the other transects.

Vertical Distribution Within the Shipping Channel

To evaluate vertical distribution of larval eulachon within the shipping channel during peak migration we pooled data from all stations (transects 1-6) within the channel and compared larval densities among the three depth strata (bottom, mid-water, and surface). We also compared larval densities among depths at shipping channel stations for each transect. Results from Transect 7 were again interpreted separately.

RESULTS

Migration Timing

Larval eulachon density varied throughout the season (Figure 3), but catches peaked between 02 April and 18 April (corresponding to sampling periods 4, 5 and 6). We found a significant difference ($P < 0.001$) in larval density among the eight sampling periods. Larval densities during periods 4, 5, and 6 were significantly greater than in all other periods but did not differ significantly from each other ($P > 0.05$). We found a significant difference ($P < 0.001$) in larval density among individual transects during peak migration, although only Transect 6 differed significantly (lower larval density) from the others ($P < 0.05$; Figure 4).

Cross-Channel Larval Distribution

Larval densities outside the shipping channel were significantly greater ($P < 0.001$) than densities inside the channel when data from all transects 1-6 were combined. We found no significant differences between larval densities within and outside the shipping channel at transects 1, 2, and 4 ($P = 0.524, 0.961, 0.969$ respectively) when these transects were analyzed individually (Figure 5). Larval densities were significantly greater outside the shipping channel for transects 3, 5 and 6 ($P = 0.031$, $P < 0.001$, $P < 0.001$ respectively) when these transect were analyzed individually (Figure 5). Furthermore, when limiting analyses to stations ≥ 12.2 m in depth (the minimum depth of the shipping channel), we found that larval densities were significantly greater outside the shipping channel than within the shipping channel ($P < 0.001$).

With data from transects 1-6 combined, larval densities decreased across the river from the Washington shore to the Oregon shore (Figure 6). Station 1 larval densities were significantly greater than those at all other stations, station 2 densities were significantly greater than those at stations 3, 4, and 5, and station 3 densities were significantly greater than those at station 4 ($P < 0.05$ in all cases). This trend is most apparent in transects 5-7 (Figure 7).

Larval densities were also significantly greater ($P = 0.033$) at stations located outside the shipping channel than stations located within the channel at Transect 7 (Figure 7).

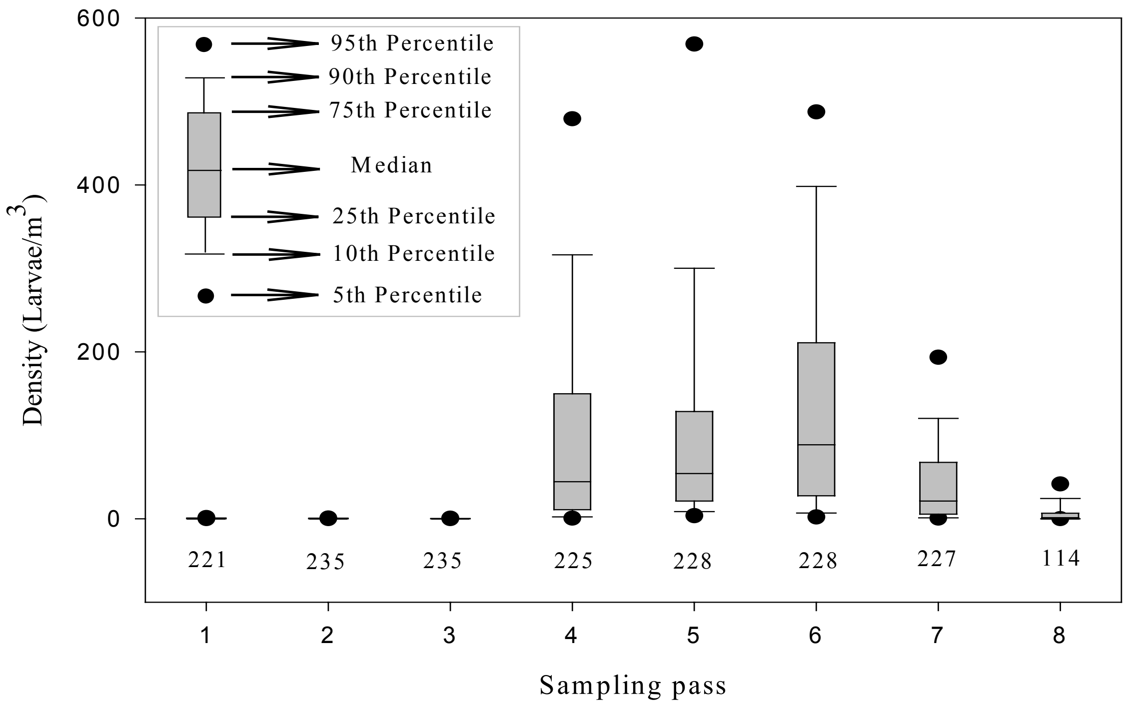

Figure 3. Larval eulachon densities in the Lower Columbia River during spring, 2000. Numbers below plots indicate sample size.

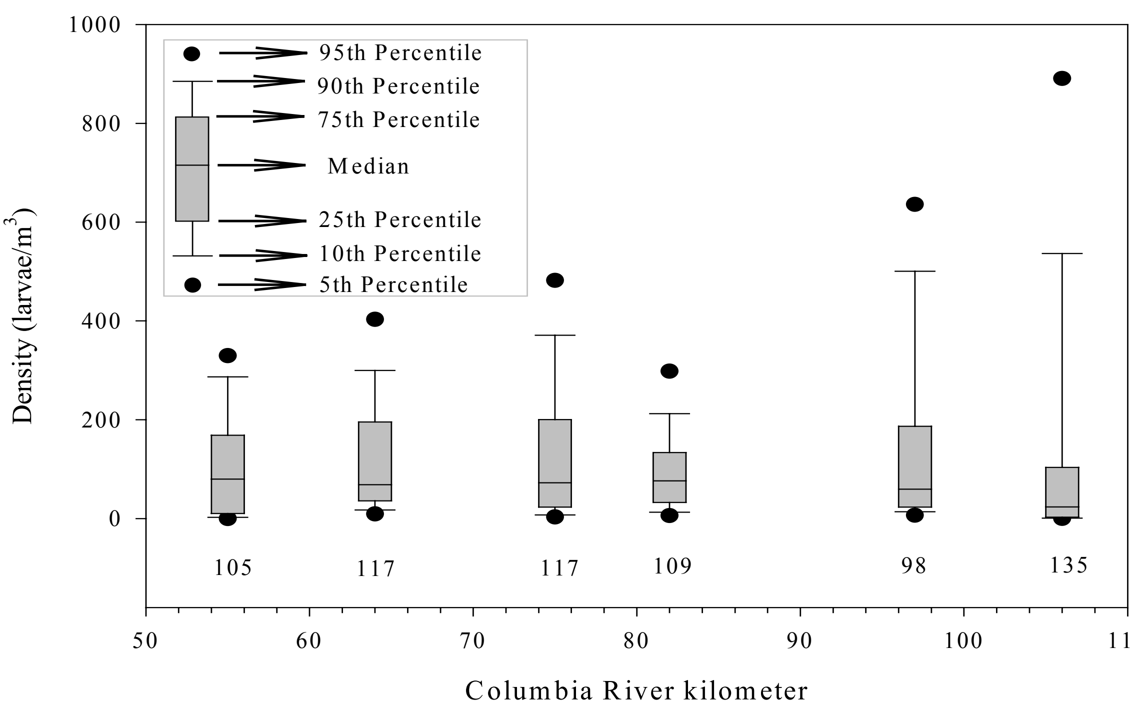

Figure 4. Larval eulachon densities at various sites in the Lower Columbia River during peak migration, spring 2001. Numbers below plots indicate sample size.

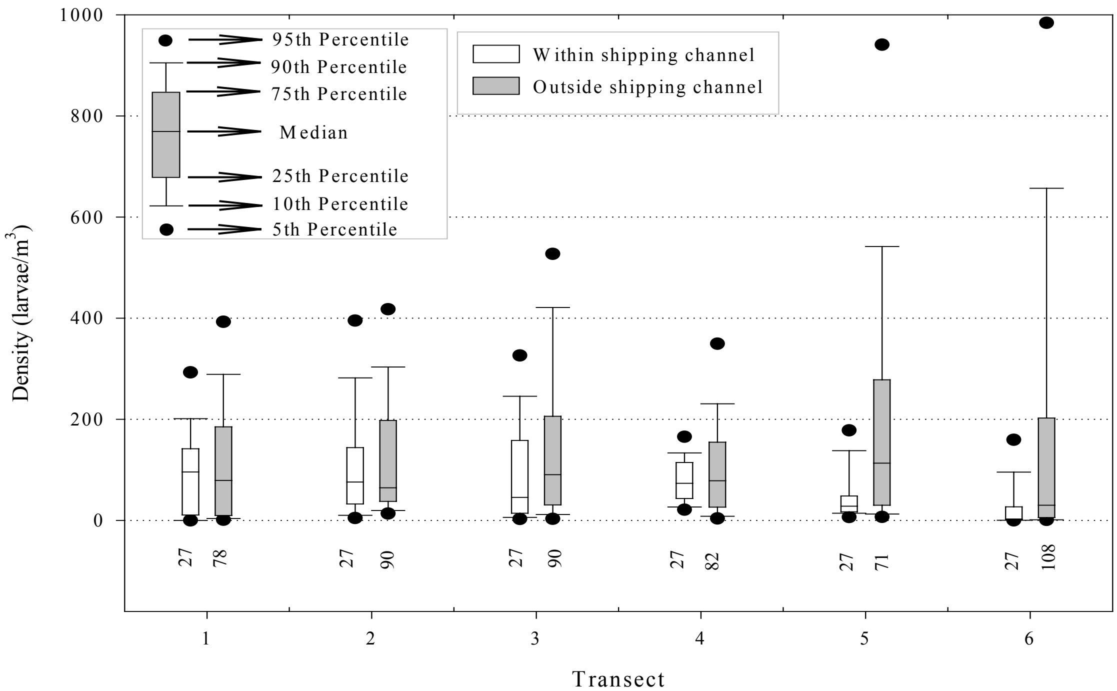

Figure 5. Larval eulachon densities inside and outside the Lower Columbia River shipping channel during the peak of migration, spring 2001. Numbers below plots indicate sample size.

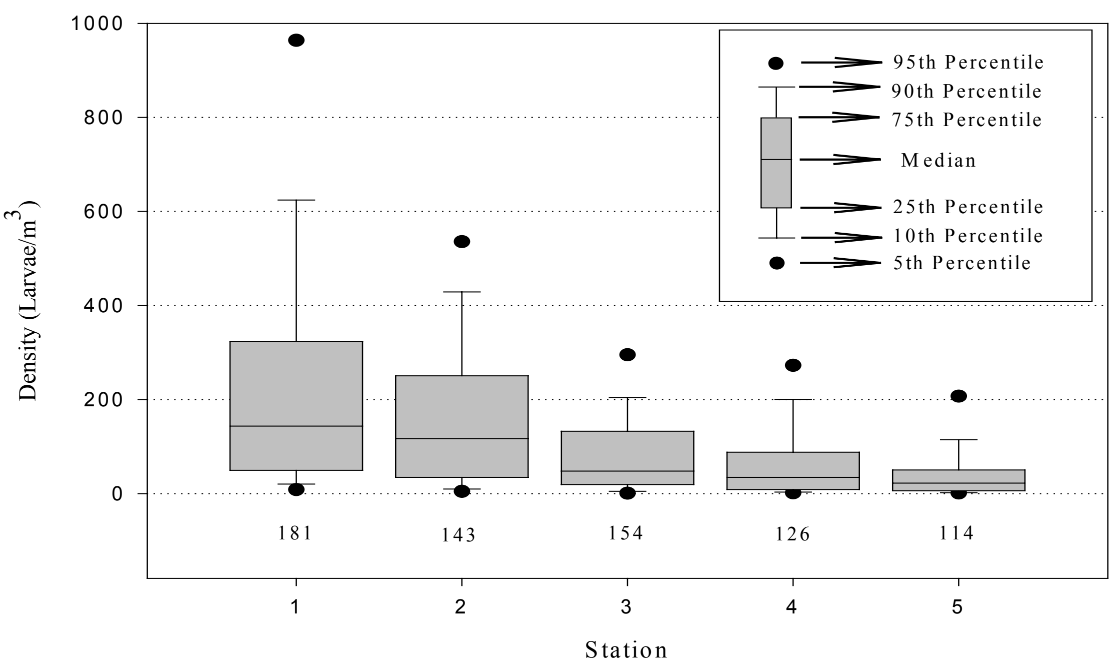

Figure 6. Cross channel distribution of larval eulachon in the Lower Columbia River during the peak of migration, spring 2001. Numbers below plots indicate sample size.

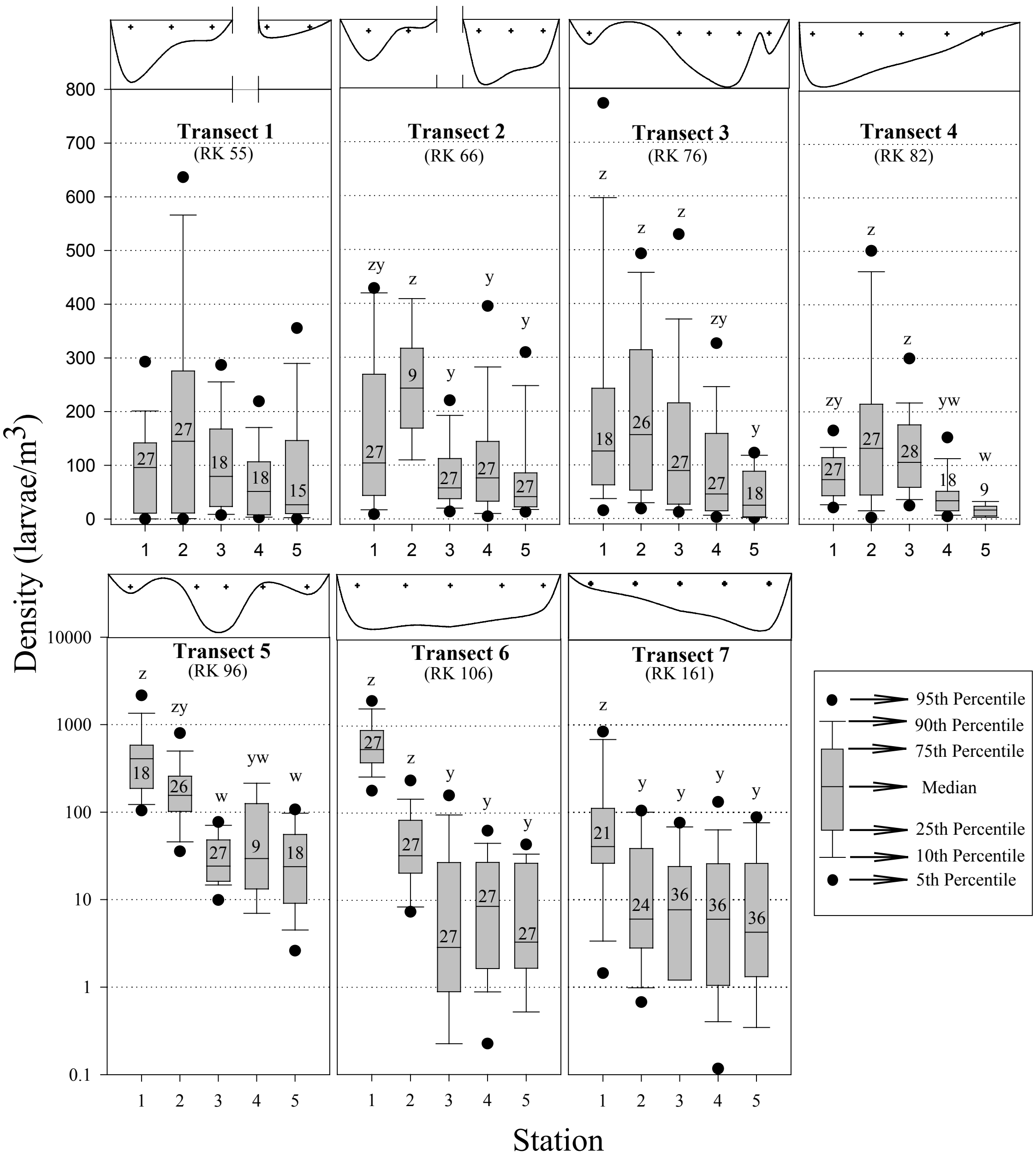

Figure 7. Cross river eulachon larval distibution at seven transects in the Lower Columbia River during the peak of migration, spring 2001. Data groups with letters contain significant differences in larval density among stations (Kruskall-Wallace ANOVA; P<0.05); within these groups, catches without a letter in common differ (P<0.05). Note logarithmic scale for transects 5 -7. Schematics of channel morphology at each transect are shown above each data group. Scaling is not consistent among plots.

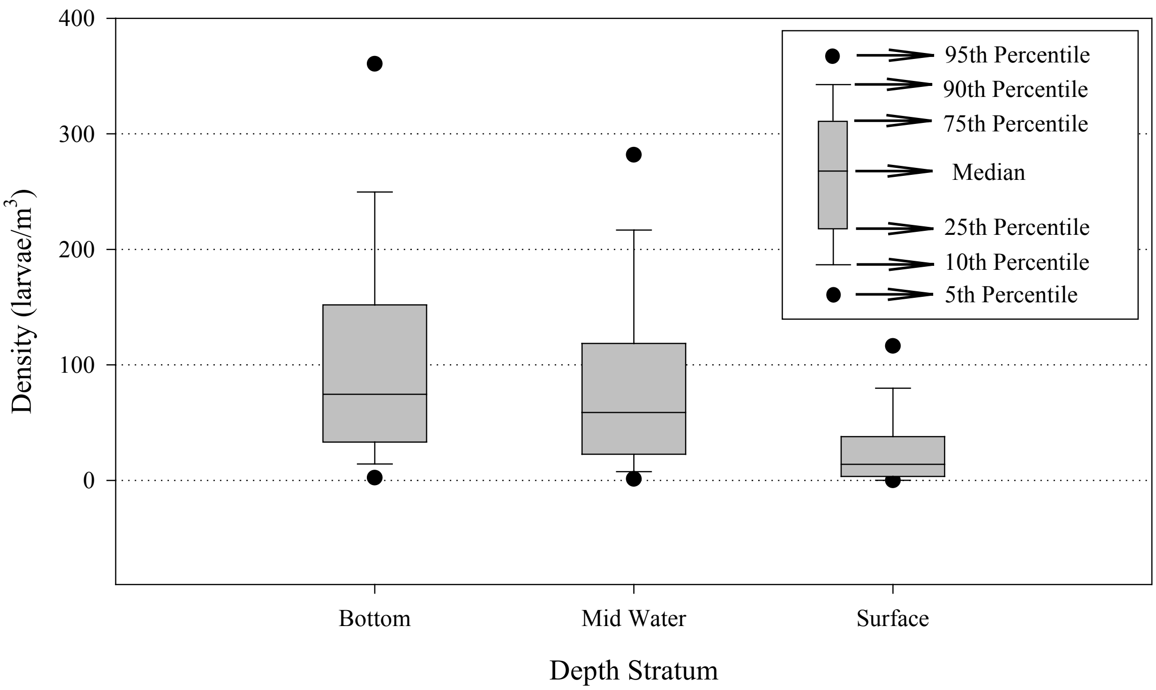

Figure 8. Vertical distribution of larval eulachon in the shipping channel of the Lower Columbia River during peak migration, spring 2001. Each plot represents 54 samples.

Catches at Station 1 were significantly greater than catches at all other stations. We found no significant differences in larval densities among stations 2, 3, 4 and 5.

Vertical Distribution Within the Shipping Channel

We found a significant difference ($P < 0.001$) in larval densities among depth strata of sampling stations within the shipping channel (Figure 8). Larval densities did not differ significantly ($P > 0.05$) between bottom and mid-water strata; however, both bottom and mid-water larval densities were significantly greater ($P < 0.05$ in both cases) than surface larval density.

We found no significant differences in larval density among depth strata for shipping channel stations of transects 1, 4 and 5 when these were analyzed separately ($P = 0.076$, 0.067, 0.093 respectively). We did find significant differences in larval densities among depth strata for shipping channel stations of transects 2, 3 and 6 ($P = 0.006$, < 0.001, 0.018 respectively). Larval densities in bottom samples were significantly greater than in surface samples ($P < 0.05$ in all cases), but were not significantly different than mid-water samples ($P > 0.05$ in all cases). Mid-water larval densities were greater than surface densities for transects 2 and 3 ($P < 0.05$ for both) but not for transect 6 ($P > 0.05$).

Larval densities differed significantly among depth strata at Transect 7 sampling stations within the shipping channel ($P < 0.001$). Larval densities in bottom samples were significantly greater than densities in mid-water and surface samples ($P < 0.05$ for both).

DISCUSSION

The eulachon spawning migration of 2001 was one of the largest in recent years (WDFW 2001). Substantial numbers of adults migrated as far upriver as Bonneville Dam (RK 234) and into all the major lower Columbia River tributaries (Grays, Elochoman, Kalama, Lewis, and Sandy rivers). Commercial landings from the Columbia River were slightly higher than recent years but were still low compared to historical catches (WDFW 2001). This was possibly a result of restrictions on total effort during the season, because catch per unit effort (pounds per delivery) was the highest recorded since 1993.

The timing of adult and larval migrations was later in 2001 than in 2000 (Howell and Uusitalo 2001). Peak larval densities for 2001 were recorded in early/mid April as compared to mid March in 2000. The late arrival of adults in 2001 may have been influenced by water temperature of the river. Generally, temperatures below 4 ^{o}C inhibit entry of spawning eulachon adults into the Columbia River (Smith and Saalfeld 1955). During 2001, the bulk of adult spawners entered the river after mid February, when temperature of the Columbia River exceeded 4 ^{o}C.

Within the study area, migrating larval eulachon were more abundant outside the shipping channel than within the channel, with densities highest along the Washington shore. This was especially evident at transects 5 and 6. Transect 6 is located approximately 3 km downstream from the mouth of the Cowlitz River, which is a well documented spawning area for eulachon (Smith and Saalfeld 1955; Hymer 1994; WDFW 2001). Transect 5 is located < 2 km downstream from Barlow Point (Washington shore), which was identified as a likely location of eulachon spawning (Romano et al.2002).

Cross-channel distribution of larvae at Transect 3 does not reflect the trend seen at transects 5 and 6 despite its location downstream of, and in close proximity to, Eagle Cliff (RK 82), which is also a documented eulachon spawning site (Loeffel 1954; Smith and Saalfeld 1955). Although eulachon eggs were collected on artificial substrates in the vicinity of Eagle Cliff (Romano et al. 2002) the number of eggs caught at this location was low despite substantial sampling effort. These observations suggest that the majority of spawning in the study area could have occurred in the Cowlitz River and the Columbia River in the vicinity of Transect 5. The trends seen in successive downstream transects would then be the result of gradual cross-channel dispersion of larvae.

Cross-channel distribution of larvae at Transect 7 (RK 161) suggests that some mainstem spawning may have occurred on the Washington shore. This is important because spawning in the Columbia River has never been recorded upstream of Martin's Bluff (RK 128; Loeffel 1954) and we collected no eggs above the mouth of the Kalama River (RK 117) during our study of eulachon spawning distribution (Romano et al. 2002). Transect

7 is also located upstream of all Columbia River tributaries in which eulachon are known to spawn, with the exception of the Sandy River (RK 194; Figure 1). Large numbers of adult eulachon were observed in the Sandy River in 2001 (personal observation, lead author) where they presumably spawned. . The even distribution of larvae across the river through stations 2 – 5 at Transect 7 suggests cross-river dispersal from a major upstream source such as the Sandy River.

Our finding that larval eulachon density in the shipping channel was greatest in the lower portion of the water column is consistent with observations made by Loeffel (1954) and Smith and Saalfeld (1955). It is unclear what mechanisms might affect the distribution of larvae in the water column. Anecdotal laboratory observations suggest larval eulachon exhibit pelagic swim up behavior (Wendler 1937; Howell 2002) and positive phototropism (Howell 2002). This is an adaptive behavior documented in other ichthyoplankton species to facilitate feeding, lateral transport, and predator avoidance (Fortier and Leggett 1983; Manuel and O'Dor 1997). Eulachon larvae subsist on yolk sac contents on their migration to rearing areas in the Columbia River estuary and Pacific Ocean, where exogenous feeding is assumed to begin (Smith and Saalfeld 1955). Given the limits of yolk sac storage, rapid flushing to the ocean may be crucial for survival. We speculated that vertical migration of larvae into the top of the water column on ebb tides (where velocities generally are greater), might expedite the journey. Our results however do not support, and in fact somewhat contradict this theory. The lower Columbia River is subject to strong tidal influences that produce complex, turbulent flow conditions and because larval eulachon are relatively weak swimmers, depth distributions are most likely dictated by local hydraulic conditions.

Sampling for this study was conducted during daylight hours and on ebb tides only. This study design does not allow analysis of any effects of diel and tidal cycles on larval distribution. In addition, inter-annual variation in spawning site locations and run size may also influence distribution. In a year of high spawner abundance such as 2001, larval abundance was not significantly greater in proposed dredging areas than in other areas of the river. In years of high abundance, dredging-related mortality (through entrainment) may not be significant relative to the population as a whole. Without data from multiple seasons it is not possible to know how larval distribution during migration differs (if at all) in years of low abundance. In addition, mechanisms controlling eulachon recruitment and survival are poorly understood, and little is understood on how variability in habitat conditions in the freshwater environment affects larvae survival.

Given the variability in distribution and timing of eulachon larval migration, scheduling of dredging to reduce impacts to migrating larvae would be confined to the short term. Unlike spawning runs of most anadromous salmonid species, where estimates of stock size provide the basis for development of reliable forecasts, no developed forecasting or assessment model exists for eulachon. Currently only in-season commercial monitoring exists to evaluate run size and timing. Perhaps the most realistic and reliable strategy for reducing dredging related impacts to eulachon would be to avoid dredging in areas of high spawning concentration. This would require more research on the annual variation in use of specific spawning areas.

ACKNOWLEDGMENTS

We thank Peter Barber, Brad Cady, Jody Gabriel, Michele Hughes, Robin Mills, Francesca Saenz, Steve West, and Nicole Wolters for assistance in field collection of the data and laboratory analyses. John DeVore (WDFW) and David Ward (ODFW) helped with initial study conception, design, and analysis of data. David Ward (ODFW) and Brad James (WDFW) reviewed a draft of this manuscript. Kim Larson (USACE) provided assistance as project manager. The U. S. Army Corps of Engineers funded this work (contracts W66QKZ10745277 and W66QKZ13237198).

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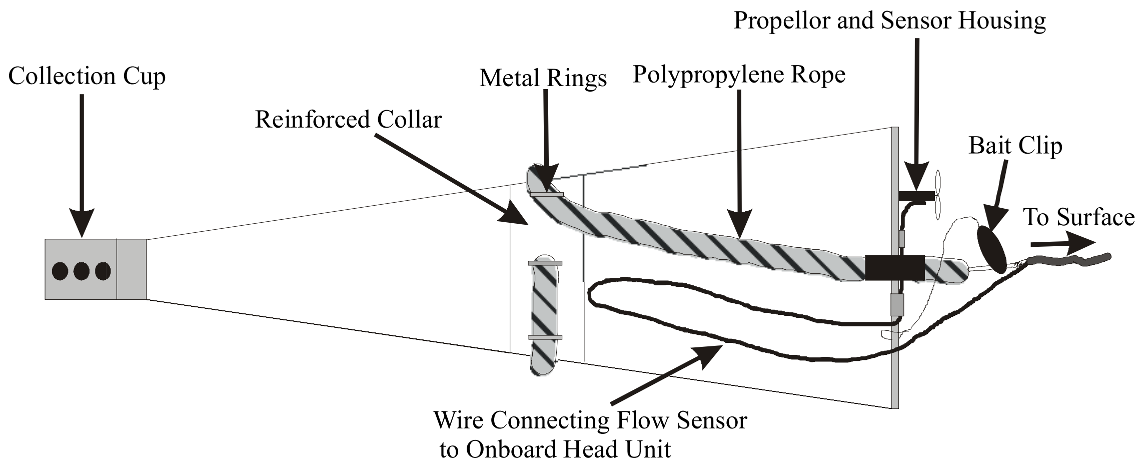
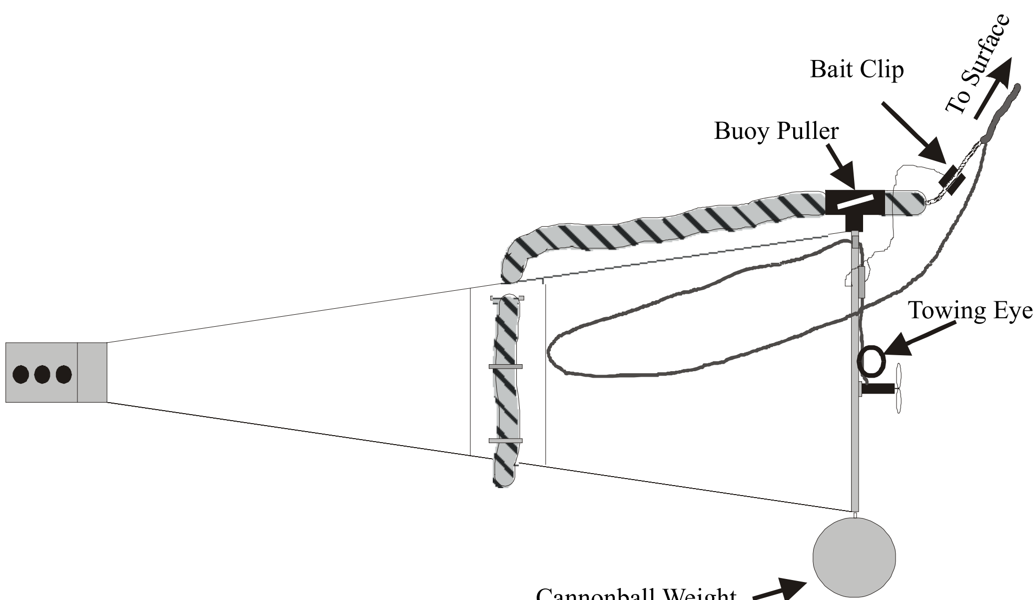
APPENDIX A

Schematic diagrams of modified plankton net gear used in 2001 larval eulachon sampling

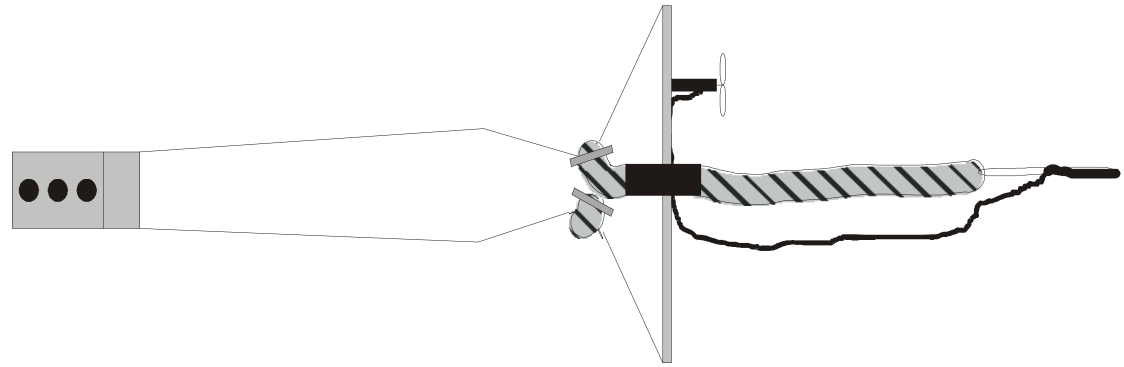


I) Net Open - Plan View

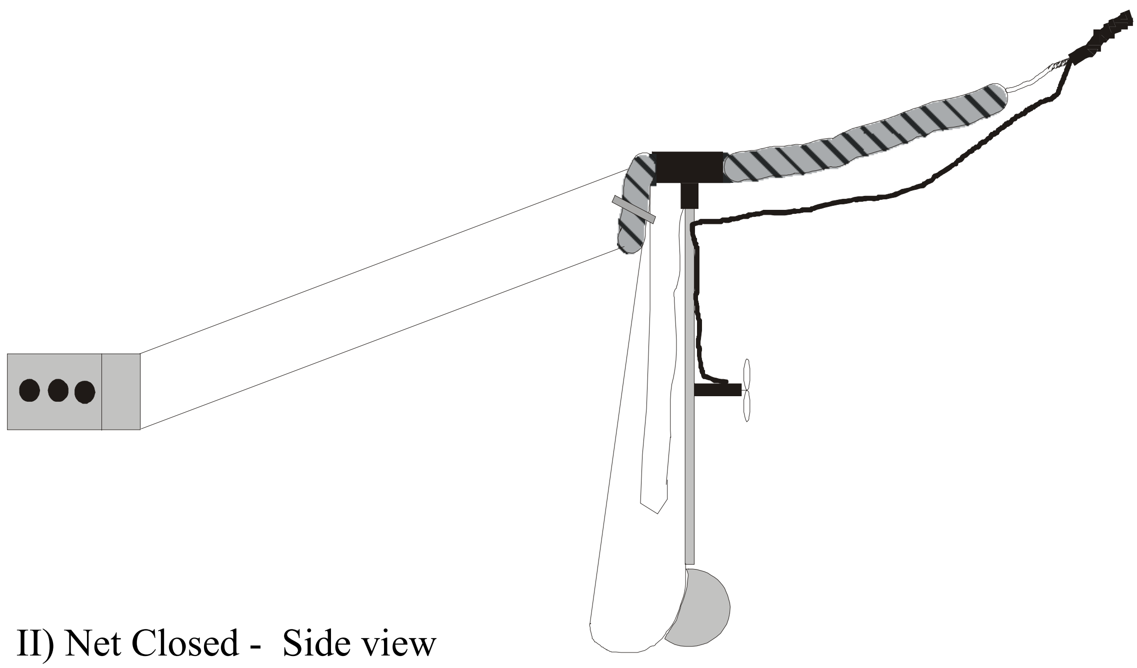


II) Net Open - Side view

Appendix Figure A-1. Schematic diagrams of modified plankton net used in 2001 USACE larval smelt sampling.

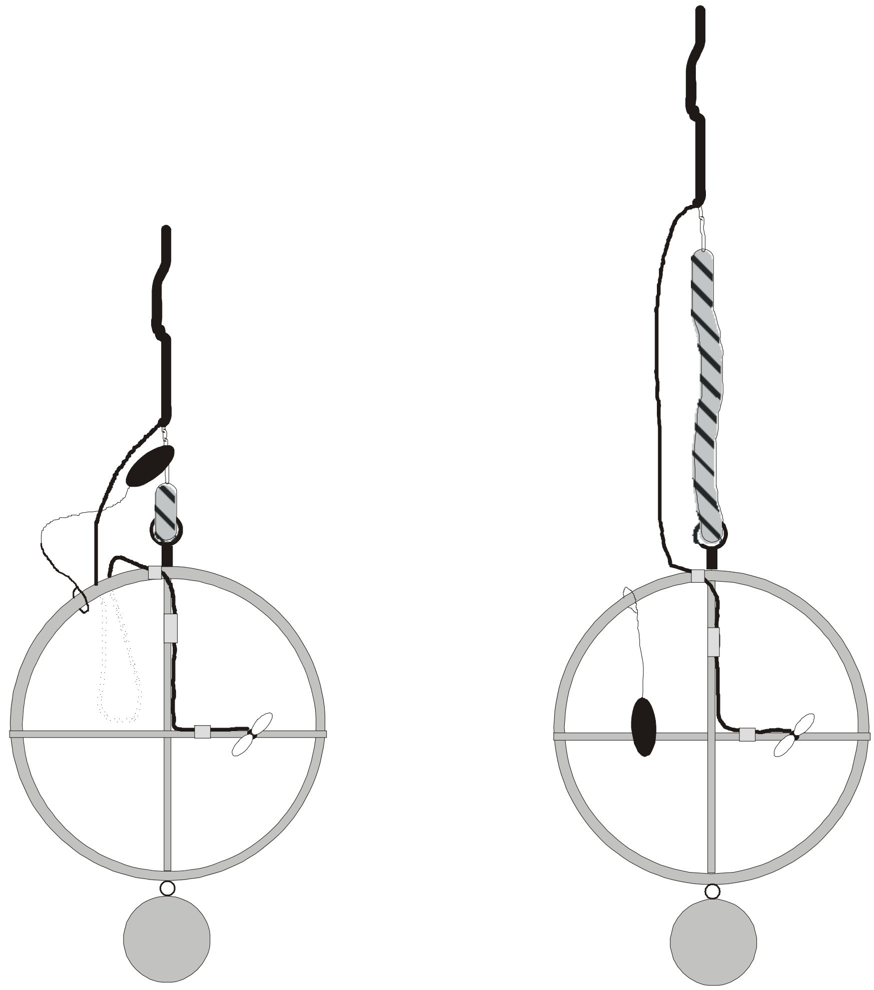


I) Net Closed - Plan View



II) Net Closed - Side view

Appendix Figure A-2. Schematic diagrams of modified plankton net used in 2001 USACE larval smelt sampling.

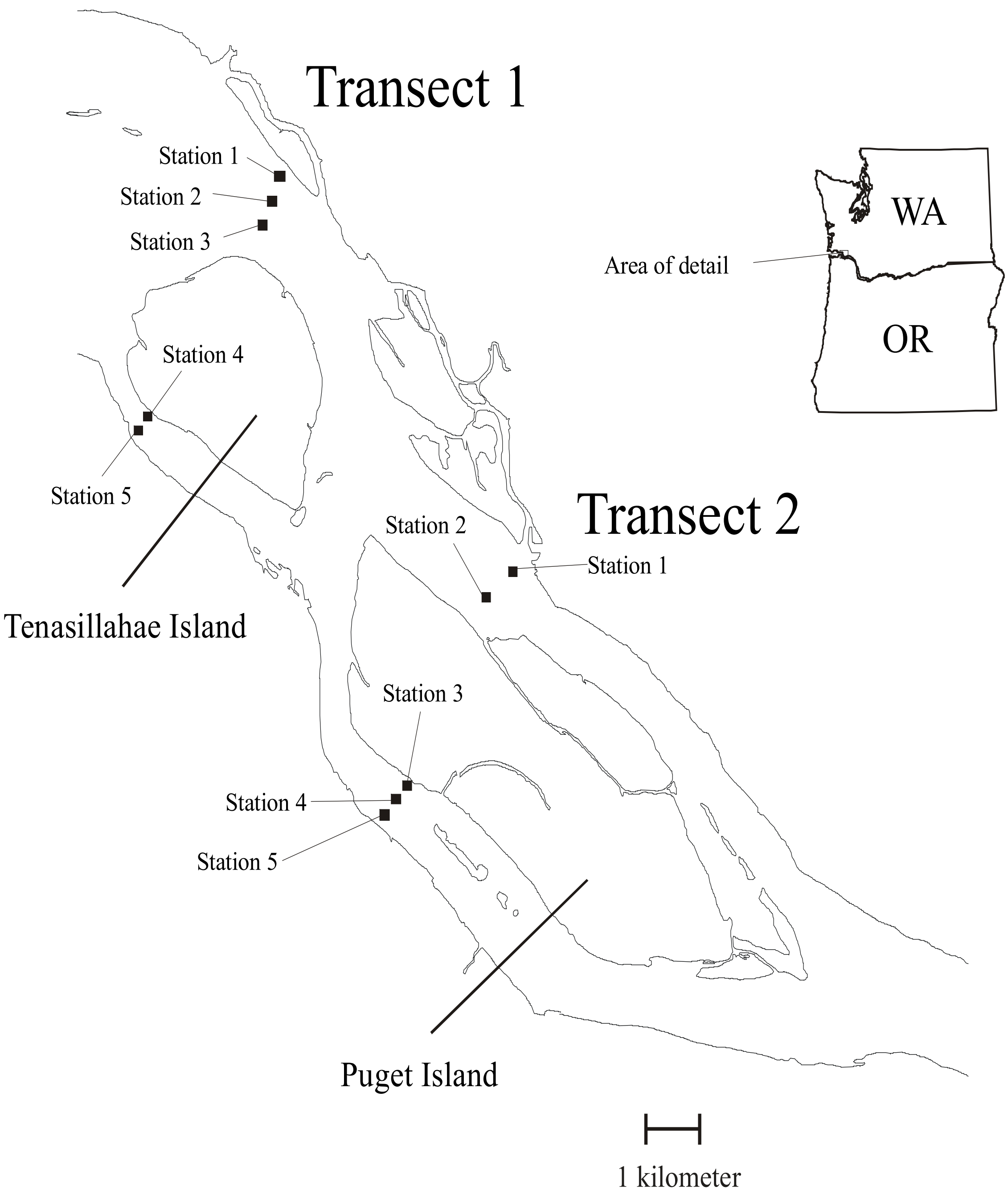


I) Net Open - Forward View II) Net Closed - Forward View

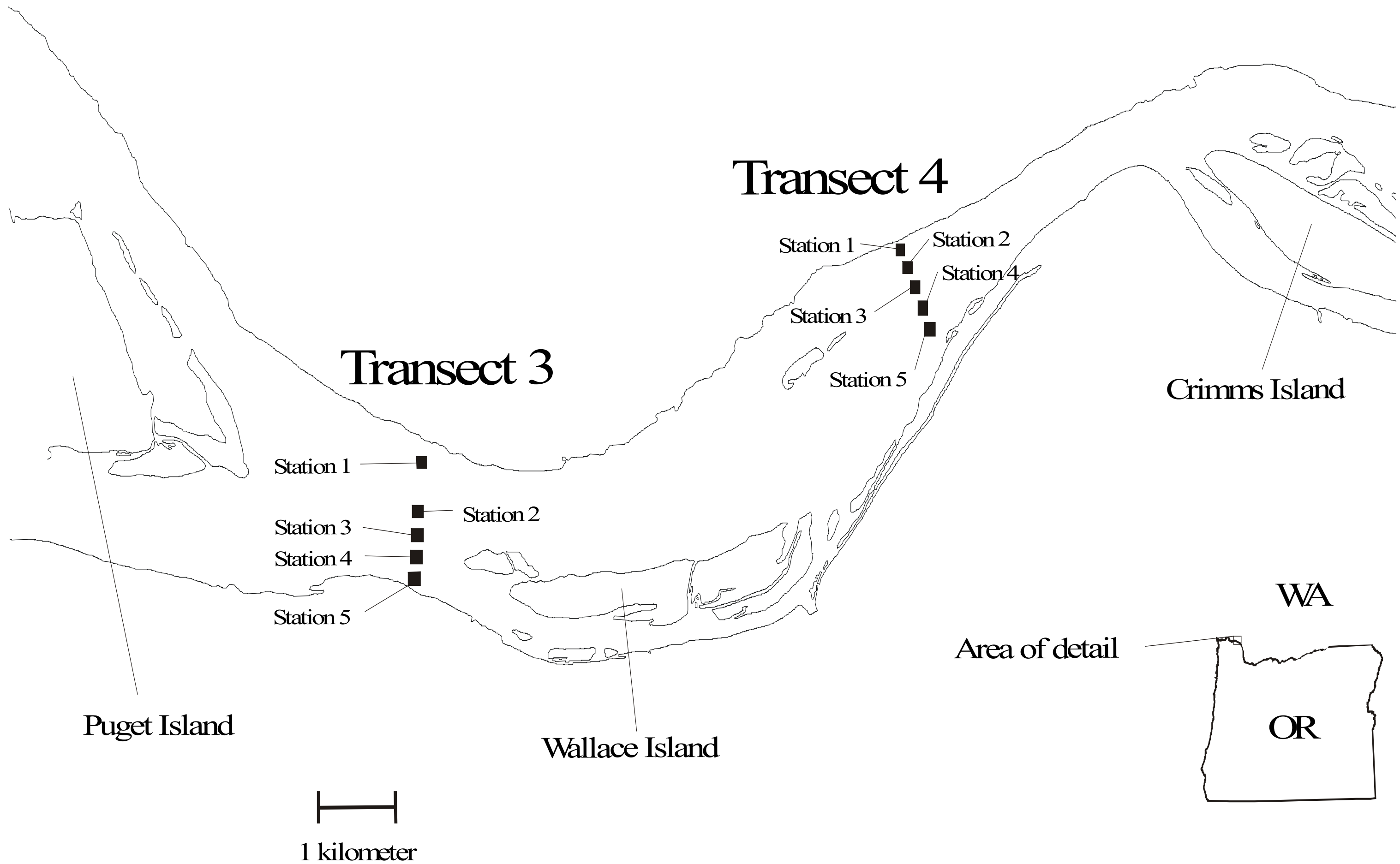
Appendix Figure A-3. Schematic diagrams of modified plankton net used in 2001 USACE larval smelt sampling.

APPENDIX B

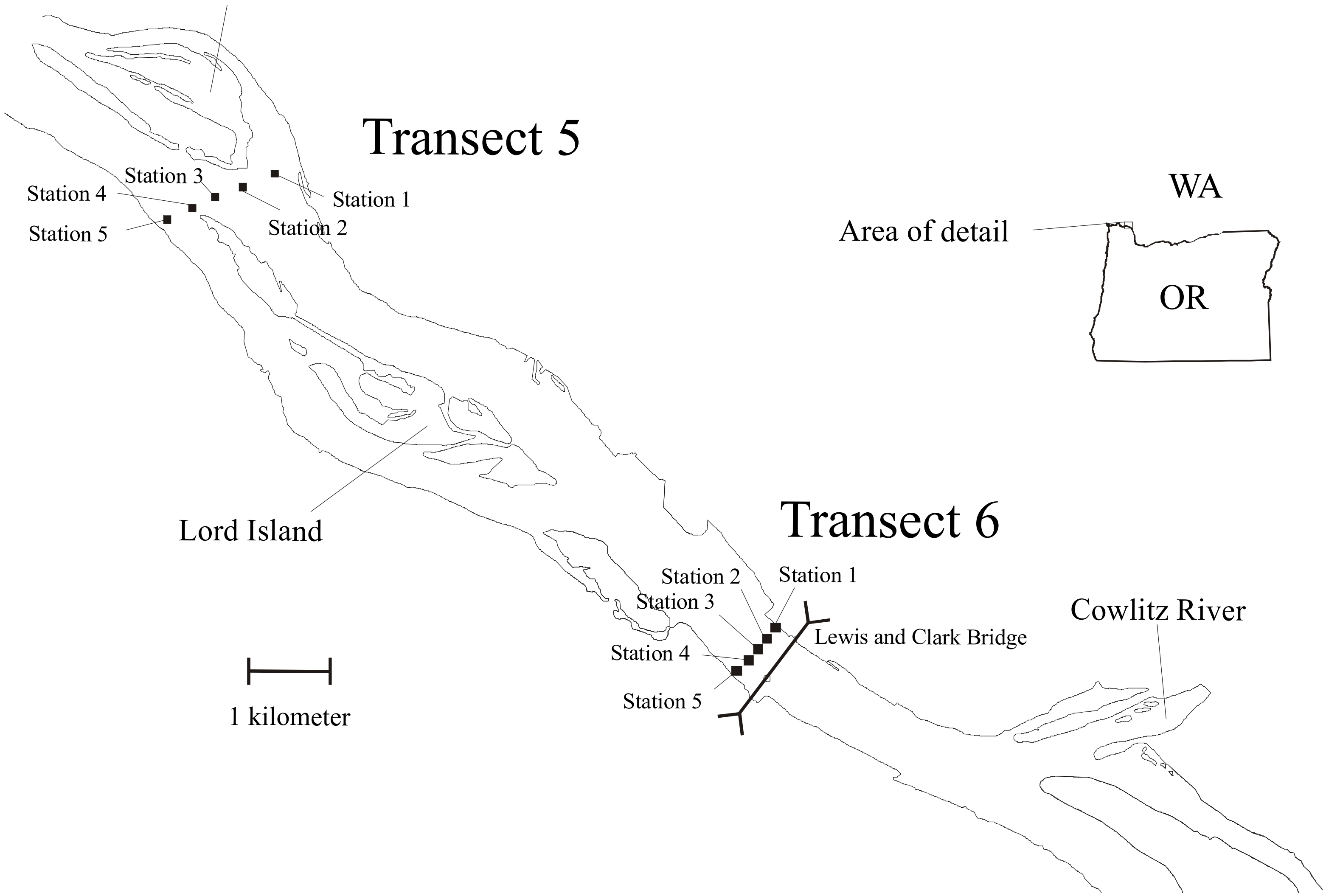
Larval eulachon sampling sites, 2001



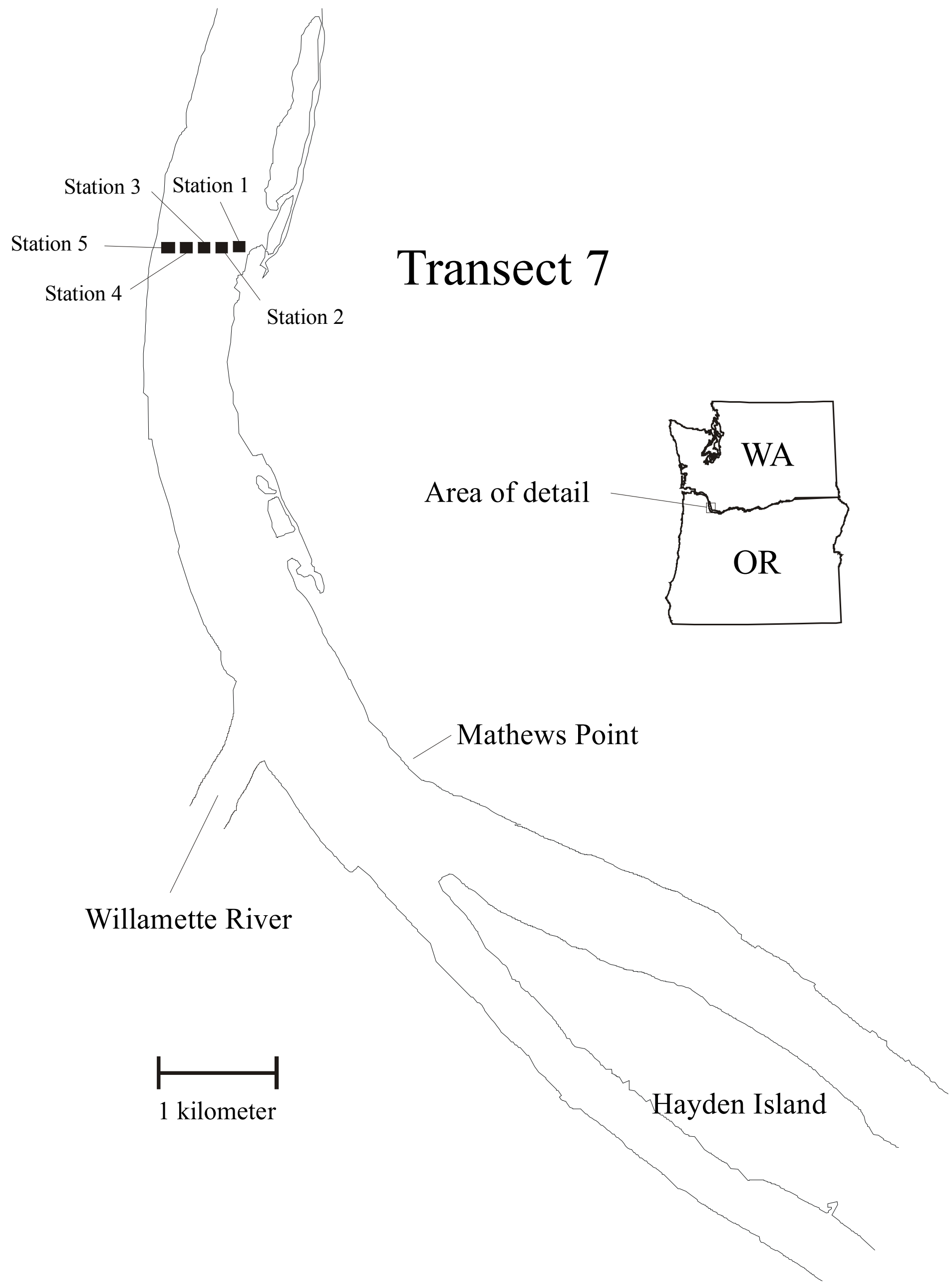
Appendix Figure B-1. 2001 USACE larval smelt sampling sites, Transect 1 (RK 55) and Transect 2 (RK 66), lower Columbia River.



Appendix Figure B-2. 2001 USACE larval smelt sampling sites, Transect 3 (RK 76) and Transect 4 (RK 82), lower Columbia River.



Appendix Figure B-3. 2001 USACE larval smelt sampling sites, Transect 5 (RK 96) and Transect 6 (RK 106), lower Columbia River.



Appendix Figure B-4. 2001 USACE larval smelt sampling sites, Transect 7 (RK 161), lower Columbia River.

REPORT C

USE OF AN ARTIFICIAL SUBSTRATE TO CAPTURE EULACHON EGGS IN THE LOWER COLUMBIA RIVER

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Final Report to U. S. Army Corps of Engineers
Contract Number W66QKZ13237198

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CONTENTS

ABSTRACT

We used artificial substrates to collect eulachon (Thaleichthys pacificus) eggs in the lower Columbia River from river kilometer (RK) 48 to 137 over the period 26 February – 29 March 2001. This method has been used to capture eggs of other species, but this is the documented use of substrate frames to catch eulachon eggs. We did not attempt to standardize, stratify or randomize substrate placement among depths or habitat types, but typically two substrates were fished every 1.6 km. Depths of sampling ranged from 1 to 13 m, and distance from the riverbank ranged from 5 to >90 m. Eggs were collected in 23 of 147 sets, all between RK 55 and 120. We captured eggs throughout the sampling period and peak catch rates occurred on 9 and 13 March 2001. The greatest numbers of eggs were captured in RK 90 to 98 and RK 107 to 111. The bottom composition of areas in which eggs were collected varied, but was dominated by medium to fine sand. We conclude that in 2001 eulachon spawned over a wide range of the mainstem lower Columbia River. Further, we believe that artificial substrates can be a useful tool to assist in identifying the timing and location of eulachon spawning.

INTRODUCTION

The eulachon *Thaleichthys pacificus* is an anadromous fish that spawns in the lower reaches of 30 to 40 coastal rivers and streams, from the Klamath River drainage in California, to the Bering Sea, Alaska. The Columbia River supports one of the world's largest spawning populations of the species (DFO 1999), and is the site of an important commercial and recreational eulachon fishery. Historically, commercial landings of eulachon in the Columbia River have been highly variable. In 1948 and again in 1951 the commercial catch of eulachon in the Columbia River exceeded 450,000 kg, yet in 1992 and again in 1994 the commercial catch fell below 450 kg. A sharp decline in commercial landings occurred in 1990 and continued through 1999. It is unclear how much of the decline is caused by a decrease in the number of spawning eulachon or by in-season adjustments to harvest regulations. The 2001 commercial eulachon fishery exceeded 79,400 kg and was considered to be quite strong (WDFW and ODFW 2001).

Eulachon spawning in the Columbia River generally begins in January or February and is completed by late April. Spawning adults have been observed in the river as early as December. Active spawning has been observed in tributaries of the Lower Columbia River including the Cowlitz, Kalama, Lewis, and Sandy rivers (Smith and Saalfeld 1955). Little is known about the spawning distribution of eulachon in the mainstem lower Columbia River. Eulachon eggs have been caught in plankton nets in the lower Columbia River but exact spawning locations have proved difficult to locate. Smith and Saalfeld (1955) identified two locations in the mainstem Columbia River as eulachon spawning locations (one upriver of the mouth of the Kalama River at river kilometer (RK) 117 and the other near RK 82). These findings were based on the presence of spent and partially spent fish in commercial catches from these areas.

Depending on her size, a female eulachon can produce from 17,000 to 60,000 eggs (Hart and McHugh 1944; Smith and Saalfeld 1955). Eulachon eggs are small, with an average diameter between 0.8 and 1.0 mm. Eulachon eggs contain a double membrane, the outer of which ruptures shortly after fertilization and remains attached to the egg by a single point, forming a short stalk or peduncle. The free edges of the outer membrane are highly adhesive and capable of sticking to substrate material (Hart and McHugh 1944). Smith and Saalfeld (1955) reported that eulachon spawn primarily over substrates of fine pea-sized gravel.

The lower Columbia River is routinely dredged to maintain a shipping channel with a minimum depth of 12.2 m and minimum width of 182 m. The U. S. Army Corps of Engineers (USACE) has proposed an increase in dredging operations to deepen the existing channel, which would allow larger vessels access to the ports of Longview, WA and Portland, OR (USACE 1999). To assess potential impacts of channel deepening operations on eulachon, the USACE contracted with the Oregon Department of Fish and Wildlife (ODFW) and the Washington Department of Fish and Wildlife (WDFW) to characterize the eulachon spawning run and larval migration from the lower Columbia River. The objective of this study was to locate and characterize eulachon spawning sites within the lower Columbia River, including the proposed channel-deepening area.

This study is based on the assumption that if eggs are captured on an artificial substrate then adult fish have spawned in the immediate vicinity. Prior to this study, artificial substrates had not been used to catch eulachon eggs. Artificial substrates have been used to collect white sturgeon *Acipenser transmontanus* eggs in the Columbia River (McCabe and Beckman 1990; Parsley et al. 1993; McCabe and Tracy 1994) and rainbow (American) smelt *Osmerus mordax* eggs in Maine (Rothschild 1961). This method has proven useful in identifying spawning locations of both species. The artificial substrates used in the present study were based on the design of McCabe and Beckman (1990). Similar to white sturgeon eggs, eulachon eggs are demersal and highly adhesive. Eulachon eggs however are much smaller than white sturgeon eggs and prior to this study it was not clear if this would affect our results.

METHODS

Study Area

This study was conducted in the lower Columbia River, from RK 48 to RK 137 (near the mouth of the Lewis River; Figure 1). Several points throughout this area are being considered as potential channel deepening, or in-river dredge spoil disposal sites for the proposed USACE channel-deepening project (USACE 1999). A shipping channel is currently maintained throughout the length of the study area.

Artificial Substrate Construction

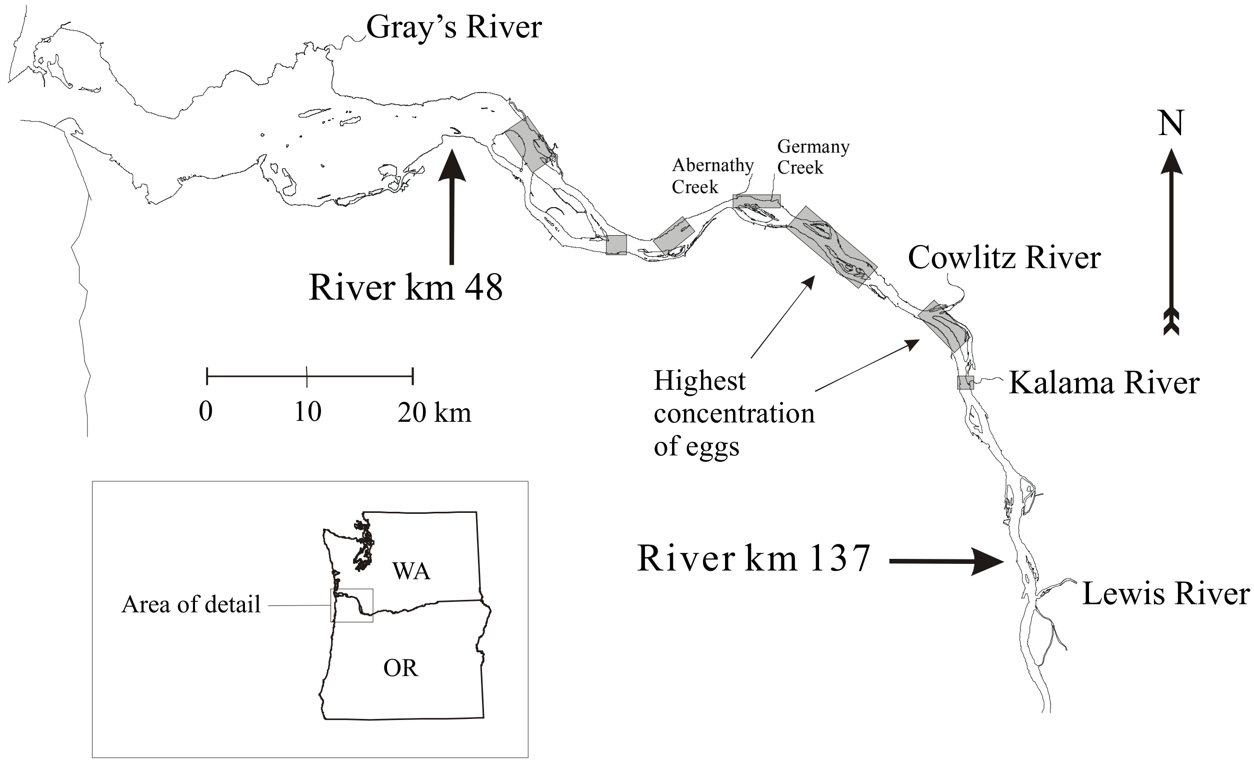


Figure 1. Artificial-substrate sampling was conducted from RK 48 – 137 in the Columbia River. Shaded areas indicate sampling sites where eulachon eggs were successfully captured 26 February – 29 March 2001.

The artificial substrates used in this study were constructed following the methods outlined by McCabe and Beckman (1990), with the exception of the substrate material available for eggs to adhere. The frames consisted of a 76-cm x 91-cm angle-iron outer-frame with strips of flat iron bar to provide support. Three strips of iron bar were welded into place on one side of the frame and three more were secured with nuts and bolts on the other side. Two 76-cm x 91-cm pieces of commercially available, low nap indoor-outdoor carpet material, placed back to back, were used as an egg adhesion surface. The carpet was secured in the frame by the two sets of flat iron bar. Securing the iron bar on one side of the frame with nuts and bolts facilitated easy removal of the carpet pieces. Although McCabe and Beckman (1990) utilized latex-coated animal hair material as an egg adhesion surface, we chose carpet material with a 2 to 4 mm nap depth because of concerns that the depth of animal hair would make it difficult to find the smaller eulachon eggs.

We used two types of anchors to secure substrates in place on the river bottom. A three fluke anchor constructed of steel bars (13 mm diameter), PVC pipe (8 cm diameter) and concrete, similar to those employed by McCabe and Beckman (1990) was used on approximately 25 % of the substrates. The remaining 75 % were secured with a 9-kg pyramid shaped lead weight. Buoy lines were connected to all substrates to mark the location. Length of line used depended on water depth and velocity. We generally used line equivalent to approximately 1.5 times the depth to account for tidal variation. The location of each substrate was recorded from a Global Positioning System (GPS) unit on board the deploy vessel. Upon retrieval, the location of the substrate was taken from the onboard GPS unit to determine if the substrate had moved from its original location.

Sampling Methods

Sampling in the lower Columbia River with artificial substrates commenced on 26 February and lasted until 29 March 2001. We sampled from RK 48.3 to RK 136.8, with at least two artificial substrates placed every 1.6 RK (except between RK 59.6 and RK 61.2 within which only one substrate was placed). We made no attempt to standardize or stratify substrate placement among depths or habitat types. Depths of sampling ranged from 0.9 to 12.8 m and distance from the riverbank ranged from 5 m to greater than 90 m. Sampling at greater depths was problematic because substrates tended to get covered in silt when placed in deeper water. Generally, substrates placed deeper and farther from the riverbank tended to silt in the most, whereas substrates placed close to the riverbank in shallow water tended to silt in the least.

We partitioned sampling into three rounds. The first sampling round was conducted from 26 February to 28 February 2001. Sampling in this round was limited to river kilometers 80.5 – 83.7, and 7 substrates were set. Substrates were initially placed in locations believed to be eulachon spawning locations (Smith and Saalfeld 1955) to test artificial substrates as a viable means of catching eulachon eggs. The second sampling round was conducted from 8 March to 14 March 2001, and a total of 17 substrates were deployed. These were placed over a wider range of the river, from RK 86.9 – RK 109.4. During the final sampling round, which lasted from 19 March to 29 March 2001, artificial substrates were set from RK 48.3 – RK 136.8, to characterize spawning distribution over a larger area. At least two substrates were set every 1.6 km (except that only one substrate was placed between RK 59.6 and RK 61.2).

All substrates were left in the water for a minimum of 18 hours to ensure that sampling occurred throughout an entire tide cycle and during both day and night. Most substrates were allowed to fish for <24 hours; however one substrate was not retrieved on the first attempt and had to be retrieved at a lower tide. The substrate fished for 40 hours and was not included in our analysis. Two other substrates were lost through unknown causes.

We used a Ponar grab sampler to determine composition of bottom material at sites where eggs were caught. Bottom samples collected in the field were brought back to the lab for analysis. In the lab, samples were dried and then passed through a series of sieves to determine particle size. We used a modified Wentworth classification (Orth 1983) to classify particle size of bottom material. Some locations consisted of bottom material with a particle size that was too large to sample with the Ponar device. These locations were directly adjacent to rip rap riverbanks. Additionally, we were unable to sample the bottom material at three sites. River velocity was too strong at one site (mouth of the

Kalama River) to sample with the Ponar device. Two other sites (mouth of Abernathy Creek) were dry because of a decrease in river level when we returned to sample the bottom material.

RESULTS

Only one of the seven substrates we deployed during the first sampling round caught eggs, for a success rate of 14.3%. The substrates fished for a total of 71.2 h (effort), and three eggs were caught, resulting in a catch per unit effort (CPUE) of 0.04 eggs/h. The average set depth was 7.0 m, and the average catch was 0.43 eggs/set.

Of the 17 substrates set during the second round of sampling, nine caught eggs, yielding a success rate of 52.9%. Effort totaled 449.3 h during this period for a CPUE of 0.17 eggs/h. The average set depth was 4.7 m, and the average catch was 1.88 eggs/set.

Thirteen of 123 substrates set during the final sampling round caught eggs for a success rate of 10.6%. Effort totaled 2,691 h during this period for a CPUE of 0.02 eggs/h. The average set depth was 7.4 m, and the average catch was 0.36 eggs/set.

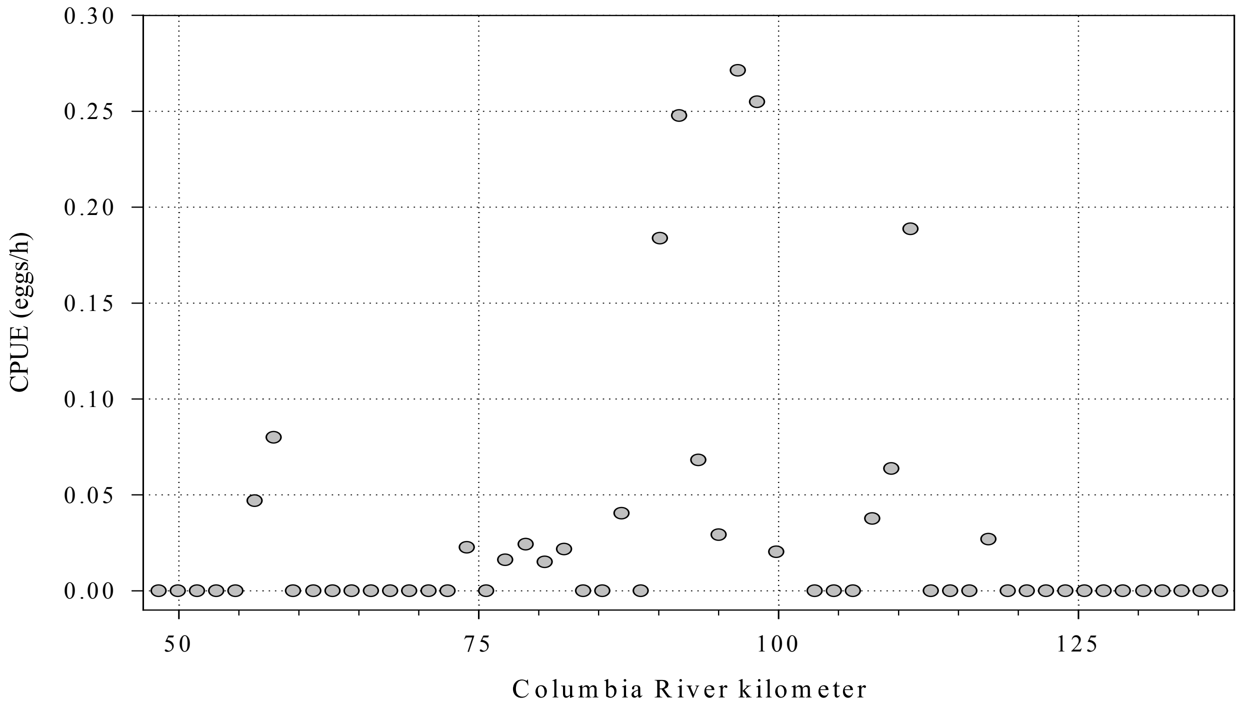
We set 147 substrates over the study, 23 of which successfully caught eulachon eggs for an overall success rate of 15.6%. A total of 122 eggs were caught for an average of 0.84 eggs/substrate. Egg catches in a single set ranged from zero to 27. Catch rates were highest between RK 90 and RK 98 and between RK 107 and RK 111 (Figure 2). Daily CPUE ranged from 0 eggs/h to 0.20 eggs/h (Figure 3). The greatest daily CPUE occurred on 9 March (0.20 eggs/h of effort) and 13 March (0.16 eggs/h of effort). Sampling days that occurred before 9 March and after 13 March averaged less than 0.08 eggs/h of effort. River bottom composition at sites where eggs were caught varied, yet was dominated by medium to fine sand (Table 1).

DISCUSSION

Although we believe this is the first time artificial substrates have been used to collect eulachon eggs, artificial substrates have been used to collect eggs of the rainbow (American) smelt (Rothschild 1961). Similar to eulachon, rainbow smelt are broadcast spawners, laying highly adhesive eggs that readily become attached to stream substrates. Rothschild (1961) used 3.1-cm x 12.7-cm strips of heavy canvas as an egg-depositional surface, attached to a glazed black ceramic tile (11.4 cm x 11.4 cm). Since 1988, artificial substrates have been used in the Columbia River to collect white sturgeon eggs (McCabe and Beckman 1990; Parsley et al. 1993; McCabe and Tracy 1994). Although the design employed by Rothschild (1961) was effective at catching smelt eggs, we chose to follow the design of McCabe and Beckman (1990) because it had been successfully used in the high flows of the Columbia River.

We caught eulachon eggs over a larger area of the river (RK 56.3 to RK 117.5) than previously described as spawning habitat (Smith and Saalfield 1955). The area in which we caught the highest concentration of eggs (between RK 90.1 and RK 98.2) has not previously been documented as a spawning location.

Figure 2. Egg catch/h for each river 1.6 kilometers sampled. Sampling was conducted between river kilometers 48 and 137.



The strength of the eulachon spawning run in the lower Columbia River varies throughout the course of a single season; therefore, CPUE may vary spatially and temporally with the peak of spawning. This may explain why CPUE was highest on 9 and 13 March; however, this result must be interpreted cautiously because sampling on any one day was limited to a small area of the river (most days approximately 9.7 river kilometers were covered). Observed temporal differences in CPUE may be influenced by daily spatial differences in sampling.

Although catch varied among sample times and locations, we have shown that eulachon eggs can be caught with artificial substrates. This is important because the presence of viable eggs indicates that spawning is occurring in the vicinity. This is the first known study to show that eulachon spawning occurs at many points throughout the lower Columbia River, from RK 56.3 (Price Island) to RK 117.5 (mouth of the Kalama River). We were unable to use substrates within areas designated for channel deepening because of the dynamic nature of the bottom in these areas. In 2000 we attempted to fish several artificial substrates in areas proposed for deepening and the frames were quickly buried

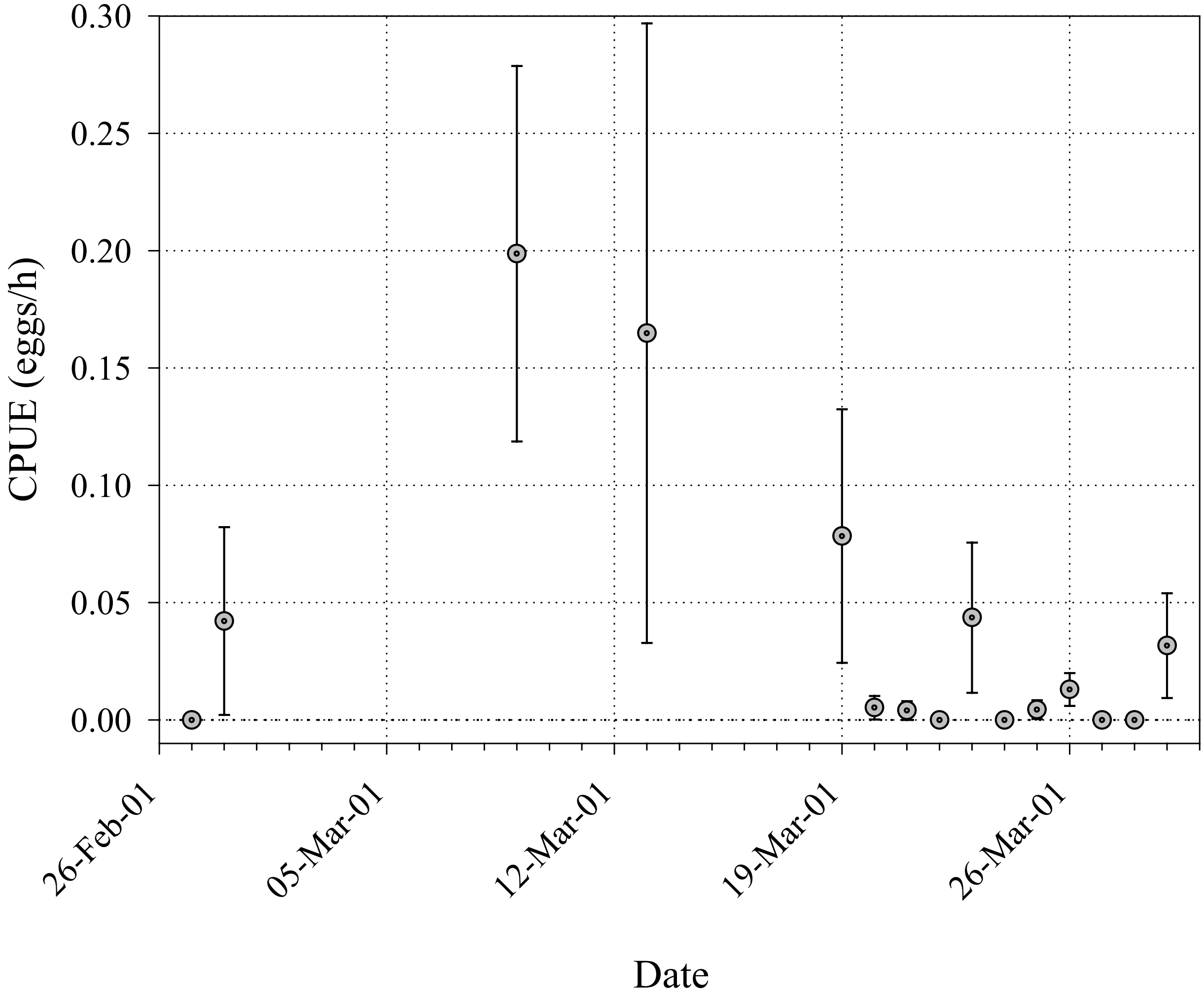


Figure 3. Egg catch/h listed by date each artificial substrate was retrieved. No substrate frames were examined 1-8, 10-12, or 14-18 March 2001. Bbars represent one standard error.

in sand, which made them ineffective and difficult to retrieve. Substrate movement is typical in the sand wave environment found on the bottom of the riverine areas proposed for channel deepening. Sand waves in this reach are generally large, with heights of 1.8-3.7 m and lengths up to 150-m (personal communication with Karl Eriksen, Portland District, USACE). Given the dynamic nature of channel substrates, we believe these areas do not provide stable surfaces that would allow an adhesive egg to incubate for 30 d. We considered that eggs incubating in near-shore areas in the proximity of dredging activities might be affected if these activities alter flow patterns or increase sedimentation; however, hydraulic models completed by the USACE indicate dredging will not alter the river's flow patterns. The USACE also expects the average annual bedload transport in the main river channel to remain within the existing range of 75,000-300,000 m^3/yr (USACE 1999). To reduce unforeseen impacts on eulachon eggs, channel-

Table 1. Summary of artificial substrate data for sites where eggs were caught. RK = river kilometer. CPUE = eggs/h. Bottom composition based on a modified Wentworth classification.

RK	Date	Depth (m)	Eggs	CPUE	Bottom composition
56.3	03/29/01	11.6	3	0.14	Large particles associated with rip rap
57.9	03/29/01	9.4	5	0.24	Medium to fine sand
74.0	03/26/01	8.5	1	0.05	Coarse to medium sand with pebbles
77.2	03/26/01	9.4	1	0.05	Mixed cobble and pebbles
78.9	03/26/01	9.1	1	0.05	Medium to fine sand
80.5	03/25/01	4.6	1	0.05	Coarse to medium sand
82.1	02/27/01	12.8	3	0.13	Pebble
86.9	03/08/01	1.8	1	0.03	No sample taken
86.9	03/08/01	1.8	3	0.10	No sample taken
90.1	03/08/01	3.0	18	0.62	Cobble and pebble mix
90.1	03/08/01	7.6	2	0.07	Medium to fine sand
91.7	03/19/01	9.8	11	0.49	Medium to fine sand
93.3	03/19/01	7.3	3	0.13	Medium to fine sand
93.3	03/08/01	4.6	2	0.07	Large particles associated with rip rap
95.0	03/19/01	8.5	2	0.09	Medium to fine sand
96.6	03/08/01	4.0	14	0.51	Medium to fine sand
98.2	03/12/01	0.9	3	0.13	Medium to fine sand
98.2	03/12/01	12.8	27	1.20	Medium to fine sand
99.8	03/21/01	4.0	1	0.04	Medium to fine sand
107.8	03/23/01	5.5	4	0.15	Medium to fine sand
109.4	03/08/01	2.7	5	0.19	Medium to fine sand
111.0	03/23/01	8.2	10	0.37	Medium to fine sand
117.5	03/20/01	9.8	1	0.05	No sample taken

deepening operations could be scheduled to avoid areas in which we caught the greatest number of eulachon eggs during the typical peak spawning period.

ACKNOWLEDGMENTS

We thank Peter Barber, Brad Cady, Jody Gabriel, Robin Mills, Francesca Saenz, and Steve West for assistance in field collection of the data. John DeVore (WDFW), Nancy Uusitalo (WDFW), and David Ward (ODFW) helped with initial study concept, design, and analysis of data. Brad James (WDFW) reviewed a draft of this manuscript. Kim Larson (USACE) provided assistance as project manager. The U. S. Army Corps of Engineers funded this work (contracts W66QKZ10745277 and W66QKZ13237198).

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REPORT D

CHARACTERIZATION OF DEVELOPMENT IN COLUMBIA RIVER PROLARVAL EULACHON *Thaleichthys pacificus* USING SELECTED MORPHOMETRIC CHARACTERS.

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Vancouver, Washington 98661

Final Report to U. S. Army Corps of Engineers
Contract Number W66QKZ13237198

November 2002

CONTENTS

ABSTRACT

Objectives of this study were to artificially propagate eulachon larvae, establish a time/temperature dependent developmental baseline, and subsequently evaluate the efficacy of the methodology used. Adult brood fish were collected from the Cowlitz and Sandy rivers, transported to propagation facilities, held until ripe, and artificially spawned in the laboratory. Eggs were successfully incubated in water filled petrie dishes and hatched 47 days after fertilization, accumulating 752 thermal units – approximately twice that documented by previous workers. At the peak of hatching, larvae were transferred to a chiller and allowed to develop at 53 oF. Larvae were allowed to develop in petrie dishes and survived 21 days before total yolk-sac absorption. Larvae were preserved in 10% buffered formalin at post-hatch ages of 0, 6, 12, 24, 36 and 48 hours, and then subsequently at intervals of 24 hours until total yolk sac absorption. Total length, snout to vent length, and yolk sac length of preserved fish were measured to characterize larval development. Newly hatched larvae showed a marked curvature in the anterior portion of their bodies and gradually assumed a straighter form after approximately 72 hours. Coiling proved problematic for obtaining true measurements of total and snout to vent lengths. Yolk sac measurements were unaffected by coiling and showed a more linear trend over time. Results indicated that changes in larval morphology were not identifiable over a time scale of even a few days. Static environmental conditions in our experiment appear to have retarded larval development. Morphometric analyses of larvae collected in the field from known spawning areas showed that identifiable development does occur as larvae migrate to the estuary and ocean. Repetition of this experiment with propagation conducted under more natural conditions might lead to increased developmental rates allowing changes to be identified over short time periods; however, this may be precluded by the high morphological variability in individuals observed in each age class.

Introduction

Active spawning of eulachon *Thaleichthys pacificus* has been observed in various tributaries of the lower Columbia River, including the Cowlitz, Kalama, Lewis, and Sandy rivers (Smith and Saalfeld 1955). However, little is known about the spawning distribution of eulachon in the mainstem Columbia River.

Catches of very recently hatched eulachon larvae in plankton net hauls might indicate proximal spawning grounds and hence provide a useful tool for mapping and defining spawning habitat distribution in the mainstem Columbia River. To achieve this, developmental observations from larvae of known ages are required to provide a baseline against which larval assemblages collected in the field can be compared.

Upon hatching, eulachon larvae are incorporated into the drift and, depending on local current velocities, are presumably transported substantial distances from their spawning grounds in relatively short periods of time. For an aging methodology to be an effective tool in pinpointing spawning areas, short-term developmental changes measured on an hourly time scale must be identified.

Eulachon larvae have been successfully propagated by several workers for various studies that include spawning substrate preference (Wendler 1937), assessment of possible population heterogeneity in the lower Columbia River and its tributaries (Delacy and Batts 1963), and effects of temperature on incubation periods (Smith and Saalfeld 1955). Although Parente and Snyder (1970) provide a pictorial record and discussion of egg and (to a limited extent) larval development, a systematic, quantitative assessment of eulachon larval development has not been previously described as it has for related species such as the rainbow smelt *Osmerus mordax* (Cooper 1978). Given the lack of information regarding eulachon larval development, the objectives of this study were to artificially propagate larvae, establish a time/temperature dependent developmental baseline and subsequently evaluate the efficacy of the methodology used.

Methods

Artificial Propagation

Adult brood fish were collected with dip-nets from the Cowlitz River (6 March 2001) and Sandy River (14 March 2001). Broodstock collected from the Cowlitz River (39 males and 42 females) were transported to facilities of the Oregon Department of Fish and Wildlife (ODFW) in Clackamas and held in large circulating tanks (males and females separated) until ripe. The fish matured rapidly in the holding tanks - probably a result of high water temperatures observed in the Clackamas spring water (57 ^{o}F) relative to the Cowlitz River (43 ^{o}F). Despite the separation of the sexes, all of the females extruded their eggs and subsequently died during the night of 11 March 2001. However, one female from this batch had been sacrificed for initial fertilization experiments on 8 March. Broodstock collected from the Sandy River (15 males and 12 females) were ripe upon collection and were artificially spawned on 14 and 15 March 2001.

Eggs were manually stripped from females into glass Petrie dishes and covered with milt from ripe males. Water was added to activate the spermatozoa and thus initiate fertilization. The eggs/milt were gently stirred with the caudal fin of a eulachon (Wendler 1937) to ensure adequate mixing of sex products.

After a short period (minutes) the eggs were gently washed with fresh water and then transferred to two incubation environments consisting of 1) McDonalds jars supplied with water from a closed system cooled by a portable chiller unit to 48^{o}F, and 2) water-filled petrie dishes placed into a walk-in chiller to incubate at a constant temperature of 48 ^{o}F. During the incubation period, water in the petrie dishes was changed daily and dead/fungused eggs were removed. All water used in the propagation experiments came from the local spring at the ODFW Clackamas complex.

At the peak of hatching, larvae were transferred to water-filled Petrie dishes so that each dish contained larvae emergent within a 30-minute time period. Larvae were then transferred to the chiller and allowed to develop. Chiller temperature was adjusted to 53 ^{o}F to reflect temperature of the Columbia River.

Larvae were preserved in 10% buffered formalin at post-hatch ages of 0, 6, 12, 24, 36 and 48 hours, then subsequently at intervals of 24 hours until total yolk sac absorption. Preservation of the 24-hour age class failed so no results from this time period are included.

Morphometric Characters

Basic morphometric observations were chosen to characterize larval development. Morphometric measurements included total length, snout to vent length, and yolk sac length (Figure 1). Measurements were made with an ocular micrometer read to the nearest 0.1mm. Ten larvae per age class were examined.

Measurements were also obtained from larvae taken in plankton net tows from the Cowlitz River and the lower Columbia River shipping channel in the vicinity of Price Island (river kilometer 55). Fifty individuals from each sample were randomly selected for characterization. These measurements were taken to compare development in larvae taken from a known spawning area (Cowlitz River) against those from a location in the study area assumed to be substantially downstream from major spawning areas.

DATA ANALYSIS

Analysis of Variance procedures was used to test for significant differences in yolk sac length between age classes of propagated larvae. Tukey's multiple comparison procedure was used to isolate differences among groups. Linear regression analyses were conducted to define at-hatching values for each of the morphometric characters. T-tests were used to test for significant differences in morphometric characters between larvae taken from the Cowlitz River and the Columbia River. Tests were conducted at $\alpha = 0.05$ level of significance.

RESULTS

The majority of the fertilized eggs (approximately 60,000 eggs) were placed in the McDonalds jar system to incubate. No eggs survived after a day in this environment because of the failure of the chiller unit and stresses induced by turbulence on the eggs. Eggs incubated in the petrie dishes were initially subject to high mortality and fungusing as a result of overcrowding. We reduced egg densities and mortality was reduced.

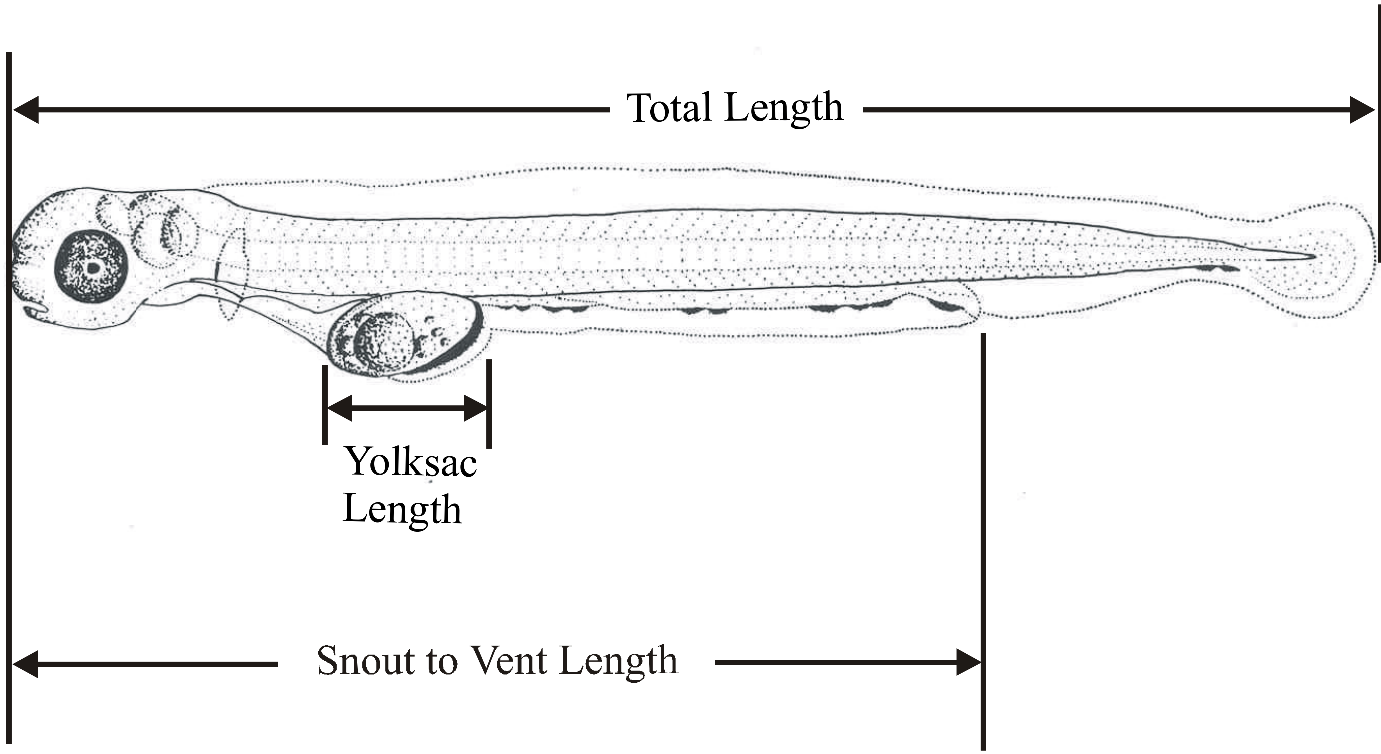


Figure 1. Morphometric characters used in eulachon larval development study.

Eggs fertilized on 8 March began hatching on 24 April and continued through 29 April. Eggs fertilized on 14 March began hatching 01 May and continued through 10 May. For each batch, first hatch occurred approximately 47 days after fertilization. Water
temperature throughout this period was a constant 48 °F. Using 32 °F as the assumed biological zero for eulachon (Delacy and Batts, 1963) the eggs accumulated 752 Thermal Units (TU's) before hatching.

Most larvae were observed to emerge tail first from their egg casing. Initial observations showed that the time between rupture of the egg membrane and full emergence of the larvae varied widely from a few minutes to several hours (see Parente and Snyder, 1970 for a pictorial record of a eulachon larva hatch sequence). Many individuals at this stage showed a marked curvature in the anterior portion of their bodies (probably a remnant of coiling in the egg) and gradually assumed a straighter form after approximately 72 hours (Figure 2). Coiling proved problematic for obtaining true measurements of total and snout to vent lengths. Data for these characters appears to show a relatively rapid rate of growth from hatching to approximately 72 hours, after which length increases were less pronounced (Figure 3). This is attributable to coiled larvae straightening out over time (Figure 2). Yolk sac measurements were unaffected by coiling and showed a more linear trend over time (Figure 3).

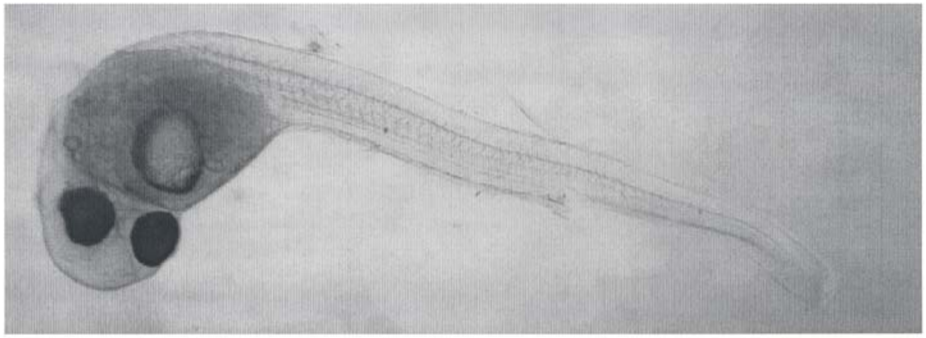
Larvae were strongly attracted to and stimulated by light sources. When placed in water-filled beakers most individuals exhibited pelagic swim-up behavior, remaining at the water surface for extended periods. Yolk absorption was complete 21 days after hatching and few individuals survived beyond this age.

Mean total length of larvae at hatching (0 hours) was 4.3 mm (+/- 0.51 SD). Mean snout-to-vent length at hatching was 3.0 mm (+/- 0.82 SD). Mean yolk sac length at hatching was 0.86 mm (+/- 0.14 SD). However, at hatching total length and snout-to-vent length means were assumed invalid because of imprecise measurements taken from coiled individuals. Linear regression analysis of total length and snout-to-vent length with 0, 6, 12 and 36-hour age class data removed gave a total length at-hatching value of 5.7mm (R^2=0.372, SE = 0.39) and snout to vent length at-hatching value of 4.1 mm (R^2=0.333, SE=0.38). Linear regression analysis of all yolk sac data gave an at-hatching length of 0.8 mm (R^2 = 0.746, SE = 0.118). Analysis of variance showed no statistically significant differences in mean yolk sac length between age classes 0, 6, 12, 36, 72 and 96 hours post-hatch (Tukey multiple comparison, $P > 0.05$).

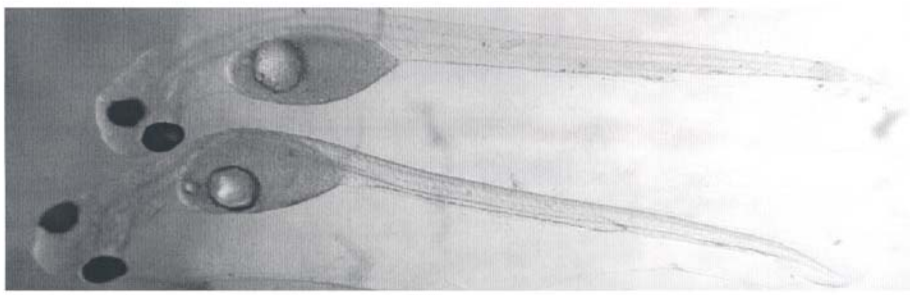
Significant differences between the mean values of each morphometric character were observed between larval assemblages collected in the Cowlitz River and in the Columbia River in the vicinity of Price Island (t-tests, $P < 0.001$ in all cases; Table 1 and Figure 4).

DISCUSSION

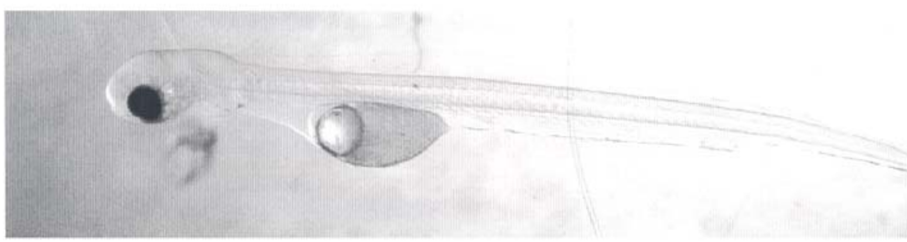
Our results show that changes in eulachon larval morphology are not identifiable over a time scale of even a few days. Since it is likely that currents in the Columbia River would carry larvae substantial distances (kilometers) in the matter of only a few hours it appears unlikely that spawning areas could be located using our proposed methodology. However, morphometric data from larvae collected from the Columbia and Cowlitz rivers



0 Hours post hatch.



36 hours post hatch.



72 hours post hatch.

Figure 2. Diminishment of remnant egg coiling over time in artificially propagated larval eulachon.

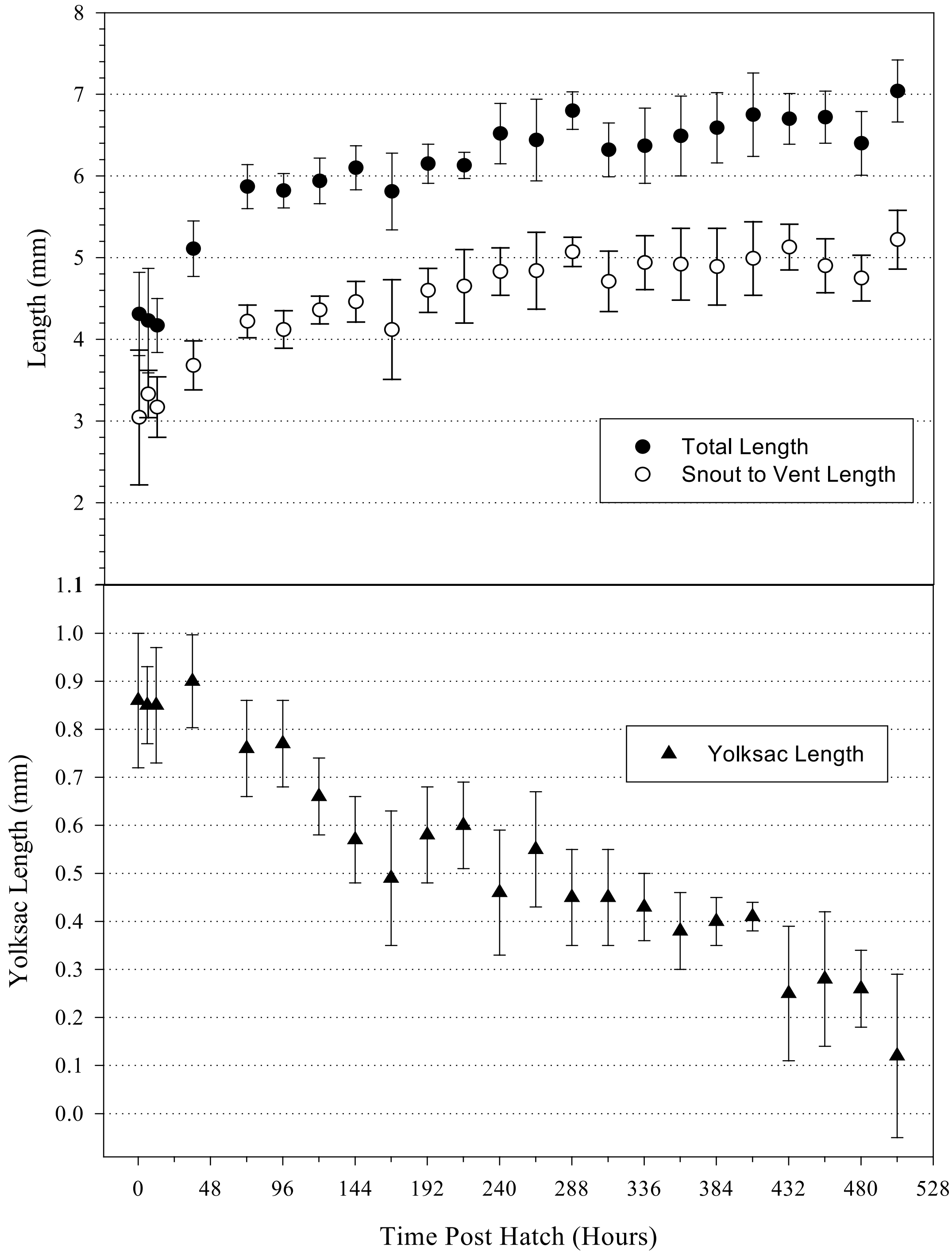


Figure 3. Morphological changes in artificially propagated eulachon larvae over time. Individual plots are means with error bars representing 1 standard deviation.

Table 1. Mean (standard deviation) morphometric measurements (mm) of

larval eulachon taken from the Cowlitz and Columbia rivers in April 2001.

Origin	Number examined	Total length	Snout to vent length	Yolk sac length
Cowlitz River	50	5.5 (0.5)	4.0 (0.4)	0.9 (0.1)
Columbia River	50	6.1 (0.4)	4.5 (0.3)	0.5 (0.1)

suggest that identifiable development does occur as larvae migrate to the estuary and ocean (Figure 4, Table 1).

In this study eggs accumulated 752 TU's before hatching – a figure markedly greater than that observed in previous investigations. Smith and Saalfeld (1955) reported TU's of 378 & 369.6 from hatchery experiments in 1946 (Kalama River Hatchery) and 1949 (University of Washington School of Fisheries), whereas Delacy and Batts (1963) found a range of 349.7 to 387.9 TU's in their investigations. Wendler (1937) reported larvae hatched 24 days after fertilization at a mean water temperature of 40.7 ^{o}F during incubation - translating to approximately 209 TU's. Adult eulachon first entered the Cowlitz River in the first week of March 2001 (personal observation) and plankton net sampling by staff of Washington Department of Fish and Wildlife showed larvae were present in substantial numbers during the last week of March. Water temperature in the Cowlitz during this time was around 48^{o}F. This leads to a very rough estimate of 336 TU's for egg incubation in the Cowlitz this year (21 days at 48^{o}F), a figure close to those reported in previous experiments.

It is unclear why the incubation period was so protracted in our study although eggs were incubated in the absence of light, continuous water exchange, and temperature fluctuations. This provided relatively static environmental conditions compared to those in all previous studies and under natural conditions. Environmental conditions in our experiment may also have protracted the development of larvae. In Parente and Snyder (1970) a photograph of a six-day-old eulachon larva shows almost complete utilization of yolk sac contents – a stage reached after almost 21 days for larvae in our experiment.

The remnant coiling observed in many hatchlings in our experiment could be considered a useful qualitative descriptor of larval age. However it was not seen in any larvae collected from the Cowlitz River despite the close proximity of the sampling location to spawning areas. This suggests the characteristic was also an artifact of our experimental conditions.

Repetition of this experiment with propagation conducted under more natural conditions might lead to increased developmental rates allowing changes to be identified over short time periods. However, the high morphological variability in individuals observed in each age class in our study (Figure 3) as well as those larvae taken from the Cowlitz River (a site where all individuals are presumably of very similar ages; Figure 4) might still preclude this.

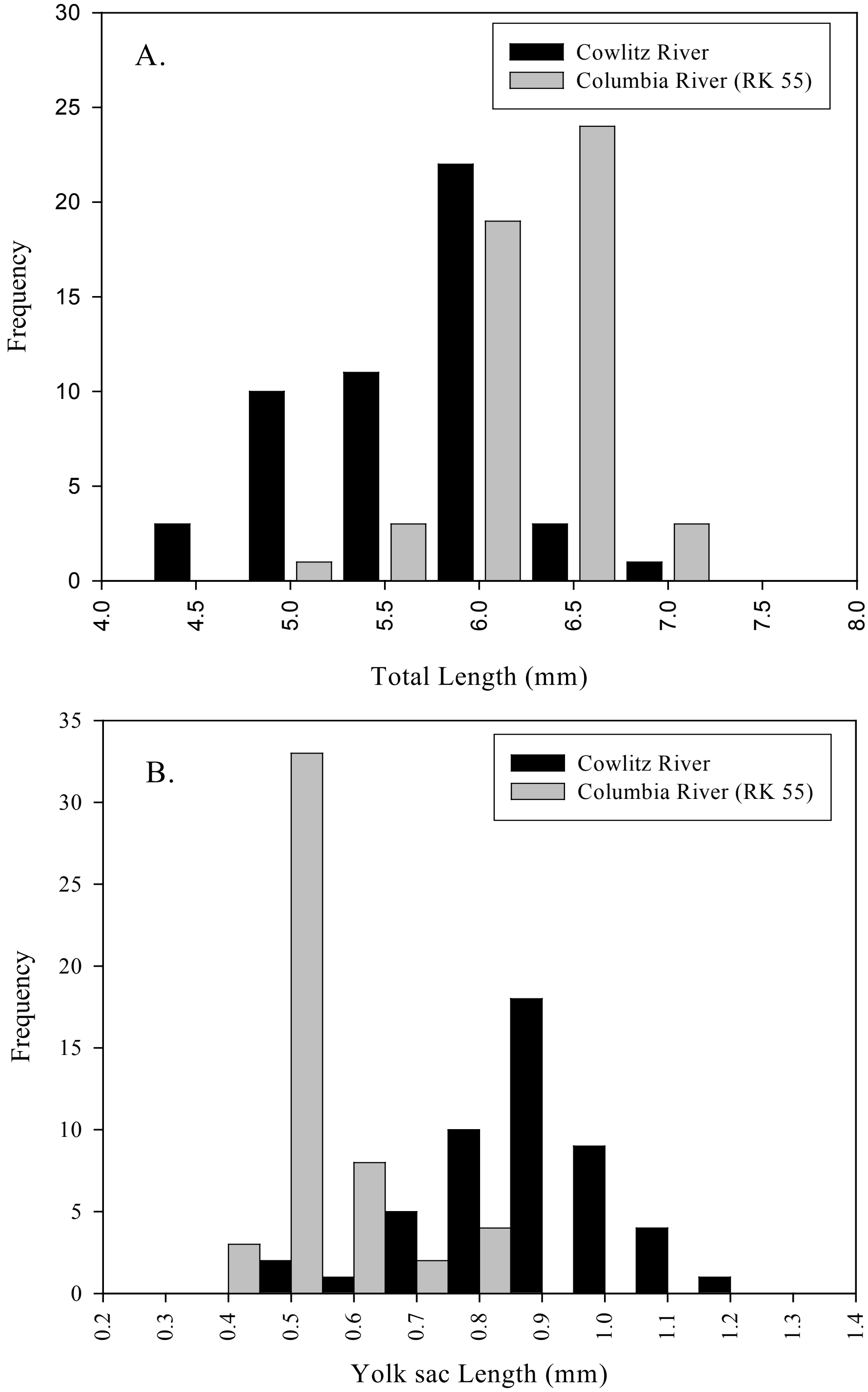


Figure 4. Length frequency distributions for A) total length and B) yolksac length in prolarval eulachon taken in plankton net tows in the Cowlitz and Columbia Rivers during April, 2001. N = 50 larvae for each location.

ACKNOWLEDGMENTS

We thank Peter Barber, Jody Gabriel, Robin Mills, and Steve West for assistance in laboratory analysis. John DeVore (WDFW) helped with initial study conception. Brad James (WDFW), Dave Ward (ODFW) and Tom Rien (ODFW) reviewed a draft of this manuscript. Kim Larson (USACE) provided assistance as project manager. This work was funded by the U. S. Army Corps of Engineers (contracts W66QKZ 10745277 and W66QKZ13237198).

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EXHIBIT K-3

EVALUATION REPORT
FISH STRANDING
(REVISED)

Table of Contents
Exhibit K-3
Evaluation Report
Fish Stranding In the Lower Columbia River

Evaluation Report
Fish Stranding
In the Lower Columbia River

Concerns were expressed by federal and state agencies regarding the increased potential for stranding of juvenile salmon with respect to the Channel Improvement Project. Based on these concerns, the Portland District Army Corps of Engineers conducted a pilot study of juvenile stranding at three locations in the lower Columbia River. The goal of the study was to provide information to determine what factors may influence stranding and make recommendations in regards to what data needs to be collected in 2003 to accurately assess how different factors contribute to stranding.

Day and night juvenile salmonid stranding surveys were conducted at three locations in the lower Columbia River in the summer of 2002. During the surveys, data was collected on beach habitat, passing vessels, wakes generated by the vessels and stranding of fish.

In approximately 120 survey hours, 35 tugs/barges and 56 deep draft vessels were observed. Twenty-one Chinook juveniles were stranded ranging in length from 48mm to 136mm. In addition, 174 fish of other species were stranded, 162 of which were vessel related. Possible stranding influences included the time of day, beach slope, vessel draft, tide stage and gas saturation levels at Bonneville Dam.

The 2002 work was a pilot study, the results of which will be used to design the monitoring necessary to implement the monitoring action for stranding required by the May, 2002 NOAA Fisheries and USFWS Biological Opinions (MA-6). In addition, the Corps will implement the compliance action for stranding called for by the Biological Opinions (CA-12).

EFFECTS OF VESSEL WAKE STRANDING OF JUVENILE SALMONIDS IN THE LOWER COLUMBIA RIVER, 2002 – A PILOT STUDY

September 26, 2002

Submitted to:

US Army Corps of Engineers, Portland
Portland District
P.O. Box 2946
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ACKNOWLEDGEMENTS

This work was funded by the US Army Corps of Engineers under the direction of Kim Larson. Assistance in project planning was provided by Ben Meyer and Michelle Day of National Marine Fisheries Service. The Columbia River Pilots provided important data regarding shipping schedules and vessel characteristics. Robert Radakovich and the Consolidated Diking Improvement District #1 of Longview, Washington provided access to private land for sampling purposes. Ray Beamesderfer provided valuable advice in project design and through report review. Thanks to Caryn Ackerman for diligently enduring all night surveys and assisting with data analysis and report preparation. The time and generosity of the aforementioned added significantly to the quality of this study and is greatly appreciated.

EXECUTIVE SUMMARY

We conducted day and night juvenile salmonid stranding surveys at three locations in the lower Columbia River in the summer of 2002. During the surveys we collected data on beach habitat, passing vessels, wakes generated by those vessels, and stranding of fish.

In approximately 120 survey hours we observed 35 tugs/barges and 56 deep draft vessels. Twenty-one chinook juveniles were stranded ranging in length from 48mm to 136mm. In addition, 174 fish of other species were stranded, 162 of which were vessel related. We considered possible influences of time of day, beach slope, vessel draft, tide stage, and gas saturation levels at Bonneville dam on stranding of salmonids. Other studies have correlated wake amplitude to stranding (Bauersfeld 1977). We found that wake amplitude was related to distance of vessel from shore, vessel draft and vessel length.

The results of this pilot study were used to make recommendations for a more comprehensive study in 2003.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

INTRODUCTION

Wakes from deep draft vessels traveling within the lower Columbia River navigation channel have been implicated as a cause for stranding of juvenile salmonids (*Oncorhynchus* spp.). Stranding occurs when juveniles are caught in a vessel's wake and are deposited on shore while the wake recedes or is absorbed. Stranding typically results in mortality unless another wave carries the fish back into the water. The current proposal to deepen the navigation channel in the Columbia River has heightened concern with juvenile stranding because the deeper loaded vessels that are anticipated to use the deeper channel may produce larger wakes.

Two previous studies have documented vessel wake induced stranding of juvenile salmonids in the lower Columbia. Bauersfeld (1977) observed stranding of 2,397 juvenile salmonids from 216 deep draft vessels. He estimated 145,003 chinook salmon (*O. tshawytcha*), 1,359 coho salmon (*O. kisutch*), and 4,771 chum salmon (*O. keta*) were stranded by vessels in a 33 mile reach of the Columbia River between the Willamette and Cowlitz rivers between February and July 1975. Daily estimates of stranding were as high as 117 fish per vessel. Bauersfeld (1977) found that the ability of a vessel to strand fish is a function of the size of the wave it produces. Vessel wake has been shown in laboratory tests to be related to vessel speed, channel depth, distance from shore, and vessel draft (Hay 1968, Johnson 1968).

Hinton and Emmett (1994) studied vessel wake induced stranding in the lower Columbia in 1992 and 1993. Surveys were conducted from April to September in 1992 and in March through July in 1993 at eight sites in the lower Columbia River. They collected data on vessel characteristics, habitat attributes, number of fish utilizing water adjacent to the beach, and number of fish stranded. Hinton and Emmett documented vessel wake induced stranding of only five juvenile salmonids after observing 145 vessels. They concluded that numerous factors including river-surface elevation, beach slope, vessel design and speed, the distance between the passing vessel and the beach, and numerous biological factors interact to produce stranding.

Based on these concerns, the Portland District of the United States Army Corps of Engineers (USACE) subcontracted to S.P. Cramer and Associates to conduct a pilot study of juvenile stranding at three locations on the lower Columbia River. The goal of the study was to provide information to determine what factors may influence stranding, and make recommendations in regards to what data needs to be collected in 2003 to accurately assess how different factors contribute to stranding.

METHODS

Survey Location and Timing

The three locations selected for stranding surveys were all located between the mouth of the Willamette River and the mouth of the Columbia River. The sites included Willow Bar on Sauvie Island (RM 96.5), Barlow Point (RM 61.5) and County Line Park (RM 51.5) (Figure 1). The Sauvie Island and Barlow Point sites were selected because of previous observations of stranding by National Marine Fisheries Service (NMFS) personnel. The County Line Park location was selected because it was one of the sites surveyed in the study by Hinton and Emmett (1994). These sites were selected because we expected to observe stranding, and should not be considered representative of all beaches in the lower Columbia.

Figure 1. Map of lower Columbia River and locations of juvenile stranding survey sites.

Two surveys were done at each location. Each location was surveyed once between June 24 and July 5, and a second time between July 29 and August 3. Survey timing was based on outmigration timing of chinook subyearlings and peak timing of shipping. Outmigration of chinook subyearlings peaked in late June and early July (Figure 2). Shipping schedules were obtained from the Columbia River Pilots Association website (www.colrip.com/main/PublicView001.asp). Each survey consisted of eight to ten hours of day sampling and eight to ten hours of night sampling.

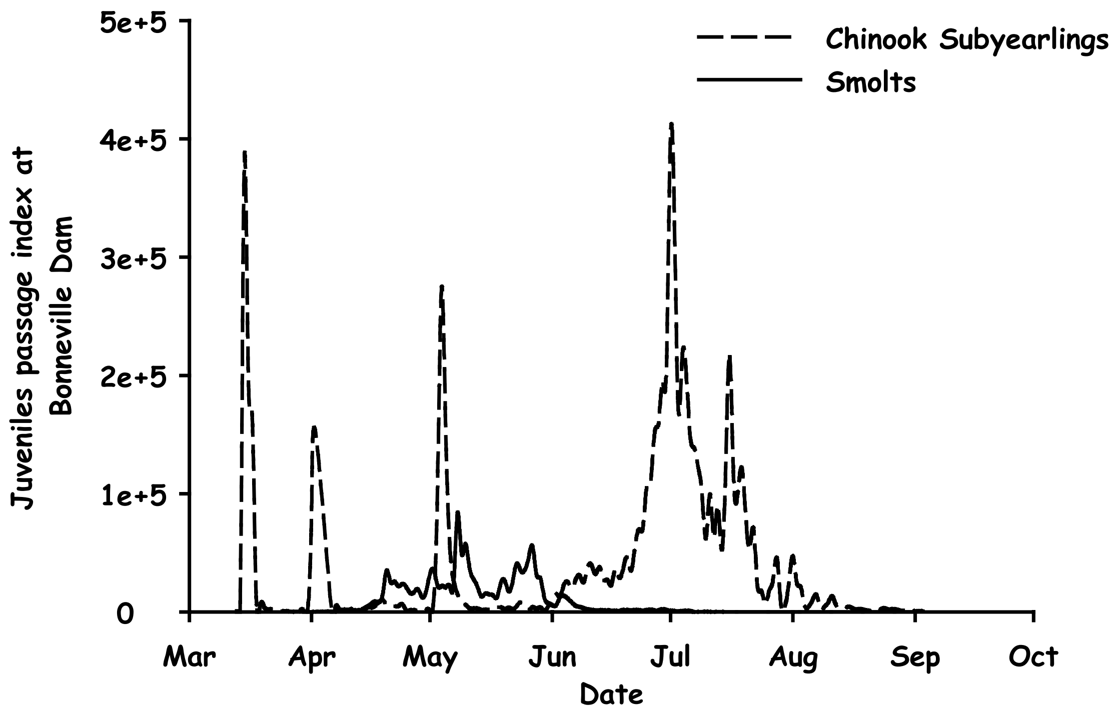


Figure 2. Passage of Chinook, coho, sockeye, and steelhead smolts and subyearling chinook over Bonneville Dam in 2002. Data obtained from the Columbia River Data Access in Real Time website (http://www.cqs.washington.edu/dart/dart.html).

Habitat Measurements

Habitat measurements were taken at low tide during the first set of surveys. Measurements were made for portions of the survey area likely to be influenced in tidal and wake actions. We established upstream and downstream boundaries of the survey and total length of beach surveyed. Then we divided the survey area into reaches based on beach slope, substrate, and vegetation. Survey and reach boundaries were marked with GPS coordinates and flagging. Lengths were measured using a hip chain. For each reach we determined the slope using a clinometer and staff gauge. We made three evenly spaced measurements for each reach and then averaged them to get the reach slope. We visually estimated the percentage composition of substrate comprised by three different size classes: fines (0-2mm), gravels (2-64mm) and cobble/boulder (>64mm). We also visually estimated the percentage of the beach that was vegetated. Percentage vegetated was defined as the percentage of area at the beach surface composed of vegetation. Shrub or grass overstory was not considered as part of the estimate. Vegetation was composed primarily of beach grasses and small willows. The distance from the vessel to shore and channel depth was taken from maps provided by the USACE. Diagrams of each survey area including high and low tide marks, locations of slope measurements and other key features can be found in appendix A.

Gauge Placement and Data

Three staff gauges marked in 0.1m intervals were placed in the survey area to monitor tide changes and wake effects. Gauges were placed in a location that was representative of a majority of the beach. The three gauges were placed in a line perpendicular to the main channel. Three gauges were used so that the gauges could remain in the same position throughout the survey, and at least one gauge would be readable from shore at any tide stage. The gauges were calibrated to each other so that upon data entry the readings on any gauge could be truthed to a single gauge.

As a vessel passed the survey area, one surveyor using a voice recorder monitored wake effects from the vessel. As the vessel approached the survey area, the surveyor noted the exact time of day (in seconds) and began making readings with every 0.1m change in gauge level. Readings ended when wake action ceased. The voice recorded tapes were later transcribed, and each reading was correlated to the exact time of day (in seconds) that it was made. From this data we obtained wake profiles for each vessel, and were able to determine the amount of drawdown and wake heights. In addition, gauges were monitored throughout the survey to determine changes in tide level.

Columbia River stage data for the Longview, Washington gauge was obtained from the USACE online data website for the survey period (http://www.nwd-wc.usace.army.mil/cgi-bin/DataQuery).

Vessel Data

During surveys, vessel data, stranding, and wake size was recorded for all shipping vessels including deep draft vessels and tugs with and without tows.

Speed was estimated for all vessels during daytime surveys. Speed was estimated by selecting downstream and upstream transects across the river, estimating the distance between those transects using a hip chain and calculating the time it took the vessel to pass between the transects. Transects were established by standing in a fixed point in the survey area and establishing a landmark on the far shore that would be fixed and visible for the duration of the study. Since the distance between the transects was estimated, speed estimates should not be viewed as actual speed. Thus, the estimates are useful for comparing speeds between vessels within a survey site, but not useful for comparing speeds of vessels in different survey sites. Also, speed could not be estimated for vessels passing at night because we were unable to see the transect landmark on the far shore.

Other vessel data included direction (upstream/downstream) and vessel name. A picture was taken of each vessel in daytime surveys. Additional data including vessel length, vessel type, draft, and load status were obtained by calling the Columbia River Pilots Association.

We calculated river depth for each vessel because of changes in river stages between sampling periods from flow management and changes within periods from tidal influence. We began with the depth of the main channel at Columbia River Datum (CRD) for each location as derived from maps from the USACE. Then, we adjusted these depths for each survey date based on changes in mean daily river stages at Longview, Washington (USACE online data). We assumed that the lowest river stage observed during the sampling period was equal to the gauge reading at CRD. Next, we adjusted the depths for each vessel based on readings from our gauges during surveys. We assumed that our mean gauge reading was equal to the mean daily gauge reading at Longview, Washington. For each vessel, we adjusted the depth based on what the gauge reading was when the vessel passed as compared to the average gauge reading for the survey period. While this method does not provide accurate depth measurements, it is useful for comparing relative differences in depths between vessels and its effect on stranding and wake size.

To compare the magnitude of drawdown and wake action between vessels, we calculated a wake amplitude. This was considered to be the difference in gauge readings between the lowest reading during the drawdown, and the maximum wake height gauge reading.

Fish Pass Methods

A pass was conducted over the entire survey area upon arrival at the site, immediately prior to a vessel passing (when possible) and immediately following the passage of a vessel and cessation of its wake. The start and end time of each pass was noted. When a fish was found we noted which reach it was in. If it was not a salmonid we identified it. If it was live we returned it and if not we removed it from the beach so as not to be counted on subsequent surveys. If it was a salmonid we identified it and noted the presence or absence of an adipose fin. It was alive we returned it, and if it was dead we measured the fork length and preserved it in a cooler to be turned over to NMFS personnel.

Recommendations

We calculated the mean and variance of number of fish stranded per deep draft vessel, and applied methods described by Eckblad (1991) to determine how many deep draft vessels need to be observed in next year’s study to obtain a mean number of fish stranded per deep draft vessel with various accuracies. Our data was not normally distributed so we applied a logarithmic transformation as described in Elliott (1977).

RESULTS

Habitat

The surveyed area of each site was approximately 200-300m long. Sauvie Island and Barlow Point were separated into two reaches, and County Line Park was separated into 3 reaches. Gradients among reaches ranged from 1.6 (Reach 2, Barlow Point) to 11.9 (Reach 3, County Line Park)(Table 1). Substrate was largely fines at all sites, and all reaches were primarily unvegetated (Table 1). Pictures of each of the sites, and GPS boundaries of each reach can be found in appendix B.

Table 1. Habitat characteristics of each of the sample sites in the lower Columbia. Habitat data was taken at low tide during the first survey.

				% Substrate				Slope (%)			
Location	Date	Reach	Length (m)	Fines	Gravel	Cob./ Bldr.	% Veg.	1	2	3	Avg
Sauvie Island	1-Jul	1	131	100	0	0	8	7	6.5	5	6.2
		2	102.8	100	0	0	1	5.5	4.5	6	5.3
Barlow Point	5-Jul	1	111	100	0	0	10	2.2	2.8	4	3
		2	84	70	0	30	20	1.5	1.8	1.5	1.6
County Line Park	24-Jun	1	80.9	90	0	10	0	11.2	11.7	4.9	9.3
		2	121	95	0	5	0	3	3	2.8	2.9
		3	48.5	95	0	5	0	11	12.1	12.8	11.9

River stages in the lower Columbia were approximately 3 feet higher during the first survey period than the second. The average daily gauge reading in Longview for the first survey period ranged from 6.1 feet to 7.8 feet, and from 3.8 to 4.3 in the second survey period (Figure 3).

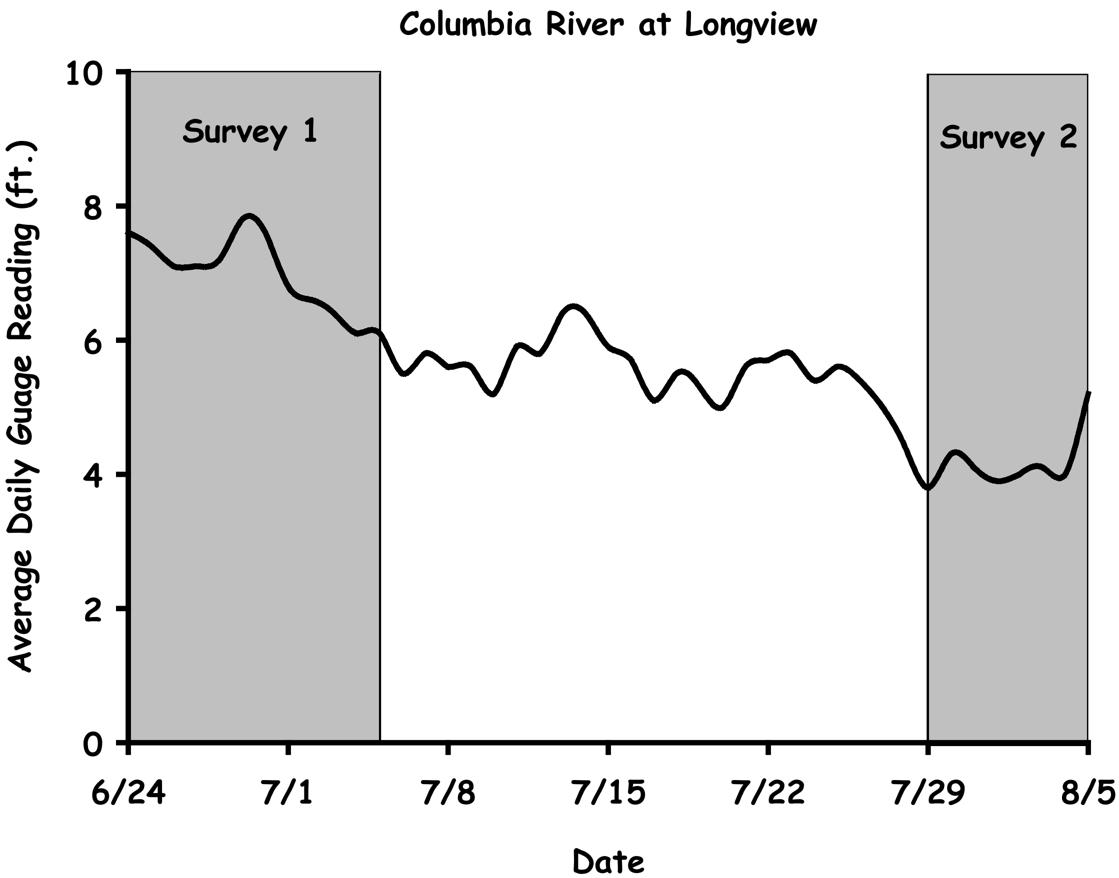


Figure 3. Average daily gauge reading at Longview, Washington from July 24, 2002 to August 5, 2002. Data obtained from USACE online data website (http://www.nwd-wc.usace.army.mil/cgi-bin/DataQuery).

Tidal changes caused a 1.6m change in gauge levels at County Line Park and as little as a 0.2m change in levels at Sauvie Island during the first survey (Figure 4, Figure 5). Tidal influences were greater at Barlow Point and Sauvie Island during the second survey, but were greater at County Line Park during the first survey. There doesn't appear to be any relation between timing of vessel passage with tidal stage or time of day (Figure 4, Figure 5).

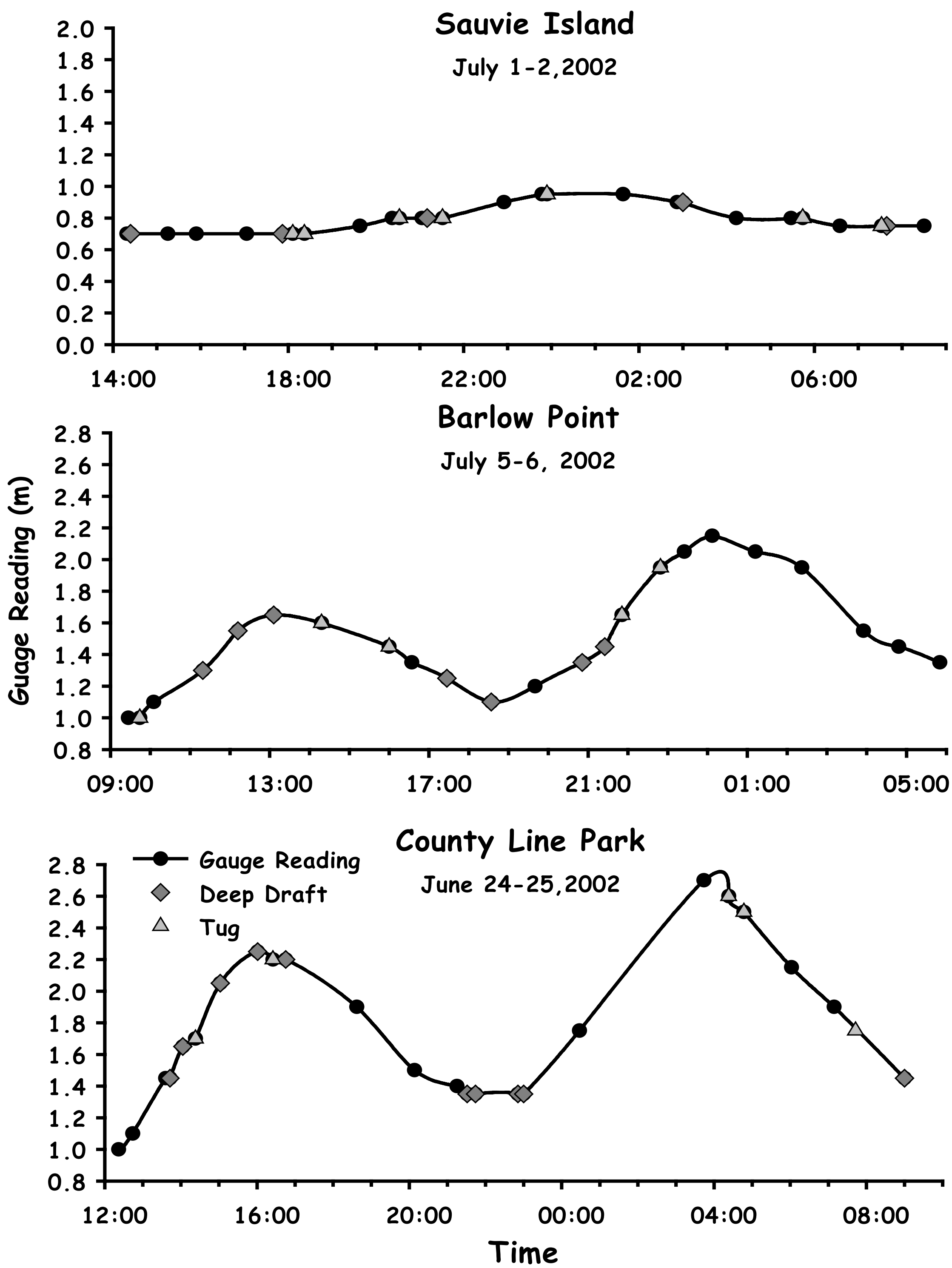
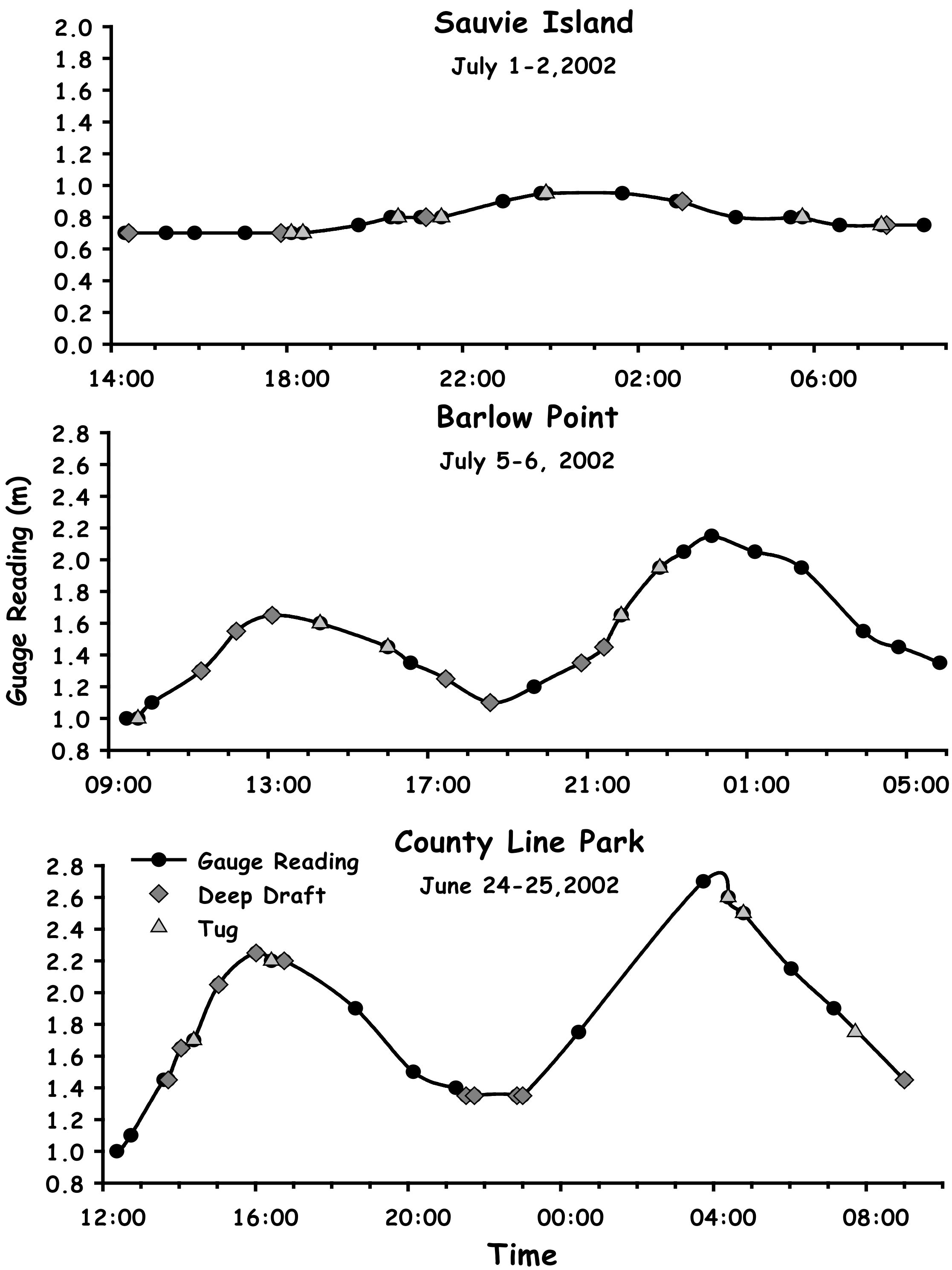


Figure 4. Baseline gauge readings at each of the three survey sites during the first survey period. Diamonds and triangles demote the time and tide stage of

vessel passings.



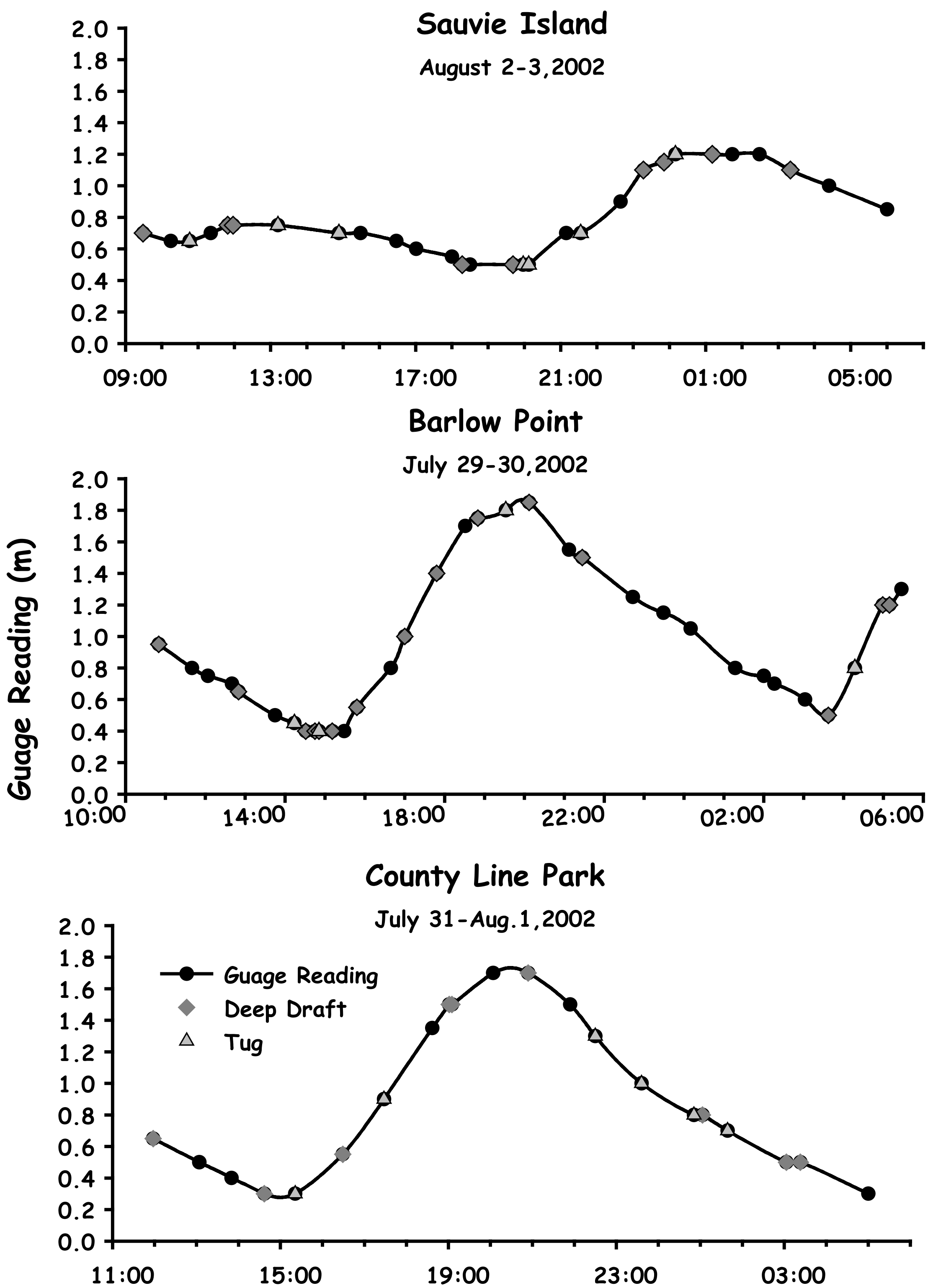


Figure 5. Baseline gauge readings at each of the three survey sites during the second survey period.

Vessels

A total of 91 vessels were observed during surveys including 35 tugs and 56 deep draft vessels (Table 2). Thirty-eight vessels were observed during the first round of surveys compared to 51 in the second (Table 2). A majority of vessels (63 of 91) were observed during day surveys (Figure 6).

Table 2. Number of deep draft vessels and tugs observed at each survey site during each survey period.

	Deep Draft			Tugs			
Location	**Survey 1**	**Survey 2**	**Sub-total**	**Survey 1**	**Survey 2**	**Sub-total**	**Total**
Sauvie Island	5	9	14	6	7	13	**27**
Barlow Point	7	14	21	5	4	9	**30**
County Line Park	10	11	21	7	6	13	**34**
Total	**22**	**34**	**56**	**18**	**17**	**35**	**91**

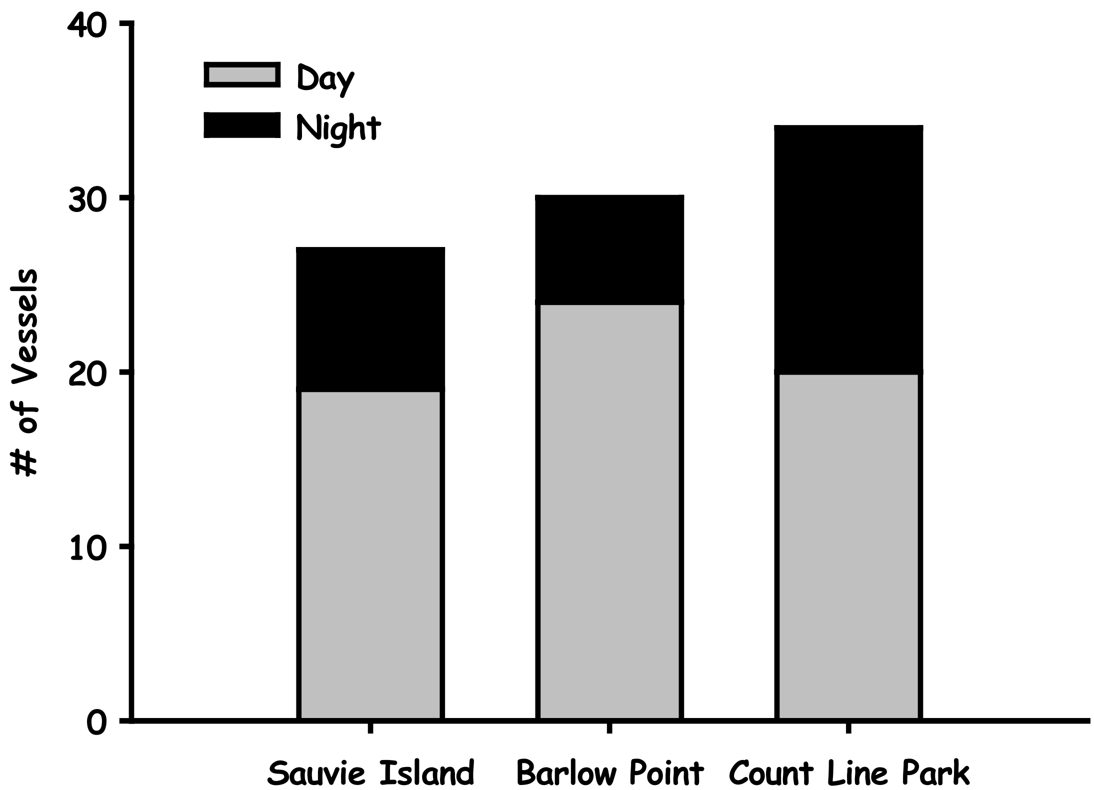


Figure 6. Number of vessels observed at each survey during day and night surveys.

Six different types of vessels were observed. Tugs were the dominant vessel type at 39% of observations. Among deep draft vessels, bulk carriers comprised another 35% of total observations, and the remainder were car ships, oil tankers, container ships, and general cargo carriers (Figure 7). Pictures of each of the vessel types can be seen in figures 8 through 10 except general cargo carrier. Photos were not available because these vessels only passed at night.

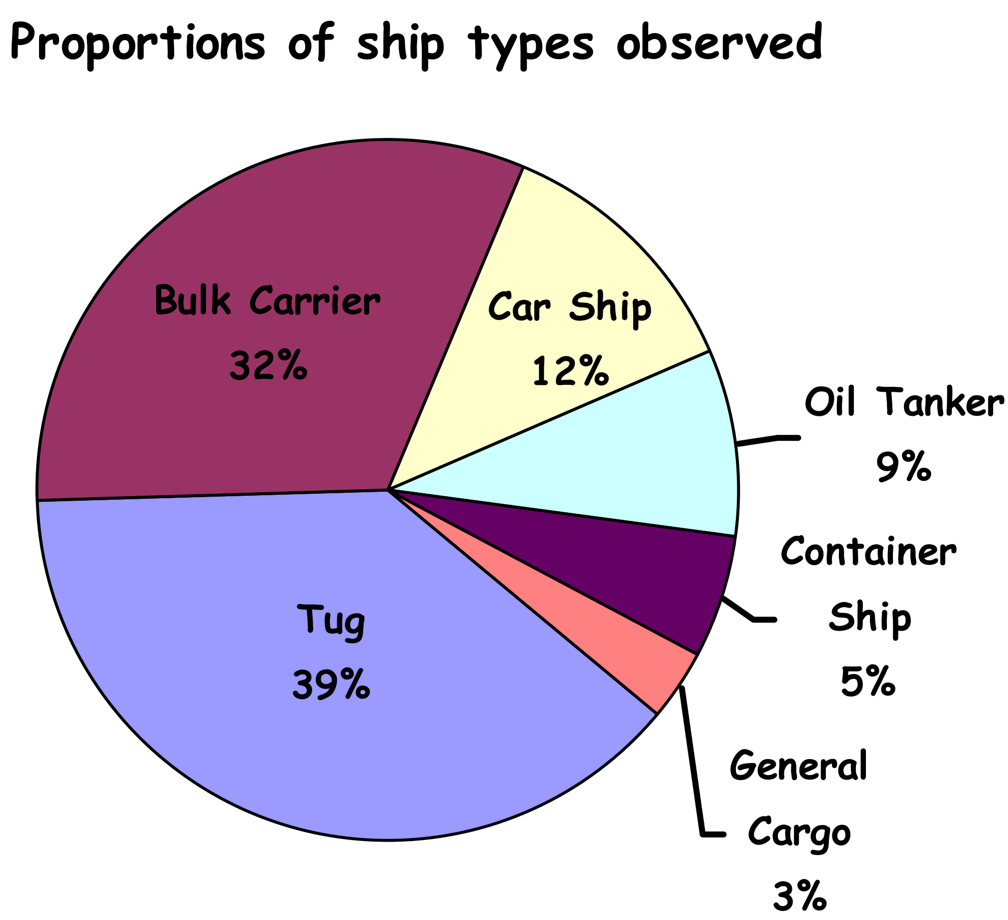


Figure 7. Percentage composition of total observations of each vessel type.

Figure 8. Top: Picture of tug at Barlow Point. Bottom: Picture of the Laurel Island, a bulk carrier at Sauvie Island.

Figure 9. Top: Picture of the Century Highway #1, a car ship at Barlow Point. Bottom: Picture of the Fulmar, an oil tanker at Barlow Point.

Figure 10. Picture of the Hyundai Admiral, a container ship at County Line Park.

We found that vessels produced wake profiles of similar shape, but of varying magnitude. In general, wake profiles of deep draft vessels show a drawdown as the vessel began to pass the survey area, followed by an intial surge, and subsequent wake action. Tugs showed no evidence of a drawdown, and much less wake action than the deep draft vessels (Figure 11). This is not surprising since the tugs are much smaller, draft less water and move slower than the deep draft vessels. The average speed of tugs was 7.5 knots compared to 10.5 knots for deep draft vessels. The wake amplitude for deep draft vessels averaged 0.52m as compared to 0.16m for tugs.

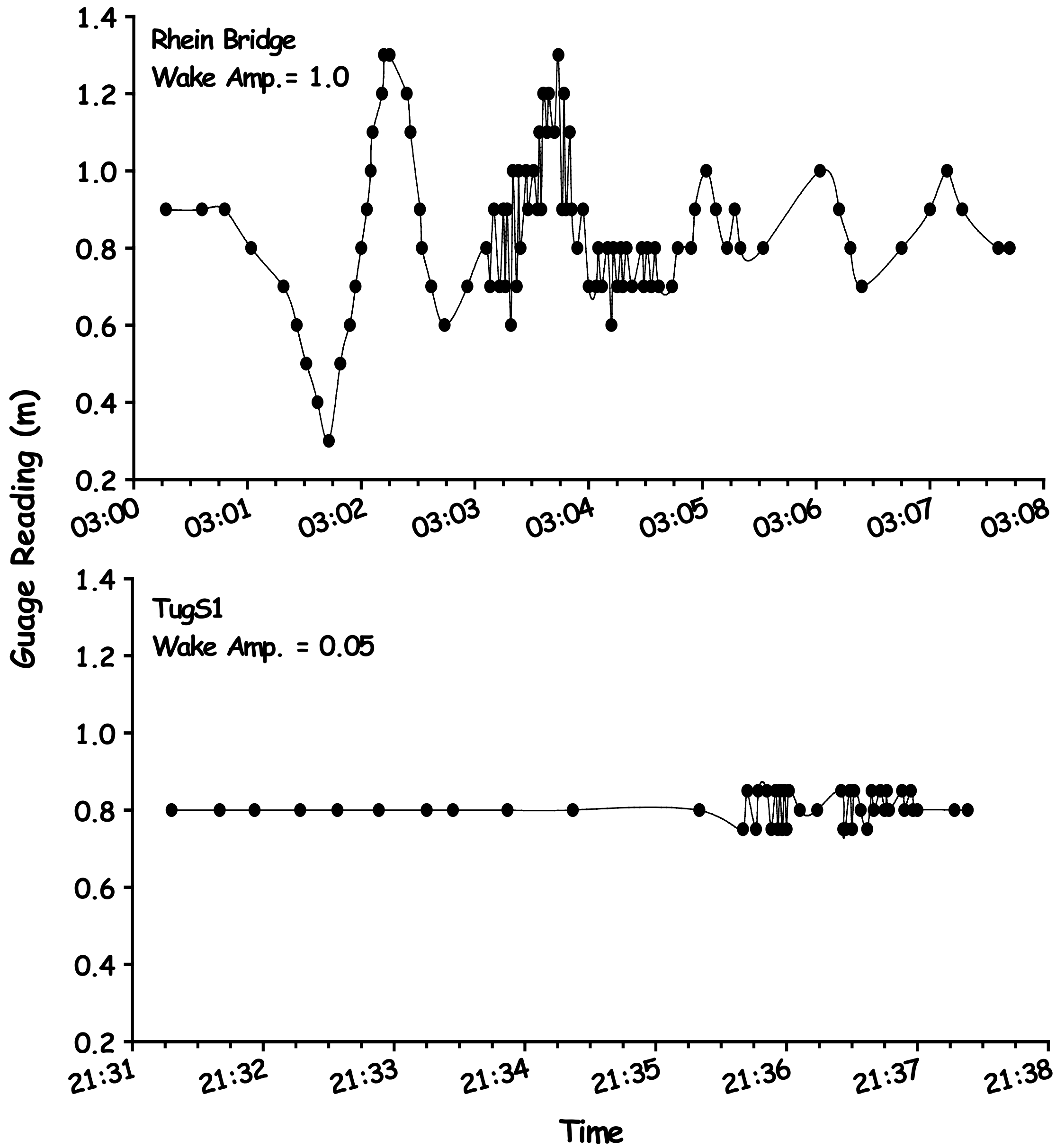


Figure 11. Wake profile of a deep draft vessel (top) and tug (bottom) at Sauvie Island, July 1 and 2, 2002.

The average wake amplitude from deep draft vessels was the largest at County Line Park of the three sites (Table 3). The vessels drafting the most were observed at Barlow Point. All vessel data for each vessel can be found in appendix C.

Table 3. Characteristics of deep draft vessels and their wakes at each of the three survey sites.

Location	Direction	# Vessels	Distance from shore (m)	Avg. Est. Depth (m)	Est. Speed (knots)	Avg. Draft (m)	Avg. Drawdown (m)	Avg. Wake Amplitude
Sauvie Island	US	6	331	14.9	7.5	8.1	0.35	0.63
	DS	8	442	14.3	8.6	8.4	0.25	0.58
Barlow Point	US	14	497	14.0	11.1	8.7	0.14	0.33
	DS	7	387	13.7	13.7	9.4	0.26	0.43
County Line	US	11	331	14.5	9.4	7.9	0.29	0.55
Park	DS	10	238	15.0	10.4	8.5	0.37	0.75

A stepwise regression using our data showed that vessel length, draft and distance from shore were significantly related to wake amplitude ($P<0.05$). Distance to shore was the variable most highly correlated to wake amplitude ($r^2 = 0.29$). Field observations confirmed this. The main channel at Barlow Point was further from shore than at the other two sites, and we noticed during surveys that wake amplitude was smaller given similar sized vessels and speeds.

Stranded Fish

We observed stranding of 21 juvenile chinook salmon during surveys. (Table 4) All of the stranding was observed during the second survey period from July 29 to August 3, 2002. Twelve chinook were stranded at Barlow Point, 9 at County Line Park, and none at Sauvie Island. At Barlow Point, 10 chinook were stranded by one vessel (Table 4). All of the stranding observed occurred during night surveys. Twenty of the stranded chinook were unclipped, and one could not be identified as to the presence of an adipose fin (Table 4). That fish appeared to have been wounded by a bird, leaving a wound where the adipose fin would have been. The wound likely played a role in the fish being stranded since it was much larger (136mm) than the other fish stranded (48-90mm) (Table 5).

Table 4. Summary of observations of juvenile chinook stranding. Included are the location, reach, date, time and vessel characteristics.

Date	Time	Vessel	Location	Reach	Draft (m)	Wake Amplitude (m)	Chinook		
							Clipped	Unclipped	Unknown
29-Jul	21:34	K & A	Barlow	2	8.2	0.3	0	1	0
30-Jul	3:44	Fairy Queen	Barlow	2	12.1	0.2	0	10	0
30-Jul	4:24	Tug	Barlow	2	--	0	0	1	0
31-Jul	20:59	Cielo de Vancouver	County Line	2	9.8	1.05	0	1	0
1-Aug	1:10	Hanjin Osaka	County Line	1	9.3	1	0	1	0
1-Aug	1:10	Hanjin Osaka	County Line	2	9.3	1	0	2	1

1-Aug	2:45	Serena	County Line	2	7.7	0.7	0	4	0

Table 5. Lengths of stranded juvenile chinook. * Denotes the fish with the injury.

Location	Date	Vessel	Reach	Fork Length (mm)
Barlow Point	29-Jul	K & A	2	90
Barlow Point	30-Jul	Fairy Queen	2	63
Barlow Point	30-Jul	Tug	2	72
County Line Park	31-Jul	Cielo de Vancouver	2	53
County Line Park	1-Aug	Hanjin Osaka	1	78
County Line Park	1-Aug	Hanjin Osaka	2	79
County Line Park	1-Aug	Hanjin Osaka	2	48
County Line Park	1-Aug	Hanjin Osaka	2	136*
County Line Park	1-Aug	Serena	2	62
County Line Park	1-Aug	Serena	2	64
County Line Park	1-Aug	Serena	2	55
County Line Park	1-Aug	Serena	2	77

Seventeen of the 21 salmonids were stranded at Barlow Point reach 2 and County Line Park reach 2. These two reaches had the lowest slopes of all reaches at 1.6% and 2.9% respectively indicating lower sloped beaches are more conducive to stranding than higher sloped beaches.

There was some indication that tide stage may influence stranding. The Fairy Queen which stranded 10 chinook, passed Barlow Point at low tide. In addition, the Serena which stranded 4 chinook passed County Line Park as the river was approaching low tide. However, the Serena was soon followed by the Seven Seas and Pactrader, neither of which stranded salmonids. At low tide, more beach is exposed allowing for a greater chance of stranding. At high tide at reach 2 at Barlow Point and reach 3 at County Line Park, no beach was left available for stranding because the water had come up to the rip-rap at the high end of the beach.

We observed stranding of 174 non-salmonids. These included three-spined stickleback (*Gasterosteus aculeatus*), eastern banded killfish (*Fundulus diaphanous*), common carp (*Cyprinus carpio*), yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), peamouth (*Mylocheilus caurinus*), and sculpin (*Cottus spp.*). Stranding of 162 of the 174 fish were vessel related. Of these, 129 were stranded at Barlow Point (Table 6). Of the 12 non-vessel related strandings, eight were stranded by the outgoing tide, and 4 were found during initial passes upon site arrival. Lengths of the stranded non-salmonids were not taken, but all were estimated to be less than 100mm in length.

Table 6. Summary of non-salmonids stranded by vessels at each of the survey sites.

Location	Reach	Stickleback	E. Killfish	C. Carp	Y. Perch	L Bass	S Bass	Sculpin	Peamouth
Sauvie Island	1	0	3	2	9	5	0	0	9
	2	0	0	0	0	0	0	0	0
Subtotal		**0**	**3**	**2**	**9**	**5**	**0**	**0**	**9**
Barlow Point	1	15	0	5	3	0	5	1	2
	2	81	7	4	0	0	3	3	0
Subtotal		**96**	**7**	**9**	**3**	**0**	**8**	**4**	**2**
County Line	1	1	0	0	0	0	0	0	1
Park	2	2	0	0	0	0	1	0	0
	3	0	0	0	0	0	0	0	0
Subtotal		**3**	**0**	**0**	**0**	**0**	**1**	**0**	**1**
Total		**99**	**10**	**11**	**12**	**5**	**9**	**4**	**12**

Effects of Sample Size on Accuracy

Our observations indicated a non-normal distribution of salmonids stranded per deep draft vessel, and a high degree of variance (Figure 12). Based on this data after it was transformed using the natural log and methods of Eckblad (1991), we estimate that to achieve a mean accuracy of +/- 20% from actual values, 1300 vessels would need to be observed using a completely random design (Figure 13). A stratified sampling design would substantially reduce the necessary sample sizes. This analysis is included as an example for further refinement in future study plans rather than a definitive assessment of sample needs.

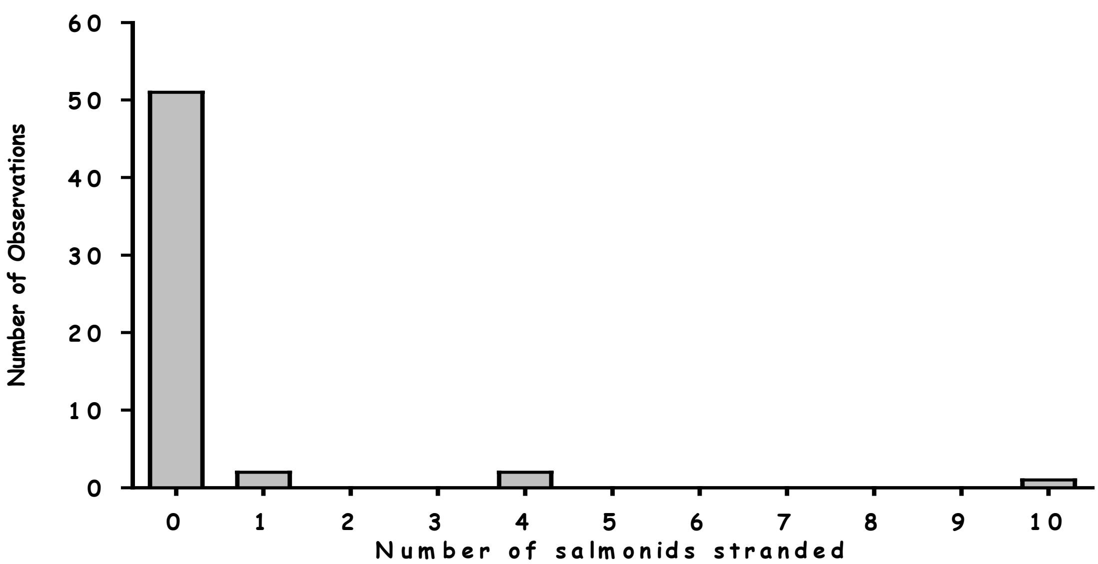
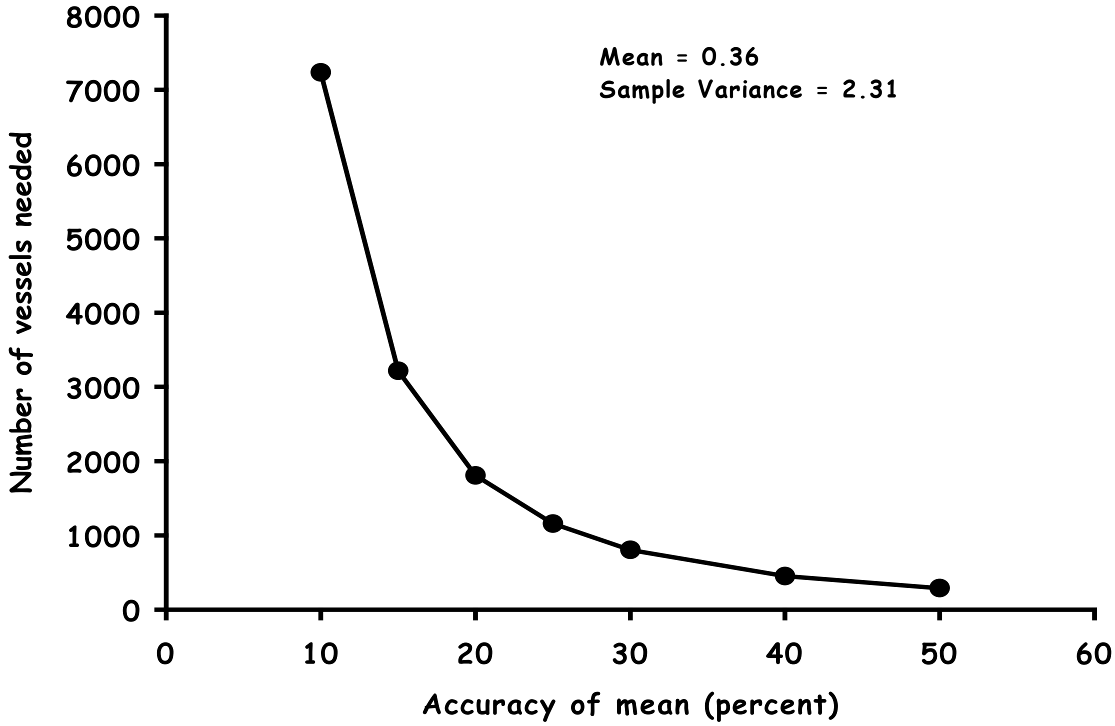


Figure 12. Frequency distribution of observations of number of salmonids stranded.



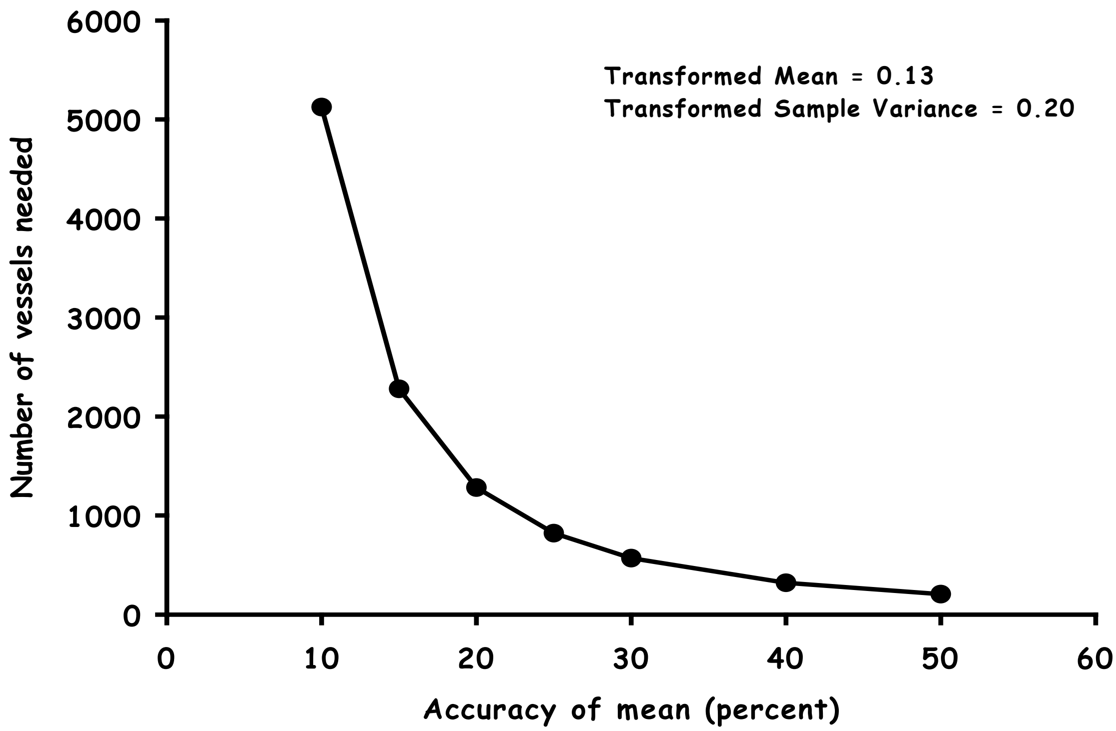


Figure 13. Number of vessels needed to estimate fish stranded per vessel with a given accuracy, expressed as +/- x percent of the mean. Top graph is base on untransformed data, and bottom graph is based on logarithmically transformed data. Transformed using the natural log.

DISCUSSION

The intent of this project was to test a sample design for a more comprehensive study. In our pilot study, we examined numerous factors that may influence stranding of juvenile salmonids including beach habitat characteristics, channel characteristics, tides, effects from the time of day and time of year, and vessel characteristics.

Stranding results from a combination of factors working together with different degrees of influence. Bauersfeld (1977) found that beach slope, time of day, and vessel draft contribute to stranding. Hinton and Emmett (1994) theorized that increased dissolved gas levels resulting in reduced swimming efficiency correlate to increased stranding. We identified tide stage as a potential confounding factor.

Bauersfeld (1977) suggested that stranding occurs only on low sloped beaches and recommended that beaches created by dredgings be contoured to a slope of 9% or more. We found that stranding only occurred on our lowest sloped beaches.

Bauersfeld (1977) found the time of day to be important in stranding. From mid-June through July, he only observed stranding at night. Our surveys took place between June 24, and August 3, and we only observed stranding at night as well.

Bauersfeld (1977) found that vessel draft was related to stranding. He found that stranding rates of 31 vessels with a draft of 7.6m or greater was 19 fish per vessel. Also, he observed stranding of 2,397 salmonids, and none were stranded by tugs. Vessels drafting less than 7.6m only stranded three fish per vessel. All the juvenile chinook we observed stranded were from vessels drafting 7.7m or greater with the exception of the chinook stranded by the tug at Barlow Point.

Bauersfeld (1977) concluded that wake size was one of the primary factors related to stranding. We found that wake amplitude was related to distance from the vessel to shore, vessel draft and vessel length.

Hinton and Emmett (1994) cited dissolved gas levels as a potential factor contributing to stranding. Reduced swimming efficiency and buoyancy regulation resulting from increased levels of dissolved gases at Bonneville dam might increase stranding.

Dissolved gas levels greater than 106% have been shown to decrease swimming performance of juvenile chinook (Schiewe 1974). In 1974 and 1975 when Bauersfeld (1977) observed significant stranding, dissolved gas saturation at Bonneville dam was typically above 110% (Hinton and Emmett 1994). In 1992 and 1993 when Hinton and Emmett (1994) observed only 6 stranded salmonids for 145 vessels, dissolved gas saturation levels were typically at or below 106% (Figure 14). During our study gas saturation levels at Bonneville dam were greater than 106% (Figure 14).

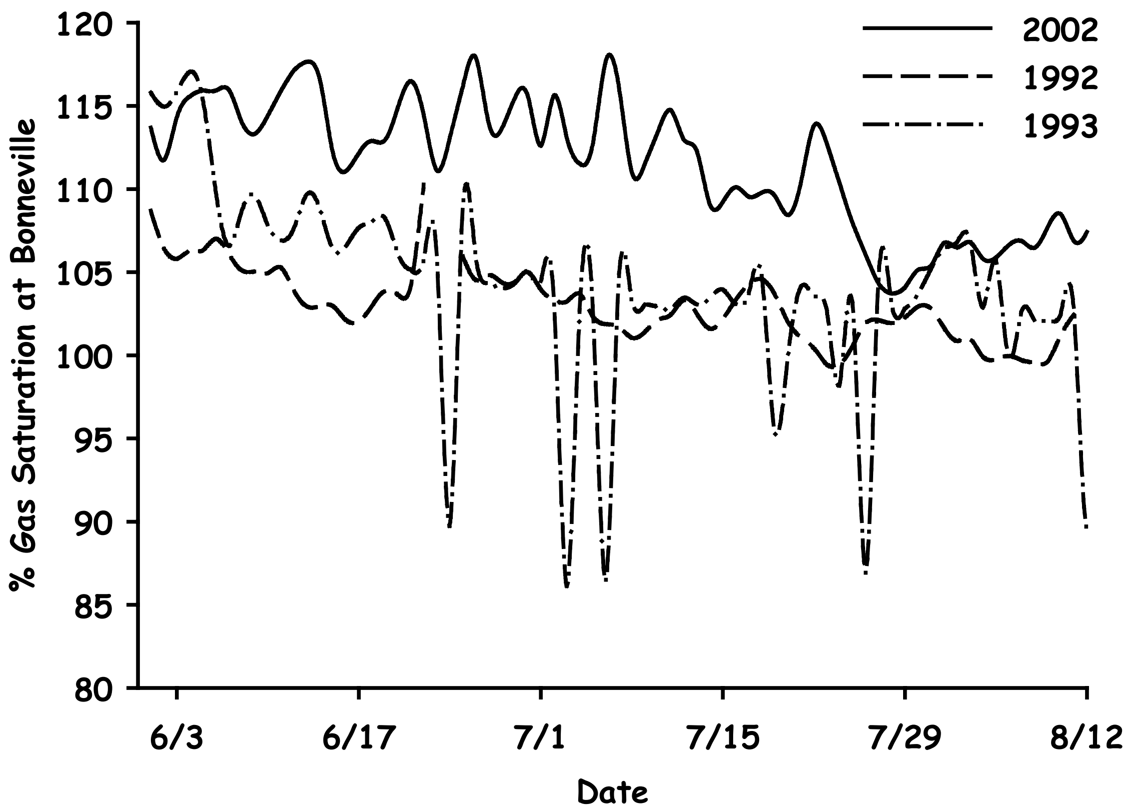


Figure 14. Average daily dissolved gas readings (%saturation) at Bonneville dam from June 1 – August 12 for 1992, 1993 and 2002. Data obtained from the Columbia River Data Access in Real Time website (http://www.cqs.washington.edu/dart/dart.html).

Hinton and Emmett (1994) beach seined at survey locations during their study of juvenile salmonids. In July, 1994 they found chinook lengths ranged from 60mm to 120mm with most chinook being 90mm. All of the dead chinook we observed stranded (with the exception of the injured fish) were in the lower end of this size range. This may indicate that only the smaller fish of the age class are being stranded.

Our survey did not specifically evaluate early season stranding when smaller fish are present. Early in the season (March and April) fry are present throughout the lower Columbia, and are highly susceptible to stranding. Observations by NMFS personnel and people we talked to while performing surveys suggest that significant vessel induced stranding may occur in early spring. In addition, Bauersfeld (1977) showed that the size class with the most stranding mortalities in 1974 and 1975 were juveniles in the 35-40mm range indicating a majority of stranding occurs early in the year.

The discrepancy in results between the studies by Bauersfeld (1977) and Hinton and Emmett (1994), high variance in observations in this study, and potential roles of multiple factors contributing to stranding indicate a substantial number of surveys and a carefully stratified sample design will be needed to accurately assess the causes and magnitude of vessel wake induced stranding of juvenile salmonids in the lower Columbia.

RECOMMENDATIONS

Because of experiences and results gained from this pilot study, we suggest that the following recommendations be considered in planning a more comprehensive study in 2003.

1. Use methods from this pilot study to collect habitat, vessel, wake, and stranding data.

We believe that the data we collected in this study was sufficient to determine what effects habitat, tidal and vessel characteristics have on juvenile stranding given the benefits of a larger sample size, and beach seining data. However, we suggest that at least three people be used during stranding surveys. For the purposes of the pilot study, two people was sufficient because we saw relatively little stranding. If more fish were stranded which will likely be the case earlier in the year, it will be necessary to have three surveyors per crew. A method for estimating vessel speed at night should be used. It is likely that speed is a contributing factor to stranding, and if stranding occurs primarily at night, it will be helpful to have estimated speeds for vessels passing at night. Radar guns may be a possibility.

2. Conduct surveys throughout the period of smolt and subyearling outmigration.

Bauersfeld (1977) observed significant levels of vessel induced stranding from February through July. We recommend that surveys encompass this time frame with the potential for going into August depending on hatchery release schedules of subyearling chinook. Beginning in February will allow for the observation of the magnitude of stranding of swim-up fry, and continuing through August will allow for observation of the magnitude of stranding of smolts and subyearling chinook.

3. Surveys should be conducted at numerous sites with various slopes throughout the lower Columbia.

Surveys should be conducted on at least as many sites as would be needed to accurately statistically estimate the extent of stranding in the lower Columbia River between the Willamette River and Astoria. Beaches of varying slopes should be monitored to better understand the importance of beach slope in stranding.

4. Conduct a general inventory of beaches with the potential for stranding in the lower Columbia.

A survey of the amount of beach where stranding could potentially occur would aid in estimating the total amount of stranding that occurs in the lower Columbia. This inventory would allow for sample sites chosen to be a representative sample of the population of beaches.

5. Base sample effort and sample sites on desired accuracy of stranding estimates.

High variance in results from this study, and differences in results between Bauersfeld (1977) and Hinton and Emmett (1994) indicate substantial sampling will be needed to accurately estimate the magnitude of stranding in the lower Columbia. A stratified sampling design will minimize sampling effort while maximizing sampling efficiency for a given budget.

6. Conduct beach seining to evaluate presence, abundance, size distribution and origin of juveniles subject to potential stranding.

Evaluating factors that contribute to stranding is difficult if it is unknown as to whether juveniles are present at the site when vessels pass. Without presence/absence data, it is impossible to determine if fish were not stranded because they weren't there, or because the environmental factors and vessel characteristics weren't conducive to stranding.

Abundance of juveniles at a beach prior to stranding is important because it can be used in conjunction with stranding data to estimate what proportion of fish present are being stranded.

Using seining to sample size distribution of juveniles is important for determining differences in length, weight and condition factor between fish stranded, and those present offshore of the beach. Making this comparison will help clarify differences in condition between fish stranded and those in the population.

Through seining, it will be possible to estimate the wild to hatchery ratio of the population subject to stranding, and compare this to the ratio of wild to hatchery among stranded fish.

7. Evaluate physiological condition of stranded salmonids.

An important question when evaluating the impacts of vessel wake induced stranding and mortality of salmonids, is whether mortality incurred is compensatory or additive. A physiological evaluation of stranded juveniles may give an indication of the health of the fish prior to stranding, and provide understanding of the impacts of the mortalities incurred on the population.

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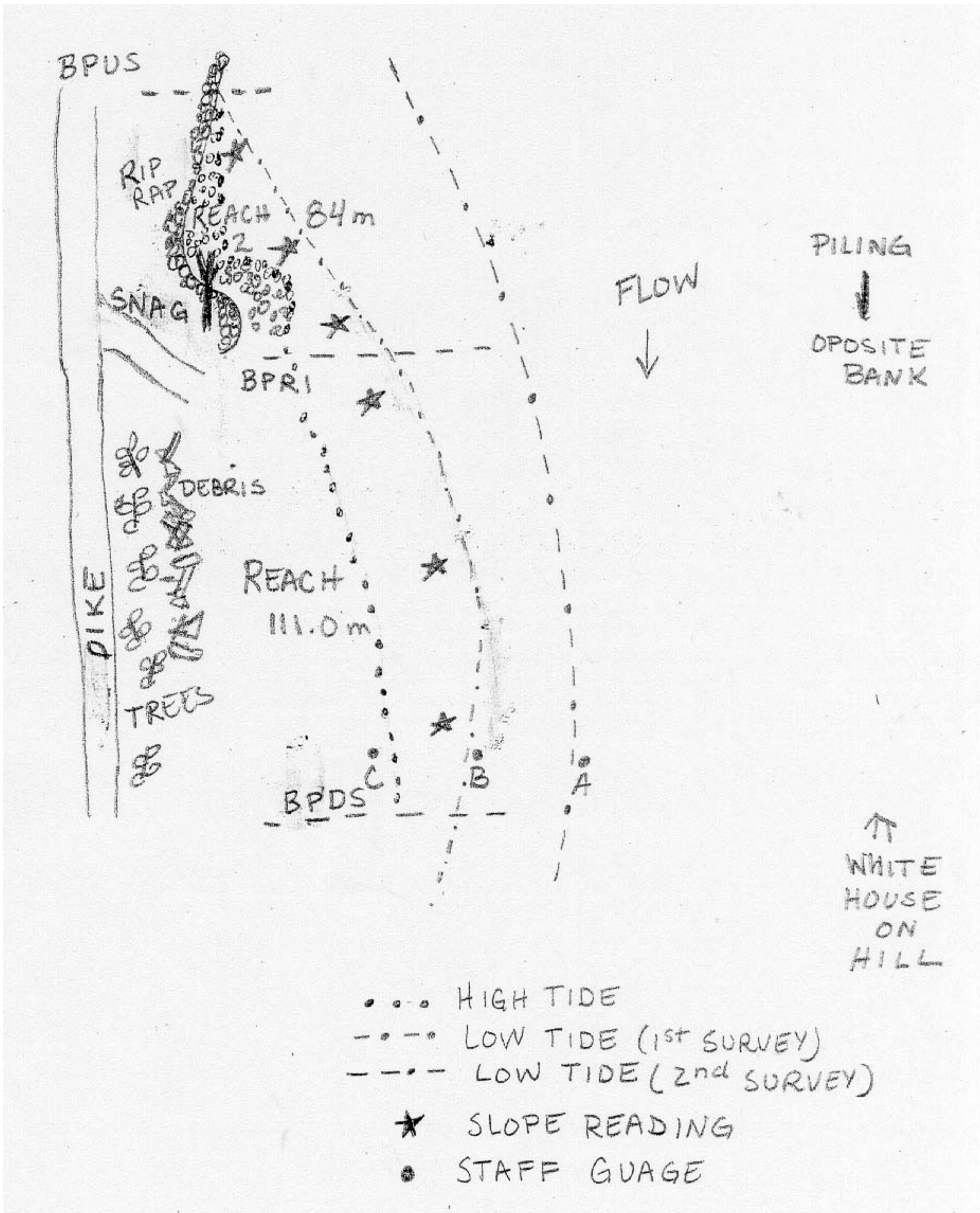
APPENDICIES

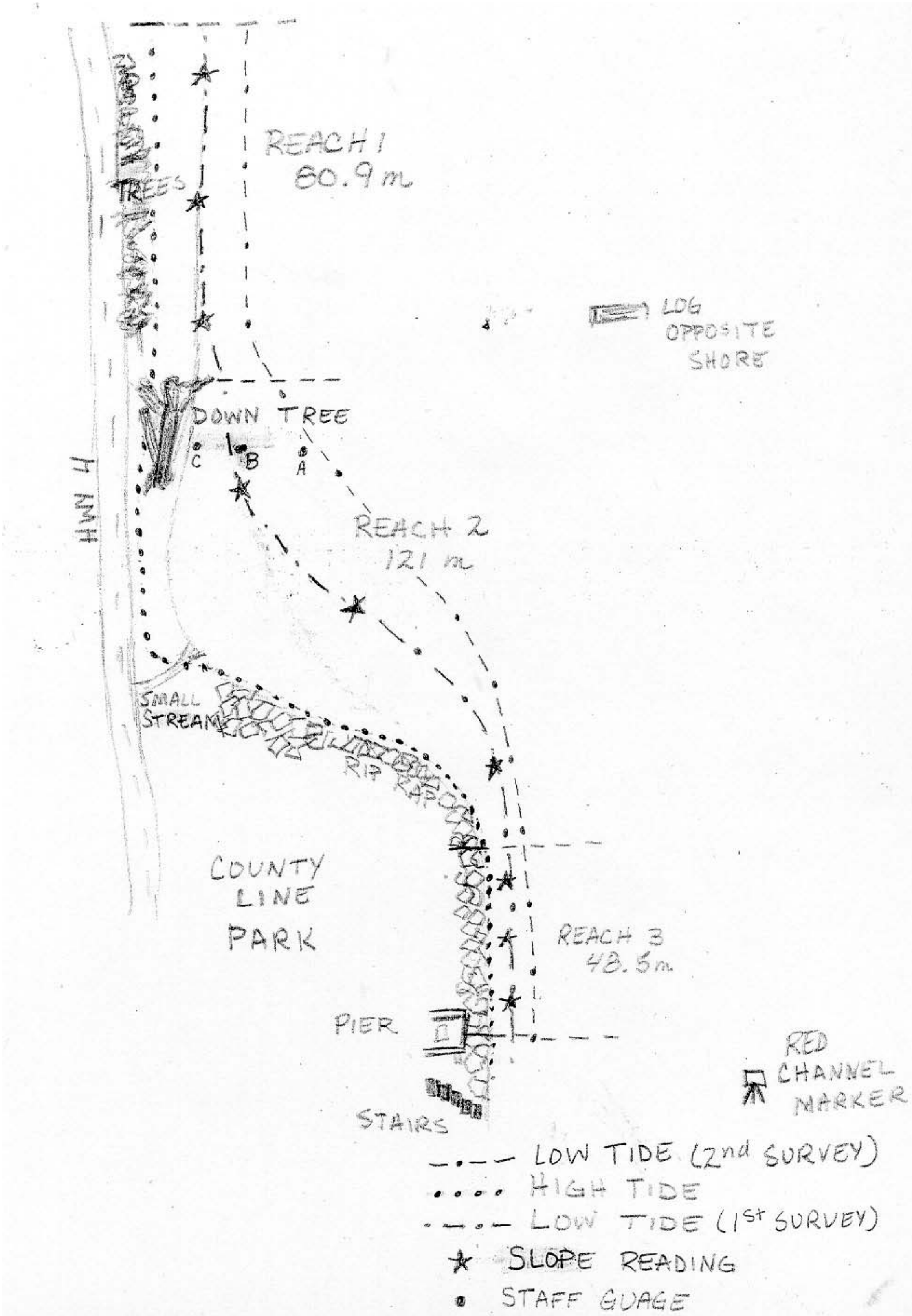
Appendix A: Survey site diagrams

Barlow Point



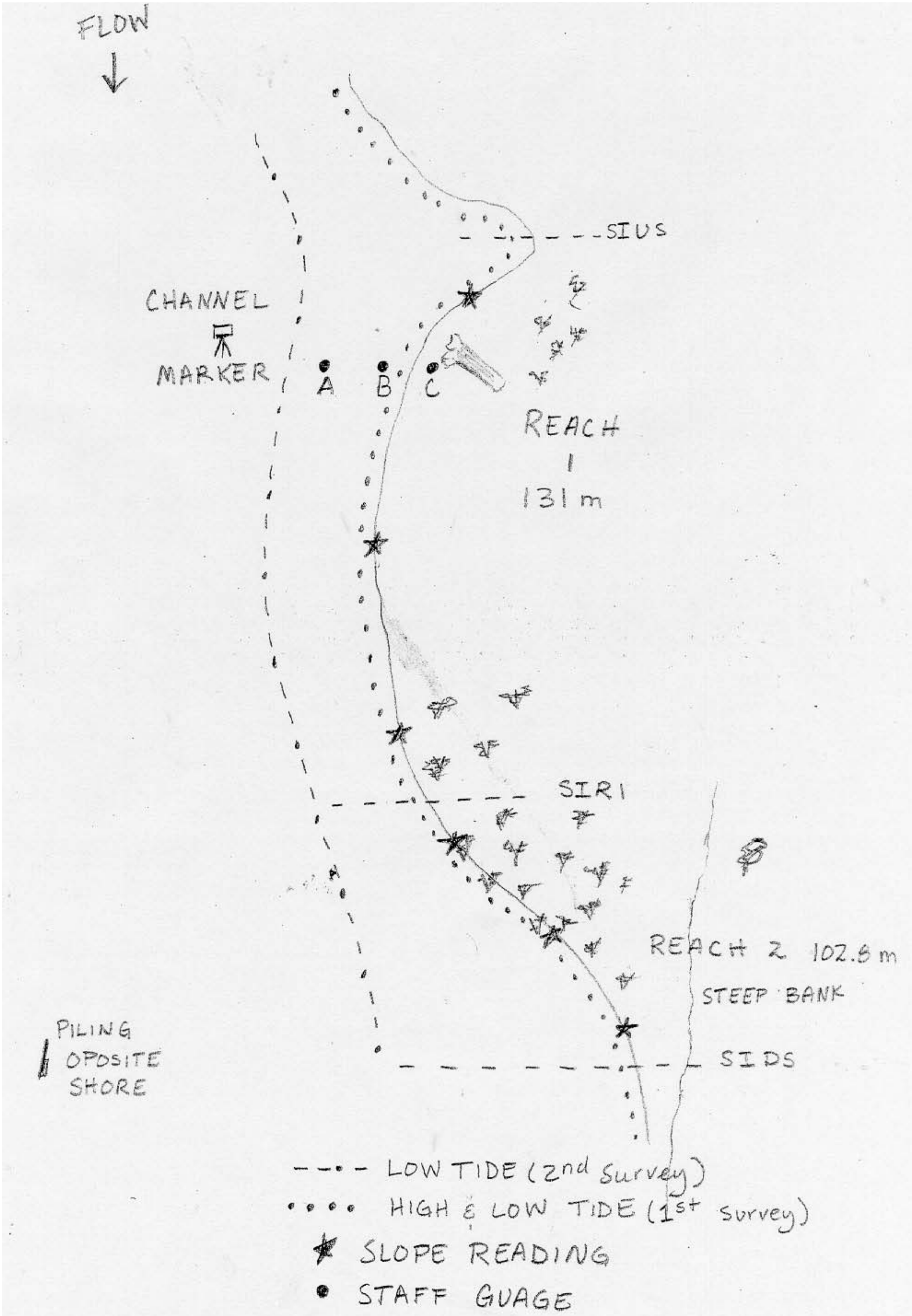
Appendix Figure 1. Drawing of Barlow Point survey area

County Line Park



Appendix Figure 2. Drawing of County Live Park survey area

Sauvie Island



Appendix Figure 3. Drawing of Sauvie Island survey area.

Appendix B: Survey site pictures and GPS locations

Appendix Table 1. GPS locations of reach breaks for each survey area.

GPS Description	10T	UTM	N	W
County Line Park boundary of reach 2/3	0483172	5113423	46.10.451	123.13.081
County Line Park downstream boundary	0483126	5113402	46.10.439	123.13.116
County Line Park boundary of reach 1/2	0483255	5113492	46.10.488	123.13.017
County Line Park upstream boundary	0483337	5113524	46.10.506	123.12.953
Sauvie Island upstream boundary	0517975	5063434	45.43.454	122.46.141
Sauvie Island boundary of reach 1/2	0518048	5063549	45.43.516	122.46.083
Sauvie Island downstream boundary	0518025	5063650	45.43.570	122.46.102
Barlow Point downstream boundary	0497325	5110580	46.08.928	123.02.078
Barlow Point reach 1/2 boundary	0497404	5110500	46.08.884	123.02.017
Barlow Point upstream boundary	0497474	5110470	46.08.868	123.01.962

Appendix Figure 4. Photo of Barlow Point Reach 1 looking downstream.

Appendix Figure 5. Barlow Point Reach 2 looking downstream.

Appendix Figure 6. Barlow Point Reach 2 looking upstream.

Appendix Figure 7. County Line Park Reach 1 looking upstream

Appendix Figure 8. County Line Park reach break between Reach 1 and Reach 2 (upstream)

Appendix Figure 9. County Line Park Reach 2 looking upstream.

Appendix Figure 10. County Line Park Reach 3 looking upstream.

Appendix Figure 11. Sauvie Island Reach 1 looking downstream.

Appendix Figure 12. Sauvie Island Reach 1 looking upstream.

Appendix Figure 13. Sauvie Island Reach 2 looking downstream.

Appendix C: Vessel data

Appendix Table 2. Vessel data

Location	Date	Vessel Name	Pass #	Est. Speed (knots)	Direction	Drawdown (m)	Max Wake (m)	Amplitude (m)	Ship Length (m)	Draft (m)	Type	Est. Depth	Dist to Shore (m)	Comment
County Line	24-Jun	Skaugran	3	--	US	0.5	0.4	0.9	183	8.7	CAR	15.1	331	No picture taken, missed upstream speed gate time
County Line	24-Jun	Bright State	4	10.476	US	0.1	0.2	0.3	138	--	GC	15.3	331	River pilots did not have draft on this ship
County Line	24-Jun	TugCL1	5	7.128	US	0	0.2	0.2	--	--	TUG	15.3	331	Tug pulling a container barge
County Line	24-Jun	Joint Spirit	7	9.396	DS	0.3	0.1	0.4	152	10.4	BC	15.7	238	
County Line	24-Jun	BargeCL1	9	4.536	US	0.7	0.5	1.2	--	--	TUG	15.9	331	Tug pushing a container barge, crossed paths with Westwood Marianne in survey area
County Line	24-Jun	Westwood Marianne	9	11.178	DS	0.7	0.5	1.2	200	9.0	BC	15.9	238	Crossed paths with Barge 1 in survey area
County Line	24-Jun	TugCL2	10	--	DS	0	0.3	0.3	--	--	TUG	15.8	238	Tug named Ernst Campbell, towing barge named Energizer, no speed obtained
County Line	24-Jun	Chevron Colorado	11	10.476	DS	0.4	0.4	0.8	198	7.9	OT	15.8	238	
County Line	24-Jun	General Villa	13	7.722	US	0.1	0.3	0.4	175	7.6	BC	15.0	331	Too dark for picture
County Line	24-Jun	Kapitan Afanasyev	14	--	US	0.3	0.3	0.6	184	8.5	CS	15.0	331	Too dark for speed or picture
County Line	24-Jun	TugCL3	15	--	DS	--	--	--	--	--	TUG	15.0	238	Too dark for picture, speed, or load status. Ship snuck up on us, no wake measurements
County Line	24-Jun	Maersk Sun	16	--	DS	0.3	0.5	0.8	157	7.6	CAR	15.0	238	Too dark for speed or picture
County Line	24-Jun	Ken Shin	17	--	US	0.3	0.2	0.5	172	6.7	BC	15.0	331	Too dark for speed or picture
County Line	25-Jun	TugCL4	18	--	DS	0	0.2	0.2	--	--	TUG	16.1	238	Too dark for speed or picture
County Line	25-Jun	TugCL5	19	7.83	DS	0	0.1	0.1	--	--	TUG	16.0	238	Too dark for picture
County Line	25-Jun	BargeCL2	21	7.02	DS	0	0	0	--	--	TUG	15.5	238	Barge named Miki Hana
County Line	25-Jun	Ocean Duke	22	--	US	0	0.1	0.1	175	6.7	BC	15.0	331	No speed recorded
Sauvie Island	1-Jul	Hyundai # 108	2	9.342	DS	0.15	0.5	0.65	174	8.2	CAR	14.7	442	
Sauvie Island	1-Jul	Liberty Spirit	4	9.18	DS	0.4	0.4	0.8	225	10.7	BC	14.7	442	
Sauvie Island	1-Jul	BargeS1	5	6.426	DS	0	0.1	0.1	--	--	TUG	14.7	442	Carrying grain or sawdust
Sauvie Island	1-Jul	BargeS2	6	5.184	US	0	0.05	0.05	--	--	TUG	15.4	331	Barge named the Nancy Ann
Sauvie Island	1-Jul	BargeS3	8	3.618	US	0	0	0	--	--	TUG	15.5	331	Barge named Lissy Too
Sauvie Island	1-Jul	Star Kim	10	6.912	US	0.15	0.2	0.35	174	6.7	BC	15.5	331	
Sauvie Island	1-Jul	TugS1	11	5.832	DS	0	0.05	0.05	--	--	TUG	14.8	442	Tug named Pacific Sassanda. Too dark for picture
Sauvie Island	2-Jul	BargeS4	12	--	US	0	0.15	0.15	--	--	TUG	15.6	331	Too dark for speed or picture
Sauvie Island	2-Jul	Rhein Bridge	13	--	DS	0.6	0.4	1	276	11.1	CS	14.8	442	Too dark for speed or picture

Location	Date	Vessel Name	Pass #	Est. Speed (knots)	Direction	Drawdown (m)	Max Wake (m)	Amplitude (m)	Ship Length (m)	Draft (m)	Type	Est. Depth	Dist to Shore (m)	Comment
Sauvie Island	2-Jul	BargeS5	15	6.966	US	0	0.15	0.15	--	--	TUG	15.5	331	
Sauvie Island	2-Jul	Rubin Dragon	17	8.802	DS	0.1	0.4	0.5	169	6.1	BC	14.7	442	
Barlow Point	5-Jul	BargeBP1	2	14.85	DS	0	0.3	0.3	--	--	TUG	14.1	387	
Barlow Point	5-Jul	Green Lake	4	12.69	US	0.15	0.1	0.25	200	8.2	CAR	14.1	497	
Barlow Point	5-Jul	New Spirit	6	10.152	US	0.1	0.1	0.2	189	11.0	BC	14.3	497	
Barlow Point	5-Jul	Christoforo Columbo	8	11.124	US	0.3	0.2	0.5	207	10.4	CS	14.5	497	
Barlow Point	5-Jul	BargeBP2	10	4.212	US	--	--	--	--	--	TUG	14.4	497	No wake height because 3 yachts passed during vessel passage creating large wakes. Likely no wake would have been created because of slow speed. Barge named Sea Hawk and Pacific.
Barlow Point	5-Jul	BargeBP3	12	6.966	US	0	0.1	0.1	--	--	TUG	14.3	497	Barge labeled James River
Barlow Point	5-Jul	Twinkle	14	11.124	US	0.1	0.25	0.35	153	7.3	BC	14.1	497	
Barlow Point	5-Jul	Eternal Clipper	16	9.126	US	0.05	0.1	0.15	164	8.5	CAR	13.9	497	
Barlow Point	5-Jul	Petersfield	18	10.152	US	0.05	0.25	0.3	187	7.0	GC	14.2	497	Too dark for picture
Barlow Point	5-Jul	Perseverance	19	10.8	US	0	0.2	0.2	187	10.7	OT	14.2	497	Too dark for picture
Barlow Point	5-Jul	TugBP1	20	4.482	US	0	0	0	--	--	TUG	14.4	497	Too dark for picture
Barlow Point	5-Jul	TugBP2	22	--	US	0	0.2	0.2	--	--	TUG	14.7	497	Too dark for speed or picture
Barlow Point	29-Jul	Galena Bay	2	--	US	0.15	0.25	0.4	201	7.9	OT	13.6	497	No speed recorded
Barlow Point	29-Jul	Maple Ace II	4	13.176	US	0.25	0.15	0.4	188	8.2	CAR	13.3	497	
Barlow Point	29-Jul	TugBP3	5	--	DS	0	0.1	0.1	--	--	TUG	13.4	387	No speed recorded
Barlow Point	29-Jul	Ace Century	6	16.146	DS	0.1	0.1	0.2	177	9.8	BC	13.3	387	
Barlow Point	29-Jul	Sunny Success	7	16.146	DS	0.1	0	0.1	180	11.6	BC	13.3	387	Pass the same as for BargeBP4 because ships were so close together
Barlow Point	29-Jul	BargeBP4	7	18.738	DS	0	0.1	0.1	--	--	TUG	13.3	387	Pass the same as Sunny Success because the ships were so close together
Barlow Point	29-Jul	Ocean Duke	8	11.88	US	0.1	0.1	0.2	175	7.3	BC	13.0	497	
Barlow Point	29-Jul	Century Hwy No. 1	9	9.612	DS	0.3	0.2	0.5	186	7.9	CAR	13.5	387	
Barlow Point	29-Jul	Fulmar	10	16.956	DS	0.3	0.15	0.45	182	7.3	OT	13.7	387	
Barlow Point	29-Jul	Nena F	11	9.882	DS	0.3	0.3	0.6	182	7.0	BC	13.9	387	
Barlow Point	29-Jul	Chevron Colorado	13	11.502	US	0.1	0.25	0.35	198	10.4	OT	14.0	497	
Barlow Point	29-Jul	BargeBP5	15	8.91	US	0	0	0	--	--	TUG	14.3	497	
Barlow Point	29-Jul	Pactrader	17	10.8	US	0.1	0.35	0.45	169	7.9	BC	14.4	497	

Location	Date	Vessel Name	Pass #	Est. Speed (knots)	Direction	Drawdown (m)	Max Wake (m)	Amplitude (m)	Ship Length (m)	Draft (m)	Type	Est. Depth	Dist to Shore (m)	Comment
Barlow Point	29-Jul	K + A	19	--	US	0.1	0.3	0.4	177	8.2	BC	14.2	497	Too dark for speed or picture
Barlow Point	30-Jul	Fairy Queen	20	--	DS	0.4	0.2	0.6	190	12.1	BC	13.6	387	Too dark for speed or picture
Barlow Point	30-Jul	BargeBP6	21	--	US	0	0	0	--	--	TUG	13.6	497	Too dark for speed or picture
Barlow Point	30-Jul	New York Hwy.	23	--	US	0.35	0.05	0.4	--	8.5	CAR	14.0	497	Not enough time before Ansaz & Serity to do pass. Too dark for speed or picture
Barlow Point	30-Jul	Ansax & Serity	23	--	DS	0.35	0.2	0.55	--	10.1	BC	14.3	387	Not enough time in after New York Hwy to do pass. Too dark for speed or picture
Sauvie Island	2-Aug	Blue Ridge	1	--	US	0.5	0.3	0.8	201	8.5	OT	14.5	331	Ship passed just as we arrived on site, no time for speed or picture.
Sauvie Island	2-Aug	BargeS6	3	11.124	DS	0	0.15	0.15	--	--	TUG	13.8	442	
Sauvie Island	2-Aug	Ankora	5	7.776	DS	0.25	0.15	0.4	169	10.3	BC	13.8	442	
Sauvie Island	2-Aug	Green Lake	6	8.046	US	0.5	0.55	1.05	200	8.8	CAR	14.6	331	
Sauvie Island	2-Aug	BargeS7	8	7.02	US	0	0.15	0.15	--	--	TUG	14.6	331	
Sauvie Island	2-Aug	BargeS8	10	5.508	DS	0	0.1	0.1	--	--	TUG	13.8	442	
Sauvie Island	2-Aug	Lantau Queen	12	8.64	DS	0.15	0.4	0.55	186	6.7	BC	13.7	442	
Sauvie Island	2-Aug	Ocean Rose	14	8.046	DS	0.1	0.3	0.4	157	6.4	BC	13.7	442	
Sauvie Island	2-Aug	BargeS9	15	8.424	US	0	0.2	0.2	--	--	TUG	14.4	331	
Sauvie Island	2-Aug	BargeS10	16	5.454	DS	0	0.2	0.2	--	--	TUG	13.7	442	
Sauvie Island	2-Aug	TugS2	18	--	DS	0	0.3	0.3	--	--	TUG	13.9	442	Too dark for speed or picture
Sauvie Island	2-Aug	Serifopoulo	19	--	DS	0.25	0.1	0.35	183	7.3	OT	14.0	442	Too dark for speed or picture
Sauvie Island	3-Aug	Pan Hope	20	--	US	0.05	0.15	0.2	164	6.9	BC	15.0	331	Too dark for speed or picture
Sauvie Island	3-Aug	BargeS11	21	--	US	0	0.15	0.15	--	--	TUG	15.0	331	Too dark for speed or picture
Sauvie Island	3-Aug	Moldanger	22	--	US	0.5	0.3	0.8	180	11.2	OT	15.0	331	Too dark for speed or picture
Sauvie Island	3-Aug	Anangel Progress	23	--	US	0.4	0.2	0.6	225	6.4	BC	15.0	331	Too dark for speed or picture
County Line	31-Jul	Hyundai Admiral	2	8.532	US	0.45	0.45	0.9	275	11.2	CS	14.1	331	
County Line	31-Jul	Hyundai # 103	4	10.908	US	0.3	0.2	0.5	184	8.5	CAR	13.7	331	
County Line	31-Jul	TugCL6	6	8.91	DS	0	0.2	0.2	--	--	TUG	13.7	238	
County Line	31-Jul	Maersk Sun	8	12.204	DS	0.25	0.45	0.7	158	7.0	CAR	13.9	238	
County Line	31-Jul	BargeCL3	10	4.968	US	0	0.2	0.2	--	--	TUG	14.3	331	
County Line	31-Jul	Laurel Island	12	9.342	DS	0.35	0.15	0.5	169	9.8	BC	14.7	238	Pactrader so close behind that it may have influenced the max wake measurement for this ship.

Location	Date	Vessel Name	Pass #	Est. Speed (knots)	Direction	Drawdown (m)	Max Wake (m)	Amplitude (m)	Ship Length (m)	Draft (m)	Type	Est. Depth	Dist to Shore (m)	Comment
County Line	31-Jul	Pactrader	12	10.098	DS	0.2	0.4	0.6	169	5.7	BC	14.9	238	Not enough time between this and Laurel Island to do separate passes.
County Line	31-Jul	Pacific Ace	13	--	DS	--	--	--	150	10.4	BC	15.0	238	Too dark to read guage with naked eye, not dark enough to get reflection from flashlight, too dark for speed or picture. Visual observation indicated little change in guage levels from pass of vessel.
County Line	31-Jul	Cielo de Vancouver	13	--	DS	0.45	0.6	1.05	185	9.8	BC	15.1	238	Too dark for speed or picture. Too close to Pacific Ace to do pass between.
County Line	31-Jul	BargeCL4	15	--	DS	0	0.05	0.05	--	--	TUG	14.9	238	Too dark for speed or picture, or to tell load status.
County Line	31-Jul	TugCL7	17	--	DS	0	0.2	0.2	--	--	TUG	14.3	238	Too dark for speed or picture, or to tell load status.
County Line	1-Aug	BargeCL5	19	--	US	0	0	0	--	--	TUG	14.1	331	Too dark for speed or picture.
County Line	1-Aug	Hanjin Osaka	20	--	US	0.6	0.4	1	290	9.3	CS	14.1	331	Too dark for speed or picute.
County Line	1-Aug	TugCL8	21	--	DS	0	0.2	0.2	--	--	TUG	14.0	238	Too dark for speed or picute.
County Line	1-Aug	Serena	22	--	DS	0.4	0.3	0.7	200	7.7	GC	13.8	238	Too dark for speed or picute. Technical difficulties, no wake profile.
County Line	1-Aug	Seven Seas	23	--	US	0.2	0.2	0.4	157	5.8	BC	13.8	331	Too dark for speed or picute.
County Line	1-Aug	Pactrader	24	--	US	0.3	0.2	0.5	169	5.7	BC	13.8	331	Too dark for speed or picute.

Appendix D: Fish stranding data

Location	Date	Pass #	Pass Reason	Vessel	Start Time	End Time	Reach	Unclipped Chinook	Unknown Chinook	3-Spined Stickleback	Eastern Killfish	Common Carp	Yellow Perch	LM Bass	SM Bass	Sculpin	Peamouth
County Line Park	24-Jun	1	INITIAL	--	12:25	12:40	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	1	INITIAL	--	12:25	12:40	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	1	INITIAL	--	12:25	12:40	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	2	PRE	--	13:34	13:36	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	2	PRE	--	13:34	13:36	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	2	PRE	--	13:34	13:36	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	3	VESSEL	Skaugran	13:46	13:52	1	0	0	0	0	0	0	0	0	0	1
County Line Park	24-Jun	3	VESSEL	Skaugran	13:46	13:52	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	3	VESSEL	Skaugran	13:46	13:52	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	4	VESSEL	Bright State	14:10	14:16	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	4	VESSEL	Bright State	14:10	14:16	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	4	VESSEL	Bright State	14:10	14:16	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	5	VESSEL	TugCL1	14:30	14:38	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	5	VESSEL	TugCL1	14:30	14:38	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	5	VESSEL	TugCL1	14:30	14:38	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	6	PRE	--	14:58	15:00	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	6	PRE	--	14:58	15:00	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	6	PRE	--	14:58	15:00	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	7	VESSEL	Joint Spirit	15:08	15:18	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	7	VESSEL	Joint Spirit	15:08	15:18	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	7	VESSEL	Joint Spirit	15:08	15:18	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	8	PRE	--	15:50	15:57	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	8	PRE	--	15:50	15:57	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	8	PRE	--	15:50	15:57	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	9	VESSEL	BargeCL1 & Westwood Marianne	16:10	16:14	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	9	VESSEL	BargeCL1 & Westwood Marianne	16:10	16:14	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	9	VESSEL	BargeCL1 & Westwood Marianne	16:10	16:14	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	10	VESSEL	TugCL2	16:30	16:40	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	10	VESSEL	TugCL2	16:30	16:40	2	0	0	0	0	0	0	0	0	0	0

Location	Date	Pass #	Pass Reason	Vessel	Start Time	End Time	Reach	Unclipped Chinook	Unknown Chinook	3-Spined Stickleback	Eastern Killfish	Common Carp	Yellow Perch	LM Bass	SM Bass	Sculpin	Peamouth
County Line Park	24-Jun	10	VESSEL	TugCL2	16:30	16:40	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	11	VESSEL	Chevron Colorado	16:50	16:55	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	11	VESSEL	Chevron Colorado	16:50	16:55	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	11	VESSEL	Chevron Colorado	16:50	16:55	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	12	PRE	--	21:21	21:26	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	12	PRE	--	21:21	21:26	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	12	PRE	--	21:21	21:26	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	13	VESSEL	General Villa	21:37	21:43	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	13	VESSEL	General Villa	21:37	21:43	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	13	VESSEL	General Villa	21:37	21:43	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	14	VESSEL	Kapitan Afansayev	21:50	22:04	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	14	VESSEL	Kapitan Afansayev	21:50	22:04	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	14	VESSEL	Kapitan Afansayev	21:50	22:04	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	15	VESSEL	TugCL3	22:20	22:34	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	15	VESSEL	TugCL3	22:20	22:34	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	15	VESSEL	TugCL3	22:20	22:34	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	16	VESSEL	Maersk Sun	22:57	22:58	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	16	VESSEL	Maersk Sun	22:57	22:58	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	16	VESSEL	Maersk Sun	22:57	22:58	3	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	17	VESSEL	Ken Shin	23:05	23:13	1	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	17	VESSEL	Ken Shin	23:05	23:13	2	0	0	0	0	0	0	0	0	0	0
County Line Park	24-Jun	17	VESSEL	Ken Shin	23:05	23:13	3	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	18	VESSEL	TugCL4	4:29	4:32	1	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	18	VESSEL	TugCL4	4:29	4:32	2	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	18	VESSEL	TugCL4	4:29	4:32	3	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	19	VESSEL	TugCL5	4:52	4:32	1	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	19	VESSEL	TugCL5	4:52	4:32	2	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	19	VESSEL	TugCL5	4:52	4:32	3	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	20	PRE	--	7:27	7:33	1	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	20	PRE	--	7:27	7:33	2	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	20	PRE	--	7:27	7:33	3	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	21	VESSEL	BargeCL2	7:47	7:52	1	0	0	0	0	0	0	0	0	0	0

Location	Date	Pass #	Pass Reason	Vessel	Start Time	End Time	Reach	Unclipped Chinook	Unknown Chinook	3-Spined Stickleback	Eastern Killfish	Common Carp	Yellow Perch	LM Bass	SM Bass	Sculpin	Peamouth
County Line Park	25-Jun	21	VESSEL	BargeCL2	7:47	7:52	2	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	21	VESSEL	BargeCL2	7:47	7:52	3	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	22	VESSEL	Ocean Duke	9:06	9:13	1	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	22	VESSEL	Ocean Duke	9:06	9:13	2	0	0	0	0	0	0	0	0	0	0
County Line Park	25-Jun	22	VESSEL	Ocean Duke	9:06	9:13	3	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	1	INITIAL	--	14:13	14:19	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	1	INITIAL	--	14:13	14:19	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	2	VESSEL	Hundai # 108	14:29	14:34	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	2	VESSEL	Hundai # 108	14:29	14:34	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	3	PRE	--	17:40	17:44	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	3	PRE	--	17:40	17:44	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	4	VESSEL	Liberty Spirit	17:58	18:05	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	4	VESSEL	Liberty Spirit	17:58	18:05	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	5	VESSEL	BargeS1	18:12	18:17	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	5	VESSEL	BargeS1	18:12	18:17	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	6	VESSEL	BargeS2	18:27	18:32	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	6	VESSEL	BargeS2	18:27	18:32	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	7	PRE	--	20:24	20:27	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	7	PRE	--	20:24	20:27	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	8	VESSEL	BargeS3	20:36	20:41	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	8	VESSEL	BargeS3	20:36	20:41	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	9	PRE	--	21:06	21:08	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	9	PRE	--	21:06	21:08	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	10	VESSEL	Star Kim	21:17	21:21	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	10	VESSEL	Star Kim	21:17	21:21	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	11	VESSEL	TugS1	21:37	21:42	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	1-Jul	11	VESSEL	TugS1	21:37	21:42	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	12	VESSEL	BargeS4	0:01	0:09	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	12	VESSEL	BargeS4	0:01	0:09	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	13	VESSEL	Rhein Bridge	3:08	3:25	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	13	VESSEL	Rhein Bridge	3:08	3:25	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	14	PRE	--	5:38	5:40	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	14	PRE	--	5:38	5:40	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	15	VESSEL	BargeS5	5:48	5:52	1	0	0	0	0	0	0	0	0	0	0

Location	Date	Pass #	Pass Reason	Vessel	Start Time	End Time	Reach	Unclipped Chinook	Unknown Chinook	3-Spined Stickleback	Eastern Killfish	Common Carp	Yellow Perch	LM Bass	SM Bass	Sculpin	Peamouth
Sauvie Island	2-Jul	15	VESSEL	BargeS5	5:48	5:52	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	16	PRE	--	7:26	7:29	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	16	PRE	--	7:26	7:29	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	17	VESSEL	Rubin Dragon	7:45	7:49	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Jul	17	VESSEL	Rubin Dragon	7:45	7:49	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	1	INITIAL	--	9:24	9:28	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	1	INITIAL	--	9:24	9:28	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	2	VESSEL	BargeBP1	9:50	9:55	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	2	VESSEL	BargeBP1	9:50	9:55	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	3	PRE	--	11:04	11:06	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	3	PRE	--	11:04	11:06	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	4	VESSEL	Green Lake	11:26	11:32	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	4	VESSEL	Green Lake	11:26	11:32	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	5	PRE	--	12:04	12:07	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	5	PRE	--	12:04	12:07	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	6	VESSEL	New Spirit	12:20	12:28	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	6	VESSEL	New Spirit	12:20	12:28	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	7	PRE	--	12:44	12:51	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	7	PRE	--	12:44	12:51	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	8	VESSEL	Christoforo Columbo	13:13	13:20	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	8	VESSEL	Christoforo Columbo	13:13	13:20	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	9	PRE	--	14:10	14:13	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	9	PRE	--	14:10	14:13	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	10	VESSEL	BargeBP2	14:23	14:28	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	10	VESSEL	BargeBP2	14:23	14:28	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	11	PRE	--	15:55	15:57	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	11	PRE	--	15:55	15:57	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	12	VESSEL	BargeBP3	16:06	16:10	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	12	VESSEL	BargeBP3	16:06	16:10	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	13	PRE	--	17:19	17:22	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	13	PRE	--	17:19	17:22	2	0	0	0	0	0	0	0	0	2	0
Barlow Point	5-Jul	14	VESSEL	Twinkle	17:34	17:39	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	14	VESSEL	Twinkle	17:34	17:39	2	0	0	0	0	0	0	0	0	0	0

Location	Date	Pass #	Pass Reason	Vessel	Start Time	End Time	Reach	Unclipped Chinook	Unknown Chinook	3-Spined Stickleback	Eastern Killfish	Common Carp	Yellow Perch	LM Bass	SM Bass	Sculpin	Peamouth
Barlow Point	5-Jul	15	PRE	--	18:27	18:31	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	15	PRE	--	18:27	18:31	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	16	VESSEL	Eternal Clipper	18:41	18:45	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	16	VESSEL	Eternal Clipper	18:41	18:45	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	17	PRE	--	20:41	20:47	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	17	PRE	--	20:41	20:47	2	0	0	1	0	0	0	0	0	0	0
Barlow Point	5-Jul	18	VESSEL	Petersfield	20:59	21:03	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	18	VESSEL	Petersfield	20:59	21:03	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	19	VESSEL	Perseveranc e	21:32	21:39	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	19	VESSEL	Perseveranc e	21:32	21:39	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	20	VESSEL	TugBP1	21:56	22:01	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	20	VESSEL	TugBP1	21:56	22:01	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	21	PRE	--	22:44	22:46	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	21	PRE	--	22:44	22:46	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	22	VESSEL	TugBP2	22:55	22:59	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	5-Jul	22	VESSEL	TugBP2	22:55	22:59	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	1	INITIAL	--	10:43	10:48	1	0	0	0	0	0	0	0	1	0	0
Barlow Point	29-Jul	1	INITIAL	--	10:43	10:48	2	0	0	3	0	0	0	0	0	0	0
Barlow Point	29-Jul	2	VESSEL	Galena Bay	10:59	11:08	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	2	VESSEL	Galena Bay	10:59	11:08	2	0	0	9	0	0	0	0	1	0	0
Barlow Point	29-Jul	3	PRE	--	12:42	12:49	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	3	PRE	--	12:42	12:49	2	0	0	2	0	0	0	0	0	0	0
Barlow Point	29-Jul	4	VESSEL	Mapel Ace II	12:57	13:10	1	0	0	2	0	0	0	0	0	0	0
Barlow Point	29-Jul	4	VESSEL	Mapel Ace II	12:57	13:10	2	0	0	3	0	0	0	0	0	0	0
Barlow Point	29-Jul	5	VESSEL	TugBP3	14:20	14:25	1	0	0	2	0	0	0	0	0	0	0
Barlow Point	29-Jul	5	VESSEL	TugBP3	14:20	14:25	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	6	VESSEL	Ace Century	14:38	14:42	1	0	0	2	0	0	0	0	0	0	0
Barlow Point	29-Jul	6	VESSEL	Ace Century	14:38	14:42	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	7	VESSEL	Sunny Success & BargeBP4	14:53	15:00	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	7	VESSEL	Sunny Success & BargeBP4	14:53	15:00	2	0	0	1	0	0	0	0	0	0	0
Barlow Point	29-Jul	8	VESSEL	Ocean Duke	15:19	15:25	1	0	0	1	0	0	0	0	0	0	0

Location	Date	Pass #	Pass Reason	Vessel	Start Time	End Time	Reach	Unclipped Chinook	Unknown Chinook	3-Spined Stickleback	Eastern Killfish	Common Carp	Yellow Perch	LM Bass	SM Bass	Sculpin	Peamouth
Barlow Point	29-Jul	8	VESSEL	Ocean Duke	15:19	15:25	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	9	VESSEL	Century Hwy. #1	15:53	16:13	1	0	0	5	0	5	3	0	4	0	2
Barlow Point	29-Jul	9	VESSEL	Century Hwy. #1	15:53	16:13	2	0	0	0	0	2	0	0	1	0	0
Barlow Point	29-Jul	10	VESSEL	Fulmar	17:07	17:17	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	10	VESSEL	Fulmar	17:07	17:17	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	11	VESSEL	Nena F	17:56	18:02	1	0	0	3	0	0	0	0	0	0	0
Barlow Point	29-Jul	11	VESSEL	Nena F	17:56	18:02	2	0	0	9	0	0	0	0	0	0	0
Barlow Point	29-Jul	12	PRE	--	18:39	18:43	1	0	0	1	0	0	0	0	0	0	0
Barlow Point	29-Jul	12	PRE	--	18:39	18:43	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	13	VESSEL	Chevron Colorado	18:56	19:02	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	13	VESSEL	Chevron Colorado	18:56	19:02	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	14	PRE	--	19:25	19:29	1	0	0	1	0	0	0	0	0	0	0
Barlow Point	29-Jul	14	PRE	--	19:25	19:29	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	15	VESSEL	BargeBP5	19:36	19:40	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	15	VESSEL	BargeBP5	19:36	19:40	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	16	PRE	--	20:03	20:05	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	16	PRE	--	20:03	20:05	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	17	VESSEL	Pactrader	20:13	20:18	1	0	0	0	0	0	0	0	1	0	0
Barlow Point	29-Jul	17	VESSEL	Pactrader	20:13	20:18	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	18	PRE	--	21:21	21:26	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	18	PRE	--	21:21	21:26	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	19	VESSEL	K + A	21:34	21:45	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	29-Jul	19	VESSEL	K + A	21:34	21:45	2	1	0	1	1	0	0	0	0	0	0
Barlow Point	30-Jul	20	VESSEL	Fairy Queen	3:44	4:10	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	30-Jul	20	VESSEL	Fairy Queen	3:44	4:10	2	10	0	50	3	2	0	0	0	3	0
Barlow Point	30-Jul	21	VESSEL	BargeBP6	4:24	4:34	1	0	0	0	0	0	0	0	0	1	0
Barlow Point	30-Jul	21	VESSEL	BargeBP6	4:24	4:34	2	1	0	0	0	0	0	0	0	0	0
Barlow Point	30-Jul	22	PRE	--	4:56	5:04	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	30-Jul	22	PRE	--	4:56	5:04	2	0	0	0	0	0	0	0	0	0	0
Barlow Point	30-Jul	23	VESSEL	New York Hwy. + Ansax & Serity	5:18	5:24	1	0	0	0	0	0	0	0	0	0	0
Barlow Point	30-Jul	23	VESSEL	New York Hwy. +	5:18	5:24	2	0	0	8	3	0	0	0	1	0	0

Location	Date	Pass #	Pass Reason	Vessel	Start Time	End Time	Reach	Unclipped Chinook	Unknown Chinook	3-Spined Stickleback	Eastern Killfish	Common Carp	Yellow Perch	LM Bass	SM Bass	Sculpin	Peamouth
				Ansax & Serity													
Sauvie Island	2-Aug	1	VESSEL	Blue Ridge	9:34	9:39	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	1	VESSEL	Blue Ridge	9:34	9:39	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	2	PRE	--	10:41	10:45	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	2	PRE	--	10:41	10:45	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	3	VESSEL	BargeS6	10:51	10:55	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	3	VESSEL	BargeS6	10:51	10:55	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	4	PRE	--	11:46	11:49	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	4	PRE	--	11:46	11:49	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	5	VESSEL	Ankora	11:54	11:56	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	5	VESSEL	Ankora	11:54	11:56	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	6	VESSEL	Green Lake	12:04	12:16	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	6	VESSEL	Green Lake	12:04	12:16	2	0	0	0	3	2	9	5	0	0	9
Sauvie Island	2-Aug	7	PRE	--	13:10	13:12	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	7	PRE	--	13:10	13:12	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	8	VESSEL	BargeS7	13:17	13:21	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	8	VESSEL	BargeS7	13:17	13:21	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	9	PRE	--	14:51	14:53	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	9	PRE	--	14:51	14:53	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	10	VESSEL	BargeS8	15:00	15:05	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	10	VESSEL	BargeS8	15:00	15:05	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	11	PRE	--	18:14	18:17	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	11	PRE	--	18:14	18:17	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	12	VESSEL	Lantau Queen	18:23	18:27	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	12	VESSEL	Lantau Queen	18:23	18:27	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	13	PRE	--	19:37	19:40	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	13	PRE	--	19:37	19:40	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	14	VESSEL	Ocean Rose	19:48	19:51	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	14	VESSEL	Ocean Rose	19:48	19:51	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	15	VESSEL	BargeS9	20:00	20:04	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	15	VESSEL	BargeS9	20:00	20:04	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	16	VESSEL	BargeS10	20:13	20:17	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	16	VESSEL	BargeS10	20:13	20:17	2	0	0	0	0	0	0	0	0	0	0

Location	Date	Pass #	Pass Reason	Vessel	Start Time	End Time	Reach	Unclipped Chinook	Unknown Chinook	3-Spined Stickleback	Eastern Killfish	Common Carp	Yellow Perch	LM Bass	SM Bass	Sculpin	Peamouth
Sauvie Island	2-Aug	17	PRE	--	21:30	21:33	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	17	PRE	--	21:30	21:33	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	18	VESSEL	TugS2	21:37	21:40	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	18	VESSEL	TugS2	21:37	21:40	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	19	VESSEL	Serifopoulo	23:22	23:26	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	2-Aug	19	VESSEL	Serifopoulo	23:22	23:26	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	3-Aug	20	VESSEL	Pan Hope	0:01	0:06	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	3-Aug	20	VESSEL	Pan Hope	0:01	0:06	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	3-Aug	21	VESSEL	BargeS11	0:15	0:21	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	3-Aug	21	VESSEL	BargeS11	0:15	0:21	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	3-Aug	22	VESSEL	Moldanger	1:20	1:27	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	3-Aug	22	VESSEL	Moldanger	1:20	1:27	2	0	0	0	0	0	0	0	0	0	0
Sauvie Island	3-Aug	23	VESSEL	Anangel Progress	3:29	3:38	1	0	0	0	0	0	0	0	0	0	0
Sauvie Island	3-Aug	23	VESSEL	Anangel Progress	3:29	3:38	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	1	INITIAL	--	11:50	11:54	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	1	INITIAL	--	11:50	11:54	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	1	INITIAL	--	11:50	11:54	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	2	VESSEL	Hyundai Admiral	12:06	12:13	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	2	VESSEL	Hyundai Admiral	12:06	12:13	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	2	VESSEL	Hyundai Admiral	12:06	12:13	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	3	PRE	--	14:31	14:35	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	3	PRE	--	14:31	14:35	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	3	PRE	--	14:31	14:35	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	4	VESSEL	Hyundai #103	14:44	14:50	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	4	VESSEL	Hyundai #103	14:44	14:50	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	4	VESSEL	Hyundai #103	14:44	14:50	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	5	PRE	--	15:14	15:20	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	5	PRE	--	15:14	15:20	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	5	PRE	--	15:14	15:20	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	6	VESSEL	TugCL6	15:27	15:30	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	6	VESSEL	TugCL6	15:27	15:30	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	6	VESSEL	TugCL6	15:27	15:30	3	0	0	0	0	0	0	0	0	0	0

Location	Date	Pass #	Pass Reason	Vessel	Start Time	End Time	Reach	Unclipped Chinook	Unknown Chinook	3-Spined Stickleback	Eastern Killfish	Common Carp	Yellow Perch	LM Bass	SM Bass	Sculpin	Peamouth
County Line Park	31-Jul	7	PRE	--	16:20	16:24	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	7	PRE	--	16:20	16:24	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	7	PRE	--	16:20	16:24	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	8	VESSEL	Maersk Sun	16:33	16:41	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	8	VESSEL	Maersk Sun	16:33	16:41	2	0	0	0	0	0	0	0	1	0	0
County Line Park	31-Jul	8	VESSEL	Maersk Sun	16:33	16:41	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	9	PRE	--	17:22	17:26	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	9	PRE	--	17:22	17:26	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	9	PRE	--	17:22	17:26	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	10	VESSEL	BargeCL3	17:35	17:38	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	10	VESSEL	BargeCL3	17:35	17:38	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	10	VESSEL	BargeCL3	17:35	17:38	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	11	PRE	--	18:53	18:57	1	0	0	1	0	0	0	0	0	0	0
County Line Park	31-Jul	11	PRE	--	18:53	18:57	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	11	PRE	--	18:53	18:57	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	12	VESSEL	Laurel Island & Pactrader	19:09	19:16	1	0	0	1	0	0	0	0	0	0	0
County Line Park	31-Jul	12	VESSEL	Laurel Island & Pactrader	19:09	19:16	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	12	VESSEL	Laurel Island & Pactrader	19:09	19:16	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	13	VESSEL	Pacific Ace & Cielo de Vancouver	20:59	21:08	1	1	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	13	VESSEL	Pacific Ace & Cielo de Vancouver	20:59	21:08	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	13	VESSEL	Pacific Ace & Cielo de Vancouver	20:59	21:08	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	14	PRE	--	22:19	22:19	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	14	PRE	--	22:19	22:19	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	14	PRE	--	22:19	22:19	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	15	VESSEL	BargeCL4	22:36	22:46	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	15	VESSEL	BargeCL4	22:36	22:46	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	15	VESSEL	BargeCL4	22:36	22:46	3	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	16	PRE	--	23:30	23:34	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	16	PRE	--	23:30	23:34	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	16	PRE	--	23:30	23:34	3	0	0	0	0	0	0	0	0	0	0

Location	Date	Pass #	Pass Reason	Vessel	Start Time	End Time	Reach	Unclipped Chinook	Unknown Chinook	3-Spined Stickleback	Eastern Killfish	Common Carp	Yellow Perch	LM Bass	SM Bass	Sculpin	Peamouth
County Line Park	31-Jul	17	VESSEL	TugCL7	23:42	23:48	1	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	17	VESSEL	TugCL7	23:42	23:48	2	0	0	0	0	0	0	0	0	0	0
County Line Park	31-Jul	17	VESSEL	TugCL7	23:42	23:48	3	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	18	PRE	--	0:45	0:49	1	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	18	PRE	--	0:45	0:49	2	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	18	PRE	--	0:45	0:49	3	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	19	VESSEL	BargeCL5	0:56	0:58	1	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	19	VESSEL	BargeCL5	0:56	0:58	2	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	19	VESSEL	BargeCL5	0:56	0:58	3	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	20	VESSEL	Hanjin Osaka	1:10	1:35	1	1	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	20	VESSEL	Hanjin Osaka	1:10	1:35	2	2	1	2	0	0	0	0	0	0	0
County Line Park	1-Aug	20	VESSEL	Hanjin Osaka	1:10	1:35	3	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	21	VESSEL	TugCL8	1:46	1:50	1	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	21	VESSEL	TugCL8	1:46	1:50	2	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	21	VESSEL	TugCL8	1:46	1:50	3	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	22	VESSEL	Serena	2:45	3:00	1	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	22	VESSEL	Serena	2:45	3:00	2	4	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	22	VESSEL	Serena	2:45	3:00	3	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	23	VESSEL	Seven Seas	3:05	3:10	1	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	23	VESSEL	Seven Seas	3:05	3:10	2	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	23	VESSEL	Seven Seas	3:05	3:10	3	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	24	VESSEL	Pactrader	3:30	3:36	1	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	24	VESSEL	Pactrader	3:30	3:36	2	0	0	0	0	0	0	0	0	0	0
County Line Park	1-Aug	24	VESSEL	Pactrader	3:30	3:36	3	0	0	0	0	0	0	0	0	0	0

EXHIBIT K-4
EVALUATION REPORT DUNGENESS CRABS (REVISED)

Table of Contents
Exhibit K-4
Evaluation Report
Dungeness Crab (Revised)

Evaluation Report
Dungeness Crab

This report provides information regarding the impacts of dredging and disposal on Dungeness crab (*Cancer magister*) from construction of the Channel Improvement Project. Attached are two reports, one from Pacific International (PI) Engineering on the review and evaluation of the existing information on dredging and disposal impacts to Dungeness crabs in the Columbia River (Attachment A). The second is a final report from Pacific Northwest National Laboratory's (PNNL's) Marine Sciences Laboratory on the entrainment of crabs by dredging in the lower Columbia River (Attachment B). This study evaluated entrainment rates of Dungeness crab at the lower river shoals that would be expected to have crab. The entrainment rates are then used to calculate the loss of crabs to the population and fishery. It also includes information developed by PNNL on a preliminary salinity model to predict crab distribution and abundance based on salinity values. The information needs and study requirements were developed by a working group of Oregon and Washington State agencies, NOAA Fisheries, the Corps and the sponsor Ports. This group has reviewed the preliminary results of these studies and their comments were incorporated where appropriate. The results from these studies will be used to confirm projected impacts and schedule dredging to minimize impacts to crabs.

Direct measurements of crab entrainment rates were collected at three locations, in the lower Columbia River [Desdomona Shoals (CRM4.6-10), Upper Sands (CRM 13.6-17.5), and Miller Sands (21.4-25.2)] during the summer of 2002. These shoals spanned the range where Dungeness crab could occur in the project area. Entrainment rates for all age classes of crabs ranged from zero at Miller Sands to 0.224 crabs per cubic yard (cy) at Desdemona Shoals in June 2002. The overall average entrainment rate at Desdemona Shoals in September was 0.120 crabs per cy. A modified Dredge Impact Model (DIM) used the summer 2002 direct entrainment rates to project adult equivalent loss to the population and loss to the fishery for the Channel Improvement Project. Crab adult equivalent loss at age 2+ for project construction ranges from a worst case of 281,528 crabs to a best case of 38,811 crabs (of these amounts the increment associated with Channel Improvement is 166,888 crabs and 18,039 crabs). This translates to a loss to the fishery of between 44,342 and 7,252 crabs (the increment associated with Channel Improvement is 26,285 crabs and 3,347 crabs). This loss to the fishery compares to annual landings of 5.3 million crabs in the Washington and Oregon region around the Columbia River. To improve these projections, entrainment data from Flavel Bar is needed, since it represents a middle point in the distribution of crabs.

Crab losses from maintenance dredging for the 40-foot channel maintenance (no action alternative) and the 43-foot alternative maintenance (proposed project) were estimated for year one and year 20. Year one was selected because it was anticipated to have the largest dredging volume. Year 20 was selected because it represents a reasonable planning horizon for dredged material management planning. Additionally, 20 years represents a point in time beyond which dredging volumes will be considered constant. Projected adult equivalent loss in "no action" maintenance years 1 and 20 are 44,643 and 25,503 crabs, respectively. Projected loss to the fishery in "no action" maintenance years one and 20 are 7,031 and 4,017 crabs, respectively. Projected adult equivalent loss for maintenance of the 43-foot project (including quantities from the 40-foot as well as additional increment due to the 43-foot project) in years one and 20 are

56,840 and 25,612 crabs, respectively (the increment associated with channel improvement project is 12,197 crabs and 109 crabs). Projected loss to the fishery for maintenance of the project in years 1 and 20 are 8,953 and 4,035 crabs, respectively (the increment associated with channel improvement project is 1,922 crabs and 18 crabs). In other words, by maintenance year 20 or sooner, entrainment associated with the channel improvement project is effectively equal to that of the No Action Alternative.

The literature, analyses of salinity intrusion scenarios, and the summer 2002 site-specific data on entrainment and salinity, all indicate that bottom salinity influences crab distribution and entrainment, especially at lower salinity. It is now clear from field measurements of entrainment rates and salinity during a period of low river flow (90-150 Kcfs) and high salinity intrusion that entrainment rates are zero where bottom salinity is less than 16 o/oo most of the time. Further, entrainment rates of 2+ and older crab fall with decreasing salinity in a clear and consistent manner. More elaboration of the crab distribution - salinity model, especially concerning salinity and the movements of 1+ crab, is needed to make final recommendations on dredge timing to minimize impacts. It is anticipated that additional entrainment data will be collected at Flavel Shoal as well as potentially the other shoals in the summer of 2003 depending on availability of funds.

Based on the Corps' earlier analysis in the Final Integrated Feasibility Report for channel improvements and Environmental Impact Statement (1999 Final IFR/EIS), the attached PI Engineering report, and the attached PNNL report, it is anticipated that this impact will not have any significant affect on population structure or dynamics. Other factors such as, ocean climate conditions and natural population cycles have a far greater effect on the crab population levels. The Corps will use the salinity-abundance model to schedule dredging and disposal to further avoid and minimize impacts to crab.

ATTACHMENT A

PACIFIC INTERNATIONAL ENGINEERING PLLC

Report for the Final Supplemental Environmental Impact Statement

The Impacts of the Columbia River Channel Improvement Project Dredging and Disposal on Dungeness Crabs (*Cancer magister*)

1. Introduction

The U.S. Army Corps of Engineers (Corps) and six lower Columbia River ports (Portland, St. Helens, Longview, Kalama, Woodland and Vancouver) propose to deepen the authorized 40-foot deep channel to a depth of 43 feet. This action would result in the dredging (with a hopper or pipeline dredge) of sections along the navigation channel in the Columbia River from Columbia River Mile (CRM) 106.5 to CRM 3.0. The Corps analyzed the impacts of deepening in the Final Integrated Feasibility Report for channel improvements and Environmental Impact Statement (1999 Final IFR/EIS) for the Columbia and Lower Willamette Rivers Navigation Channel, Oregon and Washington (Corps 1999).

This report provides information regarding the impacts of dredging and disposal to Dungeness crabs (*Cancer magister*) that has been developed since the 1999 Final IFR/EIS (Corps 1999) and the Draft Supplemental Environmental Impact Statement (Draft SEIS) (Corps 2002) were released. Additional analyses and efforts were made based on methods discussed amongst a working group of State agencies, the Corps and the sponsor Ports. This report covers the progress made in analyzing data and assessing impacts to crabs. This report is to be accompanied by a final report from Pacific Northwest National Laboratory's (PNNL's) Marine Sciences Laboratory (Pearson et al. 2002), describing results from direct sampling of entrainment and the development of a salinity versus crab abundance model..

2. Background of Dredge Impacts Analyses

In order to analyze effects of dredging on crabs in the lower Columbia River, several separate, yet coordinated, efforts were made to understand the effects of entrainment on crab in the channel. This section of the report discusses briefly the analyses made that were described in detail in the Draft SEIS technical memorandum (Corps 2002). Because one particular method (the direct sampling in conjunction with the habitat-based approach) has proven to be most accurate thus far, it is the focus of additional discussion in the new PNNL report (Pearson et al. 2002) that accompanies this report.

2.1 Dredge Impact Model Applied to Previously Collected Data

The first approach at understanding impacts to crabs involved using an existing model (the Dredge Impact Model, or DIM) to calculate crab entrainment and immediate loss resulting from dredging in the Columbia River navigation channel. The model (Wainwright et al. 1992) was applied to density data from previous studies in the Columbia River (McCabe et al. 1986) to predict the rates of entrainment and immediate loss due to dredging in five areas between CRM 6 and CRM 25 of Reach 7 (Reach 7 extends from CRM 3 to CRM 29). The DIM was specifically developed to measure the entrainment effects of dredging on Dungeness crab in Grays Harbor, Washington (Armstrong et al. 1987; Wainwright et al. 1992). It has been an effective tool for that area, and is utilized extensively by the Corps Seattle District. Specifically, Pacific International (PI) Engineering used the Wainwright et al. (1992) version of the DIM (rather than Armstrong et al. 1987) for this analysis, as this version has been adjusted for more recent data and it is the DIM currently used by the Corps Seattle District. Therefore, this version of the DIM was applied to data from Reach 7 of the Columbia River navigation channel in order to estimate crab entrainment and immediate loss (Please see the technical memorandum from the Draft SEIS for the results of this effort [Corps 2002]). However, because the Corps Portland District, PI Engineering and WDFW were concerned that the entrainment rates in the Grays Harbor DIM were not fully appropriate for the Columbia River, and that the density data previously collected in the channel (McCabe et al. 1986) were not collected in a manner that was compatible with the DIM, another method of determining effects to crabs was initiated.

Data from the demonstration project reported in the Draft SEIS has been superceded by the direct entrainment sampling reported in Section 2.2 below and the attached PNNL report (Attachment B).

2.2 Direct Entrainment Sampling

As a result of the uncertainties with using the DIM model with the early McCabe et al (1986) data, it was decided by the interagency group that direct measurements of entrainment with a more statistically rigorous design were needed to assess crab losses. PNNL's Marine Sciences Laboratory was contracted by the Corps to design a sampling schedule and to collect additional data on crab entrainment using the Corps dredge *Essayons*. Data were collected in June, September and October 2002 (after the release of the Draft SEIS and technical memoranda), and these data are now considered the most accurate. The PNNL report, (Attachment B, discusses these data in regards to effects of dredging on crabs in the lower Columbia River.

3. Disposal

3.1 Introduction and Description

Construction of the entire Columbia River Channel Improvement Project entails disposal of 19 million cubic yards (mcy) of dredged material at a combination of upland, shoreline, and ecosystem restoration sites (14.5 mcy resulting from channel improvement and 4.5 mcy from Operations & Maintenance [O&M] dredging of the existing 40-ft channel). However, most of this material would not be disposed of in areas that are inhabited by Dungeness crab. One shoreline site and two ecosystem restoration sites within Reach 7 would be used for disposal, but they are all located above CRM 18 (see the Draft SEIS technical memorandum for more details on these areas [Corps 2002]). Based on the habitat information presented in the PNNL report (Pearson et al. 2002), disposal at these areas is not expected to contribute to crab loss.

Flowlane disposal associated with channel maintenance would occur between CRM 3 and CRM 18. The 43-ft project would add approximately 0.7 mcy to the 6.9 mcy of maintenance disposal expected from the 40-ft channel between CRM 3-5. There would also be approximately 0.1 mcy/yr of incremental maintenance material (2 mcy total over 20 years) from the 43-ft project disposed of between CRM 13-18 This would be in addition to the 1 mcy of maintenance material from the 40-ft channel expected during the 20-year project life. Since the flowlane disposal area between CRM 3-5 provides suitable crab habitat, it is likely that there will be some impact to individual crabs from this disposal. The flowlane disposal areas between CRM 13-18 provide no or only marginal crab habitat; therefore, disposal impacts to crabs at these sites are not expected.

The Corps' preferred option for ocean disposal involves no disposal of construction dredge material at the deep-water ocean disposal site (DWS), as well as no disposal of Incremental Maintenance (IM) dredge material at the DWS for the life of the project. Rather, the Corps would beneficially use the material for the creation of the ecosystem restoration sites instead of exclusively using the DWS. If the ecosystem restoration projects do not occur, then some material would be disposed of at the DWS. In this case, the maximum volume of construction material that would be placed at the DWS if it became necessary is 6 mcy. Subsequent maintenance dredging over the projected 20 years is predicted to yield approximately 6 mcy of dredged material, which may be disposed of at the DWS. No dredged material generated by the project is planned for disposal at "Site E."

A hopper dredge would be used for disposing dredged material to the flowlane disposal sites and if necessary to the DWS. It would also be used for conveying material to the sumps to be used in construction of the ecosystem restoration sites. Hydraulic pipeline would be used for creating the shoreline sites and other ecosystem restoration sites.

Disposal of dredged material at the flowlane disposal sites and the DWS from the Columbia River Channel Improvement Project has the potential to impact Dungeness crab and other biological resources by direct or indirect mechanisms. Potential impact mechanisms include burial, turbidity, dissolved oxygen (DO) reduction, and habitat alterations. Those mechanisms that are concluded to be pertinent for the Columbia River Channel Improvement Project were thoroughly evaluated relative to the potential for impacts at the DWS and general upriver areas that may support crabs in the 1999 Final IFR/EIS for this project (Corps 1999). Because the shoreline sites and ecosystem restoration sites are located upstream of significant crab distribution, no further discussion of crab losses related to these sites will be presented in this report. Only effects to the flowlane disposal sites and the DWS are discussed below.

3.2 Direct Impacts of Disposal

The loss of crabs at a disposal site is most likely related to the abundance of crabs, their level of activity, and the rate of delivery of the dredged material. Based on the information in the 1999 Final IFR/EIS (Corps 1999), crabs that cannot dig out of the material as it settles could suffer mortality. However, the deeper the water in which material is being disposed, the shallower the depth of material that would cover the bottom of the disposal site.

Crabs could be lost or injured during disposal within the flowlane due to burial; however, potential burial is likely only an issue at the one flowlane disposal site between CRM 3-5, as crabs are not expected to occur at the two sites between CRM 13-18. Although crabs would be buried by sediments during disposal, strong currents and flow within the flowlane may disperse the material and decrease the potential for death to the crabs due to burial.

The potential for losses of crab at the DWS, due to burial, is related to how the deposited material settles to the bottom. Based on the depth of the site, the barge would be located approximately 200-300 ft above the ocean floor. After release from the hopper, dredged material falls through the water column, convects/diffuses laterally, and eventually rests on the seafloor. The disposal footprint depends upon vessel speed, water depth, currents, and ambient bathymetry. The currents, speed of the vessel, and the water depth would determine whether the material settles compactly or diffusely on the ocean bottom. A model based on typical mouth of the Columbia River (MCR) conditions estimated that the time required for sand to completely settle out of the water column is approximately 200 seconds (3.3 minutes) at the DWS (Corps 1999). Overall, the conditions at the DWS are very conducive to deposition of material over a relatively wide area, at a thin enough layer, and over a long enough period so that crabs of all size classes would have an opportunity to escape from the deposited material. The potential for burial and ultimately mortality of crabs at the DWS is considered fairly low.

Crab distribution and abundance data have recently been taken at the DWS as part of the baseline survey for the site. This information is still being analyzed, but some preliminary results are discussed in Section 5.

The total area potentially affected by flowlane and ocean disposal is very small relative to total available crab habitat in the Columbia River estuary and near shore ocean area.

4. Indirect Impacts of Dredging and Disposal

4.1 Introduction

Numerous physical attributes of and processes in the estuary and lower river have the potential to affect Dungeness crab. These include salinity, temperature, turbidity, suspended sediment, bathymetry and hydrodynamics. Changes in these physical attributes and processes can directly affect crab, and can also indirectly affect crab by affecting their habitat. Extensive analyses of the physical attributes and processes in the estuary and lower river have been conducted through the ESA consultation and NEPA/SEPA review for the channel improvement project. These analyses include the efforts of the independent SEI scientific review panel, as well as the substantial subsequent efforts of the consultation biological review team, consisting of biologists and other resource specialists from the Corps, NOAA Fisheries and the US Fish and Wildlife Service. Their efforts are reflected in the Project's Biological Assessment (January, 2002) and Biological Opinions (May, 2002).[1] In addition, the Corps built upon the analysis conducted through the consultation process as the foundation for the NEPA/SEPA review in the Project's Supplemental EIS.

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[1] The rigorous reconsultation analyzed and resolved all of the concerns NMFS initially raised in August 2000 when it withdrew the first Biological Opinion, including those regarding the potential impact of project-related physical changes in the estuary on ecological conditions which Ecology had noted as a significant basis for denial of 401 certification (*see* "Reason One" in Ecology's 9/9/00 denial letter).

Much of the analysis in the early stages of the ESA consultation (i.e., the SEI scientific review process) was done with an eye toward effects on ESA-listed species (i.e., development of the ESA conceptual model).[2] Nevertheless, the resulting analysis of physical attributes and processes that was necessary input to the ESA conceptual model is directly relevant to an assessment of the project's potential effects on Dungeness crab because the same attributes and processes that have the potential to affect fish have the potential to affect crab. Accordingly, potential changes in salinity, temperature, turbidity, suspended sediment, bathymetry and hydrodynamics, which have all been identified as having the potential to affect crab, were all analyzed in the ESA consultation, as were other indicators relevant to crab such as nutrient and detrital transport and near shore habitat primary productivity. This analysis of effects on crab therefore directly benefits from the work that has been done to date for the ESA consultation and NEPA/SEPA review.

Potential effects on crab habitat include disturbance from dredging, disposal and ecosystem restoration activities. However, as discussed in Section 3.1, other than the estuarine flowlane disposal areas and the DWS, none of the disposal or ecosystem restoration areas are significantly inhabited (if at all) by Dungeness crab (i.e., the areas downstream of CRM 18). Accordingly, the only potential direct effects to crab habitat are from dredging the channel in the estuary, and from use of the estuarine flowlane disposal areas (located between CRM 3 and 18) and the DWS, which is not expected to be used at all if the ecosystem restoration features are constructed. Indirect effects on Dungeness crab resulting from both dredging and disposal are described below in Sections 4.2 and 4.3.

4.2 Indirect Effects of Dredging

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[2] As discussed above, much of the conceptual model developed for the reconsultation process is relevant for understanding potential impacts to non-ESA listed species and their habitat. For example, the model's links between physical/chemical indicators and many biological indicators provide information regarding basic ecosystem functions that are relevant to listed and non-listed species alike. As Table S6-1 of the SEIS indicates, the model provides basic information regarding:

- Habitat-forming Processes (suspended sediment, bedload, woody debris, turbidity, salinity, accretion/erosion, bathymetry);
- Habitat Types (tidal marsh and swamp, shallow water and flats, water column);
- Habitat Primary Productivity (light, nutrients, imported and resident phytoplankton production, benthic algae production, tidal marsh and swamp production); and
- Food Web (deposit feeders, mobile macroinvertebrates, insects, suspension/deposit feeders, tidal marsh macrodetritus, resident microdetritus).

For example, if someone was interested in understanding the project's effects on tidal marsh and swamp, they could use the portion of the model that addresses habitat types. Similarly, a question regarding deposit feeders, mobile macroinvertebrates or insects could be answered by reviewing the model's discussion of those indicators. Because the model was developed to review impacts to salmon, there may be some components of the ecosystem that the model does not address; however, the model provides the best available information regarding the lower Columbia River ecosystem and potential effects of the project.

Dredging would disturb the riverbed within the channel, and increase its depth by 3 feet. The channel of the Columbia River is quite dynamic compared to habitats on the margins of the River that are characterized by higher deposition rates and finer substrate. Long-period sand waves occur on the riverbed in the navigation channel, and they migrate downstream as sand is transported by the river flow. This migration of material downstream yields a benthic environment that is constantly disturbed by natural processes. A short-term change in the characteristics of the benthic communities can be expected in dredged areas in the estuary; however, these organisms are expected to recolonize the dredged areas and the habitat is expected to recover quickly (Richardson et al. 1977, Van Dolah et al. 1984 and McCabe et al. 1996, as cited in Nightingale and Simenstad 2001; also see Sections 6.1.17, 6.1.20 and 6.2.4 of Biological Assessment). In addition, sand waves are expected to re-form within dredged areas of the channel shortly after construction of the improvement project (within a period of weeks to months), thereby quickly returning the substrate (i.e., grain size, sorting and compaction) of channel-area habitat to pre-construction conditions. Accordingly, any indirect effect to crab from this immediate riverbed disturbance should be minimal. Such effects would also be similar to the effects from annual O&M dredging (the No Action Alternative).

Other potential indirect effects on crab habitat include potential ecosystem changes resulting from any anticipated changes in turbidity, suspended sediment, turbidity, salinity, temperature, bathymetry and hydrodynamics. Such effects on crab habitat, if any, are expected to be minimal because the analysis of the projected changes to these physical parameters shows minimal if any change as a result of channel improvement. The analysis of these physical indicators is summarized in Table 1, which provides citations to the relevant sections of the Biological Assessment and the Supplemental EIS.

Indicator / physical attribute or process	Historic and Existing Conditions (BA Sections)	Anticipated Effect from Channel Improvement (BA & SEIS Sections)	Summary
Suspended Sediment	2.2.1.1 2.3.1.1	6.1.1 (BA) 6.2.2.1 (SEIS)	• Suspended sediment transport historically had high natural variability • Flow regulation has reduced variability somewhat and has reduced annual transport • Concentration is a function of flow rate and also has high variability • Project is not expected to change volume or rate of suspended sediment transport • Some temporary increases to suspended sediment concentration may occur in vicinity of dredging and disposal activities • Temporary increases are generally small compared to background levels and are all well within range of natural variability
Turbidity / Turbidity Maximum	2.2.1.4 2.3.1.4	6.1.4 (BA) 6.3 (SEIS)	• Like suspended sediment, turbidity levels vary with flow levels and have relatively high level of natural variability • Similarly, flow regulation has reduced natural variability in turbidity • Estuarine Turbidity Maximum (ETM) has been observed in both north and south channels • ETMs shift up to 9 miles each day with tides and river discharge, and have been observed between River Miles (CRM) 5 and 20 • Project is not expected to result in observable increases in turbidity in areas where neither dredging nor disposal is occurring • In areas where dredging and disposal are occurring, temporary localized increases in turbidity are expected to occur • Temporary localized increases are generally small and are not likely to produce detectable effects on plant growth • Project may result in some upstream shift in ETMs (up to 1 mile) due to changes in salinity intrusion, but anticipated shift is much less than daily fluctuation caused by tidal cycle
Salinity	2.2.1.5 2.3.1.5	6.1.5 (BA) 6.2.2.3 (SEIS)	• Salinity intrusion into estuary varies with channel depth, strength of tides and river flows • Salinity intrusion likely had high historic seasonal variability given higher historic variability in flows • Seasonal variability has likely been reduced by flow regulation

			• Salinity intrusion is driven by tidal forcing processes that also drive location of ETM • Modeling results predict minor increases in salinity due to deepening navigation channel (up to 0.5 ppt in shallow embayments, and up to 5 ppt in the channel itself) • Predicted embayment changes are much smaller than natural temporal variations due to normal variations in freshwater flow and tidal dynamics
TEMPERATURE	2.2.6.5 2.3.6.5	6.1.35 (BA) 6.3 (SEIS)	• River temperature varies depending on flow, season and climate conditions • Historic temperatures in the mainstem in the estuary were likely cooler than today due to numerous factors, including: slowed river flow, reduced riparian canopy, agricultural runoff, and industrial discharges • Primary factor potentially affecting temperature in the estuary after project construction would be increased intrusion of cooler ocean water, which would result in reducing, rather than increasing temperatures in the estuary • However, given the negligible projected change in salinity after construction, a change in temperature is not anticipated
BATHYMETRY / HYDRO-DYNAMICS	2.2.1.7 2.2.5.2 2.3.1.7 2.3.5.2	6.1.7 6.1.26 (BA) 6.2.2.1 6.2.2.2 6.2.2.4 (SEIS)	• Flow regulation has reduced the overall flow volume and velocity as well as historic natural variability in velocities • No dredging (and therefore no change in bathymetry) proposed for approximately 55% of the channel in the estuary • Models predict insignificant changes in velocity from deepening (from –0.2 to 0.2 ft/sec in the channel and from –0.05 to 0.05 ft/sec in the shallow regions outside the channel), which are much smaller than natural variation • Models also predict minimal changes in surface water elevation from deepening (from –0.02 to +0.02 foot in the estuary), again, much lower than natural variation • Slight predicted changes in river hydraulics/hydrodynamics are too small to affect sand transport or accretion/erosion in the estuary
NUTRIENT / DETRITAL TRANSPORT & NEARSHORE HABITAT PRIMARY PRODUCTIVITY	2.2.3 2.3.3	6.1.5.2 6.1.11 – 6.1.16 (BA) 6.7.1.1 (SEIS)	• Relative to historic conditions, primary productivity in the estuary has shifted from a marsh-based macrodetrital food web to a microdetrital food web • The effect of potential shift in location of ETM after construction on distribution of nutrients in the estuary is expected to be immeasurably small • No changes to primary productivity are anticipated as a result of the project

4.3 Indirect Effects of Disposal

Disposal in the flowlane areas would disturb the riverbed habitat within the channel. As with disturbances to the benthic environment caused by dredging (Section 4.2), the riverbed and the benthic organisms present there are expected to recover from the disturbance of disposal relatively quickly (Richardson et al. 1977, Van Dolah et al. 1984 and McCabe et al. 1996, as cited in Nightingale and Simenstad 2001; also see Sections 6.1.17, 6.1.20 and 6.2.4 of Biological Assessment). Any potential impact to crab habitat resulting from these disturbances is expected to be limited to the flowlane disposal area likely inhabited by crab at CRM 3-5. Furthermore, similar impacts currently occur from annual flowlane disposal (the No Action Alternative). Therefore, any indirect effect to habitat is expected to be minimal.

The benthic habitat at the DWS is not subjected to high wave and current action. This results in a fine-grained substrate and a stable environment as compared to inshore environments. The stability of the area likely promotes a higher diversity of benthic species with greater densities as compared to the inshore benthic community (Corps 1999). The inshore community, adapted to a higher-energy environment, generally comprises colonizing species, tube dwellers, and rapid burrowers. Both communities tend to show high inter- and intra-annual variability in community structure (Corps 1999).

Disposal of dredged material at the DWS would yield a small increase in the mean grain size of the substrate, which may lead to changes in the benthic community. However, after ocean disposal in June 1989, Hinton et al. (1992, as cited in Nightingale and Simenstad 2001) found there to be an increase in benthos densities when measured in June 1990. Although a slight decrease in productivity was assumed to be probable during disposal and shortly after, successful recolonization had occurred by June 1990. Therefore, the habitat alteration is expected to have essentially no adverse impact on crab populations in the area because the deposited material falls within the range of material that is suitable for this species and the prey they consume.

5. Assessment of Impact

Overall, dredging would occur in areas where the adult equivalent loss to the crab population and loss to the fishery is expected to be low (based on the 2002 studies). The results of the 2002 studies and further elaboration of the crab-salinity model will be used to evaluate and schedule dredging to minimize impacts to crabs.

An analysis of anticipated changes, if any, in physical attributes and processes in the estuary and lower river indicates that the channel improvement project's indirect effects on Dungeness crab (i.e., its effects on crab habitat and prey) will be minimal. Information on individual physical indicators is summarized in Table 1. A more complete presentation of this information can be found in the sections of the Biological Assessment and Supplemental EIS noted in the table.

The volume of disposal material from construction would be placed in areas that have no or few crabs. No material will be disposed in the DWS if the ecosystem restoration sites are used for disposal of material (as preferred).

The Corps' plan for addressing crab impacts has been to focus on avoiding impacts to crab through site selection. The DWS was selected following a detailed screening process. The Corps has been able to further avoid potential impacts that could have occurred at the DWS under its preferred alternative, which beneficially uses sand that originally would have gone to the DWS during construction for ecosystem restoration projects added during consultation under the Endangered Species Act (ESA). This change to the Project reduces the volume of disposal at the DWS from 6.2 to 0 mcy of construction material, and eliminates disposal of O&M material to the DWS.

MEC Analytical Services, under contract to the Corps, has further investigated the distribution and abundance of crabs and benthic organisms at the DWS. The study began in summer 2002; the data are currently being analyzed, and will likely be reported in spring 2003. Preliminary results indicate that there were more crabs found at the DWS in late summer than in early summer, by an approximate factor of 10. Additionally, the crabs were larger and softer in late summer than they were in early summer. The final results from this study will be used to verify the conclusions of this report with regard to the potential for impacts to crab due to disposal of dredged material at the DWS. Further, such data will serve as a basis for considering measures to minimize impacts to crabs in the event that the study yields conclusions of high crab populations seasonally.

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ABSTRACT

The studies reported here focus on issues regarding the entrainment of Dungeness crab related to the proposed Columbia River Channel Improvement Project and provide direct measurements of crab entrainment rates at three locations (Desdemona Shoals, Upper Sands, and Miller Sands) from RM4 to RM24 during summer 2002. Entrainment rates of all crab age classes ranged from zero at Miller Sands to 0.224 crabs per cy at Desdemona Shoals in June 2002. The overall entrainment rate at Desdemona Shoals in September was 0.120 crabs per cy. A modified Dredge Impact Model used the summer 2002 entrainment rates to project crab entrainment, adult equivalent loss, and loss to the fishery for the Channel Improvement Project. For construction dredging, estimates of overall adult equivalent loss at age 2+ range from 38,811 to 281,528 crabs. Also for construction dredging, overall losses to the fishery range from 7,252 to 44,342 crabs. For annual maintenance dredging under the Proposed Plan (43' Channel), estimates of adult equivalent loss at age 2+ range from 56,840 crabs in Year 1 to 25,612 crabs in Year 20. Also for maintenance dredging under the Proposed Plan, estimated losses to the fishery range from 8,953 to 4,035 crabs in Year 1 and 20, respectively. The worst-case projected fishery losses represent approximately 1% of the annual crab landings for the Washington and Oregon region around the Columbia River (5.3 million crabs from 1991 to 2001). To improve the projections, entrainment data from Flavel Bar and Tongue Point are needed. Similiarly, additional sampling days at each upriver location would narrow confidence limits associated with entrainment projections. The literature, analyses of salinity intrusion scenarios, and the summer 2002 site-specific data on entrainment and salinity all indicate that bottom salinity influences crab distribution and entrainment, especially at lower salinities. It is now clear from field measurements of salinity during a period of low river flow (90-150 Kcfs) and high salinity intrusion that entrainment rates are zero where bottom salinity is less than 16 o/oo most of the time. Further, entrainment rates of age 2+ and older crab decline in a clear and consistent manner as salinity decreases. More elaboration of the crab distribution- salinity model is needed, especially concerning salinity and the movements of age 1+ crab.

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EXECUTIVE SUMMARY

Proposed dredging during the Columbia River Channel Improvement Project has raised concerns about dredging-related impacts on Dungeness crab in the Columbia River Estuary. The Portland District of the U.S. Army Corps of Engineers engaged the Marine Sciences Laboratory of the U.S. Department of Energy's Pacific Northwest National Laboratory to review the state of knowledge and conduct studies concerning dredging-related impacts from entrainment on Dungeness crab from the Columbia River Channel Improvement Project. The studies accomplished three tasks regarding the entrainment of Dungeness crab related to the proposed Channel Improvement Project. The first task provided direct measurements of crab entrainment rates at three locations (Desdemona Shoals, Upper Sands, and Miller Sands) from RM4 to RM24 during summer 2002. The second task used the summer 2002 entrainment data and a modified Dredge Impact Model to project crab entrainment, adult equivalent loss, and loss to the fishery from planned dredging. The third assessed the influence of salinity on crab distribution and entrainment.

Entrainment rates for all age classes of crabs ranged from zero at Miller Sands to 0.224 crabs per cy at Desdemona Shoals in June 2002. The overall entrainment rate at Desdemona Shoals in September was 0.120 crabs per cy.

A modified Dredge Impact Model used the summer 2002 entrainment rates to project crab entrainment, adult equivalent loss, AEL and loss to the fishery associated with construction and maintenance dredging. For construction dredging, estimates of overall AEL at 2+ range from 38,811 to 281,528 crabs. Also for construction dredging, overall losses to the fishery range from 7,252 to 44,342 crabs. For annual maintenance dredging under the Proposed Plan (43' Channel), estimates of adult equivalent loss at age 2+ range from 56,840 crabs in Year 1 to 25,612 crabs in Year 20. Also for maintenance dredging under the Proposed Plan, estimated losses to the fishery range from 8,953 to 4,035 crabs in Year 1 and 20, respectively. The worst-case projected fishery losses represent approximately 1% of the annual crab landings for the Washington and Oregon region around the Columbia River (5.3 million crabs from 1991 to 2001). To improve the projections, entrainment data from Flavel Bar and Tongue Point are needed. Additional sampling days at each upriver location would also narrow confidence limits associated with entrainment projections.

The scientific literature, analyses of salinity intrusion scenarios, and the summer 2002 site-specific data on entrainment and salinity all indicate that bottom salinity influences crab distribution and entrainment, especially at lower salinities. It is now clear from field measurements of entrainment rates and salinity during a period of low river flow (90-150 Kcfs) and high salinity intrusion that entrainment rates are zero where bottom salinity is less than 16 o/oo most of the time. Further, entrainment rates for 2+ and older crab decline in a clear and consistent manner as salinity decreases. More elaboration of the crab distribution- salinity model is needed, especially concerning salinity and the movements of 1+ crab.

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CONTENTS

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FIGURES

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TABLES

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1.0 INTRODUCTION

Proposed dredging of the Columbia River has raised concerns about dredging-related impacts on Dungeness crab in the Columbia River Estuary (CRE). The Portland District of the U.S. Army Corps of Engineers (Corps) engaged the Marine Sciences Laboratory (MSL) of the U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL) to review the state of knowledge and conduct studies concerning dredging-related impacts from entrainment on Dungeness crab from the Columbia River Channel Improvement Project. Previously, MSL performed crab studies for the Corps Seattle District during that district's Grays Harbor Navigation Improvement Project (e.g., Pearson 1987, Pearson and Woodruff 1987, Pearson et al. 1987). This document focuses on issues regarding the entrainment of Dungeness crab related to the proposed Columbia River Channel Improvement Project and presents results of field studies conducted from River Mile 3 (RM3) to RM24. A separate report will describe field studies of crab entrainment during 2002 dredging at the Mouth of the Columbia River (MCR).

This document first presents a general background on Dungeness crab biology, the influence of salinity on crab distribution, and the use of a modified Dredge Impact Model (DIM) to estimate entrainment impacts to Dungeness crab for the Columbia River Channel Improvement Project. The document then presents the methods and results from three tasks. The first task was to conduct field studies during the spring and summer of 2002 aboard the Corps' Dredge *Essayons* to measure crab entrainment rates in some of the areas to be dredged during the proposed project. The second task was to use the 2002 data to estimate crab entrainment impacts for the dredging planned for the Channel Improvement Project. The third task was to postulate scenarios of different salinity regimes and assess their potential influence on crab distribution. The document concludes with a discussion of the results of the three tasks.

1.1 Biology of Dungeness Crab

Dungeness crabs use both the nearshore ocean environment and the estuary in their life cycle (Tasto 1983, Armstrong et al. 1987, Rooper et al. 2002). Adult female crabs extrude fertilized eggs in the fall and carry the extruded eggs until hatching in the ocean in late winter. After a 4 to 5 month larval period, the megalopae, the last larval stage, settle to the bottom to become the first crab instar stage (Young of the Year or YOY). In the spring, large numbers of YOY enter the estuaries of the West Coast as late megalopae and perhaps as first true crab. YOY (age 0+) crabs in the estuary grow faster than those in the ocean. Juvenile crabs (age 1+) found in the estuary derive either from 0+ crabs that over-wintered in the estuary or from 1+ crabs entering the estuary in the summer. To gain perspective, an understanding of the ways in which Dungeness crab use the estuary and how that use may or may not expose them to dredging activity is needed. In spring and summer, 0+ crabs can be found in the Mouth of the Columbia River (MCR) with annual average densities varying over two orders of magnitude from year to year (Larson 1993). In the Columbia River, Dungeness crabs are found from the MCR to about RM17 (McCabe et al. 1986, 1989).

It is clear that Dungeness crabs use not only estuarine navigation channels but also other estuarine habitat areas. Age 0+ crabs are found in intertidal and shallow subtidal areas on substrates with shell hash, eelgrass, or other shelter (Armstrong et al. 1987). After growing to 20-mm carapace width (CW), the 0+ crabs move to subtidal areas. Age 1+ crabs use subtidal areas and forage over intertidal areas during high tide. A recent survey of four West Coast estuaries by Rooper et al. (2002) indicates that Dungeness crabs show consistent use of some estuarine habitat types. Side channel habitat near the estuary mouth has highest crab densities, with the lower estuarine main channel and upper estuary having significantly lower densities (Table 1). The characteristics of the preferred lower side channel habitat include shell, macroalgae, shallow depths, high food abundance, temperatures <18 degrees C, and salinities above 25 o/oo. The coastal estuaries are estimated to be the basis for 20% to 40% of West Coast Dungeness crab fishery production (Armstrong personal communication). The estuaries appear to provide relatively steady contributions to annual crab production while nearshore ocean environments provide crab production that is quite variable from year to year (Armstrong personal communication).

1.2 Salinity Influences on Crab Distribution

Salinity has long been suspected to influence the distribution and abundance of Dungeness crabs in west coast estuaries (Tasto 1983, Stevens and Armstrong 1984, McCabe et al. 1986). The notion that low salinity restricts crab distribution is supported by findings that Dungeness crabs are weak osmoregulators and become inactive under low salinity (McGaw et al. 1999). Dungeness crabs were previously thought not to survive at salinities less than 12 o/oo, but recent laboratory studies suggest the ability to survive brief exposure to low salinity. Dungeness crabs show adaptive physiological responses under 6 to 8 h exposures to 50% seawater (about 16 o/oo) (Brown and Terwillger 1992, 1999, McGaw and McMahon 1996, McGaw et al. 1999). Dungeness crabs can acclimate to continuous exposure to 50% seawater (about 16 o/oo) for 4 days (McGaw and Mahon 1996) and survive 24-h exposure to a salinity of 8 o/oo (McGaw et al. 1999).

Although Dungeness crab can survive brief exposure to low salinities, studies suggest that they do so by being inactive and isolating themselves. Dungeness crabs can detect a 4% decrease and 5% increase from ambient salinity (Sugarman et al. 1983) and exhibit behavioral responses to lowered salinity that serve to isolate the osmoregulatory organs from the changing salinity (Sugarman et al. 1983, McGaw et al. 1999). Sugarman et al. (1983) found that the threshold at which 50% of Dungeness crab close their mouthparts and seal the branchial chamber was 50% seawater (15.5 o/oo). McGaw et al. (1999) observed that under decreases to 75%, 50%, and 25% seawater (about 24, 16, and 8 o/oo), Dungeness crabs initially showed an immediate increase in movement that lasted less than one hour, after which time the crabs buried and became inactive. Crabs not only became inactive but also retracted the antennules and closed their mouthparts to seal the branchial chamber. At 25% seawater (8 o/oo), the antennules were retracted almost 100% of the time. When the antennules are retracted and the branchial chamber sealed, the chemosensory abilities of Dungeness crabs to detect food and other chemical cues are substantially reduced.

Although previous field studies using linear models have found low correlations between crab density and salinity (Stevens and Armstrong 1984, McCabe et al. 1986), our examination of the data of Stevens and Armstrong (1984) using logarithmic models as well as linear models revealed that mean station density for 1+ and older crabs is logarithmically related to mean bottom salinity (Figure 1). The relationship between salinity and 0+ crab density appears to be more complex (Figure 1). Regression of logarithmically transformed data of Stevens and Armstrong (1984) for 1+ and older crab yields a significant regression equation (p=0.004) with an R-squared of 71% (Figure 2). This equation enables forecasting of crab density from salinity data. For example, predicted crab density at a bottom salinity of 16 o/oo is less than 1% of that at 32 o/oo (Figure 2). It is hypothesized that at bottom salinities above 30 o/oo crab density is governed by factors other than salinity and that as bottom salinity falls below 30 o/oo crab density falls logarithmically. Coupling the above salinity-crab density relationship with examination of the complex salinity regime in the Columbia River Estuary enables us to elaborate a conceptual model of the influence of salinity on crab distribution along the South Channel.

Salinity intrusion in the Columbia River is complex and dynamic compared to other estuaries. Two factors contribute to that complexity (Jay and Smith 1990). First, the Columbia River Estuary has extremely large freshwater flows moving through a shallow estuary. Second, the Columbia River Estuary has two channels. Tidal exchange dominates in the North Channel, which is saltier. River flow dominates in the South Channel, which is less salty. River flow levels and neap-spring tide transitions interact to produce the greatest salinity intrusion at neap tides during low flows (Table 2). The interaction of river flow and tidal exchange leads to general declines in bottom salinity at the South Channel as one moves upriver (Table 3). Bottom salinity at and above RM 10 shows substantial variation (Table 3).

Examination of the river flow records for 2001/2002 and the CORIE/ELCIRC models enables discernment of recent extremes in salinity intrusion. From October 2001 to October 2002, the combined river flow has varied from a low of 80 Kcfs on October 8 2001 to a high of 433 Kcfs on April 17 2002 (Figure 3). Predictions of the bottom salinity from the CORIE/ELCIRC Model (http://www.ccalmr.ogi.edu/CORIE/) also reveal that mean bottom salinity decreases moving upriver along the South Channel and that salinity intrusion varies with river flow (Figure 4). Using the CORIE/ELCIRC predictions for CORIE stations greater than 10 m deep in the South Channel indicates that mean bottom salinities at RM18 would be 10 o/oo for May 21 2002 with a river flow of 292 Kcfs and 23 o/oo for September 1 2002 with a river flow of 133 Kcfs.

1.3 Entrainment Measurements and Modeling

Armstrong and his colleagues (Armstrong et al. 1987, Wainwright et al. 1990, Wainwright et al. 1992) developed the Dredge Impact Model (DIM) for use in the Grays

Harbor Navigation Improvement Project of the Corps Seattle District. The model evolved over the years and Wainwright et al. (1992) gives a succinct overview of its present form. The DIM takes as inputs the volume of material to be dredged and the density of crab in the environment, applies an entrainment function plus age- and season-specific schedules of post-entrainment mortality and natural survival, and yields an estimate of loss to the crab fishery. The actual loss to the fishery is a function of harvest rate. The entrainment function, a key component of the model, was developed from several years of paired observations of the number of crab entrained per cubic yard (cy) dredged versus the crab density (crabs/hectare) determined by scientific trawling. For Grays Harbor, the model was successfully employed to minimize crab impacts through dredge scheduling and to estimate project impacts.

In reviewing the model for use in gaining perspective on crab impacts in the Columbia River, the model structure was found to be generally applicable but the entrainment function and the available data on crab density are not appropriate for use to estimate the effects of dredging on the Columbia River crab population and crab fishery. The entrainment function is probably site specific. The slope of entrainment function in Grays Harbor appears to differ substantially from what the available data from Columbia River indicate (Figure 5). Also, the relationship between crab density from trawls and crab density from dredge entrainment are not the same in Grays Harbor as in the Columbia River (Table 4). Therefore, it would not be appropriate to apply the entrainment function from Grays Harbor to the Columbia River until and unless paired trawling and entrainment measurements provide site-specific data to validate the function. The appropriate site-specific data to evaluate the applicability of the Grays Harbor entrainment function for the Columbia River are not presently available.

Another required input to the DIM is data on crab density by size class and season for the different reaches to be dredged. There is no recent data of this type from the Columbia River. The crab density data from the Columbia River was taken in the 1980's for different purposes, and spatial coverage is sparse for reaches of the Columbia River to be dredged (McCabe et al. 1986, 1989).

To gain perspective on the dredge entrainment impacts using currently available data, a modified DIM (Figure 6) was used in the analysis here. The modified DIM does not depend on the entrainment function from Grays Harbor or trawl data from the Columbia River. The modification employs the entrainment rates directly observed on a Corps dredge in the Columbia River in summer 2002.

1.4 Overview of Entrainment Measurements, Projections, and Scenario Analyses

This document reports the results of three tasks:

- Direct measurements of crab entrainment in the field
- Projections of crab entrainment during the dredging planned for the Channel Improvement Project

- Modeling and scenario analysis of the influence of salinity on crab distribution

In the first task, the scientific team made direct measurements of crab entrainment rates on the Corps' Dredge *Essayons*, which is equipped with a basket sampler into which a portion of the dredged materials entering the vessel's hopper can be diverted to obtain entrainment samples. During the summer 2002 maintenance dredging, the scientific team sampled at the mouth of the Columbia River (MCR), Desdemona Shoals, Upper Sands, and Miller Sands (Figure 7). Although some results from crab entrainment measurements from the MCR will be discussed here, the MCR studies will be fully detailed in a separate report. The first task also included measurements of fluid flow in the piping to the dredge's basket sampler to determine the factors for sample volumes in calculations of entrainment rates. A modified DIM used the data from the first task to calculate the Adult Equivalent Loss (AEL) and Loss to Fishery (LF) for the volume of materials dredged at each location in summer 2002. The second task used the entrainment rates measured in the summer of 2002 to make projections of crab entrainment using the modified DIM with the dredged volumes planned for the Channel Improvement Project. The third task used a model for the relationship between salinity and crab density to assess relative crab distribution under several scenarios of salinity intrusion in the Columbia River Estuary. The third task included an analysis of the relationship between entrainment rate and bottom salinity using the summer 2002 data.

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MATERIALS AND METHODS

1.5 Methods for Direct Measurements of Entrainment Rates

1.5.1 Summary of Field Activities

MSL researchers directly measured crab entrainment aboard the Corps' Dredge *Essayons* in June 2002 and from July through October 2002 when the dredge was engaged in maintenance and operational dredging of the Columbia River (Table 5, Figure 7). This document reports results from sampling at Desdemona Shoals, Upper Sands, and Miller Sands. Detailed results from the sampling in the MCR are reported separately. The *Essayons* is equipped with a special basket sampler, into which a portion of the dredged materials entering the vessel's hopper can be diverted. To support the calculations of the volume of dredged material sampled by the basket sampler, measurement of the fluid flow in the pipe leading to the basket sampler was conducted in September 2002.

1.5.2 Statistical Design of Field Sampling

Before the start of field measurements to determine entrainment rates for Dungeness crab on the Columbia River, the study team developed sampling designs and data analysis plans for the June sampling and for the July to October sampling. To aid in the development of the June sampling design, the Portland District provided previously collected raw data on entrainment rates from the study of Larson (1993). Examination of the Larson (1993) data revealed that the entrainment rates exhibited three major variance components: 1) Day-to-day variability, 2) Load-to-load variability, and 3) Sample-to-sample variability within loads. The day-to-day variability was the dominant variance component. Because day-to-day variability dominated, the study team recommended that sampling occur every day of the five days of dredging projected for June 2002. To select appropriate sampling rates to address load-to-load and sample-to-sample variances, coefficients of variation (CV) for various combinations of sampling rates were calculated based on the Larson (1993) data (Table 6). A CV of 0.125 was required for the estimates of entrainment in order to be 95% confident of being within ±25% of the true value. To obtain the desired precision for the June 2002 sampling, the study team sampled each day of dredging, selecting half the loads at random and sampling 10 basket samples per load.

To develop the sampling design for the summer 2002 sampling, the results of the June 2002 were examined. Again, the day-to-day variability proved to be the dominant variance component. To select appropriate sampling rates to address load-to-load and sample-to-sample variances for the summer 2002 sampling, coefficients of variation (CV) for various combinations of sampling rates were calculated based on the June 2002 data (Table 7). A CV of 0.125 was required for the estimates of entrainment in order to be 95% confident of being within ±25% of the true value. To obtain the desired precision for the summer 2002, the study team sampled each day of dredging, selecting half the loads at random and sampling 3 basket samples per load.

1.5.3 Methods for Entrainment Observation

Researchers conducted crab entrainment studies aboard the Corps' Dredge *Essayons* in June and from July through October 2002 when the dredge was engaged in maintenance and operational dredging of the Columbia River (Table 5, Figure 7).

The data for estimation of crab entrainment rates were derived from a two-stage sampling scheme. The first stage involved the random sampling of approximately half (50%) of the loads collected by the dredge. The second stage involved the random sampling of dredged material within the selected loads. Hence, there were two aspects to the sampling protocol: (1) the random selection of loads, and (2) the random selection of "basket" samples within a load. In June, 9 or 10 basket samples per load were processed. From July to October, 3 basket samples per load were processed. These basket samples were randomly distributed through the period of load collection, which typically took about an hour.

Four sets of data sheets were used to record field data. These included load by load records, sample records, within-load records, and a daily log. The load by load record sheet included a randomly determined schedule constructed to indicate which loads to sample and which not to sample. Total load volumes [cubic yards (cy)] and distances (ft) were recorded onto these sheets for all loads during the duration of the survey, whether sampled or not; this information was obtained from the *Essayons'* dredge logbook. Sample records were used to record data on individual basket samples taken within a load, including numbers, size, and sex of Dungeness crab entrained. Within-Load records summarized the crab, fish, and mollusks enumerated in each basket sample, along with the volume of the basket sample. Finally, the daily log was used to record pertinent weather conditions, personnel involved, dredge operations, and deviations from normal operating procedures (e.g., repairs, gear modification).

On-deck sampling proceeded according to the following procedures. When ready to sample, the researcher communicated to the vessel bridge via radio to request the use of hydraulics to operate the crab basket sampler and gate valve, and for closure of starboard valve V17 (Figure 8). This configuration allowed the researcher to sample approximately ½ the volume of a single drag arm, or ¼ the total volume of material being loaded by the dredge. The hydraulic gate valve was operated on-deck by the researcher to allow dredged material to flow to the basket sampler. A time interval of approximately 30 seconds (45 seconds at MCR) usually yielded a manageable volume of dredged materials sample. Therefore, standard valve-timing procedures were as follows (time period in parentheses): the valve was opened (from 0 to 11 sec), valve remained fully open until 15-second mark (from 11 to 15 sec), and valve was closed (from 15 to 28 sec). In all cases, the start time (hh:mm) and time increments (seconds) at which valve closure was initiated and fully closed were recorded. Calculation of sample volumes is explained in a later section of this report.

The basket sampler was then tilted on its side using the second hydraulic valve. The researcher communicated to the bridge that the hydraulics were no longer required and received information on the average load rate and ship speed. From July through October, the researcher measured and recorded the temperature (^{o}C) and salinity (o/oo) of pumped seawater obtained from a catch pan under the cage using a YSI Model 556 multiple probe system (MPS). Finally, the basket sampler was emptied of sample using 5-gallon buckets, and the sample dumped onto the sorting table.

Researchers sorted whole and parts of living organisms from the sample and identified and enumerated individuals from the following taxa: crab (*Cancer magister* and other species), shrimp (e.g., *Crangon* spp.), razor clam, and all fish species. In cases where an animal other than crab was crushed or pieces were collected, the animal was counted only if the head was present (See details below on quantifying crushed crab). The relative abundance of other species (e.g., olive snail, polychaetes) was noted. Total length (length from the tip of the upper jaw to the end of the caudal fin) of fishes was also recorded.

The carapace widths (CW) of all crabs were measured using calipers, and larger crabs were sexed. If ½ a carapace was present, this was measured and total CW was estimated. In cases where a crab was crushed or pieces were collected, we consistently quantified only those crabs for which we collected more than ½ carapace, or other matched pieces (e.g., telson, legs, chela, thorax) constituting 1/3 of a crab. When these criteria were not met (e.g., only 2 legs collected), the presence of crab pieces was noted qualitatively ("YES") under the UID (unidentified) crab column on the record sheet. All crabs and crab pieces were dumped into the dredge hopper to minimize duplicate counts on subsequent passes.

Finally, the sediment type (e.g., sand, mud, gravel, shell) and vegetation was noted, the basket sampler was cleaned with a pressure washer, and the process restarted. All data sheets were completed and errors corrected with a single line that was initialed and dated. At the end of each load, researchers reviewed the data sheets for completeness, accuracy, and legibility.

1.5.4 Modifications to Standard Sampling Procedures

Slight changes were made to sampling procedures on some dates to maximize data collection during limited sampling windows or mechanical delays. When a mechanical issue prevented sampling of a load scheduled to be sampled, researchers skipped ahead on the random number schedule to the next load to be sampled when operations returned to normal.

There were also situations due to extreme ebb tides or equipment damage when only a single drag arm was used to dredge the channel. In these cases, the volume of dredged material flowing into the vessel was reduced by ½. To maintain adequate sample volumes flowing to the basket sampler, the port side valves (V16 and V17) that distributed loads into the hold were closed when sampling occurred (Figure 8).

1.5.5 Calculating Sample Volume

In previous studies, the sample volumes used to estimate crab entrainment were based on full flows of a 66 cm discharge pipe over a 30-60 second sampling interval (Larson 1993). Coarse estimates of mean flow rates of the discharge pipes were calculated on a load-by-load basis by dividing total pumping time (PT) by total load (cy) (see formulae on p. 7, Larson 1993). Therefore, sample volume was based on flow rate multiplied by sampling interval (total time valve was open).

Observations made during our June sampling effort suggested that procedures for calculating the sample volumes needed to be refined to take into account the depth of fluid in the pipe and the timing of opening and closing the hydraulic gate valves. Flow volumes associated with the dredge hopper discharge pipes were calculated using the following methods.

Computation of the area based on the depth (or degree to which the gate is opened) is based on the following:

> The ratio of instantaneous cross-sectional area (Ai) to the half-pipe cross-sectional area (Amax) is used to proportionally reduce the full-pipe flow (Qmax) to estimate the instantaneous flow Qi
>
> Qi=Ai/Amax * Qmax
>
> The time series of Qi are time-integrated to get a cumulative volume V = sum of (Qi * dt) over the 28 second period, or
>
> V= sum of Ai/Amax * Qmax*dt.
>
> But Amax, Qmax and dt do not change so that
>
> V = dt*Qmax/Amax * sum of Ai
>
> The effective sampling interval, Teff = V/Qmax, or
>
> Teff= (dt*Qmax/Amax * sum of Ai) /Qmax
>
> This reduces to Teff = dt*(sum of Ai)/ Amax (hence no functional connection to input Q).

This allows for estimation of Teff with some assumptions:

- After the gate is opened further than half-way, there is no longer an influence on flow
- The non-linear processes are neglected. No friction, no contraction, no acceleration

- The cross-sectional average velocity is uniform regardless of how far the gate is opened; flow rate is only a function of cross-sectional area available for flow. The average cross-sectional velocity is the same when the pipe is half-full or barely open.

The estimate of effective sampling period (Teff) is based upon the rate the gate valve is opened, the time it stays open, and the rate it is closed; it is not sensitive to overall flow rate. Flows are reduced during the first half of both the gate valve opening and closing intervals. Assuming the pipe is ½ full and standard valve-timing procedures (opening from 0 to 11 sec, fully open from 11 to 15 sec, closing from 15 to 28 sec), the effective sampling period is 21.4 seconds.

Sample volume was calculated by multiplying effective sampling time (t) by mean load rate (cy/t) of the discharge pipe feeding the basket sampler. As in Larson (1993), mean load rates of the discharge pipes were calculated on a load-by-load basis by dividing total pumping time (PT) by total load volume in cy (Y). Flow measurements were conducted to clarify what proportion of the total flow (load rate) was diverted into the crab sampler.

1.5.6 Flow Measurements

Flow measurements were conducted to verify the assumption that the basket sampler was receiving 25% of the total load of dredged materials. A FLO-DAR (Model 460 / Data Logger Serial Number: 46000141 / Meter Serial Number: BA0239) open channel, non-contact, radar flow meter was used to estimate velocity, level, and flow of the slurry contained within the pipe. Specifications and accuracy of the instruments were as follows:

<u>Velocity Measurement</u>
Method: Radar
Range: 0.75 to 20 ft/s
Accuracy: ±0.1 ft/s (±0.5%)

<u>Level Measurement</u>
Method: Ultrasonic
Operating Range: 0.25 to 60 in.
Temperature Compensated
Accuracy: ±0.25 in. (1%)

<u>Flow Measurement</u>
Based on Continuity Equation.
Accuracy: ±5.0% of reading typical where flow is in a channel with uniform flow conditions.

The sensor was mounted approximately 5 ft downstream of the basket sampler valve, by cutting a hole 6 inches wide by 20 inches long centered on the 26-inch inside diameter pipe. Flanges were welded on top of the pipe, raising the sensor 5 inches off the top of the pipe. Five inches were used as the offset in the data collection for pipe level measurement. The sensor was mounted and connected to data loggers, which in turn were connected to a Dell Inspiron 3800 computer to monitor and record real time measurements.

Initial readings were taken to establish best flow conditions by closing valves 17 starboard and 16 starboard with the basket sampler valve open. This allowed for total starboard dredged materials flow past the sensor. Flow measurements were taken with both port and starboard dredge motors balanced at 250, 275, and 300 rpm. The optimum setting was found at 275 rpm, with 300 rpm providing too much flow and 250 rpm causing excessive flow pulsing.

Flow measurements were compared between two different piping configurations (total starboard flow vs. normal configuration during crab sampling). To measure total starboard flow, measurement data was logged for approximately 10 to 15 minutes with the dredge motor at 275 rpm, the 17 starboard and 16 starboard valves closed, and the basket sampler valve open. To measure flows associated with the typical piping configuration observed during crab sampling, the 16 starboard valve was reopened and measurements logged for approximately 10 to 15 minutes. These flow measurements were then repeated several times over the course of normal dredging operations. When in normal configurations for crab sampling, the pipe was always a minimum of half-full.

Instrument readings indicate that flow coming into the crab basket sampler as a proportion of total flow coming onboard was 0.26 with a 95% Confidence Interval (CI) from 0.23 to 0.29. These results provided no evidence to reject the value of 0.25 used by Larson (1993). Therefore, all calculations of sediment load and crab entrainment use factor of 0.25 to correct for the proportion of total flow (load rate) diverted into the basket sampler.

1.5.7 Calculation of Adult Equivalent Loss and Loss to Fishery for Summer 2002 Dredged Volumes

To calculate Adult Equivalent Loss (AEL) and Loss to the Fishery (LF) for the dredged volumes accomplished in summer 2002, we used a modified DIM that does not depend on the entrainment function from Grays Harbor or previous trawl data from the Columbia River. The modification employs the entrainment rates directly measured on the Corps' Dredge *Essayons* in the Columbia River. The approach (Figure 6) includes the following steps:

1. Use entrainment rates (R as crabs per cy) directly measured on the dredge (no need to reference trawl density).
2. Multiply these entrainment rates by the dredged volumes to give the number of crabs entrained (E as number of crab).
3. Apply the post-entrainment mortality rates from Wainwright et al. (1992) to give immediate losses.

4. Apply the natural survival rates from Wainwright et al. (1992) to give Adult Equivalent Loss (AEL as number of crab) to midwinter Age 2+. (To obtain the AEL at Age 2+ for Age 3+ crab, the number of Age 3+ crab was back-calculated to its equivalent at Age 2+ using the reciprocal of the survival rate.)
5. Apply a survival rate of 45% to midwinter Age 3+ (Armstrong et al. 1991) to give AEL at Age 3+.
6. Apply observed sex ratios and a harvest rate of 70% (Wainwright et al. (1992) to give loss to the fishery (LF as number of crab).
7. Calculate variance and 95% confidence intervals for E, AEL, and LF.
8. Compare the loss to the fishery (LF) to the landings (WDFW and ODFW) from the Columbia River Area to give perspective on the estimated impact.

1.5.8 Statistical Analyses and Calculation of Variance and Confidence Limits

Estimating Numbers of Entrained Crabs

In a random sample of loads, crab entrainment densities were estimated from a random sample of dredged material. Hence, the sampling design consists of a two-stage sampling scheme; Stage 1: Random sample of h of H loads and Stage 2: Random sample of dredged materials based b of B basket samples. The estimator of total entrainment for a specific age-class (i.e., size class) of crabs can be expressed as follows:

$$\hat{E}_i = \frac{\sum_{j=1}^{h}\left[\frac{V_j}{b_j}\sum_{l=1}^{b_j} x_{ijl}\right]}{\sum_{j=1}^{h} V_j} \cdot \sum_{j=1}^{H} V_j \qquad (1)$$

where

x_{ijl} = number of age class i $(i = 1, \ldots, A)$ crabs/Y^3 measured in the *l*th basket sample $(l = 1, \ldots, b_j)$ in the *j*th load $(j = 1, \ldots, h)$;

b_j = number of basket samples observed in the *j*th load $(j = 1, \ldots, h)$;

h = number of loads selected for sampling of crab density;

h H = total number of loads at a dredged location;

H V_j = total volume of dredged materials in the *j*th load $(j = 1, \ldots, h)$.

In turn, x_{ijl} can be expressed in terms of the number of crabs counted and the volume of the *l*th basket sample of the *j*th load where

$$x_{ijl} = \frac{c_{ijl}}{w_{jl}}$$

where

c_{ijl} = number of age class i crabs $(i=1,\ldots,A)$ in the lth basket sample $(l=1,\ldots,b_i)$ in the jth load $(j=1,\ldots,h)$;
w_{jl} = volume of the material sampled in the lth basket sample $(l=1,\ldots,b_i)$ in the jth load $(j=1,\ldots,h)$.

As such, the estimator of total crab entrainment for age class i crabs $(i=1,\ldots,A)$ can be expressed as

$$\hat{E}_i = \frac{\sum_{j=1}^{h}\left[V_j \frac{\sum_{l=1}^{b_j} c_{ijl}}{\sum_{l=1}^{b_j} w_{jl}}\right]}{\sum_{j=1}^{h} V_j} \cdot \sum_{j=1}^{H} V_j. \tag{2}$$

Estimators (1) and (2) will be the same if sample values $w_{ij} = w_i$ are equal within a load. Because sample volumes varied between basket samples, estimator (2) is the preferred estimator of total entrainment.

The variance of $\hat{E}_i$ is found by taking the variance in stages. The variance of $\hat{E}_i$ (Equation 2) can then be expressed as follows:

$$Var\left(\hat{E}_i \middle| E_i\right) = H^2\left(1-\frac{h}{H}\right)\frac{\sum_{j=1}^{H}\left(V_j R_{ij} - R_i V_j\right)^2}{h(H-1)} + \frac{H}{h}\sum_{j=1}^{H}\left[V_j^2 \cdot Var\left(\hat{R}_{ij}\right)\right] \tag{3}$$

where

$$R_{ij} = \frac{\sum_{l=1}^{B_j} c_{ijl}}{\sum_{l=1}^{B_j} w_{jl}} =$$ true density of age class i crabs (i.e., crabs/Y^3) in the jth load $(j=1,\ldots,H)$;

$$R_i = \frac{\sum_{j=1}^{H} R_{ij} V_j}{\sum_{j=1}^{H} V_j} =$$ true density of crabs (i.e., crabs/Y^3) across all H levels;

$$Var\left(\hat{R}_{ij}\right) = \frac{\left(1-\frac{b_j}{B_j}\right)}{b_j \bar{w}_j}\frac{\sum_{l=1}^{B_j}\left(c_{ijl} - R_{ij} w_{jl}\right)^2}{\left(B_j - 1\right)};$$

and where

$$\bar{w}_j = \frac{\sum_{l=1}^{B_j} w_{jl}}{B_j} = \text{ average volume of basket sample in the } i\text{th load;}$$

$B_j =$ total number of possible basket samples within the jth load.

Variance formula (3) cannot be used to analyze the field data because it is dependent upon unknown parameter values. Instead, an estimated variance must be calculated and used in confidence interval estimates.

An approximately unbiased variance estimator for $\hat{E}$ can be written as follows:

$$\hat{V}ar\left(\hat{E}_i \middle| E_i\right) = H^2\left(1-\frac{h}{H}\right)\frac{\sum_{j=1}^{h}\left(V_j\hat{R}_{ij} - \hat{R}_i V_j\right)^2}{(h-1)} + \frac{H}{h}\sum_{j=1}^{h} V_j^2 \cdot \hat{V}ar\left(\hat{R}_{ij}\right) \qquad (4)$$

where

$$\hat{R}_{ij} = \frac{\sum_{l=1}^{b_j} c_{ijl}}{\sum_{l=1}^{b_j} w_{jl}},$$

$$\hat{R}_i = \frac{\sum_{j=1}^{h}\left[V_j \frac{\sum_{l=1}^{b_j} c_{ijl}}{\sum_{l=1}^{b_j} w_{jl}}\right]}{\sum_{j=1}^{h} V_j}, \qquad (5)$$

$$\hat{V}ar\left(\hat{R}_{ij}\right) = \frac{\left(1-\frac{b_j}{B_j}\right)}{b_j\bar{w}_j^2}\frac{\sum_{l=1}^{b_j}\left(c_{ijl} - \hat{R}_{ij}w_{jl}\right)^2}{\left(b_j - 1\right)},$$

which, when B_j is very large, simplifies to

$$\hat{V}ar\left(\hat{R}_{ij}\right) = \frac{\sum_{l=1}^{b_j}\left(c_{ijl} - \hat{R}_{ij}w_{jl}\right)^2}{\bar{w}_j^2 b_j\left(b_j - 1\right)},$$

and where

$$\overline{w}_j = \frac{\sum_{l=1}^{b_j} w_{jl}}{b_j}.$$

Asymptotic $(1-\alpha)$ 100% confidence interval estimates for $\hat{E}_i$ can be calculated as

$$\hat{E}_i \pm Z_{1-\frac{\alpha}{2}} \sqrt{\hat{V}ar\left(\hat{E}_i \middle| E_i\right)}.$$

Estimating the Entrainment Rate

The entrainment rate (R_i) for the *i*th age class of crabs can be defined by Equation (5) or equivalently as the ratio of the total number of crabs entrained to the total volume of dredged material collected where

$$R_i = \frac{E_i}{\sum_{j=1}^{H} V_j}.$$

The entrainment rate (R_i) can be estimated by the ratio

$$\hat{R} = \frac{\hat{E}_i}{\sum_{j=1}^{H} V_j} \tag{6}$$

with associated variance estimator

$$\hat{V}ar\left(\hat{R}_i \middle| R_i\right) = \frac{\hat{V}ar\left(\hat{E}_i \middle| E_i\right)}{\left[\sum_{j=1}^{H} V_j\right]^2}. \tag{7}$$

Estimating Adult Equivalent Loss (AEL)

The estimate of adult equivalent loss (AEL) for the Dungeness crab entrainment can be expressed as follows:

$$\hat{A}EL = \sum_{i=1}^{A} \hat{E}_i \cdot \hat{M}_i \cdot \hat{S}_i \tag{8}$$

where

$\hat{E}_i$ = estimate of total crabs entrained of age class $i \ (i = 1, \ldots, A)$;

$\hat{M}_i$ = estimate of direct mortality associated with the dredging operation on crabs entrained of age class $i \ (i = 1, \ldots, A)$;

$\hat{S}_i$ = estimate of the survival probability from age class $i \ (i = 1, \ldots, A)$ to age of interest;

A = number of age classes (i.e., 2+ or 3+).

A

Estimates of $\hat{M}_i$ and $\hat{S}_i$ used in the assessment did not have associated variance estimators. Hence, the contribution of $Var(\hat{M}_i)$ and $Var(\hat{S}_i)$ could not be propagated to the overall variance of the AEL estimates. Instead, $\hat{M}_i$ and $\hat{S}_i$ were treated as known constants when calculating the variance of $\widehat{AEL}$. In which case,

$$\widehat{Var}\left(\widehat{AEL}\right) = \sum_{i=1}^{A}\left[Var\left(\hat{E}_i \middle| E_i\right) \cdot \hat{M}_i^2 \cdot \hat{S}_i^2\right]. \tag{9}$$

Equation (9) will underestimate the true variance of the AEL estimates when $\hat{M}_i$ and $\hat{S}_i$ are measured with error.

Estimating Loss to Fishery (LF)

The loss to the fishery (LF) of harvestable crabs was estimated by the quantity

$$\widehat{LF} = \hat{H} \cdot \sum_{i=1}^{A} \hat{G}_i \hat{E}_i \hat{M}_i \hat{S}_i \tag{10}$$

where

$\hat{G}_i$ = estimated fraction of the *i*th age class composed of males,

$\hat{H}$ = estimated probability of harvesting a male crab in the Dungeness fishery.

$\hat{H}$

Again, assuming the values of $\hat{G}_i$ and $\hat{H}$ are known constants, the variance of $\widehat{LF}$ can be estimated by the formula

$$\widehat{Var}\left(\widehat{LF}\right) = \hat{H}^2 \cdot \sum_{i=1}^{A}\left[\widehat{Var}\left(\hat{E}_i \middle| E_i\right) \cdot \left(\hat{G}_i \cdot \hat{M}_i \cdot \hat{S}_i\right)^2\right]. \tag{11}$$

Equation (11) will underestimate the true variance of $\widehat{LF}$ when H and G_i are measured with error.

1.6 Methods for Projections of Impacts using Modified DIM

Projections of crab AEL and LF associated with future construction dredging were made based on work quantity calculations provided by the USACE Portland District (Table 8). The total dredging prism volumes for each location include two increments: 1) dredging to bring the channel to the 40-foot depth currently authorized and 2) new work dredging to channel from the 40-depth to the new 43-foot depth. In all cases, projections are compiled by age class (age 2+ and 3+) and crab sex. These projections were calculated for each of the following upriver bar areas: Desdemona (Lower and Upper combined), Flavel Bar, Upper Sands, and Tongue Point.

For each bar area, we employed the DIM approach outlined above with two modifications. First, entrainment rates (R, as crabs per cy) and sex ratios corresponded to those measured at a particular bar area in 2002. Flavel Bar and Tongue Point were not sampled in 2002. For these two areas, we employed the entrainment rates for sampled locations both upriver and downriver from the areas of interest. Second, entrainment rates ® were multiplied by the projected dredged volumes (Table 8) to yield the number of crabs entrained (E, as number of crab). The maintenance and deepening projections were run for each of the following cases:

Projected Volumes – Upriver Bar Area	Data Source – Entrainment Rate and Sex Ratio
Desdemona	Desdemona, June 2002
Desdemona	Desdemona, Sept 2002
Flavel Bar	Desdemona, June 2002
Flavel Bar	Desdemona, Sept 2002
Flavel Bar	Upper Sands, Sept 2002
Upper Sands	Upper Sands, Sept 2002
Tongue Point	Upper Sands, Sept 2002
Tongue Point	Miller Sands, Oct 2002
Miller Sands	Miller Sands, Oct 2002

Projections of crab AEL and LF associated with future maintenance dredging were made based on work quantity calculations provided by the USACE Portland District (Table 9). DIM runs were made for Year 1 and Year 20 following construction. The maintenance dredging volumes are expected to decline over the 20 years following construction. The worst-case assumptions were used to project entrainment during maintenance dredging.

1.7 Approach for Analysis of Salinity and Crab Distribution

To assess the influence of salinity on crab distribution, we applied the salinity-crab density model developed from the Stevens and Armstrong (1984) data (described in Introduction section above) to several scenarios for salinity intrusion into the Columbia

River Estuary. The salinity-crab density model was developed for Ages 1+ and older and does not address Age 0+. The scenarios examined include the following:

- Six conditions from Jay and Smith (1990) (Table 3) that cover salinity intrusion under low and high river flow and spring and neap tides
- The median under low river flow conditions from Jay and Smith (1990) (Table 3)
- Bottom salinity forecasts from CORIE/ELCIRC for May and September of 2002

The above scenarios were used to develop a series of distributions of bottom salinity by river mile along the South Channel. The salinity-crab density model was used to forecast the relative crab density by river mile for each distribution of bottom salinity by river mile. Predicted crab density is then plotted by river mile.

In addition to the assessment of the scenarios for salinity intrusion, we also regressed the entrainment rates determined for each dredged area during the summer of 2002 against two measures of bottom salinity for the dredged area. For the entrainment rates in June taken at Desdemona Shoals, we used the bottom salinities taken from the bottom CTD deployed at CORIE Station RED2, the station closest to Desdemona Shoals. For all the other areas and times, we used the bottom salinities taken from the dredged materials during the crab entrainment sampling. The two measures of salinity used were the percentage of salinity observations at and above 32 o/oo and the percentage of salinity observations at and below 16 o/oo.

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RESULTS

1.8 Direct Measurements of Crab Entrainment

While the Corps' Dredge *Essayons* was conducting maintenance dredging in the Columbia River, the scientific team made direct measurements of crab entrainment at Desdemona Shoals in June and September 2002, at Upper Sands in September, and at Miller Sands in October (Table 5). The team sampled 66 of the total of 123 loads dredged at these locations. The total number of basket samples taken at these locations was 348. The data from these samples appears in Appendix A.

1.8.1 Entrainment Rates ®

Dungeness crabs were found in the entrainment samples at Desdemona Shoals and Upper Sands; however, no crab or crab parts were found in the 140 basket samples taken at Miller Sands in October 2002. The total entrainment rates for all age classes varied from zero at Miller Sands to 0.224 crab/cy at Desdemona Shoals in June 2002 (Table 10). At Desdemona Shoals, June entrainment samples were largely composed of Age 1+ crabs, but by September entrainment samples were dominated by Age 2+ crabs (Table 10). At Upper Sands, only Age 0+ and Age 1+ crabs were found in the entrainment samples. Other species entrained in moderate numbers included *Crangon* shrimp, Pacific sand lance (*Ammodytes hexapterus*), and eulachon (*Thaleichthys pacificus*) (Appendix A5).

1.8.2 DIM Results for Dredged Volumes Accomplished in Summer 2002

The results of applying the DIM for dredged volumes accomplished during summer 2002 are summarized in Table 11 and Table 12, and detailed in Appendix A. The lowest dredge impacts were observed at Miller Sands, and the highest at Desdemona Shoals in June. Crab AEL at Age 2+ ranged from zero at Miller Sands, to 6,314 crabs (95% Confidence Interval (CI) of 5,403 to 7,225 crabs) at Desdemona Shoals in June 2002. Loss to the fishery ranged from zero at Miller Sands, to 1,194 crabs (95% CI of 1,004 to 1,384 crabs) at Desdemona in June 2002. The AEL at Age 2+ and the loss to the fishery at Upper Sands were less than 1% of the AEL and LF at Desdemona Shoals in June 2002.

1.9 Projections of Crab Entrainment for Channel Improvement Project

The Channel Improvement Project involves planned construction dredging at four locations between RM3 and RM20: Desdemona Shoals, Flavel Bar, Upper Sands, and Tongue Point (Tables 8 and 9). Crab entrainment, AEL at 2+, AEL at 3+, and loss to fishery (LF) were projected for two construction increments (dredging to 40' and from 40 to 43') and four annual maintenance scenarios (40' Channel Maintenance under the No Action Alternative in Year 1 and Year 20; 43'Channel Alternative Maintenance under the Proposed Plan in Year 1 and Year 20) for these locations using the entrainment rates directly measured in the summer of 2002. In total, nine sets of projections were run

(Appendix B). Two sets of projections were conducted for Desdemona Shoals based on June and September 2002 entrainment data, respectively. Sets of projections were also run for Upper Sands and Miller Sands. Three sets of projections for Flavel Bar and two for Tongue Point were made using the entrainment rates measured from the nearest areas up and down river of the area of interest.

The results of construction projections are summarized in Table 13 (dredging to 40') and Table 14 (dredging from 40' to 43'), and detailed in Appendix B. In general, the lowest projected AEL at age 2+ was observed at Tongue Point, whereas the highest projected AEL at 2+ were observed at Flavel Bar. Construction projections for AEL at Age 2+ range from zero at Tongue Point using the Miller Sands entrainment rates, to 117,834 crabs (95% CI of 71,066 to 164,602 crabs) at Flavel Bar using the September Desdemona Shoals entrainment rates. Similarly, loss to the fishery from construction ranged from zero at Tongue Point using the Miller Sands entrainment rates, to 18,559 crabs (95% CI of 11,193 to 25,925 crabs) at Flavel Bar using the September Desdemona entrainment rates.

The worst-case (highest AEL and LF) and best-case (lowest AEL and LF) projections during construction dredging are summarized by location in Table 15. Estimated total AEL at 2+ ranges from 20,772 to 114,640 crabs during construction dredging to 40' (Table 15). Most of this loss would occur in Desdemona Shoals under either the best or worst case assumption. Estimated total AEL at 2+ ranges from 18,039 to 166,888 crabs during construction dredging from 40' to 43'. Flavel Bar contributes the greatest portion of this loss (117,834 crabs) under the worst-case assumption, whereas Desdemona Shoals contributes the greatest portion (16,023 crab) using the best-case assumption. Projected overall AEL at 2+ from both increments of construction dredging ranges from 38,811 to 281,528 crabs. Overall projected losses to the fishery from construction dredging range from 7,252 to 44,342 crabs.

Projections of crab AEL at 2+ and LF under annual maintenance dredging for the No Action Alternative (40' Channel) and the Proposed Plan (43' Channel) are summarized by location and year in Table 16. These values reflect the following worst-case (highest loss) projections: Flavel Bar (Entrainment rate [R] from Desdemona September), Desdemona (R from Desdemona September), Tongue Point (R from Upper Sands), and Upper Sands (R from Upper Sands). Projected losses from maintenance dredging generally mirror estimated dredging volumes, which are predicted to be higher in Year 1 than in Year 20.

For maintenance dredging under the No Action Alternative (40' Channel), estimated total AEL at 2+ ranges from 44,643 crabs in Year 1 to 25,503 crabs in Year 20 (Table 16). Most of this loss is predicted to occur at Flavel Bar in both Year 1 (40,295 crab) and Year 20 (21,155 crab). For maintenance dredging under the Proposed Plan (43' Channel), the estimated total AEL at 2+ ranges from 56,840 crabs in Year 1 to 25,612 crabs in Year 20. Again, Flavel Bar contributes the greatest portion of this loss in both Year 1 (50,369 crabs) and Year 20 (21,155 crabs). For maintenance dredging under the Proposed Plan

(43' Channel), projected losses to the fishery are 8,953 and 4,035 in Year 1 and 20, respectively.

1.10 Analysis of Salinity and Crab Distribution

Using the Jay and Smith (1990) conditions, modeling indicates that the highest crab densities are seaward of RM10. Of the six conditions modeled (Table 3), the highest crab densities are seaward of RM5 with moderate crab densities at RM10 under maximum intrusion for two conditions: 1) low river flow and spring tides, and 2) high river flow and spring tides (Figure 9). The condition showing the furthest upriver extent of crab densities is for maximum intrusion under low river flow and neap tides. Under this condition for furthest upstream extent of crab densities, predicted crab density at RM18 is about 8% of that at RM0. For the field salinity measurements of Jay and Smith (1990), the low river flows ranged from 120 to 150 Kcfs, and the high river flows, from 535 to 570 Kcfs. Under the median of the low flow conditions of the Jay and Smith (1990) conditions, crab densities predicted at and above RM10 are less than 1% of those predicted at RM0 (Figure 10).

From October 2001 to October 2002, the river flow ranged from slightly less than 100 Kcfs to a brief peak of about 430 Kcfs (Figure 3). Plots of the bottom salinities forecast by the CORIE/ELCIRC model for May 21, 2002 and September 1, 2002 (Figure 11) show that salinity intrusion was greater under a river flow of 133 Kcfs in September than under a river flow of 292 Kcfs in May. For the May flow, predicted crab density at RM13 was less than 1% of that predicted at RM1 (Figure 11). For the September flow, predicted crab density at RM13 was about 9% of that at RM1.

Site-specific data from the Columbia River in summer 2002 support the concept that salinity influences crab distribution. In summer 2002, entrainment rates fell as the bottom waters became fresher (Table 15). At Miller Sands, where bottom salinities were less than 16 o/oo for 100% of the salinity measurements, no crab or crab parts were entrained in any of the 140 basket samples. In the MCR, where bottom salinities were above 28 o/oo for 98% of salinity measurements, crabs were consistently entrained over the course of the summer sampling. For all age classes, 1+ and older, regression analysis showed that the natural logarithms of the entrainment rate for each dredged area were significantly related to the percentage of salinity observations less than 16 o/oo but not to the percentage of salinity above 32 o/oo (Table 16). For age 1+ crabs alone, the natural logarithms of the entrainment rates were not significantly related to either measure of salinity. At Desdemona Shoals, age 1+ crabs had a higher entrainment rate ($R = 0.193$ crab/cy) in June 2002 when bottom waters were fresher (16% of salinity observations less than 16 o/oo) than the rate ($R = 0.022$ crab/cy) in September when the bottom waters were saltier (0 % of the salinity observations less than 16 o/oo). For age 2+ and older, regression analysis revealed that the natural logarithms of the entrainment rates were significantly related to both the percentage of salinity observations above 32 o/oo and the percentage below 16 o/oo (Table 16). The parameter explained explaining the highest percentage of the variation in regressions was the percentage of salinity observations less than 16 o/oo.

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DISCUSSION

The entrainment rates reported here constitute a major step in quantifying crab entrainment in the Columbia River Estuary above RM3. The previous measurements of entrainment rates in the Columbia River were much more limited. For example, entrainment rates measured by Larson (1993) were restricted to the Mouth of the Columbia River, whereas the pilot sampling by PIE in spring 2002 at Desdemona Shoals was restricted to one day.

Entrainment rates (in areas where crab occurred) measured in this report were from the middle of the range to the low end of those reported in previous studies. Entrainment rates for all age classes reported here for the summer of 2002 ranged from 0.020 to 0.224 crabs per cy for locations above RM4 and below RM20 (Table 9). In comparison, Larson (1993) reported annual average entrainment rates in the MCR (below RM3) ranging from 0.32 to 10.78 crabs per cy for 0+ crab and from 0.03 to 0.18 crabs per cy for 1+ and older crab. Other studies in the Grays Harbor estuary reported entrainment rates that ranged from 0.03 to 0.5 crabs per cy (Wainwright et al. 1992). The rates of Wainwright et al. (1992) were derived from 14 surveys of 2 to 3 days each conducted over several years.

It should be noted that the entrainment rates reported and used here are based on sampling conducted during the summer months of a single year. Crab abundance in the Columbia River and other estuaries is know to vary by season, and from year to year within a season. For example, we attribute the relatively few 0+ crab found in the summer 2002 samples to not having sampled in May and early June when large numbers of 0+ crab enter the lower estuary (McCabe et al. 1986, 1989; Larson 1993). McCabe et al. (1989) found that the density of 0+ crab at Flavel Bar had declined substantially (0 to 10 crabs/ha) by July in each of the four years they conducted their studies.

Entrainment rates also may change at a particular location over time, based on crab movement patterns that are likely influenced by season, salinity, population structure, and behavioral interactions. For example, the entrainment rate for all age classes at Desdemona Shoals declined from 0.224 crabs per cy in June, to 0.120 crabs per cy in September (Table 9). Age 1+ crab contributed the most to the higher June entrainment rate, while the entrainment rate for 1+ crab in September was about 11% of that in June. Similarly, McCabe et al. (1989) found 1+ crab (their Size Class II) at Flavel Bar to have a 4-year average density of 517 crabs/ha in June and 35 crabs/ha in September (about 6% of the June average). This change in age 1+ crab entrainment rates at Desdemona Shoals could be related to seasonal migration patterns. Armstrong et al. (1987) found that some component of the age 1+ crab population entered the Grays Harbor Estuary from the ocean in the spring, and migrated out of the estuary to the ocean in the fall. Differences in the salinity regime in the Columbia River Estuary from June to September may also have influenced crab distribution. From late May through early July 2002, river flows ranged between 300 and 400 Kcfs; in September, river flows ranged from 90 to 150 Kcfs. Avoidance of low salinity water at high river flows may have caused the 1+ crab to move from the shallower areas to the deeper and saltier waters of the channels.

The following projections, listed with entrainment source data in parentheses, represented worst-case losses (AEL at 2+) for the combination of both construction dredging increments: Flavel Bar (Desdemona September), Desdemona (Desdemona September), Upper Sands (Upper Sands), and Tongue Point (Upper Sands). Best-case losses were as follows: Desdemona (Desdemona June), Flavel Bar (Upper Sands), Upper Sands (Upper Sands), Tongue Point (Miller Sands). It should be noted that although Desdemona June total entrainment values are higher, Desdemona September data have a greater source of impact on projected adult losses because samples were dominated by older crabs. For locations not sampled in 2002 (Flavel Bar and Tongue Point) entrainment rates for sampled locations downriver yielded the highest projected losses (worst case); conversely, entrainment rates from adjacent upriver locations yielded lowest projected losses (best case).

Projections for crab entrainment during the Channel Improvement Project have some assumptions that need to be noted. First, the projections were based on currently planned dredge volumes. These projections will need to be changed if the dredged volumes at the planned locations are modified; actual impacts will depend on the volumes finally dredged during the project. Second, crab entrainment data were not collected at Flavel Bar and Tongue Point, and we attempted to bound the projected range of likely impacts by using data collected in adjacent areas. As a result, projections for Flavel Bar are probably overestimated by using data from Desdemona Shoals and underestimated by using data from Upper Sands. We recommend a high priority be given to obtaining entrainment data from upriver areas (Flavel Bar and Tongue Point) not sampled during 2002. Third, location specific entrainment data encompassed a range of effort that was generally dictated by the dredge schedule. In general, the coefficient of variation (CV) falls as sampling effort (e.g., number of sampling days) increases. More sampling days at each upriver location would narrow the confidence limits associated with entrainment projections. Finally, the estimates made in this paper are constrained by many of the same assumptions noted by Armstrong et al. (1987) and Wainwright et al. (1992), for estimates of crab size-at-age, mortality, survival, and exploitation rates.

The crab loss projections in this paper fall within the range reported by previous authors for Grays Harbor (Armstrong et al. 1987, Wainwright et al. 1992). Our estimates reflect a loss of approximately 38,811 to 281,528 age 2+ crabs for the combined construction increments, and of 25,612 to 56,840 age 2+ crabs for annual maintenance under the Proposed Plan (43' Channel). These estimates correspond to fishery losses of approximately 7,252 to 44,342 age 3+ male crabs for the combined construction increments, and of 4,035 to 8,953 age 3+ male crabs for annual maintenance under the Proposed Plan. Worst-case projected fishery losses represent about 1% of the annual crab landings for the Washington and Oregon region around the Columbia River (5.3 million crabs from 1991 to 2001). In the hypothetical Grays Harbor confined disposal scenario presented by Wainwright et al. (1992), estimated losses of age 2+ crabs ranged from 166,000 to 587,000 crabs. Wainwright et al.'s (1992) estimates correspond to fishery losses from 37,000 to 134,000 age 3+ male crabs, which represented 1% to 4% of the average annual catch by the Washington coast fishery.

The scientific literature, scenario analyses, and the summer 2002 site-specific data on entrainment and salinity all indicate that bottom salinity influences crab distribution, especially at lower salinities. It is now clear from field measurements of entrainment rates and salinity during a period of low river flow (90-150 Kcfs) and high salinity intrusion that entrainment rates are zero where bottom salinity is less than 16 o/oo most of the time. This result is supported by physiological studies that indicate that Dungeness crab are stressed and become inactive at 16 o/oo. Also, McCabe et al. (1986) found no crab at stations with average bottom salinities of 3.5 and 8 o/oo (above RM18) and found crab only "infrequently" at stations with average bottom salinities of 15.9 (about RM14) and 20.2 (about RM12). The model for the influence of salinity on crab distribution and entrainment needs further development. The relationship of the 1+ crab to salinity appears to be more complex than that for the 2+ and older crabs, for which the regressions between the logarithm of crab entrainment rate and the percentage of salinity observations below 16 o/oo were significant and explained a high degree (91%) of the variation.

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2.0 FIGURES

Figure 1. Crab Density (crab/ha) as a Function of Bottom Salinity. Plotted from Data of Stevens and Armstrong (1984). Note logarithmic scale.

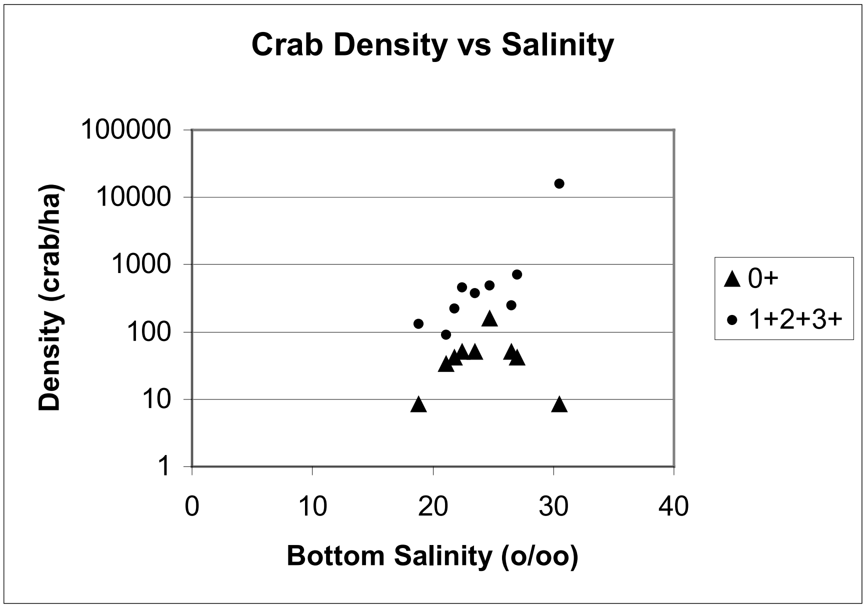


Figure 2. The Relationship Between Crab Density and Bottom Salinity from Regression Equation. Based on Data of Stevens and Armstrong (1984).

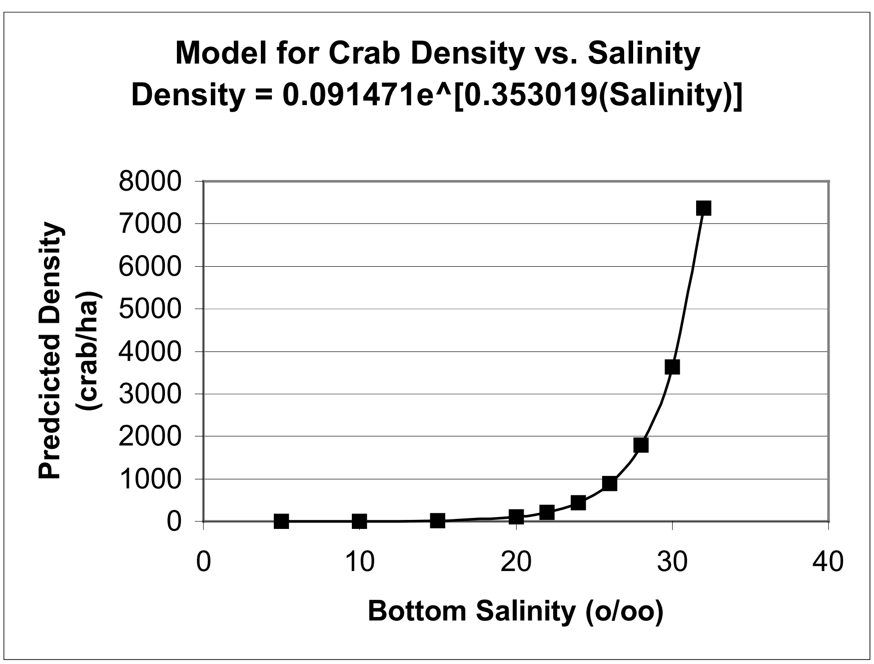


Figure 3. River Flow in the Columbia River Estimated by Combining Flow Measurements at Bonneville Dam and the Willamette River.

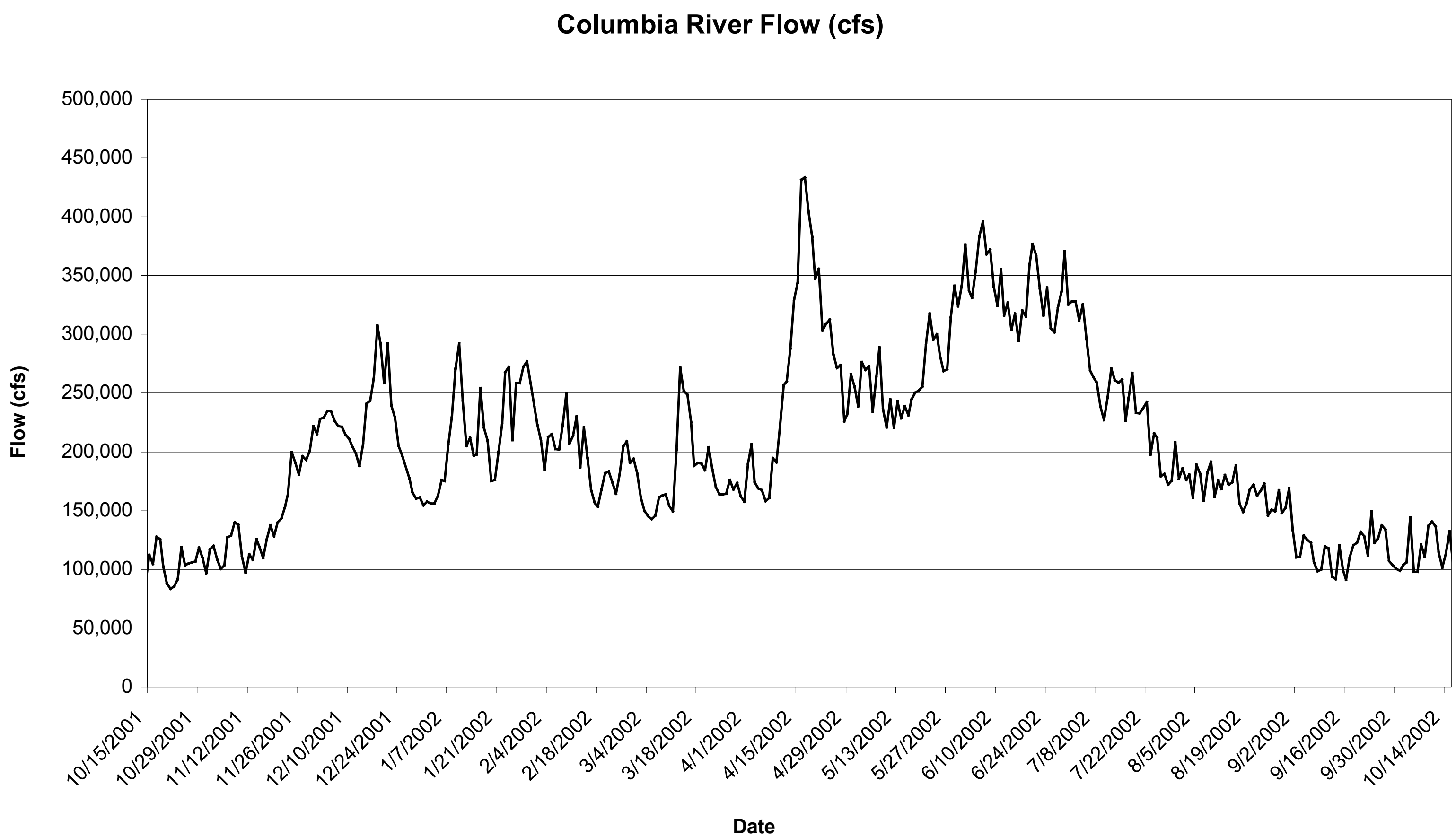


Figure 4. Bottom Salinity from CORIE Mean Salinity Profile Predicted by ELCIRC Model for May 21 and September 1, 2002.

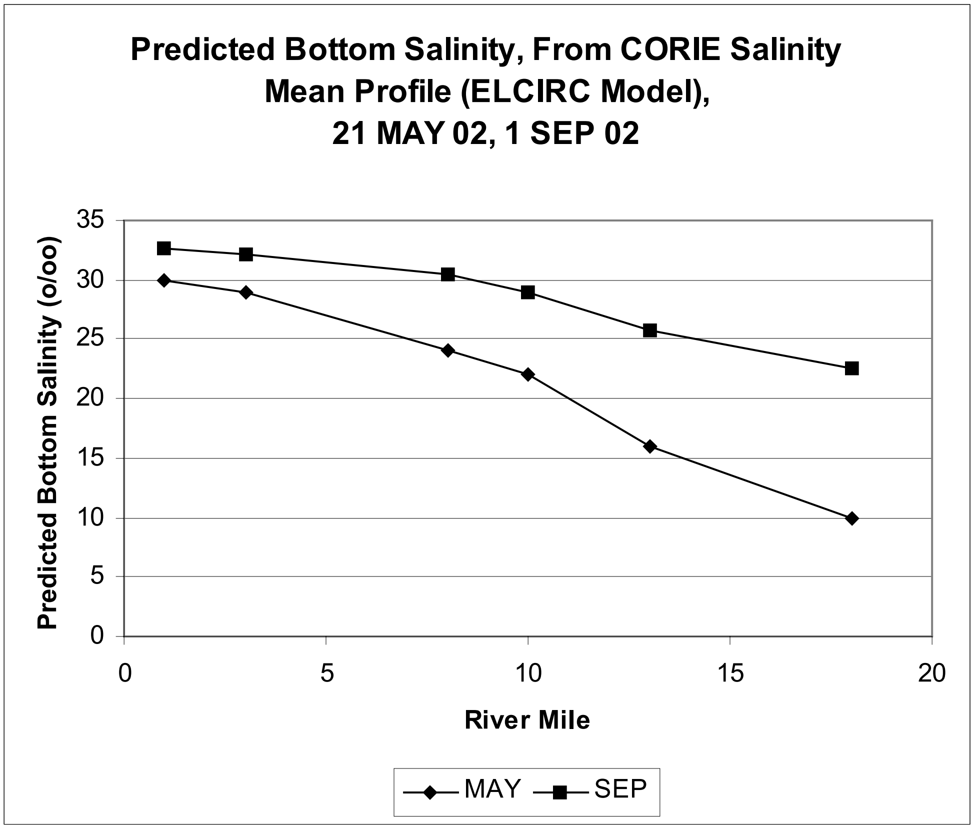


Figure 5. The Entrainment Function from the Grays Harbor Dredge Impact Model with Data from Columbia River Plotted on Same Scale

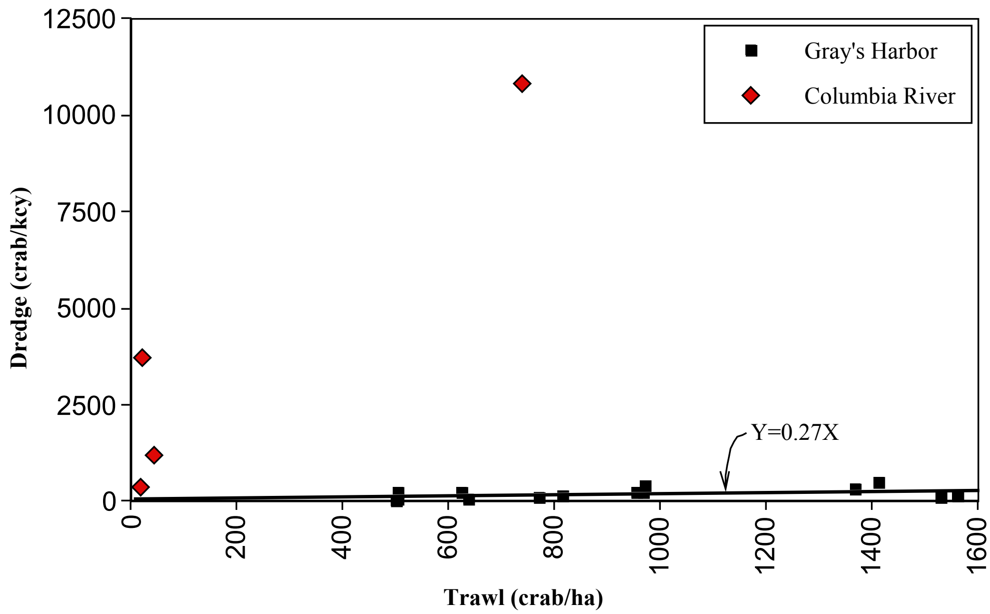


Figure 6. The Structure of a Modified Model for Estimating Entrainment Impacts on Dungeness Crab.

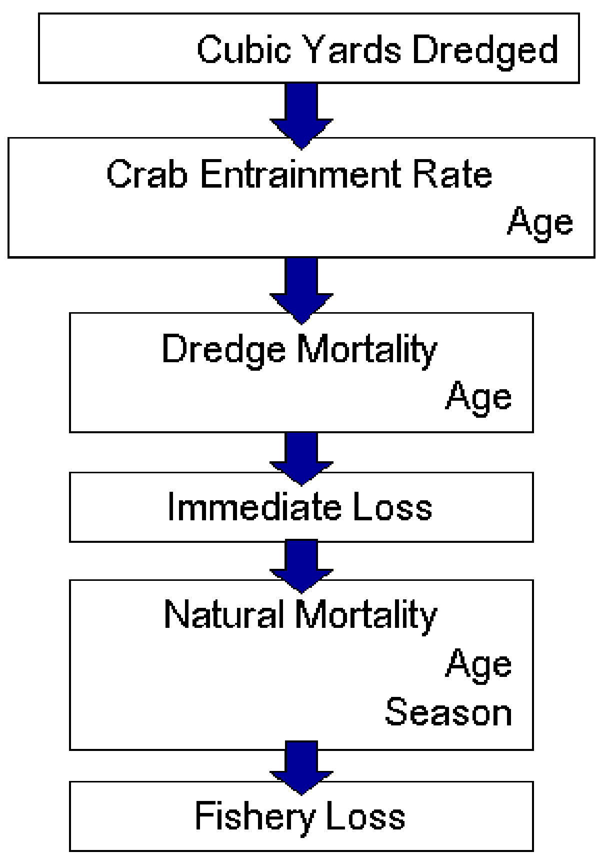


Figure 7. Map of the Study Area with Sampling Areas, Summer 2002.

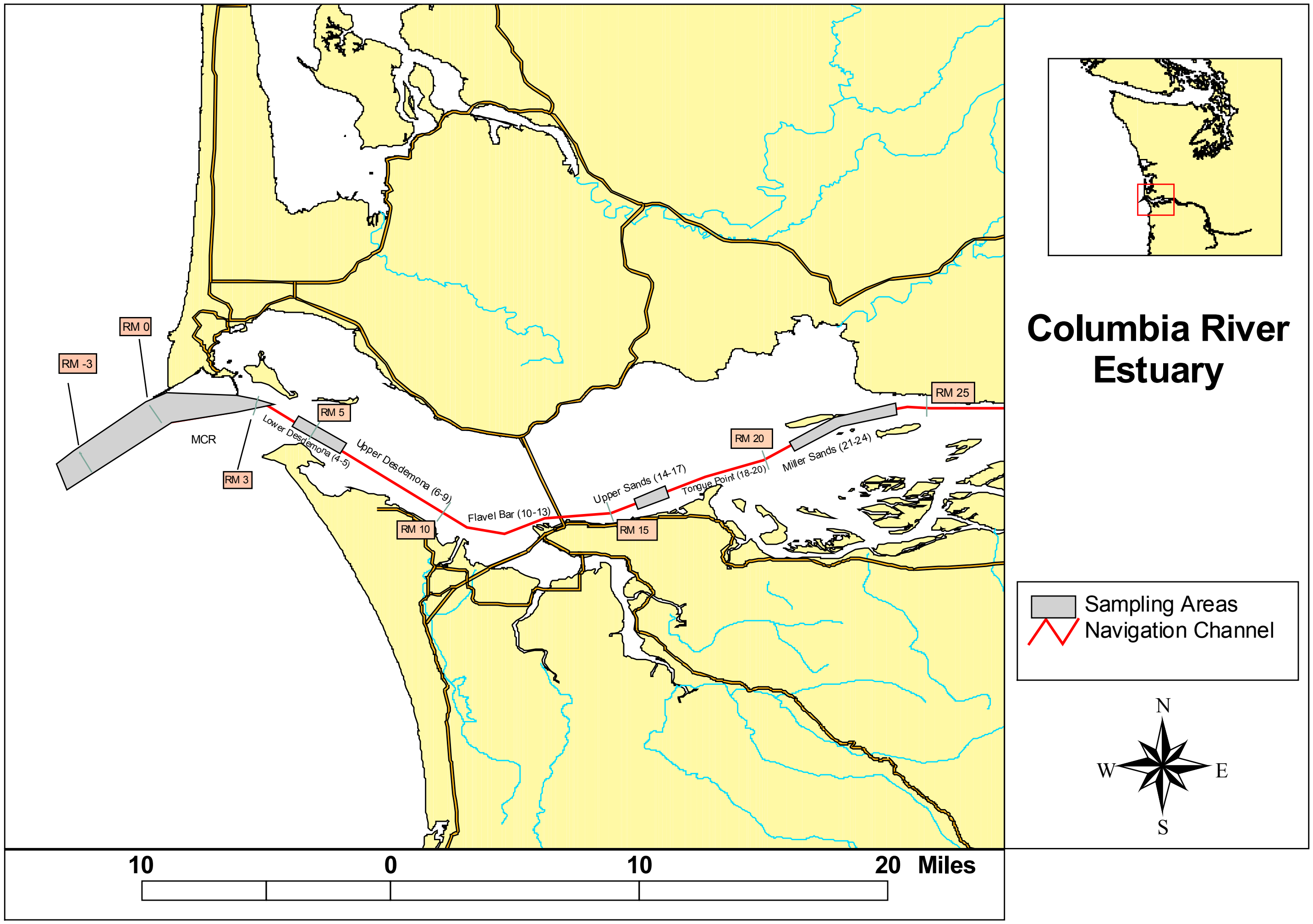


Figure 8. Diagram of the Piping and Valving on the Corps' Dredge *Essayons,* Summer 2002.

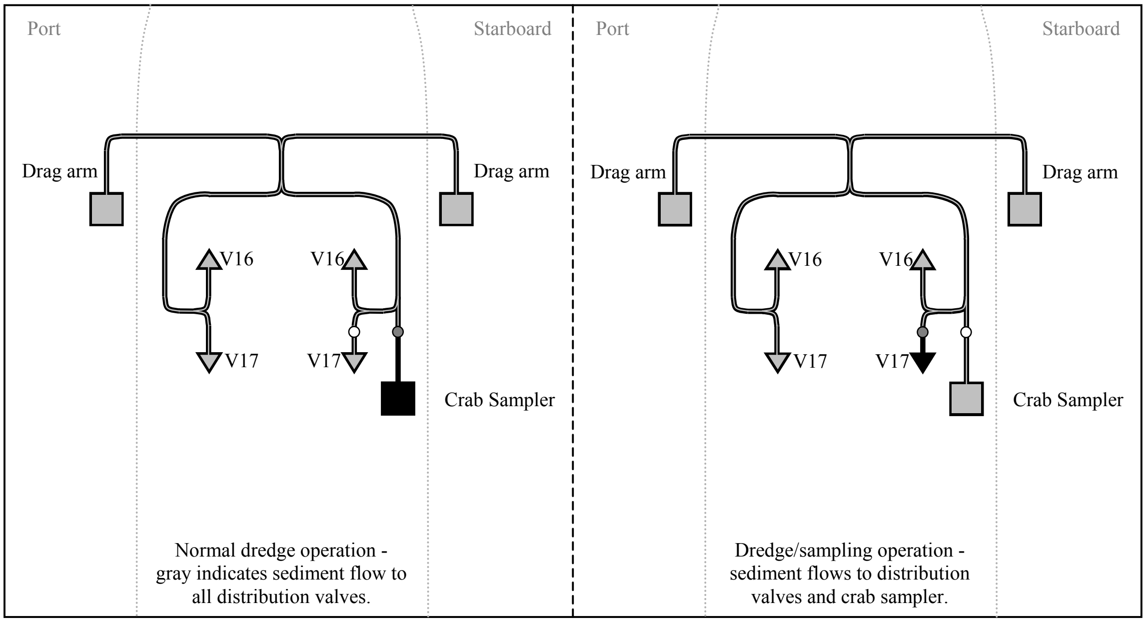


Figure 9. Predicted Crab Density for Six Salinity Intrusion Conditions. From Jay and Smith (1990).

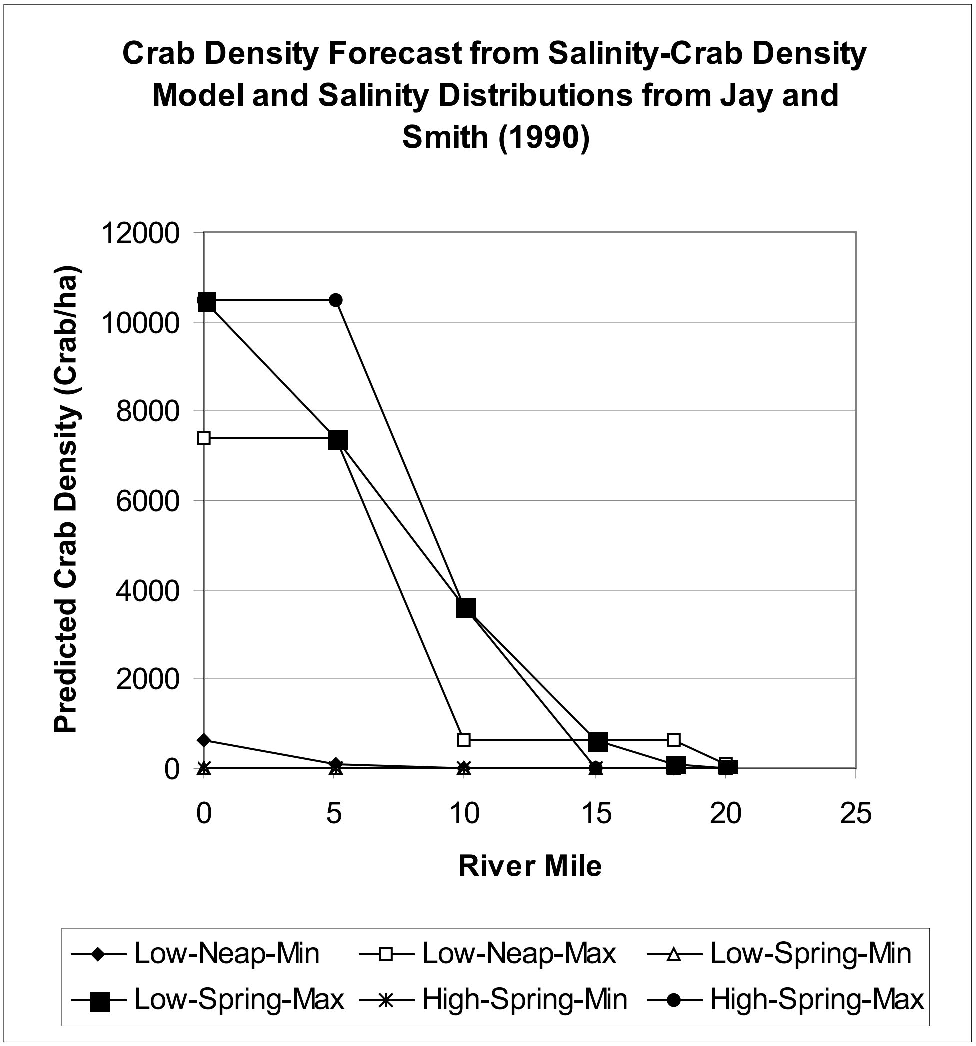


Figure 10. Predicted Crab Density for the Median Low Flow Salinity Intrusion. From Jay and Smith (1990).

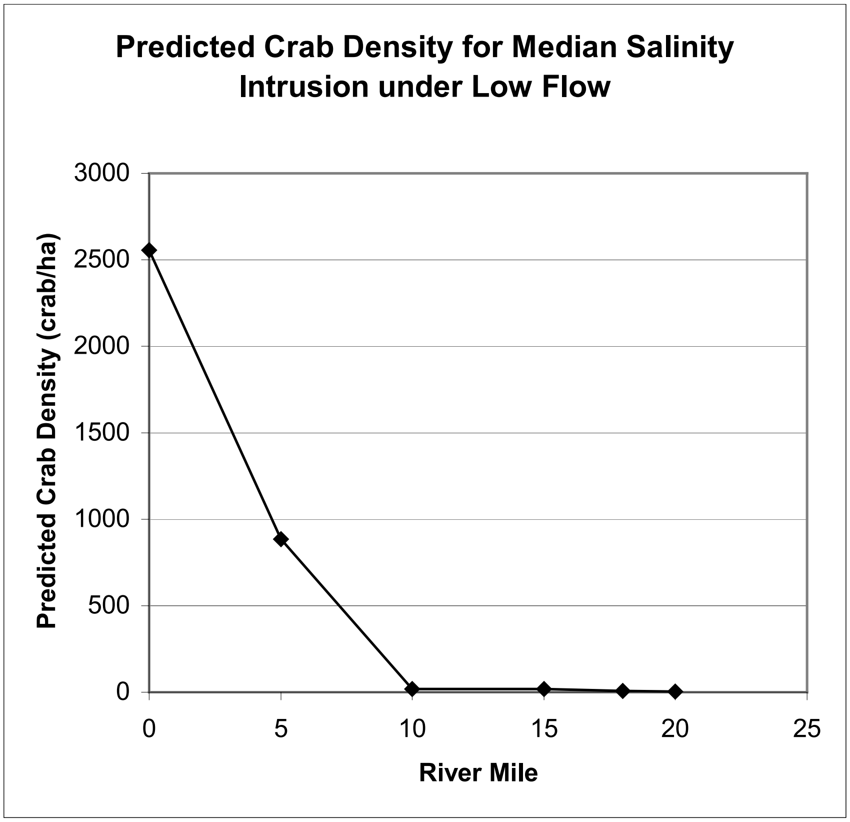
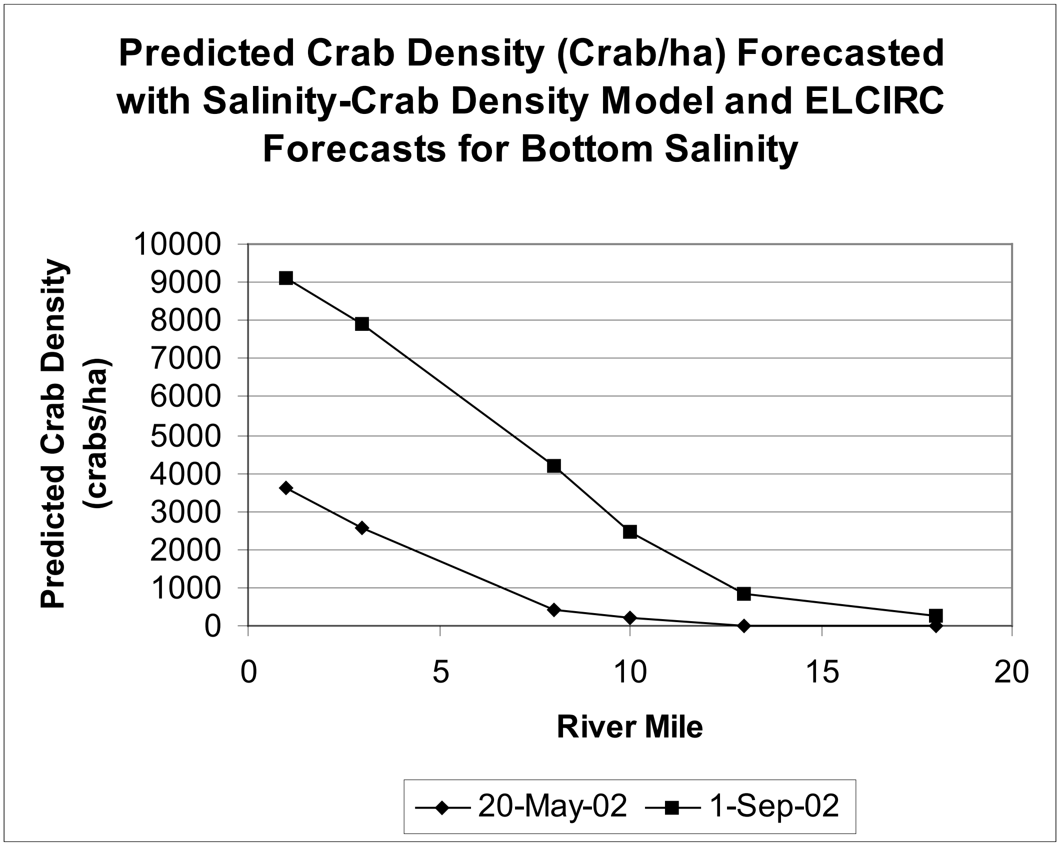


Figure 11. Predicted Crab Density Forecasted with the Salinity Crab Density Model and the ELCIRC Forecasts for Bottom Salinity.



3.0 TABLES

Table 1. 1+ Crab Densities by Habitat Type. From Rooper et al. (2002). Densities interpreted from graphs in Rooper et al. (2002) and other data taken from tables in Rooper et al. (2002).

Bay	n	Mean 1+ Density (crab/ha)		
		Lower Main Channel	Lower Side Channel	Upper Estuary
Grays Harbor	9	483	1722	228
Willapa Bay	9	270	772	216
Yaquina Bay	3	630	830	296
Coos Bay	3	571	1300	695
Mean		489	1156	359
Mean Salinity (o/oo)		28.5	26.1	25.1
Tide Flat (%)		20.7	53	40.1

Table 2. Isohaline Positions in the Columbia River as a Function of River Flow and Tidal Regime. Data taken from Graphs in Jay and Smith (1990).

Conditions			Isohaline Position (River Mile)				
Flow	Tide	Max/Min	30 o/oo	25 o/oo	20 o/oo	15 o/oo	10 o/oo
Low Flow	Neap	Minimum	0	3.8	5.0	5.4	6.5
Low Flow	Neap	Maximum	7.3	18.3	23.8	24.6	25.0
Low Flow	Spring	Minimum	0	0	0	5.4	7.1
Low Flow	Spring	Maximum	11.1	14.3	17.1	18.9	20.4
High Flow	Spring	Minimum	0	0	0	0	0
High Flow	Spring	Maximum	9.6	11.8	12.9	14.6	15.0

Table 3. Salinity Intrusion as a Function of River Mile in the Columbia River. Data taken from Graphs in Jay and Smith (1990).

Conditions			Within Isohaline at Position				
Flow	**Tide**	**Max/Min**	**RM5**	**RM10**	**RM15**	**RM18**	**RM20**
Low Flow	Neap	Minimum	20.0	5.0	5.0	5.0	5.0
Low Flow	Neap	Maximum	32.0	25.0	25.0	25.0	20.0
Low Flow	Spring	Minimum	15.0	5.0	0.5	0.0	0.0
Low Flow	Spring	Maximum	32.0	30.0	25.0	20.0	15.0
High Flow	Spring	Minimum	0.0	0.0	0.0	0.0	0.0
High Flow	Spring	Maximum	33.0	30.0	10.0	0.0	0.0
Median of Low Flow			26.0	15.0	15.0	12.5	10.0

Table 4. Crab Density Determined by Scientific Trawling and Calculated from Dredge Entrainment. The data from Wainwright et al. (1990) are from Grays Harbor, where the trawl and entrainment observations were paired. The data from Larson (1993) are from the Columbia River and the observations were not paired.

Total Crab			0+			1+		
Wainwright et al. 1990			Larson (1993)			Larson (1993)		
	Crab Density (crab/ha)			Crab Density (crab/ha)			Crab Density (crab/ha)	
Station	**by Trawl**	**by Dredge**	**Station**	**by Trawl**	**by Dredge**	**Station**	**by Trawl**	**by Dredge**
1	625	208	May-85	333	15,831	May-85	13	118
1.5	1367	352	May-86	0	3004	May-86	31	210
2	1530	148	May-87	1636	25764	May-87	37	288
3	956	322	May-88	1758	No Data	May-88	32	No Data
3.5	502	49	Jun-85	56848	35943	Jun-85	7	70
Mean	1004	216	Jun-86	424	3894	Jun-86	71	183
			Jun-87	576	8527	Jun-87	14	295
			Jun-88	303	1822	Jun-88	9	96
			Mean	7735	13541	Mean	27	180
RATIO Dredge to Trawl		**0.215**	RATIO Dredge to Trawl		**1.751**	RATIO Dredge to Trawl		**6.729**

Table 5. Sampling Effort Associated with Various Locations of Crab Entrainment Sampling on the Dredge *Essayons* During Summer 2002.

Location	River Mile	Dates (2002)	Total Dredged Volume (cy)	Total Loads Dredged	Total Loads Sampled	Total Basket Samples
Desdemona Shoals	+4 to +7	11 to 15 JUN	186,737	33	17	169
Desdemona Shoals	+4 to +7	17 SEP	30,012	6	4	12
Upper Sands	+16	23 SEP	54,036	9	9	27
Miller Sands	+21 to +24	1 to 8 OCT	443,563	75	36	140
Mouth of Columbia River	-3 to +3	8 JUL to 15 OCT	2,763,119	489	214	643

Table 6. Coefficients of Variation of Different Rates of Basket Samples per Dredge Load. Based on Data of Larson (1993).

Basket Samples Per Load	CV	
	All Loads	1/2 Loads
2	0.139	0.221
3	0.113	0.187
4	0.098	0.167
5	0.088	0.154
6	0.08	0.144
7	0.074	0.137
8	0.07	0.131
9	0.066	0.127
10	0.062	0.123

Table 7. Coefficients of Variation of Different Rates of Basket Samples per Dredge Load. Based on Data from June 2002. Note: The column for 0+ crab uses all 17 loads of which only 5 detected 0+ age class; precision calculations based on only the loads with observed crabs yields a CV of 0.114 for 2 basket samples per load.

Basket Samples per Load	Age Class			
	0+	1+	2+	3+
1	0.185	0.064	0.151	0.268
2	0.149	0.049	0.103	0.24
3	0.135	0.043	0.086	0.23
4	0.127	0.04	0.076	0.224
5	0.122	0.038	0.07	0.221

Table 8. Projected Dredge Volumes for Future Construction Dredging (to 40' and from 40' to 43') Associated With the Columbia River Channel Improvement Project.

Dredging to 40'			Dredging from 40' to 43'		
River Mile	Location	Volume (cy)	River Mile	Location	Volume (cy)
4	Lower Desdem.	94,688	4	Lower Desdem.	222,412
5		196,724	5		353,916
6	Upper Desdem	66,193	6	Upper Desdem	0
7		1,039	7		0
8		52,398	8		8,742
9		62,851	9		8,742
10	Flavel Bar	329,296	10	Flavel Bar	49,732
11		535,074	11		298,900
12		239,608	12		121,292
13		65,743	13		72,425
14	Upper Sands	171,432	14	Upper Sands	54,585
15		271,842	15		51,945
16		306,717	16		47,557
17		108,631	17		0
18	Tongue Point	174,113	18	Tongue Point	14,775
19		162,864	19		6,976
20		127,219	20		13,283
Total		2,966,432	Total		1,325,282

Summary of Planned Construction Volumes

Location	To 40'	From 40' to 43'	Combined
MCR	ND	ND	ND = No Data
Desdemona (Upper and Lower)	473,893	593,812	1,067,705
Flavel Bar	1,169,721	542,349	1,712,070
Upper Sands	858,622	154,087	1,012,709
Tongue Pt	464,196	35,034	499,230
Miller Sands	ND	ND	ND

Table 9. Projected Volumes During Year 1 and Year 20 Maintenance Dredging Associated with 40-foot Channel Maintenance (No Action Alternative) and the 43-foot Alternative (Proposed Plan).

Location	40-foot Channel Maintenance (No Action Alternative)		43-foot Alternative Maintenance (Proposed Plan)	
	Year 1	Year 20	Year 1	Year 20
Desdemona	40,000	40,000	60,000	40,000
Flavel Bar	400,000	210,000	500,000	210,000
Upper Sands	50,000	50,000	100,000	100,000
Tonque Point	270,000	270,000	330,000	330,000

Table 10. Entrainment Rates from Direct Measurements in Summer 2002.

	Age Class				
Area	0+	1+	2+	3+	All
Desdemona June	0.005	0.193	0.024	0.001	0.224
Desdemona Sept	0.000	0.022	0.065	0.033	0.120
Upper Sands	0.010	0.010	0.000	0.000	0.021
Miller Sands	0.000	0.000	0.000	0.000	0.000

Table 11. Summary of Entrainment Rates (R), Entrainment (E), Adult Equivalent Loss (AEL), and Loss to Fishery (LF) with 95% Confidence Intervals (CI) for the Dredged Volumes Accomplished During the Summer of 2002.

Location	R	E	95%CI	AEL 2+	95%CI	AEL 3+	95%CI	LF	95%CI
Desdemona Jun	0.2236	41758.8	±4099.5	6314.1	±911.9	2841.3	±410.4	1193.9	±189.9
Desdemona Sep	0.1195	3586.2	±2068.7	3023.3	±1200.1	1360.5	±540.1	476.2	±189.0
Upper Sands	0.0205	1109.5	±1537.7	53.71	±103.5	24.2	±46.6	8.5	±16.3
Miller Sands	0.0000	0.00	n/a	0.00	n/a	0.00	n/a	0.00	n/a

Table 12. Contribution by Age Class to Adult Equivalent Loss (AEL) by Male (M) and Female (F) Crab from Summer 2002 Sampling.

			Dredged Volume	Contribution to AEL by age class				
Location	**Age Class**	**Sex**	**cubic yds**	**0+**	**1+**	**2+**	**3+**	**Total**
Desd June	2+	M	186737	1	1732	1899	158	3790
		F		1	1732	633	158	2524
Desd June	3+	M	186737	0	780	855	71	1706
		F		0	780	285	71	1136
Desd Sep	2+	M	30012	0	31	546	934	1512
		F		0	31	546	934	1512
Desd Sep	3+	M	30012	0	14	246	421	680
		F		0	14	246	421	680
Upper Sands	2+	M	54036	0	26	0	0	27
		F		0	26	0	0	27
Upper Sands	3+	M	54036	0	12	0	0	12
		F		0	12	0	0	12
Miller Sands	2+	M	443563	0	0	0	0	0
		F		0	0	0	0	0
Miller Sands	3+	M	443563	0	0	0	0	0
		F		0	0	0	0	0

Table 13. Crab AEL and LF Projected for Construction Dredging to 40'.

Location	Age Class	Sex	AEL Total	95% CI	Loss to Fishery Total	95% CI
Desd June	2+	M	12,052	±1,741	3,796	±603
		F	8,026	±592		
Desd June	3+	M	5,423	±783	3,796	±603
		F	3,612	±522		
Desd Sep	2+	M	29,909	±11,871	9,422	±3,739
		F	29,909	±11,871		
Desd Sep	3+	M	13,459	±5,342	9,422	±3,739
		F	13,459	±5,342		
Flavel Bar*	2+	M	11,008	±1,590	3,467	±3,467
		F	7,331	±1,059		
Flavel Bar*	3+	M	4,953	±716	3,467	±3,467
		F	3,299	±477		
Flavel Bar**	2+	M	27,317	±10,842	8,605	±3,415
		F	27,317	±10,842		
Flavel Bar**	3+	M	12,293	±4,879	8,605	±3,415
		F	12,293	±4,879		
Flavel Bar***	2+	M	270	±519	85	±164
		F	270	±519		
Flavel Bar***	3+	M	121	±234	85	±164
		F	121	±234		
Upper Sands	2+	M	77	±148	24	±46
		F	77	±148		
Upper Sands	3+	M	34	±66	24	±46
		F	34	±66		
Tongue Pt!	2+	M	17	±34	6	±11
		F	17	±34		
Tongue Pt!	3+	M	8	±15	6	±11
		F	8	±15		
Tongue Pt!!	2+	M	0	n/a	0	n/a
		F	0	n/a		
Tongue Pt!!	3+	M	0	n/a	0	n/a
		F	0	n/a		
Miller Sands	2+	M	0	n/a	0	n/a
		F	0	n/a		
Miller Sands	3+	M	0	n/a	0	n/a
		F	0	n/a		

* based on Desdemona JUN entrainment rates
** based on Desdemona SEP entrainment rates
*** based on Upper Sands entrainment rates
! based on Upper Sands entrainment rates
!! based on Miller Sands entrainment rates

Table 14. Crab AEL and LF Projected for Construction Dredging from 40’ to 43’.

			AEL	95% CI	Loss to Fishery	95% CI
Location	**Age Class**	**Sex**	**Total**		**Total**	
Desd June	2+	M	9,618	±1,389	3,030	±482
		F	6,405	±925		
Desd June	3+	M	4,328	±625	3,030	±482
		F	2,882	±416		
Desd Sep	2+	M	23,869	±9,474	7,519	±2,984
		F	23,869	±9,474		
Desd Sep	3+	M	10,741	±4,263	7,519	±2,984
		F	10,741	±4,263		
Flavel Bar*	2+	M	23,741	±3,429	7,478	±1,189
		F	15,811	±2,284		
Flavel Bar*	3+	M	10,683	±1,543	7,478	±1,189
		F	7,115	±1,028		
Flavel Bar**	2+	M	58,917	±23,384	18,559	±7,366
		F	58,917	±23,384		
Flavel Bar**	3+	M	26,513	±10,523	18,559	±7,366
		F	26,513	±10,523		
Flavel Bar***	2+	M	581	±1,120	183	±353
		F	581	±1,120		
Flavel Bar***	3+	M	262	±504	183	±353
		F	262	±504		
Upper Sands	2+	M	427	±822	134	±259
		F	427	±822		
Upper Sands	3+	M	192	±370	134	±259
		F	192	±370		
Tongue Pt!	2+	M	231	±444	73	±140
		F	231	±444		
Tongue Pt!	3+	M	104	±200	73	±140
		F	104	±200		
Tongue Pt!!	2+	M	0	n/a	0	n/a
		F	0	n/a		
Tongue Pt!!	3+	M	0	n/a	0	n/a
		F	0	n/a		
Miller Sands	2+	M	0	n/a	0	n/a
		F	0	n/a		
Miller Sands	3+	M	0	n/a	0	n/a
		F	0	n/a		

* based on Desdemona JUN entrainment rates
** based on Desdemona SEP entrainment rates
*** based on Upper Sands entrainment rates
! based on Upper Sands entrainment rates
!! based on Miller Sands entrainment rates

Table 15. Summary of AEL at 2+ and Losses to Fishery For Construction Dredging Under Worst- and Best-Case Assumptions.

Project Location	AEL at 2+ Under Assumptions		Loss to Fishery Under Assumptions	
	Worst-case	Best-case	Worst-case	Best-case
Dredging to 40'				
Desdemona	59,818	20,078	9,422	3,796
Flavel	54,634	540	8,605	85
Upper Sands	154	154	24	24
Tongue Point	34	0	6	0
Total	**114,640**	**20,772**	**18,057**	**3,905**
Dredging from 40' to 43'				
Desdemona	47,738	16,023	7,519	3,030
Flavel	117,834	1,162	18,559	183
Upper Sands	854	854	134	134
Tongue Point	462	0	73	0
Total	**166,888**	**18,039**	**26,285**	**3,347**
Total Dredging Volume				
OVERALL	**281,528**	**38,811**	**44,342**	**7,252**

Table 16. Summary of AEL at 2+ and Losses to Fishery For Maintenance Dredging in Year 1 and Year 20 Under Worst-Case Assumptions for Both the "No Action Alternative" and the Proposed Project.

Project Location	AEL at 2+ Under Assumptions		Loss to Fishery Under Assumptions	
	Year 1	Year 20	Year 1	Year 20
40-foot Channel Maintenance (No Action Alternative)				
Desdemona	4,030	4,030	635	635
Flavel	40,295	21,155	6,346	3,332
Upper Sands	50	50	8	8
Tongue Point	268	268	42	42
Total	**44,643**	**25,503**	**7,031**	**4,017**
43-foot Alternative Maintenance (Proposed Project)				
Desdemona	6,044	4,030	952	635
Flavel	50,369	21,155	7,933	3,332
Upper Sands	99	99	16	16
Tongue Point	328	328	52	52
Total	**56,840**	**25,612**	**8,953**	**4,035**

Table 17. Entrainment Rates by Location and the Percentage of Salinity Observations More Than 32 o/oo and Less Than 16 o/oo. Note: 0.001 has been added to rates to enable logarithmic transformation before regression.

Location	Entrainment Rate (crab/cy)			% of Salinity Observations	
	Age 1+	Age 2+3+	All Ages	>32 o/oo	<16 o/oo
Desdemona JUN	0.193	0.025	0.224	38	16
Desdemona SEP	0.022	0.098	0.121	83	0
Upper Sands	0.01	0.001	0.021	0	67
Miller Sands	0.001	0.001	0.001	0	100
MCR	0.014	0.042	0.057	96	1

Table 18. Results of Regression Analysis Between the Natural Logarithm of the Entrainment Rates and Percentage of Salinity Observations Above 32 o/oo and Below 16 o/oo. Regressions with asterisk are significant.

Salinity	Entrainment Rate		
	All Ages	Age 1+	Age 2+ & 3+
%>32 o/oo	p=0.25	p=0.51	p=0.02*
			(r^2=0.81)
%<16 o/oo	p=0.03*	p=0.15	p=0.01*
	(r^2 =0.86)		(r^2 =0.91)

APPENDIX A
EVALUATION REPORT
DUNGENESS CRAB (REVISED)

SUMMARY OF CALCULATION OF ADULT EQUIVALENT LOSS BASED ON MODIFIED DREDGE IMPACT MODEL AND DIRECT MEASUREMENT OF ENTRAINMENT RATES at Desdemona Shoals, June 2002.

WH Pearson and GD Williams
Battelle Marine Sciences Laboratory
Sequim, Washington

First Version: ***24-Jul-02*** Revised: ***4-Dec-02***
NOTE: Shaded cells are input.

This calculation run is for

Location	Start Date	End Date	Total Volume Dredged (cy)
Desdemona	***11-Jun-02***	***15-Jun-02***	***186737***

Overall Summary Statements

Adult Equivalent Loss of all age classes taken to 2+ is	**6314**	with 95% CI	**912**
We are 95% confident that the true value lies between	**5402**	and	**7226**
Adult Equivalent Loss of all age classes taken to 3 + is	**2841**	with 95% CI	**410**
We are 95% confident that the true value lies between	**2431**	and	**3252**
Number of MALE recruits lost to fishery is estimated to be	**1194**	with 95% CI	**190**
We are 95% confident that the true value lies between	**1004**	and	**1384**

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	966.0	77194.21	0.10	0.017	1.59	0.210161229	0.72	0.042557649
1+	0.19327	36091.1	3868086.21	0.60	0.160	3464.75	35648.28247	1559.14	7218.777201
2+	0.02429	4536.4	415537.73	0.86	0.649	2531.95	129448.4214	1139.38	26213.30533
3+	0.00088	165.3	14071.33	0.86	2.222	315.80	51383.08867	142.11	10405.07545
All		**41758.8**	**4374889.47**			**6314.09**	**216480.00**	**2841.34**	**43837.20**

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

<u>AGE 2+ Calculations</u>
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.80	0.052540307	0.50	0.80	0.052540307
1+	0.50	1732.38	8912.070618	0.50	1732.38	8912.070618
2+	0.25	632.99	8090.526337	0.75	1898.96	72814.73704
3+	0.50	157.90	12845.77217	0.50	157.90	12845.77217
All		**2524.06**	**29848.42**		**3790.03**	**94572.63**
						124421.05

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1991)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

<u>AGE 3+ Calculations</u>
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female	Male

Age Class	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.36	0.010639412	0.50	0.36	0.010639412
1+	0.50	779.57	1804.6943	0.50	779.57	1804.6943
2+	0.25	284.84	1638.331583	0.75	854.53	14744.98425
3+	0.50	71.05	2601.268864	0.50	71.05	2601.268864
All		**1135.83**	**6044.31**		**1705.51**	**19150.96**
					2841.340	25195.263

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	41758.8
Var(E)	4374889.5
SE E	2091.6
Z at 0.975	1.95996
95% C. I.	4099.5
CV E (%)	5.01

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	6314.1
Var(AEL2+)	216480.0
SE AEL	465.3
Z at 0.975	1.95996
95% C. I.	911.9
CV AEL (%)	7.37

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	2841.3
Var(AEL3+)	43837.2
SE AEL	209.4
Z at 0.975	1.95996
95% C. I.	410.4
CV AEL (%)	7.37

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	1705.5
Var(AEL)	19151.0
SE AEL	138.4
Z at 0.975	1.95996
95% C. I.	271.2
CV AEL (%)	8.11

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	1135.8
Var(AEL)	6044.3
SE AEL	77.7
Z at 0.975	1.95996
95% C. I.	152.4
CV AEL (%)	6.84

TOTAL LOSS TO MALE FISHERY

(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
1705.5	0.70	**1193.9**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	1193.9
Var(AEL)	9383.969446
SE LF	96.9
Z at 0.975	1.95996
95% C. I.	189.9
CV LF (%)	8.11

ADDITIONAL NOTES:

Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

Estimating Entrainment Rate, Total Entrainment, and Variance
Lower Desdemona Shoals 6/11/02 - 6/15/02
WH Pearson and GD Williams

Summary

	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	Total
R	0.005	0.193	0.024	0.001	0.224
E	966.0	36091.1	4536.4	165.3	41758.788
Var(E)	77194.21	3868086.21	415537.73	14071.33	
SE (E)	277.84	1966.75	644.62	118.62	
CV(E)	0.29	0.05	0.14	0.72	

Calculations

		Rj				Variance Rj (Variance x Load Sheet)				Entrainment (Rj x V)			
Load # (j)	V	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
1	4843	0.0370	0.2034	0.0000	0.0000	0.0006	0.0075	0.0000	0.0000	179.144	985.294	0	0
2	5752	0.0146	0.1463	0.0146	0.0146	0.0002	0.0018	0.0002	0.0002	84.1727	841.727	84.1727	84.1727
5	5605	0.0167	0.2172	0.0334	0.0000	0.0003	0.0065	0.0005	0.0000	93.6479	1217.42	187.296	0
8	4482	0.0000	0.1293	0.0259	0.0000	0.0000	0.0034	0.0007	0.0000	0	579.577	115.915	0
9	5605	0.0000	0.2125	0.0607	0.0000	0.0000	0.0032	0.0006	0.0000	0	1191.04	340.299	0
11	5605	0.0100	0.0603	0.0201	0.0000	0.0001	0.0007	0.0002	0.0000	56.3017	337.81	112.603	0
12	5617	0.0000	0.0819	0.0117	0.0000	0.0000	0.0012	0.0001	0.0000	0	460.167	65.7382	0
14	5617	0.0140	0.2664	0.0280	0.0000	0.0002	0.0050	0.0004	0.0000	78.7431	1496.12	157.486	0
15	5617	0.0000	0.3189	0.0319	0.0000	0.0000	0.0090	0.0010	0.0000	0	1791.04	179.104	0
16	5617	0.0000	0.0307	0.0153	0.0000	0.0000	0.0004	0.0002	0.0000	0	172.388	86.194	0
17	5617	0.0000	0.1268	0.0254	0.0000	0.0000	0.0026	0.0003	0.0000	0	712.347	142.469	0
18	5867	0.0000	0.2756	0.0459	0.0000	0.0000	0.0051	0.0011	0.0000	0	1617.01	269.501	0
23	5867	0.0000	0.2377	0.0170	0.0000	0.0000	0.0021	0.0003	0.0000	0	1394.78	99.6269	0
24	5867	0.0000	0.4007	0.0321	0.0000	0.0000	0.0030	0.0005	0.0000	0	2350.75	188.06	0
27	5867	0.0000	0.2656	0.0332	0.0000	0.0000	0.0069	0.0005	0.0000	0	1558.21	194.776	0
28	5867	0.0000	0.1042	0.0149	0.0000	0.0000	0.0020	0.0002	0.0000	0	611.194	87.3134	0
29	5800	0.0000	0.1837	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0	1065.67	0	0

h	17
Vh	95112
H	33
VH	186737

Estimating E

	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
numerator	492.00978	18382.544	2310.5552	84.172662
denominator	95112	95112	95112	95112
R	0.005	0.193	0.024	0.001
E	966.0	36091.1	4536.4	165.3

Estimating Variance and CV

		YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
first term (Load to load variability)					
step 1	0.48485				
step 2		23744.277	2428.0157	13841.75	18.369631
		2961.3018	72887.795	3086.9842	6253.9991
		4180.0775	17990.837	2614.6449	24.604964
		537.55207	82180.258	49.479514	15.733132
		840.67488	11610.458	41671.621	24.604964
		745.69158	555744.09	555.01382	24.604964
		844.27841	391181.55	5000.6935	24.710432
		2468.7581	168515.25	442.36158	24.710432
		844.27841	497635.1	1819.0852	24.710432
		844.27841	833978.36	2526.0388	24.710432
		844.27841	139326.66	36.18898	24.710432
		921.10473	233361.63	16122.38	26.958993
		921.10473	68040.508	1840.4208	26.958993
		921.10473	1480640.9	2073.2277	26.958993
		921.10473	180012.32	2729.9714	26.958993
		921.10473	273253.28	3048.5371	26.958993
		900.18718	3059.1362	19852.63	26.346776
step 3 (total)		44361.157	5011846.2	117311.03	6646.6107
step 4	16				
step 5		1344.2775	151874.13	3554.8796	201.41244
second term (Basket to basket variability)					
step 1	1.94118				
step 2		13779.057	174772.7	0	0
		7074.3161	58366.328	7145.1098	7145.1098
		8827.4797	205587.43	15821.182	0
		0	68244.316	13204.182	0
		0	99719.314	19300.512	0
		3179.913	22902.358	5675.4589	0
		0	39116.577	4326.0574	0
		6213.4408	156400.77	11074.939	0
		0	285141.46	32078.414	0
		0	13207.841	7429.4108	0
		0	83219.955	9133.8976	0
		0	175251.06	36915.639	0
		0	70581.421	9925.5124	0
		0	103152.15	15718.423	0
		0	236057.03	16861.216	0
		0	68612.72	7623.6356	0
		0	54078.859	0	0
step 3 (total)		39074.206	1914412.3	212233.59	7145.1098
step 4		75849.93	3716212.1	411982.85	13869.919
Var(E)		77194.207	3868086.2	415537.73	14071.332
SE (E)		277.83845	1966.7451	644.62216	118.62264
CV(E)		0.287623	0.0544938	0.1420999	0.7177967

Variance By Load
WH Pearson and GD Williams

Lower Desdemona Shoals
6/11/02 - 6/15/02

Load Sequence Number	Date	Sample Number	Number of Crabs YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	Sample Volume (CY) (w)	Sum of Squares (by load - w2) YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
1	6/11/02	1	0	3	0	0	6.45733	0.0571	2.8435	0	0
1	6/11/02	2	0	4	0	0	6.45733	0.0571	7.2161	0	0
1	6/11/02	3	0	0	0	0	7.96324	0.0868	2.6247	0	0
1	6/11/02	4	0	2	0	0	6.75851	0.0625	0.3906	0	0
1	6/11/02	5	1	0	0	0	6.45733	0.5793	1.7259	0	0
1	6/11/02	6	1	0	0	0	7.0597	0.5459	2.0629	0	0
1	6/11/02	7	0	2	0	0	6.45733	0.0571	0.471	0	0
1	6/11/02	8	0	0	0	0	6.45733	0.0571	1.7259	0	0
1	total	8	2	11	0	0	54.0681	1.5027	19.061	0	0
	mean (cij)		0.25	1.375	0	0					
							Rj	0.037	0.2034	0	0
							Var Rj	0.0006	0.0075	0	0
2	6/11/02	1	0	0	0	1	6.58776	0.0093	0.9294	0.0093	0.8165
2	6/11/02	2	1	1	0	0	6.89503	0.8084	8E-05	0.0102	0.0102
2	6/11/02	3	0	2	0	0	8.12409	0.0141	0.658	0.0141	0.0141
2	6/11/02	4	0	0	0	0	6.58776	0.0093	0.9294	0.0093	0.0093
2	6/11/02	5	0	1	0	0	6.89503	0.0102	8E-05	0.0102	0.0102
2	6/11/02	6	0	1	0	0	6.58776	0.0093	0.0013	0.0093	0.0093
2	6/11/02	7	0	1	0	0	6.58776	0.0093	0.0013	0.0093	0.0093
2	6/11/02	8	0	0	1	0	6.58776	0.0093	0.9294	0.8165	0.0093
2	6/11/02	9	0	1	0	0	6.58776	0.0093	0.0013	0.0093	0.0093
2	6/11/02	10	0	3	0	0	6.89503	0.0102	3.9641	0.0102	0.0102
2	total	10	1	10	1	1	68.3357	0.8986	7.4142	0.9076	0.9076
	mean (cij)		0.1	1	0.1	0.1					
							Rj	0.0146	0.1463	0.0146	0.0146
							Var Rj	0.0002	0.0018	0.0002	0.0002
5	6/11/02	1	0	0	1	0	5.822	0.0095	1.5992	0.6487	0
5	6/11/02	2	0	0	0	0	7.180	0.0144	2.4321	0.0576	0
5	6/11/02	3	0	1	1	0	5.822	0.0095	0.07	0.6487	0
5	6/11/02	4	0	1	0	0	5.822	0.0095	0.07	0.0379	0
5	6/11/02	5	0	1	0	0	5.822	0.0095	0.07	0.0379	0
5	6/11/02	6	0	1	0	0	5.822	0.0095	0.07	0.0379	0
5	6/11/02	7	0	5	0	0	5.822	0.0095	13.953	0.0379	0
5	6/11/02	8	0	2	0	0	5.822	0.0095	0.5408	0.0379	0
5	6/11/02	9	1	2	0	0	5.822	0.8149	0.5408	0.0379	0
5	6/12/02	10	0	0	0	0	6.094	0.0104	1.7519	0.0415	0
3	total	10	1	13	2	0	59.8518	0.9059	21.098	1.6236	0
	mean (cij)		0.1	1.3	0.2	0					
							Rj	0.0167	0.2172	0.0334	0
							Var Rj	0.0003	0.0065	0.0005	0
8	6/12/02	1	0	2	0	0	3.813	0	2.2707	0.0097	0
8	6/12/02	2	0	0	0	0	3.991	0	0.2664	0.0107	0
8	6/12/02	3	0	1	0	0	3.813	0	0.2569	0.0097	0
8	6/12/02	4	0	0	0	0	3.813	0	0.2431	0.0097	0
8	6/12/02	5	0	0	0	0	3.813	0	0.2431	0.0097	0
8	6/12/02	6	0	1	0	0	3.813	0	0.2569	0.0097	0
8	6/12/02	7	0	1	0	0	3.813	0	0.2569	0.0097	0
8	6/12/02	8	0	0	0	0	3.813	0	0.2431	0.0097	0
8	6/12/02	9	0	0	0	0	3.813	0	0.2431	0.0097	0
8	6/12/02	10	0	0	1	0	4.169	0	0.2906	0.796	0
4	total	10	0	5	1	0	38.6661	0	4.5712	0.8844	0
	mean (cij)		0	0.5	0.1	0					
							Rj	0	0.1293	0.0259	0
							Var Rj	0	0.0034	0.0007	0
9	6/12/02	1	0	1	1	0	6.588	0	0.16	0.36	0
9	6/12/02	2	0	0	0	0	6.588	0	1.96	0.16	0
9	6/12/02	3	0	4	0	0	6.588	0	6.76	0.16	0
9	6/12/02	4	0	2	0	0	6.588	0	0.36	0.16	0
9	6/12/02	5	0	2	1	0	6.588	0	0.36	0.36	0
9	6/12/02	6	0	1	0	0	6.588	0	0.16	0.16	0
9	6/12/02	7	0	1	1	0	6.588	0	0.16	0.36	0
9	6/12/02	8	0	0	0	0	6.588	0	1.96	0.16	0
9	6/12/02	9	0	2	1	0	6.588	0	0.36	0.36	0
9	6/12/02	10	0	1	0	0	6.588	0	0.16	0.16	0
5	total	10	0	14	4	0	65.8833	0	12.4	2.4	0
	mean (cij)		0	1.4	0.4	0					
							Rj	0	0.2125	0.0607	0
							Var Rj	0	0.0032	0.0006	0
11	6/12/02	5	0	0	0	0	10.734	0.0116	0.4185	0.0465	0
11	6/12/02	6	0	0	0	0	10.276	0.0107	0.3836	0.0426	0
11	6/12/02	7	0	0	0	0	9.818	0.0097	0.3501	0.0389	0
11	6/12/02	8	0	0	0	0	9.818	0.0097	0.3501	0.0389	0
11	6/12/02	9	0	1	0	0	9.818	0.0097	0.1667	0.0389	0
11	6/12/02	10	0	2	0	0	9.818	0.0097	1.9833	0.0389	0
11	6/12/02	11	1	2	1	0	9.818	0.8125	1.9833	0.6444	0
11	6/12/02	12	0	1	1	0	9.818	0.0097	0.1667	0.6444	0
11	6/12/02	13	0	0	0	0	9.818	0.0097	0.3501	0.0389	0
11	6/12/02	14	0	0	0	0	9.818	0.0097	0.3501	0.0389	0
6	total	10	1	6	2	0	99.5529	0.9028	6.5025	1.6114	0
	mean (cij)		0.1	0.6	0.2	0					
							Rj	0.01	0.0603	0.0201	0
							Var Rj	0.0001	0.0007	0.0002	0
12	6/12/02	1	0	0	0	0	8.902	0	0.5318	0.0109	0
12	6/12/02	2	0	0	0	0	8.505	0	0.4855	0.0099	0
12	6/12/02	3	0	0	0	0	8.505	0	0.4855	0.0099	0
12	6/12/02	4	0	1	0	0	8.505	0	0.092	0.0099	0
12	6/12/02	5	0	1	0	0	8.505	0	0.092	0.0099	0
12	6/12/02	6	0	3	1	0	8.505	0	5.305	0.8108	0
12	6/13/02	7	0	1	0	0	8.505	0	0.092	0.0099	0
12	6/13/02	8	0	0	0	0	8.505	0	0.4855	0.0099	0
12	6/13/02	9	0	0	0	0	8.505	0	0.4855	0.0099	0
12	6/13/02	10	0	1	0	0	8.505	0	0.092	0.0099	0
7	total	10	0	7	1	0	85.445	0	8.1464	0.9009	0
	mean (cij)		0	0.7	0.1	0					
							Rj	0	0.0819	0.0117	0
							Var Rj	0	0.0012	0.0001	0
14	6/13/02	1	0	0	0	0	7.397	0.0108	3.8818	0.043	0
14	6/13/02	2	0	1	0	0	7.067	0.0098	0.7787	0.0393	0
14	6/13/02	3	0	3	0	0	7.067	0.0098	1.2489	0.0393	0
14	6/13/02	4	0	5	0	0	7.397	0.0108	9.1794	0.043	0
14	6/13/02	5	1	3	0	0	7.067	0.8117	1.2489	0.0393	0
14	6/13/02	6	0	3	1	0	7.067	0.0098	1.2489	0.643	0
14	6/13/02	7	0	1	0	0	7.067	0.0098	0.7787	0.0393	0
14	6/13/02	8	0	0	0	0	7.067	0.0098	3.5436	0.0393	0
14	6/13/02	9	0	1	1	0	7.067	0.0098	0.7787	0.643	0
14	6/13/02	10	0	2	0	0	7.067	0.0098	0.0138	0.0393	0
8	total	10	1	19	2	0	71.3333	0.9019	22.702	1.6075	0
	mean (cij)		0.1	1.9	0.2	0					
							Rj	0.014	0.2664	0.028	0
							Var Rj	0.0002	0.005	0.0004	0
15	6/13/02	1	0	0	0	0	6.272	0	4	0.04	0
15	6/13/02	2	0	0	0	0	6.272	0	4	0.04	0
15	6/13/02	3	0	2	0	0	6.272	0	0	0.04	0
15	6/13/02	4	0	6	2	0	6.272	0	16	3.24	0
15	6/13/02	5	0	3	0	0	6.272	0	1	0.04	0
15	6/13/02	6	0	2	0	0	6.272	0	0	0.04	0
15	6/13/02	7	0	4	0	0	6.272	0	4	0.04	0
15	6/13/02	8	0	1	0	0	6.272	0	1	0.04	0
15	6/13/02	9	0	1	0	0	6.272	0	1	0.04	0
15	6/13/02	10	0	1	0	0	6.272	0	1	0.04	0

9	total	10	0	20	2	0	62.7232	0	32	3.6	0
	mean (cij)		0	2	0.2	0					
							Rj	0	0.3189	0.0319	0
							Var Rj	0	0.009	0.001	0
16	6/13/02	1	0	1	0	0	6.517	0	0.64	0.01	0
16	6/13/02	2	0	0	0	0	6.517	0	0.04	0.01	0
16	6/13/02	3	0	0	0	0	6.517	0	0.04	0.01	0
16	6/13/02	4	0	0	1	0	6.517	0	0.04	0.81	0
16	6/13/02	5	0	0	0	0	6.517	0	0.04	0.01	0
16	6/13/02	6	0	1	0	0	6.517	0	0.64	0.01	0
16	6/13/02	7	0	0	0	0	6.517	0	0.04	0.01	0
16	6/13/02	8	0	0	0	0	6.517	0	0.04	0.01	0
16	6/13/02	9	0	0	0	0	6.517	0	0.04	0.01	0
16	6/13/02	10	0	0	0	0	6.517	0	0.04	0.01	0
10	total	10	0	2	1	0	65.1669	0	1.6	0.9	0
	mean (cij)		0	0.2	0.1	0					
							Rj	0	0.0307	0.0153	0
							Var Rj	0	0.0004	0.0002	0
17	6/13/02	1	0	1	0	0	7.168	0	0.0083	0.0331	0
17	6/13/02	2	0	0	0	0	7.168	0	0.8264	0.0331	0
17	6/13/02	3	0	0	1	0	7.168	0	0.8264	0.6694	0
17	6/13/02	4	0	0	0	0	7.168	0	0.8264	0.0331	0
17	6/13/02	5	0	0	0	0	7.168	0	0.8264	0.0331	0
17	6/13/02	6	0	0	0	0	7.168	0	0.8264	0.0331	0
17	6/13/02	7	0	4	1	0	7.168	0	9.5537	0.6694	0
17	6/13/02	8	0	2	0	0	7.168	0	1.1901	0.0331	0
17	6/13/02	9	0	1	0	0	7.168	0	0.0083	0.0331	0
17	6/13/02	10	0	1	0	0	7.168	0	0.0083	0.0331	0
17	6/13/02	11	0	1	0	0	7.168	0	0.0083	0.0331	0
11	total	11	0	9	2	0	78.852	0	14.909	1.6364	0
	mean (cij)		0	0.818	0.182	0					
							Rj	0	0.1268	0.0254	0
							Var Rj	0	0.0026	0.0003	0
18	6/13/02	1	0	1	0	0	6.471	0	0.6137	0.0883	0
18	6/13/02	2	0	0	0	0	6.471	0	3.1804	0.0883	0
18	6/13/02	3	0	2	0	0	6.471	0	0.0469	0.0883	0
18	6/13/02	4	0	3	0	0	6.772	0	1.2847	0.0968	0
18	6/13/02	5	0	5	0	0	6.471	0	10.347	0.0883	0
18	6/13/02	6	0	3	2	0	6.471	0	1.4802	2.8994	0
18	6/13/02	7	0	1	0	0	6.471	0	0.6137	0.0883	0
18	6/13/02	8	0	1	1	0	6.471	0	0.6137	0.4939	0
18	6/13/02	9	0	1	0	0	6.772	0	0.7509	0.0968	0
18	6/13/02	10	0	1	0	0	6.471	0	0.6137	0.0883	0
12	total	10	0	18	3	0	65.3096	0	19.545	4.1169	0
	mean (cij)		0	1.8	0.3	0					
							Rj	0	0.2756	0.0459	0
							Var Rj	0	0.0051	0.0011	0
23	6/14/02	1	0	1	0	0	5.889	0	0.16	0.01	0
23	6/14/02	2	0	1	0	0	5.889	0	0.16	0.01	0
23	6/14/02	3	0	2	0	0	5.889	0	0.36	0.01	0
23	6/14/02	4	0	1	0	0	5.889	0	0.16	0.01	0
23	6/14/02	5	0	2	1	0	5.889	0	0.36	0.81	0
23	6/14/02	6	0	3	0	0	5.889	0	2.56	0.01	0
23	6/14/02	7	0	1	0	0	5.889	0	0.16	0.01	0
23	6/14/02	8	0	2	0	0	5.889	0	0.36	0.01	0
23	6/14/02	9	0	0	0	0	5.889	0	1.96	0.01	0
23	6/14/02	10	0	1	0	0	5.889	0	0.16	0.01	0
13	total	10	0	14	1	0	58.8897	0	6.4	0.9	0
	mean (cij)		0	1.4	0.1	0					
							Rj	0	0.2377	0.017	0
							Var Rj	0	0.0021	0.0003	0
24	6/14/02	1	0	2	0	0	6.23951	0	0.25	0.04	0
24	6/14/02	2	0	3	1	0	6.23951	0	0.25	0.64	0
24	6/14/02	3	0	1	0	0	6.23951	0	2.25	0.04	0
24	6/14/02	4	0	2	0	0	6.23951	0	0.25	0.04	0
24	6/14/02	5	0	3	0	0	6.23951	0	0.25	0.04	0
24	6/14/02	6	0	2	1	0	6.23951	0	0.25	0.64	0
24	6/14/02	7	0	5	0	0	6.23951	0	6.25	0.04	0
24	6/14/02	8	0	2	0	0	6.23951	0	0.25	0.04	0
24	6/14/02	9	0	3	0	0	6.23951	0	0.25	0.04	0
24	6/14/02	10	0	2	0	0	6.23951	0	0.25	0.04	0
14	total	10	0	25	2	0	62.3951	0	10.5	1.6	0
	mean (cij)		0	2.5	0.2	0					
							Rj	0	0.4007	0.0321	0
							Var Rj	0	0.003	0.0005	0
27	6/14/02	1	0	0	0	0	6.024	0	2.56	0.04	0
27	6/14/02	2	0	3	0	0	6.024	0	1.96	0.04	0
27	6/14/02	3	0	3	0	0	6.024	0	1.96	0.04	0
27	6/14/02	4	0	5	1	0	6.024	0	11.56	0.64	0
27	6/14/02	5	0	0	0	0	6.024	0	2.56	0.04	0
27	6/14/02	6	0	1	0	0	6.024	0	0.36	0.04	0
27	6/14/02	7	0	1	0	0	6.024	0	0.36	0.04	0
27	6/14/02	8	0	1	0	0	6.024	0	0.36	0.04	0
27	6/14/02	9	0	1	1	0	6.024	0	0.36	0.64	0
27	6/14/02	10	0	1	0	0	6.024	0	0.36	0.04	0
15	total	10	0	16	2	0	60.2435	0	22.4	1.6	0
	mean (cij)		0	1.6	0.2	0					
							Rj	0	0.2656	0.0332	0
							Var Rj	0	0.0069	0.0005	0
28	6/14/02	1	0	0	0	0	6.719	0	0.49	0.01	0
28	6/14/02	2	0	1	1	0	6.719	0	0.09	0.81	0
28	6/14/02	3	0	0	0	0	6.719	0	0.49	0.01	0
28	6/14/02	4	0	0	0	0	6.719	0	0.49	0.01	0
28	6/14/02	5	0	1	0	0	6.719	0	0.09	0.01	0
28	6/14/02	6	0	0	0	0	6.719	0	0.49	0.01	0
28	6/14/02	7	0	1	0	0	6.719	0	0.09	0.01	0
28	6/14/02	8	0	1	0	0	6.719	0	0.09	0.01	0
28	6/14/02	9	0	3	0	0	6.719	0	5.29	0.01	0
28	6/14/02	10	0	0	0	0	6.719	0	0.49	0.01	0
16	total	10	0	7	1	0	67.1947	0	8.1	0.9	0
	mean (cij)		0	0.7	0.1	0					
							Rj	0	0.1042	0.0149	0
							Var Rj	0	0.002	0.0002	0
29	6/14/02	1	0	1	0	0	7.620	0	0.16	0	0
29	6/14/02	2	0	3	0	0	7.620	0	2.56	0	0
29	6/14/02	3	0	0	0	0	7.620	0	1.96	0	0
29	6/14/02	4	0	2	0	0	7.620	0	0.36	0	0
29	6/14/02	5	0	0	0	0	7.620	0	1.96	0	0
29	6/14/02	6	0	2	0	0	7.620	0	0.36	0	0
29	6/14/02	7	0	1	0	0	7.620	0	0.16	0	0
29	6/14/02	8	0	1	0	0	7.620	0	0.16	0	0
29	6/14/02	9	0	2	0	0	7.620	0	0.36	0	0
29	6/14/02	10	0	2	0	0	7.620	0	0.36	0	0
17	total	10	0	14	0	0	76.1961	0	8.4	0	0
	mean (cij)		0	1.4	0	0					
							Rj	0	0.1837	0	0
							Var Rj	0	0.0016	0	0

Total Entrainment by Load
WH Pearson and GD Williams

Lower Desdemona Shoals
6/11/02 - 6/15/02

Load # (j)	Total Load Volume (V)	# Samples (b)	Total Sample Volume (v)	Totals by Age Class i				Rij			
				YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
1	4843	8	54.068119	2	11	0	0	0.0370	0.2034	0.0000	0.0000
2	5752	10	68.335726	1	10	1	1	0.0146	0.1463	0.0146	0.0146
5	5605	10	59.851841	1	13	2	0	0.0167	0.2172	0.0334	0.0000
8	4482	10	38.666143	0	5	1	0	0.0000	0.1293	0.0259	0.0000
9	5605	10	65.883333	0	14	4	0	0.0000	0.2125	0.0607	0.0000
11	5605	10	99.552859	1	6	2	0	0.0100	0.0603	0.0201	0.0000
12	5617	10	85.445042	0	7	1	0	0.0000	0.0819	0.0117	0.0000
14	5617	10	71.333263	1	19	2	0	0.0140	0.2664	0.0280	0.0000
15	5617	10	62.723167	0	20	2	0	0.0000	0.3189	0.0319	0.0000
16	5617	10	65.166926	0	2	1	0	0.0000	0.0307	0.0153	0.0000
17	5617	11	78.851981	0	10	2	0	0.0000	0.1268	0.0254	0.0000
18	5867	10	65.309609	0	18	3	0	0.0000	0.2756	0.0459	0.0000
23	5867	10	58.889738	0	14	1	0	0.0000	0.2377	0.0170	0.0000
24	5867	10	62.395079	0	25	2	0	0.0000	0.4007	0.0321	0.0000
27	5867	10	60.243525	0	16	2	0	0.0000	0.2656	0.0332	0.0000
28	5867	10	67.194701	0	7	1	0	0.0000	0.1042	0.0149	0.0000
29	5800	10	76.196078	0	14	0	0	0.0000	0.1837	0.0000	0.0000

Within Load Record **Lower Desdemona Shoals**
WH Pearson and GD Williams **6/11/02 - 6/15/02**

Load Sequence Number (j)	Date	Sample Number (l)	Start Time (h:m)	Sample Load Rate (cu yd/min)	Effective Sample Time (sec)	Sample Volume (CY) (w)	Salinity (ppt)	Number of Crabs (c) by age class (i): YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	UID
1	6/11/02	1	15:35	18.070896	21.44	6.45733	nd	0	3	0	0	
1	6/11/02	2	15:40	18.070896	21.44	6.45733	nd	0	4	0	0	Y
1	6/11/02	3	16:00	18.070896	26.44	7.96324	nd	0	0	0	0	
1	6/11/02	4	16:07	18.070896	22.44	6.75851	nd	0	2	0	0	
1	6/11/02	5	16:13	18.070896	21.44	6.45733	nd	1	0	0	0	
1	6/11/02	6	16:18	18.070896	23.44	7.0597	nd	1	0	0	0	
1	6/11/02	7	16:23	18.070896	21.44	6.45733	nd	0	2	0	0	
1	6/11/02	8	16:30	18.070896	21.44	6.45733	nd	0	0	0	0	
2	6/11/02	1	16:59	18.435897	21.44	6.58776	nd	0	0	0	1	
2	6/11/02	2	17:05	18.435897	22.44	6.89503	nd	1	1	0	0	
2	6/11/02	3	17:10	18.435897	26.44	8.12409	nd	0	2	0	0	
2	6/11/02	4	17:15	18.435897	21.44	6.58776	nd	0	0	0	0	
2	6/11/02	5	17:20	18.435897	22.44	6.89503	nd	0	1	0	0	
2	6/11/02	6	17:35	18.435897	21.44	6.58776	nd	0	1	0	0	
2	6/11/02	7	17:58	18.435897	21.44	6.58776	nd	0	1	0	0	
2	6/11/02	8	18:05	18.435897	21.44	6.58776	nd	0	0	1	0	
2	6/11/02	9	18:12	18.435897	21.44	6.58776	nd	0	1	0	0	
2	6/11/02	10	18:20	18.435897	22.44	6.89503	nd	0	3	0	0	
5	6/11/02	1	22:21	16.293605	21.44	5.82225	nd	0	0	1	0	
5	6/11/02	2	22:25	16.293605	26.44	7.18005	nd	0	0	0	0	
5	6/11/02	3	22:30	16.293605	21.44	5.82225	nd	0	1	1	0	
5	6/11/02	4	22:39	16.293605	21.44	5.82225	nd	0	1	0	0	
5	6/11/02	5	22:48	16.293605	21.44	5.82225	nd	0	1	0	0	
5	6/11/02	6	23:25	16.293605	21.44	5.82225	nd	0	1	0	0	
5	6/11/02	7	23:33	16.293605	21.44	5.82225	nd	0	5	0	0	
5	6/11/02	8	23:40	16.293605	21.44	5.82225	nd	0	2	0	0	
5	6/11/02	9	23:45	16.293605	21.44	5.82225	nd	1	2	0	0	
5	6/12/02	10	0:10	16.293605	22.44	6.09381	nd	0	0	0	0	
8	6/12/02	1	4:19	10.671429	21.44	3.81326	nd	0	2	0	0	
8	6/12/02	2	4:26	10.671429	22.44	3.99111	nd	0	0	0	0	
8	6/12/02	3	4:34	10.671429	21.44	3.81326	nd	0	1	0	0	
8	6/12/02	4	4:42	10.671429	21.44	3.81326	nd	0	0	0	0	
8	6/12/02	5	4:49	10.671429	21.44	3.81326	nd	0	0	0	0	
8	6/12/02	6	4:55	10.671429	21.44	3.81326	nd	0	1	0	0	
8	6/12/02	7	5:02	10.671429	21.44	3.81326	nd	0	1	0	0	
8	6/12/02	8	5:09	10.671429	21.44	3.81326	nd	0	0	0	0	
8	6/12/02	9	5:16	10.671429	21.44	3.81326	nd	0	0	0	0	
8	6/12/02	10	5:23	10.671429	23.44	4.16897	nd	0	0	1	0	
9	6/12/02	1	15:33	18.4375	21.44	6.58833	nd	0	1	1	0	
9	6/12/02	2	15:38	18.4375	21.44	6.58833	nd	0	0	0	0	
9	6/12/02	3	15:44	18.4375	21.44	6.58833	nd	0	4	0	0	
9	6/12/02	4	15:51	18.4375	21.44	6.58833	nd	0	2	0	0	
9	6/12/02	5	16:08	18.4375	21.44	6.58833	nd	0	2	1	0	
9	6/12/02	6	16:15	18.4375	21.44	6.58833	nd	0	1	0	0	
9	6/12/02	7	16:21	18.4375	21.44	6.58833	nd	0	1	1	0	
9	6/12/02	8	16:26	18.4375	21.44	6.58833	nd	0	0	0	0	
9	6/12/02	9	16:41	18.4375	21.44	6.58833	nd	0	2	1	0	
9	6/12/02	10	16:49	18.4375	21.44	6.58833	nd	0	1	0	0	
11	6/12/02	5	21:23	27.47549	23.44	10.7338	nd	0	0	0	0	Y
11	6/12/02	6	21:38	27.47549	22.44	10.2758	nd	0	0	0	0	
11	6/12/02	7	21:44	27.47549	21.44	9.81791	nd	0	0	0	0	
11	6/12/02	8	21:49	27.47549	21.44	9.81791	nd	0	0	0	0	Y
11	6/12/02	9	21:55	27.47549	21.44	9.81791	nd	0	1	0	0	
11	6/12/02	10	21:59	27.47549	21.44	9.81791	nd	0	2	0	0	
11	6/12/02	11	22:05	27.47549	21.44	9.81791	nd	1	2	1	0	
11	6/12/02	12	22:19	27.47549	21.44	9.81791	nd	0	1	1	0	
11	6/12/02	13	22:26	27.47549	21.44	9.81791	nd	0	0	0	0	
11	6/12/02	14	22:31	27.47549	21.44	9.81791	nd	0	0	0	0	
12	6/12/02	1	23:04	23.800847	22.44	8.90152	nd	0	0	0	0	
12	6/12/02	2	23:10	23.800847	21.44	8.50484	nd	0	0	0	0	
12	6/12/02	3	23:15	23.800847	21.44	8.50484	nd	0	0	0	0	
12	6/12/02	4	23:21	23.800847	21.44	8.50484	nd	0	1	0	0	
12	6/12/02	5	23:41	23.800847	21.44	8.50484	nd	0	1	0	0	Y
12	6/12/02	6	23:46	23.800847	21.44	8.50484	nd	0	3	1	0	
12	6/13/02	7	0:10	23.800847	21.44	8.50484	nd	0	1	0	0	
12	6/13/02	8	0:16	23.800847	21.44	8.50484	nd	0	0	0	0	
12	6/13/02	9	0:26	23.800847	21.44	8.50484	nd	0	0	0	0	Y
12	6/13/02	10	0:33	23.800847	21.44	8.50484	nd	0	1	0	0	
14	6/13/02	1	15:19	19.778169	22.44	7.39704	nd	0	0	0	0	Y
14	6/13/02	2	15:27	19.778169	21.44	7.0674	nd	0	1	0	0	
14	6/13/02	3	15:32	19.778169	21.44	7.0674	nd	0	3	0	0	
14	6/13/02	4	15:38	19.778169	22.44	7.39704	nd	0	5	0	0	
14	6/13/02	5	15:49	19.778169	21.44	7.0674	nd	1	3	0	0	
14	6/13/02	6	15:55	19.778169	21.44	7.0674	nd	0	3	1	0	
14	6/13/02	7	16:01	19.778169	21.44	7.0674	nd	0	1	0	0	
14	6/13/02	8	16:11	19.778169	21.44	7.0674	nd	0	0	0	0	Y
14	6/13/02	9	16:17	19.778169	21.44	7.0674	nd	0	1	1	0	
14	6/13/02	10	16:24	19.778169	21.44	7.0674	nd	0	2	0	0	
15	6/13/02	1	17:13	17.553125	21.44	6.27232	nd	0	0	0	0	Y
15	6/13/02	2	17:18	17.553125	21.44	6.27232	nd	0	0	0	0	Y
15	6/13/02	3	17:22	17.553125	21.44	6.27232	nd	0	2	0	0	
15	6/13/02	4	17:28	17.553125	21.44	6.27232	nd	0	6	2	0	

Load # (j)	# Samples (b)	Total Volume	Totals by Age Class i: YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
1	8	54.0681	2	11	0	0
2	10	68.3357	1	10	1	1
5	10	59.8518	1	13	2	0
8	10	38.6661	0	5	1	0
9	10	65.8833	0	14	4	0
11	10	99.5529	1	6	2	0
12	10	85.445	0	7	1	0
14	10	71.3333	1	19	2	0
15	10	62.7232	0	20	2	0
16	10	65.1669	0	2	1	0
17	11	78.852	0	10	2	0
18	10	65.3096	0	18	3	0
23	10	58.8897	0	14	1	0
24	10	62.3951	0	25	2	0
27	10	60.2435	0	16	2	0
28	10	67.1947	0	7	1	0
29	10	76.1961	0	14	0	0

15	6/13/02	5	17:32	17.553125	21.44	6.27232	nd	0	3	0	0	
15	6/13/02	6	17:38	17.553125	21.44	6.27232	nd	0	2	0	0	
15	6/13/02	7	18:02	17.553125	21.44	6.27232	nd	0	4	0	0	
15	6/13/02	8	18:09	17.553125	21.44	6.27232	nd	0	1	0	0	
15	6/13/02	9	18:16	17.553125	21.44	6.27232	nd	0	1	0	0	
15	6/13/02	10	18:23	17.553125	21.44	6.27232	nd	0	1	0	0	
16	6/13/02	1	19:09	18.237013	21.44	6.51669	nd	0	1	0	0	
16	6/13/02	2	19:17	18.237013	21.44	6.51669	nd	0	0	0	0	Y
16	6/13/02	3	19:25	18.237013	21.44	6.51669	nd	0	0	0	0	
16	6/13/02	4	19:30	18.237013	21.44	6.51669	nd	0	0	1	0	
16	6/13/02	5	19:36	18.237013	21.44	6.51669	nd	0	0	0	0	
16	6/13/02	6	19:40	18.237013	21.44	6.51669	nd	0	1	0	0	
16	6/13/02	7	19:45	18.237013	21.44	6.51669	nd	0	0	0	0	
16	6/13/02	8	20:01	18.237013	21.44	6.51669	nd	0	0	0	0	
16	6/13/02	9	20:08	18.237013	21.44	6.51669	nd	0	0	0	0	Y
16	6/13/02	10	20:15	18.237013	21.44	6.51669	nd	0	0	0	0	
17	6/13/02	1	20:58	20.060714	21.44	7.16836	nd	0	1	0	0	
17	6/13/02	2	21:03	20.060714	21.44	7.16836	nd	0	0	0	0	
17	6/13/02	3	21:08	20.060714	21.44	7.16836	nd	0	0	1	0	
17	6/13/02	4	21:13	20.060714	21.44	7.16836	nd	0	0	0	0	Y
17	6/13/02	5	21:17	20.060714	21.44	7.16836	nd	0	0	0	0	Y
17	6/13/02	6	21:22	20.060714	21.44	7.16836	nd	0	0	0	0	
17	6/13/02	7	21:38	20.060714	21.44	7.16836	nd	0	4	1	0	
17	6/13/02	8	21:44	20.060714	21.44	7.16836	nd	0	2	0	0	
17	6/13/02	9	21:53	20.060714	21.44	7.16836	nd	0	1	0	0	
17	6/13/02	10	21:58	20.060714	21.44	7.16836	nd	0	1	0	0	
17	6/13/02	11	22:09	20.060714	21.44	7.16836	nd	0	1	0	0	
18	6/13/02	1	22:43	18.108025	21.44	6.4706	nd	0	1	0	0	
18	6/13/02	2	22:47	18.108025	21.44	6.4706	nd	0	0	0	0	Y
18	6/13/02	3	22:53	18.108025	21.44	6.4706	nd	0	2	0	0	Y
18	6/13/02	4	22:57	18.108025	22.44	6.7724	nd	0	3	0	0	
18	6/13/02	5	23:02	18.108025	21.44	6.4706	nd	0	5	0	0	
18	6/13/02	6	23:07	18.108025	21.44	6.4706	nd	0	3	2	0	
18	6/13/02	7	23:11	18.108025	21.44	6.4706	nd	0	1	0	0	Y
18	6/13/02	8	23:15	18.108025	21.44	6.4706	nd	0	1	1	0	
18	6/13/02	9	23:26	18.108025	22.44	6.7724	nd	0	1	0	0	
18	6/13/02	10	23:38	18.108025	21.44	6.4706	nd	0	1	0	0	
23	6/14/02	1	10:03	16.480337	21.44	5.88897	nd	0	1	0	0	Y
23	6/14/02	2	10:10	16.480337	21.44	5.88897	nd	0	1	0	0	
23	6/14/02	3	10:15	16.480337	21.44	5.88897	nd	0	2	0	0	Y
23	6/14/02	4	10:20	16.480337	21.44	5.88897	nd	0	1	0	0	Y
23	6/14/02	5	10:24	16.480337	21.44	5.88897	nd	0	2	1	0	
23	6/14/02	6	10:29	16.480337	21.44	5.88897	nd	0	3	0	0	
23	6/14/02	7	10:56	16.480337	21.44	5.88897	nd	0	1	0	0	Y
23	6/14/02	8	11:02	16.480337	21.44	5.88897	nd	0	2	0	0	
23	6/14/02	9	11:07	16.480337	21.44	5.88897	nd	0	0	0	0	Y
23	6/14/02	10	11:11	16.480337	21.44	5.88897	nd	0	1	0	0	
24	6/14/02	1	12:22	17.46131	21.44	6.23951	nd	0	2	0	0	
24	6/14/02	2	12:26	17.46131	21.44	6.23951	nd	0	3	1	0	
24	6/14/02	3	12:31	17.46131	21.44	6.23951	nd	0	1	0	0	
24	6/14/02	4	12:34	17.46131	21.44	6.23951	nd	0	2	0	0	
24	6/14/02	5	12:38	17.46131	21.44	6.23951	nd	0	3	0	0	
24	6/14/02	6	12:51	17.46131	21.44	6.23951	nd	0	2	1	0	
24	6/14/02	7	13:01	17.46131	21.44	6.23951	nd	0	5	0	0	
24	6/14/02	8	13:08	17.46131	21.44	6.23951	nd	0	2	0	0	
24	6/14/02	9	13:12	17.46131	21.44	6.23951	nd	0	3	0	0	
24	6/14/02	10	13:18	17.46131	21.44	6.23951	nd	0	2	0	0	
27	6/14/02	1	18:17	16.859195	21.44	6.02435	nd	0	0	0	0	Y
27	6/14/02	2	18:21	16.859195	21.44	6.02435	nd	0	3	0	0	
27	6/14/02	3	18:25	16.859195	21.44	6.02435	nd	0	3	0	0	
27	6/14/02	4	18:30	16.859195	21.44	6.02435	nd	0	5	1	0	
27	6/14/02	5	18:45	16.859195	21.44	6.02435	nd	0	0	0	0	Y
27	6/14/02	6	18:53	16.859195	21.44	6.02435	nd	0	1	0	0	
27	6/14/02	7	18:59	16.859195	21.44	6.02435	nd	0	1	0	0	
27	6/14/02	8	19:04	16.859195	21.44	6.02435	nd	0	1	0	0	Y
27	6/14/02	9	19:09	16.859195	21.44	6.02435	nd	0	1	1	0	
27	6/14/02	10	19:22	16.859195	21.44	6.02435	nd	0	1	0	0	
28	6/14/02	1	20:13	18.804487	21.44	6.71947	nd	0	0	0	0	Y
28	6/14/02	2	20:18	18.804487	21.44	6.71947	nd	0	1	1	0	
28	6/14/02	3	20:22	18.804487	21.44	6.71947	nd	0	0	0	0	Y
28	6/14/02	4	20:27	18.804487	21.44	6.71947	nd	0	0	0	0	Y
28	6/14/02	5	20:33	18.804487	21.44	6.71947	nd	0	1	0	0	
28	6/14/02	6	20:36	18.804487	21.44	6.71947	nd	0	0	0	0	
28	6/14/02	7	20:41	18.804487	21.44	6.71947	nd	0	1	0	0	
28	6/14/02	8	20:46	18.804487	21.44	6.71947	nd	0	1	0	0	
28	6/14/02	9	20:49	18.804487	21.44	6.71947	nd	0	3	0	0	Y
28	6/14/02	10	20:54	18.804487	21.44	6.71947	nd	0	0	0	0	
29	6/14/02	1	22:16	21.323529	21.44	7.61961	nd	0	1	0	0	
29	6/14/02	2	22:20	21.323529	21.44	7.61961	nd	0	3	0	0	
29	6/14/02	3	22:24	21.323529	21.44	7.61961	nd	0	0	0	0	
29	6/14/02	4	22:27	21.323529	21.44	7.61961	nd	0	2	0	0	
29	6/14/02	5	22:31	21.323529	21.44	7.61961	nd	0	0	0	0	Y
29	6/14/02	6	22:35	21.323529	21.44	7.61961	nd	0	2	0	0	
29	6/14/02	7	22:40	21.323529	21.44	7.61961	nd	0	1	0	0	Y
29	6/14/02	8	22:47	21.323529	21.44	7.61961	nd	0	1	0	0	
29	6/14/02	9	23:03	21.323529	21.44	7.61961	nd	0	2	0	0	
29	6/14/02	10	23:08	21.323529	21.44	7.61961	nd	0	2	0	0	

Load Records And Rates | **Lower Desdemona Shoals** | **Sample Volume assumes 25% of total load diverted to sampler; 50% if one drag arm**

WH Pearson and GD Williams | **6/11/02 - 6/15/02**

Load Sequence	Sampling Instructions	Date	Load Time		# Passes	Wet Load Volume (cu yd)	Settled Solids Volume (cu yd)	Total Distance Travelled (ft)	No. Basket Samples Taken	Pumping Time (min)	No. Drag Arms in Operation	Ave. Load Rate per Arm (cu yd/min)	Sample Load Rate (cu yd/min)
			Start	End									
1	Sample	6/11/02	15:18	16:30	2	16000	4843	12000	8	67	2	36.141791	18.0708955
2	Sample	6/11/02	16:57	18:25	3	16545	5752	18000	10	78	2	36.8717949	18.4358974
3	Off	6/11/02	19:06	20:15	2	16510	5752	12000	0	64	2	44.9375	22.46875
4	Off	6/11/02	20:38	21:49	2	16510	5752	12000	0	66	2	43.5757576	21.7878788
5	Sample	6/11/02	22:17	0:32	2	16600	5605	18000	10	86	2	32.5872093	16.2936047
6	Off	6/12/02	0:50	2:04	3	16500	5605	16000	0	64	2	43.7890625	21.8945313
7	Off	6/12/02	2:23	3:56	3	16519	5605	16000	0	83	2	33.7650602	16.8825301
8	Sample	6/12/02	4:15	6:00	1	15319	4482	6000	10	105	2	21.3428571	10.6714286
9	Sample	6/12/02	15:30	16:56	3	16552	5605	16000	10	76	2	36.875	18.4375
10	Off	6/12/02	17:31	18:54	3	15900	5000	16000	0	73	2	34.2465753	17.1232877
11	Sample	6/12/02	20:30	22:32	5	16510	5605	22000	10	102	1	54.9509804	27.4754902
12	Sample	6/12/02	22:56	1:14	4	16500	5617	28000	10	118	1	47.6016949	23.8008475
13	Off	6/13/02	1:37	4:00	6	16520	5617	32000	0	118	1	47.6016949	23.8008475
14	Sample	6/13/02	15:15	16:36	3	16529	5617	15000	10	71	2	39.556338	19.778169
15	Sample	6/13/02	17:10	18:45	2	16524	5617	12000	10	80	2	35.10625	17.553125
16	Sample	6/13/02	19:04	20:31	2	16515	5617	10000	10	77	2	36.474026	18.237013
17	Sample	6/13/02	20:54	22:16	2	16531	5617	12000	11	70	2	40.1214286	20.0607143
18	Sample	6/13/02	22:38	0:09	3	16539	5867	16000	10	81	2	36.2160494	18.1080247

19	Off	6/14/02	0:28	1:40	3	16500	5867	18000	0	62	2	47.3145161	23.6572581
20	Off	6/14/02	1:59	3:29	3	16500	5867	16000	0	80	2	36.66875	18.334375
21	Off	6/14/02	3:50	5:09	2	16519	5867	15000	0	73	2	40.1849315	20.0924658
22	Off	6/14/02	5:35	8:14	2	15800	4843	10000	0	141	1	34.3475177	17.1737589
23	Sample	6/14/02	9:54	11:38	2	16551	5867	12000	10	89	2	32.9606742	16.4803371
24	Sample	6/14/02	12:18	13:57	3	16546	5867	18000	10	84	2	34.922619	17.4613095
25	Off	6/14/02	14:18	15:47	3	16508	5867	18000	0	77	2	38.0974026	19.0487013
26	Off	6/14/02	16:07	17:47	3	16526	5867	18000	0	90	2	32.5944444	16.2972222
27	Sample	6/14/02	18:12	19:46	2	16537	5867	12000	10	87	2	33.7183908	16.8591954
28	Sample	6/14/02	20:10	21:48	2	16540	5867	12500	10	78	2	37.6089744	18.8044872
29	Sample	6/14/02	22:13	23:36	2	15900	5800	12000	10	68	2	42.6470588	21.3235294
30	Off	6/15/02	0:06	1:32	3	16533	6029	18000	0	74	2	40.7364865	20.3682432
31	Off	6/15/02	1:53	3:20	3	16200	6029	18000	0	75	2	40.1933333	20.0966667
32	Off	6/15/02	3:43	5:12	3	16524	6029	18000	0	77	2	39.1493506	19.5746753
33	Off	6/15/02	5:34	7:36	2	16516	6029	12000	0	107	2	28.1728972	14.0864486

Summary	Total # Hauls (H)	# Hauls Sampled (h)	Total Haul Volume (V)
	33	17	186737

SUMMARY OF CALCULATION OF ADULT EQUIVALENT LOSS BASED ON MODIFIED DREDGE IMPACT MODEL AND DIRECT MEASUREMENT OF ENTRAINMENT RATES at Desdemona Shoals, September 2002

WH Pearson and GD Williams
Battelle Marine Sciences Laboratory
Sequim, Washington

First Version: ***24-Jul-02*** Revised: ***4-Dec-02***
NOTE: Shaded cells are input.

This calculation run is for

Location	Start Date	End Date	Total Volume Dredged (cy)
Desdemona	**9/17/2002**	**9/17/2002**	***30012***

Overall Summary Statements

Adult Equivalent Loss of all age classes taken to 2+ is	**3023**	with 95% CI	**1200**
We are 95% confident that the true value lies between	**1823**	and	**4223**
Adult Equivalent Loss of all age classes taken to 3+ is	**1361**	with 95% CI	**540**
We are 95% confident that the true value lies between	**820**	and	**1901**
Number of MALE recruits lost to fishery is estimated to be	**476**	with 95% CI	**189**
We are 95% confident that the true value lies between	**287**	and	**665**

Sex Ratios by Age Class Derived from Field Observations

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0	0.00	0.10	0.017	0.00	0	0.00	0
1+	0.02173	652.0	299175.46	0.60	0.160	62.59	2757.201073	28.17	558.3332174
2+	0.06518	1956.1	779430.81	0.86	0.649	1091.77	242808.4893	491.30	49168.71908
3+	0.03259	978.0	35428.67	0.86	2.222	1868.97	129371.8837	841.04	26197.80645
All		**3586.2**	**1114034.95**			**3023.34**	**374937.57**	**1360.50**	**75924.86**

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male			
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)	R = Crab Entrainment Rate (crabs/cy)
YOY	0.50	0.00	0	0.50	0.00	0	E = Crabs Entrained (number of Crabs)
1+	0.50	31.30	689.3002683	0.50	31.30	689.3002683	M = Post-Entrainment Mortality (proportion)
2+	0.50	545.89	60702.12232	0.50	545.89	60702.12232	S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1991)
3+	0.50	934.48	32342.97092	0.50	934.48	32342.97092	AEL = Adult Equivalent Loss
All		**1511.67**	**93734.39**		**1511.67**	**93734.39**	VAR(AEL) =AEL Variance
					3023.34	187468.79	

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.02
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male			
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)	R = Crab Entrainment Rate (crabs/cy)
YOY	0.50	0.00	0	0.50	0.00	0	E = Crabs Entrained (number of Crabs)
1+	0.50	14.08	139.5833043	0.50	14.08	139.5833043	M = Post-Entrainment Mortality (proportion)
2+	0.50	245.65	12292.17977	0.50	245.65	12292.17977	S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
3+	0.50	420.52	6549.451612	0.50	420.52	6549.451612	AEL = Adult Equivalent Loss
All		**680.25**	**18981.21**		**680.25**	**18981.21**	VAR(AEL) =AEL Variance
					1360.501	37962.429	

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	3586.2
Var(E)	1114035.0
SE E	1055.5
Z at 0.975	1.95996
95% C. I.	2068.7
CV E (%)	29.43

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	3023.3
Var(AEL2+)	374937.6
SE AEL	612.3
Z at 0.975	1.95996
95% C. I.	1200.1
CV AEL (%)	20.25

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	1360.5
Var(AEL3+)	75924.9
SE AEL	275.5
Z at 0.975	1.95996
95% C. I.	540.1
CV AEL (%)	20.25

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	680.3
Var(AEL)	18981.2
SE AEL	137.8
Z at 0.975	1.95996
95% C. I.	270.0
CV AEL (%)	20.25

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	680.3
Var(AEL)	18981.2
SE AEL	137.8
Z at 0.975	1.95996
95% C. I.	270.0
CV AEL (%)	20.25

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Fishery (number of crab)	
680.3	0.70	**476.2**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	476.2
Var(AEL)	9300.795197
SE LF	96.4
Z at 0.975	1.95996
95% C. I.	189.0
CV LF (%)	20.25

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

Estimating Entrainment Rate, Total Entrainment, and Variance
Lower Desdemona Shoals **9/17/2002**
WH Pearson and GD Williams

Summary

	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	Total
R	0.000	0.022	0.065	0.033	0.119
E	0.0	652.0	1956.1	978.0	3586.169
Var(E)	0.00	299175.46	779430.81	35428.67	
SE (E)	0.00	546.97	882.85	188.23	
CV(E)	0.00	0.84	0.45	0.19	

Calculations

		Rj				Variance Rj (Variance x Load Sheet)				Entrainment (Rj x V)			
Load # (j)	V	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
402	5002	0.0000	0.0869	0.2607	0.1304	0.0000	0.0076	0.0170	0.0000	0	434.6872	1304.061	652.0307
403	5002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	0
406	5002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	0
407	5002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	0

h	4
Vh	20008
H	6
VH	30012

Estimating E

	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
numerator	0	434.6872	1304.061	652.0307
denominator	20008	20008	20008	20008
R	0.000	0.022	0.065	0.033
E	0.0	652.0	1956.1	978.0

Estimating Variance and CV

		YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
first term (Load to load variability)					
step 1	0.33333				
step 2		0	106286	956574.2	239143.5
		0	11809.56	106286	26571.5
		0	11809.56	106286	26571.5
		0	11809.56	106286	26571.5
step 3 (total)		0	141714.7	1275432	318858.1
step 4	3				
step 5		0	15746.08	141714.7	35428.67
second term (Basket to basket variability)					
step 1	1.5				
step 2		0	188952.9	425144.1	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
step 3 (total)		0	188952.9	425144.1	0
step 4		0	283429.4	637716.1	0
Var(E)		0	299175.5	779430.8	35428.67
SE (E)		0	546.9693	882.8538	188.2251
CV(E)		0	0.83887	0.451335	0.19245

Variance By Load | **Lower Desdemona Shoals**
WH Pearson and GD Williams | **9/17/2002**

Load Sequence Number	Date	Sample Number	Number of Crabs YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	Sample Volume (CY) (w)	Sum of Squares (by load - w2) YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
402	9/17/02	1	0	2	1	1	7.6714	0	1.7778	1	0
402	9/17/02	2	0	0	4	1	7.6714	0	0.4444	4	0
402	9/17/02	3	0	0	1	1	7.6714	0	0.4444	1	0
1	Total	3	0	2	6	3	23.014	0	2.6667	6	0
	Mean (cij)		0	0.667	2	1					
							Rj	0	0.0869	0.2607	0.1304
							Var Rj	0	0.0076	0.017	0
403	9/17/02	1	0	0	0	0	14.33	0	0	0	0
403	9/17/02	2	0	0	0	0	14.33	0	0	0	0
403	9/17/02	3	0	0	0	0	14.33	0	0	0	0
2	Total	3	0	0	0	0	42.989	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
406	9/17/02	1	0	0	0	0	14.605	0	0	0	0
406	9/17/02	2	0	0	0	0	14.605	0	0	0	0
406	9/17/02	3	0	0	0	0	14.605	0	0	0	0
3	Total	3	0	0	0	0	43.816	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
407	9/17/02	1	0	0	0	0	12.25	0	0	0	0
407	9/17/02	2	0	0	0	0	12.25	0	0	0	0
407	9/17/02	3	0	0	0	0	12.25	0	0	0	0
4	Total	3	0	0	0	0	36.749	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0

Total Entrainment by Load | **Lower Desdemona Shoals**
WH Pearson and GD Williams | **9/17/2002**

Load # (j)	Total Load Volume (V)	# Samples (b)	Total Sample Volume (v)	Totals by Age Class i				Rij			
				YOY	1+	2+	3+	YOY	1+	2+	3+
				0-50	51-100	101-150	>150	0-50	51-100	101-150	>150
402	5002	3	23.014253	0	2	6	3	0.0000	0.0869	0.2607	0.1304
403	5002	3	42.988887	0	0	0	0	0.0000	0.0000	0.0000	0.0000
406	5002	3	43.815596	0	0	0	0	0.0000	0.0000	0.0000	0.0000
407	5002	3	36.748565	0	0	0	0	0.0000	0.0000	0.0000	0.0000

Total Entrainment by Load | **Lower Desdemona Shoals**
WH Pearson and GD Williams | **9/17/2002**

Load # (j)	Total Load Volume (V)	# Samples (b)	Total Sample Volume (v)	Totals by Age Class i				Rij			
				YOY	1+	2+	3+	YOY	1+	2+	3+
				0-50	51-100	101-150	>150	0-50	51-100	101-150	>150
402	5002	3	23.014253	0	2	6	3	0.0000	0.0869	0.2607	0.1304
403	5002	3	42.988887	0	0	0	0	0.0000	0.0000	0.0000	0.0000
406	5002	3	43.815596	0	0	0	0	0.0000	0.0000	0.0000	0.0000
407	5002	3	36.748565	0	0	0	0	0.0000	0.0000	0.0000	0.0000

Within Load Record **Lower Desdemona Shoals**
WH Pearson and GD Williams **9/17/2002**

Load Sequence Number (j)	Date	Sample Number (l)	Start Time (h:m)	Sample Load Rate (cu yd/min)	Effective Sample Time (sec)	Sample Volume (CY) (w)	Salinity (ppt)	Number of Crabs (c) by age class (i)				
								YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	UID
402	9/17/02	1	1345	12.631313	36.44	7.67142	31	0	2	1	1	Y
402	9/17/02	2	1402	12.631313	36.44	7.67142	31.29	0	0	4	1	Y
402	9/17/02	3	1436	12.631313	36.44	7.67142	32.9	0	0	1	1	Y
403	9/17/02	1	1720	23.59434	36.44	14.3296	24.98	0	0	0	0	Y
403	9/17/02	2	1732	23.59434	36.44	14.3296	23.99	0	0	0	0	Y
403	9/17/02	3	1803	23.59434	36.44	14.3296	21.12	0	0	0	0	N
406	9/17/02	1	2150	24.048077	36.44	14.6052	30.46	0	0	0	0	N
406	9/17/02	2	2205	24.048077	36.44	14.6052	30.29	0	0	0	0	Y
406	9/17/02	3	2213	24.048077	36.44	14.6052	30.28	0	0	0	0	N
407	9/17/02	1	2250	20.169355	36.44	12.2495	30.64	0	0	0	0	N
407	9/17/02	2	2339	20.169355	36.44	12.2495	30.14	0	0	0	0	N
407	9/17/02	3	2343	20.169355	36.44	12.2495	30.2	0	0	0	0	N

Load # (j)	# Samples (b)	Total Sample Volume	Totals by Age Class i			
			YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
402	3	23.01425	0	2	6	3
403	3	42.98889	0	0	0	0
406	3	43.8156	0	0	0	0
407	3	36.74856	0	0	0	0

Load Records And Rates | **Lower Desdemona Shoals** | **Sample Volume assumes 25% of total load diverted to sampler; 50% if one drag arm**

WH Pearson and GD Williams | **9/17/2002**

Load Sequence	Sampling Instructions	Date	Load Time		# Passes	Settled Solids Volume (cu yd)	Total Distance Travelled (ft)	No. Basket Samples Taken	Pumping Time (min)	No. Drag Arms in Operation	Ave. Load Rate per Arm (cu yd/min)	Sample Load Rate (cu yd/min)
			Start	End								
402	Sample	9/17/02	1345	1539	4	5002	20000	3	99	2	25.2626263	12.6313131
403	Sample	9/17/02	1711	1809	5	5002	9000	3	53	2	47.1886792	23.5943396
404	Off	9/17/02	1831	1925	2	5002	8000	0	49	2	51.0408163	25.5204082
405	Off	9/17/02	1946	2058	3	5002	9000	0	45	2	55.5777778	27.7888889
406	Sample	9/17/02	2125	2222	2	5002	9000	3	52	2	48.0961538	24.0480769
407	Sample	9/17/02	2250	2358	2	5002	9000	3	62	2	40.3387097	20.1693548

Summary	Total # Loads (H)	# Loads Sampled (h)	Total Load Volume (V)
	6	4	30012

SUMMARY OF CALCULATION OF ADULT EQUIVALENT LOSS BASED ON MODIFIED DREDGE IMPACT MODEL AND DIRECT MEASUREMENT OF ENTRAINMENT RATES at Upper Sands in September 2002.

WH Pearson and GD Williams
Battelle Marine Sciences Laboratory
Sequim, Washington

First Version: ***24-Jul-02*** Revised: ***4-Dec-02***
NOTE: Shaded cells are input.

This calculation run is for

Location	Start Date	End Date	Total Volume Dredged (cy)
Upper Sands	*23-Sep-02*	*23-Sep-02*	*54036*

Overall Summary Statements

Adult Equivalent Loss of all age classes taken to 2+ is	**54**	with 95% CI	**103**
We are 95% confident that the true value lies between	**0**	and	**157**
Adult Equivalent Loss of all age classes taken to 3 + is	**24**	with 95% CI	**47**
We are 95% confident that the true value lies between	**0**	and	**71**
Number of MALE recruits lost to fishery is estimated to be	**8**	with 95% CI	**16**
We are 95% confident that the true value lies between	**0**	and	**25**

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	559.6	313164.14	0.10	0.017	0.92	0.852589376	0.42	0.172649349
1+	0.01018	549.9	302366.19	0.60	0.160	52.79	2786.606852	23.75	564.2878875
2+	0.00000	0.0	0.00	0.86	0.649	0.00	0	0.00	0
3+	0.00000	0.0	0.00	0.86	2.222	0.00	0	0.00	0
All		**1109.5**	**615530.34**			**53.71**	**2787.46**	**24.17**	**564.46**

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

<u>AGE 2+ Calculations</u>
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.46	0.213147344	0.50	0.46	0.213147344
1+	0.50	26.39	696.6517129	0.50	26.39	696.6517129
2+	0.50	0.00	0	0.50	0.00	0
3+	0.50	0.00	0	0.50	0.00	0
All		**26.86**	**696.86**		**26.86**	**696.86**
						1393.73

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 2+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL 2+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

<u>AGE 3+ Calculations</u>
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female	Male

Age Class	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.21	0.043162337	0.50	0.21	0.043162337
1+	0.50	11.88	141.0719719	0.50	11.88	141.0719719
2+	0.50	0.00	0	0.50	0.00	0
3+	0.50	0.00	0	0.50	0.00	0
All		**12.09**	**141.12**		**12.09**	**141.12**
					24.170	282.230

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	1109.5
Var(E)	615530.3
SE E	784.6
Z at 0.975	1.95996
95% C. I.	1537.7
CV E (%)	70.71

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	53.7
Var(AEL2+)	2787.5
SE AEL	52.8
Z at 0.975	1.95996
95% C. I.	103.5
CV AEL (%)	98.30

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	24.2
Var(AEL3+)	564.5
SE AEL	23.8
Z at 0.975	1.95996
95% C. I.	46.6
CV AEL (%)	98.30

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	12.1
Var(AEL)	141.1
SE AEL	11.9
Z at 0.975	1.95996
95% C. I.	23.3
CV AEL (%)	98.30

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	12.1
Var(AEL)	141.1
SE AEL	11.9
Z at 0.975	1.95996
95% C. I.	23.3
CV AEL (%)	98.30

TOTAL LOSS TO MALE FISHERY

(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
12.1	0.70	**8.5**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	8.5
Var(AEL)	69.14641576
SE LF	8.3
Z at 0.975	1.95996
95% C. I.	16.3
CV LF (%)	98.30

ADDITIONAL NOTES:

Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)

Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).

Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

Estimating Entrainment Rate, Total Entrainment, and Variance
Upper Sands **9/23/2002**
WH Pearson and GD Williams **Assuming Sample Volume 1 (25% of total load)**

Summary

	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	Total
R	0.010	0.010	0.000	0.000	0.021
E	559.6	549.9	0.0	0.0	1109.489
Var(E)	313164.14	302366.19	0.00	0.00	
SE (E)	559.61	549.88	0.00	0.00	
CV(E)	1.00	1.00	0.00	0.00	

Calculations

Load # (j)	V	Rj				Variance Rj (Variance x Load Sheet)				Entrainment (Rj x V)	
		YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100
453	6192	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0
454	6192	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0
455	6192	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0
456	6192	0.0000	0.0888	0.0000	0.0000	0.0000	0.0079	0.0000	0.0000	0	549.87835
457	6192	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0
458	6192	0.0904	0.0000	0.0000	0.0000	0.0082	0.0000	0.0000	0.0000	559.61071	0
459	6192	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0
460	6192	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0
461	4500	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0

h	9
Vh	54036
H	9
VH	54036

Estimating E

	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
numerator	559.61071	549.87835	0	0

denominator	54036	54036	54036	54036
R	0.010	0.010	0.000	0.000
E	559.6	549.9	0.0	0.0

Estimating Variance and CV

	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
first term (Load to load variability)				
step 1 0				
step 2	4112.1366	3970.3496	0	0
	4112.1366	3970.3496	0	0
	4112.1366	3970.3496	0	0
	4112.1366	237040.09	0	0
	4112.1366	3970.3496	0	0
	245505.15	3970.3496	0	0
	4112.1366	3970.3496	0	0
	4112.1366	3970.3496	0	0
step 3 (total)	2171.8542	2096.9684	0	0
step 4 8				
step 5	0	0	0	0
second term (Basket to basket variability)				
step 1 1				
step 2	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	302366.19	0	0
	0	0	0	0
	313164.14	0	0	0
	0	0	0	0
	0	0	0	0
step 3 (total)	313164.14	302366.19	0	0
step 4	313164.14	302366.19	0	0
Var(E)	313164.14	302366.19	0	0
SE (E)	559.61071	549.87835	0	0
CV(E)	1	1	0	0

Variance By Load | **Upper Sands**
WH Pearson and GD Williams | **9/23/2002**

Load Sequence Number	Date	Sample Number	Number of Crabs YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	Sample Volume (CY) (w)	Sum of Squares (by load - w2) YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
453	9/23/02	1	0	0	0	0	12.864	0	0	0	0
453	9/23/02	2	0	0	0	0	12.864	0	0	0	0
453	9/23/02	3	0	0	0	0	12.864	0	0	0	0
1	Total	3	0	0	0	0	38.592	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
454	9/23/02	1	0	0	0	0	5.1726	0	0	0	0
454	9/23/02	2	0	0	0	0	5.1726	0	0	0	0
454	9/23/02	3	0	0	0	0	5.1726	0	0	0	0
2	Total	3	0	0	0	0	15.518	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
455	9/23/02	1	0	0	0	0	5.6554	0	0	0	0
455	9/23/02	2	0	0	0	0	5.6554	0	0	0	0
455	9/23/02	3	0	0	0	0	5.6554	0	0	0	0
3	Total	3	0	0	0	0	16.966	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
456	9/23/02	1	0	1	0	0	3.7536	0	0.4444	0	0
456	9/23/02	2	0	0	0	0	3.7536	0	0.1111	0	0
456	9/23/02	3	0	0	0	0	3.7536	0	0.1111	0	0
4	Total	3	0	1	0	0	11.261	0	0.6667	0	0
	Mean (cij)		0	0.333	0	0					
							Rj	0	0.0888	0	0
							Var Rj	0	0.0079	0	0
457	9/23/02	1	0	0	0	0	4.5608	0	0	0	0

457	9/23/02	2	0	0	0	0	4.5608	0	0	0	0
457	9/23/02	3	0	0	0	0	4.5608	0	0	0	0
5	Total	3	0	0	0	0	13.682	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
458	9/23/02	1	0	0	0	0	3.6883	0.1111	0	0	0
458	9/23/02	2	1	0	0	0	3.6883	0.4444	0	0	0
458	9/23/02	3	0	0	0	0	3.6883	0.1111	0	0	0
6	Total	3	1	0	0	0	11.065	0.6667	0	0	0
	Mean (cij)		0.333	0	0	0					
							Rj	0.0904	0	0	0
							Var Rj	0.0082	0	0	0
459	9/23/02	1	0	0	0	0	5.1726	0	0	0	0
459	9/23/02	2	0	0	0	0	5.1726	0	0	0	0
459	9/23/02	3	0	0	0	0	5.1726	0	0	0	0
7	Total	3	0	0	0	0	15.518	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
460	9/23/02	1	0	0	0	0	4.5123	0	0	0	0
460	9/23/02	2	0	0	0	0	4.5123	0	0	0	0
460	9/23/02	3	0	0	0	0	4.5123	0	0	0	0
8	Total	3	0	0	0	0	13.537	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
461	9/23/02	1	0	0	0	0	4.4036	0	0	0	0
461	9/23/02	2	0	0	0	0	4.4036	0	0	0	0
461	9/23/02	3	0	0	0	0	4.4036	0	0	0	0
9	Total	3	0	0	0	0	13.211	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0

Total Entrainment by Load **Upper Sands**
WH Pearson and GD Williams **9/23/2002**

Load # (j)	Total Load Volume (V)	# Samples (b)	Total Sample Volume (v)		Totals by Age Class i				Rij			
					YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
453	6192	3	38.592		0	0	0	0	0.0000	0.0000	0.0000	0.0000
454	6192	3	15.517756		0	0	0	0	0.0000	0.0000	0.0000	0.0000
455	6192	3	16.96608		0	0	0	0	0.0000	0.0000	0.0000	0.0000
456	6192	3	11.260673		0	1	0	0	0.0000	0.0888	0.0000	0.0000
457	6192	3	13.682323		0	0	0	0	0.0000	0.0000	0.0000	0.0000
458	6192	3	11.064835		1	0	0	0	0.0904	0.0000	0.0000	0.0000
459	6192	3	15.517756		0	0	0	0	0.0000	0.0000	0.0000	0.0000
460	6192	3	13.536766		0	0	0	0	0.0000	0.0000	0.0000	0.0000
461	4500	3	13.210714		0	0	0	0	0.0000	0.0000	0.0000	0.0000

Within Load Record **Upper Sands**
WH Pearson and GD Williams **9/23/2002**

Sample Volume = 25% of total load; 50% if one drag arm

Load Sequence Number (j)	Date	Sample Number (l)	Start Time (h:m)	Sample Load Rate (cu yd/min)	Effective Sample Time (sec)	Sample Volume (CY) (w)	Salinity (ppt)	Number of Crabs (c) by age class (i) YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	UID
453	09/23/02	1	2342	36	21.44	12.864	9.2	0	0	0	0	N
453	09/23/02	2	0003	36	21.44	12.864	10.6	0	0	0	0	N
453	09/23/02	3	nd	36	21.44	12.864	12.9	0	0	0	0	N
454	09/23/02	1	0127	18.878049	16.44	5.17259	6.7	0	0	0	0	Y
454	09/23/02	2	0151	18.878049	16.44	5.17259	15.9	0	0	0	0	N
454	09/23/02	3	0215	18.878049	16.44	5.17259	16.3	0	0	0	0	N
455	09/23/02	1	0340	20.64	16.44	5.65536	15.9	0	0	0	0	N
455	09/23/02	2	0356	20.64	16.44	5.65536	18.3	0	0	0	0	N
455	09/23/02	3	0413	20.64	16.44	5.65536	18.8	0	0	0	0	N
456	09/23/02	1	0617	13.699115	16.44	3.75356	17.19	0	1	0	0	N
456	09/23/02	2	0653	13.699115	16.44	3.75356	15.59	0	0	0	0	N
456	09/23/02	3	0712	13.699115	16.44	3.75356	14.8	0	0	0	0	N
457	09/23/02	1	0836	16.645161	16.44	4.56077	14.1	0	0	0	0	N
457	09/23/02	2	0855	16.645161	16.44	4.56077	10.6	0	0	0	0	N
457	09/23/02	3	0909	16.645161	16.44	4.56077	9.85	0	0	0	0	N
458	09/23/02	1	1151	13.46087	16.44	3.68828	9.91	0	0	0	0	Y
458	09/23/02	2	1207	13.46087	16.44	3.68828	13.69	1	0	0	0	Y
458	09/23/02	3	1235	13.46087	16.44	3.68828	12.83	0	0	0	0	N
459	09/23/02	1	1532	18.878049	16.44	5.17259	0.17	0	0	0	0	N
459	09/23/02	2	1555	18.878049	16.44	5.17259	18	0	0	0	0	N
459	9/23/02	3	1607	18.878049	16.44	5.17259	19.3	0	0	0	0	N
460	9/23/02	1	1728	16.468085	16.44	4.51226	18.9	0	0	0	0	N
460	9/23/02	2	1752	16.468085	16.44	4.51226	17.7	0	0	0	0	N
460	9/23/02	3	1823	16.468085	16.44	4.51226	16.6	0	0	0	0	N
461	9/23/02	1	1951	16.071429	16.44	4.40357	5.2	0	0	0	0	N
461	9/23/02	2	2016	16.071429	16.44	4.40357	6.7	0	0	0	0	N
461	9/23/02	3	2024	16.071429	16.44	4.40357	14	0	0	0	0	N

Load # (j)	# Samples (b)	Total Sample Volume	Tota YO' 0-5(
453	3	38.592	
454	3	15.5178	
455	3	16.9661	
456	3	11.2607	
457	3	13.6823	
458	3	11.0648	
459	3	15.5178	
460	3	13.5368	
461	3	13.2107	

Load Records And Rates **Upper Sands** **Sample Volume assumes 25% of total load diverted to sampler; 50% if one drag**
WH Pearson and GD Williams **9/23/2002**

Load Sequence	Sampling Instructions	Date	Load Time		# Passes	Settled Solids Volume (cu yd)	Total Distance Travelled (ft)	No. Basket Samples Taken	Pumping Time (min)	No. Drag Arms in Operation	Ave. Load Rate per Arm (cu yd/min)	Sample Load Rate (cu yd/min)
			Start	End								
453	Sample	9/23/02	0000	0053	2	6192	9000	3	43	2	72	36
454	Sample	9/23/02	0113	0255	3	6192	9000	3	82	2	37.7560976	18.8780488
455	Sample	9/23/02	0323	0453	4	6192	12000	3	75	2	41.28	20.64
456	Sample	9/23/02	0530	0751	4	6192	12000	3	113	2	27.3982301	13.699115
457	Sample	9/23/02	0836	1042	5	6192	15000	3	93	2	33.2903226	16.6451613
458	Sample	9/23/02	1134	1429	8	6192	20000	3	115	2	26.9217391	13.4608696
459	Sample	9/23/02	1506	1648	5	6192	15000	3	82	2	37.7560976	18.8780488
460	Sample	9/23/02	1726	1924	4	6192	12000	3	94	2	32.9361702	16.4680851
461	Sample	9/23/02	1951	2116	4	4500	10000	3	70	2	32.1428571	16.0714286

Summary	Total # Loads (H)	# Loads Sampled (h)	Total Load Volume (V)
	9	9	54036

Variance By Load **Upper Sands**
WH Pearson and GD Williams **9/23/2002**

Load Sequence Number	Date	Sample Number	Number of Crabs YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	Sample Volume (CY) (w)	Sum of Squares (by load - w2) YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
453	9/23/02	1	0	0	0	0	12.864	0	0	0	0
453	9/23/02	2	0	0	0	0	12.864	0	0	0	0
453	9/23/02	3	0	0	0	0	12.864	0	0	0	0
1	Total	3	0	0	0	0	38.592	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
454	9/23/02	1	0	0	0	0	5.1726	0	0	0	0
454	9/23/02	2	0	0	0	0	5.1726	0	0	0	0
454	9/23/02	3	0	0	0	0	5.1726	0	0	0	0
2	Total	3	0	0	0	0	15.518	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
455	9/23/02	1	0	0	0	0	5.6554	0	0	0	0
455	9/23/02	2	0	0	0	0	5.6554	0	0	0	0
455	9/23/02	3	0	0	0	0	5.6554	0	0	0	0
3	Total	3	0	0	0	0	16.966	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
456	9/23/02	1	0	1	0	0	3.7536	0	0.4444	0	0
456	9/23/02	2	0	0	0	0	3.7536	0	0.1111	0	0
456	9/23/02	3	0	0	0	0	3.7536	0	0.1111	0	0
4	Total	3	0	1	0	0	11.261	0	0.6667	0	0
	Mean (cij)		0	0.333	0	0					
							Rj	0	0.0888	0	0
							Var Rj	0	0.0079	0	0
457	9/23/02	1	0	0	0	0	4.5608	0	0	0	0

457	9/23/02	2	0	0	0	0	4.5608	0	0	0	0
457	9/23/02	3	0	0	0	0	4.5608	0	0	0	0
5	Total	3	0	0	0	0	13.682	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
458	9/23/02	1	0	0	0	0	3.6883	0.1111	0	0	0
458	9/23/02	2	1	0	0	0	3.6883	0.4444	0	0	0
458	9/23/02	3	0	0	0	0	3.6883	0.1111	0	0	0
6	Total	3	1	0	0	0	11.065	0.6667	0	0	0
	Mean (cij)		0.333	0	0	0					
							Rj	0.0904	0	0	0
							Var Rj	0.0082	0	0	0
459	9/23/02	1	0	0	0	0	5.1726	0	0	0	0
459	9/23/02	2	0	0	0	0	5.1726	0	0	0	0
459	9/23/02	3	0	0	0	0	5.1726	0	0	0	0
7	Total	3	0	0	0	0	15.518	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
460	9/23/02	1	0	0	0	0	4.5123	0	0	0	0
460	9/23/02	2	0	0	0	0	4.5123	0	0	0	0
460	9/23/02	3	0	0	0	0	4.5123	0	0	0	0
8	Total	3	0	0	0	0	13.537	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
461	9/23/02	1	0	0	0	0	4.4036	0	0	0	0
461	9/23/02	2	0	0	0	0	4.4036	0	0	0	0
461	9/23/02	3	0	0	0	0	4.4036	0	0	0	0
9	Total	3	0	0	0	0	13.211	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0

Total Entrainment by Load **Upper Sands**
WH Pearson and GD Williams **9/23/2002**

Load # (j)	Total Load Volume (V)	# Samples (b)	Total Sample Volume (v)		Totals by Age Class i				Rij			
					YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
453	6192	3	38.592		0	0	0	0	0.0000	0.0000	0.0000	0.0000
454	6192	3	15.517756		0	0	0	0	0.0000	0.0000	0.0000	0.0000
455	6192	3	16.96608		0	0	0	0	0.0000	0.0000	0.0000	0.0000
456	6192	3	11.260673		0	1	0	0	0.0000	0.0888	0.0000	0.0000
457	6192	3	13.682323		0	0	0	0	0.0000	0.0000	0.0000	0.0000
458	6192	3	11.064835		1	0	0	0	0.0904	0.0000	0.0000	0.0000
459	6192	3	15.517756		0	0	0	0	0.0000	0.0000	0.0000	0.0000
460	6192	3	13.536766		0	0	0	0	0.0000	0.0000	0.0000	0.0000
461	4500	3	13.210714		0	0	0	0	0.0000	0.0000	0.0000	0.0000

Within Load Record **Upper Sands**
WH Pearson and GD Williams **9/23/2002**

Sample Volume = 25% of total load; 50% if one drag arm

Load Sequence Number (j)	Date	Sample Number (l)	Start Time (h:m)	Sample Load Rate (cu yd/min)	Effective Sample Time (sec)	Sample Volume (CY) (w)	Salinity (ppt)	Number of Crabs (c) by age class (i) YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	UID
453	09/23/02	1	2342	36	21.44	12.864	9.2	0	0	0	0	N
453	09/23/02	2	0003	36	21.44	12.864	10.6	0	0	0	0	N
453	09/23/02	3	nd	36	21.44	12.864	12.9	0	0	0	0	N
454	09/23/02	1	0127	18.878049	16.44	5.17259	6.7	0	0	0	0	Y
454	09/23/02	2	0151	18.878049	16.44	5.17259	15.9	0	0	0	0	N
454	09/23/02	3	0215	18.878049	16.44	5.17259	16.3	0	0	0	0	N
455	09/23/02	1	0340	20.64	16.44	5.65536	15.9	0	0	0	0	N
455	09/23/02	2	0356	20.64	16.44	5.65536	18.3	0	0	0	0	N
455	09/23/02	3	0413	20.64	16.44	5.65536	18.8	0	0	0	0	N
456	09/23/02	1	0617	13.699115	16.44	3.75356	17.19	0	1	0	0	N
456	09/23/02	2	0653	13.699115	16.44	3.75356	15.59	0	0	0	0	N
456	09/23/02	3	0712	13.699115	16.44	3.75356	14.8	0	0	0	0	N
457	09/23/02	1	0836	16.645161	16.44	4.56077	14.1	0	0	0	0	N
457	09/23/02	2	0855	16.645161	16.44	4.56077	10.6	0	0	0	0	N
457	09/23/02	3	0909	16.645161	16.44	4.56077	9.85	0	0	0	0	N
458	09/23/02	1	1151	13.46087	16.44	3.68828	9.91	0	0	0	0	Y
458	09/23/02	2	1207	13.46087	16.44	3.68828	13.69	1	0	0	0	Y
458	09/23/02	3	1235	13.46087	16.44	3.68828	12.83	0	0	0	0	N
459	09/23/02	1	1532	18.878049	16.44	5.17259	0.17	0	0	0	0	N
459	09/23/02	2	1555	18.878049	16.44	5.17259	18	0	0	0	0	N
459	9/23/02	3	1607	18.878049	16.44	5.17259	19.3	0	0	0	0	N
460	9/23/02	1	1728	16.468085	16.44	4.51226	18.9	0	0	0	0	N
460	9/23/02	2	1752	16.468085	16.44	4.51226	17.7	0	0	0	0	N
460	9/23/02	3	1823	16.468085	16.44	4.51226	16.6	0	0	0	0	N
461	9/23/02	1	1951	16.071429	16.44	4.40357	5.2	0	0	0	0	N
461	9/23/02	2	2016	16.071429	16.44	4.40357	6.7	0	0	0	0	N
461	9/23/02	3	2024	16.071429	16.44	4.40357	14	0	0	0	0	N

Load # (j)	# Samples (b)	Total Sample Volume	Tota YO' 0-5(
453	3	38.592	
454	3	15.5178	
455	3	16.9661	
456	3	11.2607	
457	3	13.6823	
458	3	11.0648	
459	3	15.5178	
460	3	13.5368	
461	3	13.2107	

Load Records And Rates **Upper Sands** **Sample Volume assumes 25% of total load diverted to sampler; 50% if one drag**

WH Pearson and GD Williams **9/23/2002**

Load Sequence	Sampling Instructions	Date	Load Time		# Passes	Settled Solids Volume (cu yd)	Total Distance Travelled (ft)	No. Basket Samples Taken	Pumping Time (min)	No. Drag Arms in Operation	Ave. Load Rate per Arm (cu yd/min)	Sample Load Rate (cu yd/min)
			Start	End								
453	Sample	9/23/02	0000	0053	2	6192	9000	3	43	2	72	36
454	Sample	9/23/02	0113	0255	3	6192	9000	3	82	2	37.7560976	18.8780488
455	Sample	9/23/02	0323	0453	4	6192	12000	3	75	2	41.28	20.64
456	Sample	9/23/02	0530	0751	4	6192	12000	3	113	2	27.3982301	13.699115
457	Sample	9/23/02	0836	1042	5	6192	15000	3	93	2	33.2903226	16.6451613
458	Sample	9/23/02	1134	1429	8	6192	20000	3	115	2	26.9217391	13.4608696
459	Sample	9/23/02	1506	1648	5	6192	15000	3	82	2	37.7560976	18.8780488
460	Sample	9/23/02	1726	1924	4	6192	12000	3	94	2	32.9361702	16.4680851
461	Sample	9/23/02	1951	2116	4	4500	10000	3	70	2	32.1428571	16.0714286

Summary	Total # Loads (H)	# Loads Sampled (h)	Total Load Volume (V)
	9	9	54036

SUMMARY OF CALCULATION OF ADULT EQUIVALENT LOSS BASED ON MODIFIED DREDGE IMPACT MODEL AND DIRECT MEASUREMENT OF ENTRAINMENT RATES from Miller Sands, October 2002

WH Pearson and GD Williams
Battelle Marine Sciences Laboratory
Sequim, Washington

First Version: ***24-Jul-02*** Revised: ***4-Dec-02***

This calculation run is for

Location	Start Date	End Date	Total Volume Dredged (cy)
Miller Sands	*1-Oct-02*	*8-Oct-02*	*443563*

Overall Summary Statements

Adult Equivalent Loss of all age classes taken tc2+ is	**0**	with 95% CI	**0**
We are 95% confident that the true value lies between	**0**	and	**0**
Adult Equivalent Loss of all age classes taken to :+ is	**0**	with 95% CI	**0**
We are 95% confident that the true value lies between	**0**	and	**0**
Number of MALE recruits lost to fishery is estimated to be	**0**	with 95% CI	**0**
We are 95% confident that the true value lies between	**0**	and	**0**

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0	0.00	0.10	0.017	0.00	0	0.00	0
1+	0.00000	0.0	0.00	0.60	0.160	0.00	0	0.00	0
2+	0.00000	0.0	0.00	0.86	0.649	0.00	0	0.00	0
3+	0.00000	0.0	0.00	0.86	2.222	0.00	0	0.00	0
All		**0.0**	**0.00**			**0.00**	**0.00**	**0.00**	**0.00**

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations

Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Clas

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00	0	0.50	0.00	0
1+	0.50	0.00	0	0.50	0.00	0
2+	0.50	0.00	0	0.50	0.00	0
3+	0.50	0.00	0	0.50	0.00	0

All		0.00	0.00		0.00	0.00
						0.00

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 2+
YOY	0.00	0.00
1+	0.00	0.00
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL 2+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0000	0.0000
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.00	0.00

AGE 3+ Calculations

Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Clas

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00	0	0.50	0.00	0
1+	0.50	0.00	0	0.50	0.00	0
2+	0.50	0.00	0	0.50	0.00	0
3+	0.50	0.00	0	0.50	0.00	0
All		0.00	0.00		0.00	0.00
					0.000	0.000

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Ar
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	0.00	0.00
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0000	0.0000
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.00	0.00

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	0.0
Var(E)	0.0
SE E	0.0
Z at 0.975	1.95996
95% C. I.	0.0
CV E (%)	0.00

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	0.0
Var(AEL2+)	0.0
SE AEL	0.0
Z at 0.975	1.95996
95% C. I.	0.0
CV AEL (%)	0.00

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	0.0
Var(AEL3+)	0.0
SE AEL	0.0
Z at 0.975	1.95996
95% C. I.	0.0
CV AEL (%)	0.00

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	0.0
Var(AEL)	0.0
SE AEL	0.0

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	0.0
Var(AEL)	0.0
SE AEL	0.0

Z at 0.975	1.95996
95% C. I.	0.0
CV AEL (%)	0.00

Z at 0.975	1.95996
95% C. I.	0.0
CV AEL (%)	0.00

TOTAL LOSS TO MALE FISHERY

(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
0.0	0.70	**0.0**

Harvest rate of 0.70 is taken from Armstrong et al. (1987)

Loss to Fishery with Confidence Limits

Loss to Fishery	0.0
Var(AEL)	0
SE LF	0.0
Z at 0.975	1.95996
95% C. I.	0.0
CV LF (%)	0.00

ADDITIONAL NOTES:

Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)

Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).

Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

rmstrong et al. 1987

Estimating Entrainment Rate, Total Entrainment, and Variance
Miller Sands **10/1/02 - 10/8/02**
WH Pearson and GD Williams

Summary

	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	Total
R	0.000	0.000	0.000	0.000	0.000
E	0.0	0.0	0.0	0.0	0.000
Var(E)	0.00	0.00	0.00	0.00	
SE (E)	0.00	0.00	0.00	0.00	
CV(E)	0.00	0.00	0.00	0.00	

Calculations

Load # (j)	V	Rj				Variance Rj (Variance x Load Sheet)				Entrainment (Rj x V)			
		YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	
462	5045	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
464	5045	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
465	4810	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
467	4928	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
470	3601	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
473	5903	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
475	5903	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
476	5903	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
478	5903	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
481	5903	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
484	5915	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
485	5915	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
487	6053	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
490	6017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
492	6017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	
495	5940	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0	

496	5940	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
499	6103	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
502	6103	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
503	6103	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
505	6217	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
507	6217	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
509	6091	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
511	6091	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
514	6257	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
515	6257	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
517	6257	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
519	6257	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
521	6243	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
522	6243	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
524	6270	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
525	6270	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
527	6243	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
530	6040	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
531	6040	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0
534	5815	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0

h	36
Vh	211858
H	75
VH	443563

Estimating E

	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
numerator	0	0	0	0
denominator	211858	211858	211858	211858
R	0.000	0.000	0.000	0.000
E	0.0	0.0	0.0	0.0

Estimating Variance and CV

		YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
first term (Load to load variability)					
step 1	0.52				
step 2		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
step 3 (total)		0	0	0	0
step 4	35				
step 5		0	0	0	0
second term (Basket to basket variability)					
step 1	2.08333				
step 2		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0

	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
step 3 (total)	0	0	0	0
step 4	0	0	0	0
Var(E)	0	0	0	0
SE (E)	0	0	0	0
CV(E)	0	0	0	0

Variance By Load | **Miller Sands**
WH Pearson and GD Williams | **10/1/02 - 10/8/02**

Load Sequence Number	Date	Sample Number	Number of Crabs YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	Sample Volume (CY) (w)	Sum of Squares (by load - w2) YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
462	10/1/02	1	0	0	0	0	6.4384	0	0	0	0
462	10/1/02	2	0	0	0	0	6.4384	0	0	0	0
462	10/1/02	3	0	0	0	0	6.4384	0	0	0	0
462	10/1/02	4	0	0	0	0	6.4384	0	0	0	0
1 Total		4	0	0	0	0	25.754	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
464	10/1/02	1	0	0	0	0	4.6078	0	0	0	0
464	10/1/02	2	0	0	0	0	4.6078	0	0	0	0
464	10/1/02	3	0	0	0	0	4.6078	0	0	0	0
464	10/1/02	4	0	0	0	0	4.6078	0	0	0	0
2 Total		4	0	0	0	0	18.431	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
465	10/1/02	1	0	0	0	0	5.4014	0	0	0	0
465	10/1/02	2	0	0	0	0	5.4014	0	0	0	0
465	10/1/02	3	0	0	0	0	5.4014	0	0	0	0
465	10/1/02	4	0	0	0	0	5.4014	0	0	0	0
3 Total		4	0	0	0	0	21.606	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
467	10/1/02	1	0	0	0	0	5.6261	0	0	0	0
467	10/1/02	2	0	0	0	0	5.6261	0	0	0	0
467	10/1/02	3	0	0	0	0	5.6261	0	0	0	0
467	10/1/02	4	0	0	0	0	5.6261	0	0	0	0
4 Total		4	0	0	0	0	22.505	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
470	10/1/02	1	0	0	0	0	5.6061	0	0	0	0
470	10/1/02	2	0	0	0	0	5.6061	0	0	0	0
470	10/1/02	3	0	0	0	0	5.6061	0	0	0	0
470	10/1/02	4	0	0	0	0	5.6061	0	0	0	0
5 Total		4	0	0	0	0	22.424	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
473	10/2/02	1	0	0	0	0	5.7765	0	0	0	0
473	10/2/02	2	0	0	0	0	5.7765	0	0	0	0
473	10/2/02	3	0	0	0	0	5.7765	0	0	0	0
473	10/2/02	4	0	0	0	0	5.7765	0	0	0	0
6 Total		4	0	0	0	0	23.106	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
475	10/2/02	1	0	0	0	0	5.9464	0	0	0	0
475	10/2/02	2	0	0	0	0	5.9464	0	0	0	0
475	10/2/02	3	0	0	0	0	5.9464	0	0	0	0
475	10/2/02	4	0	0	0	0	5.9464	0	0	0	0
7 Total		4	0	0	0	0	23.786	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
476	10/2/02	1	0	0	0	0	5.184	0	0	0	0
476	10/2/02	2	0	0	0	0	5.184	0	0	0	0
476	10/2/02	3	0	0	0	0	5.184	0	0	0	0
476	10/2/02	4	0	0	0	0	5.184	0	0	0	0
8 Total		4	0	0	0	0	20.736	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
478	10/2/02	1	0	0	0	0	6.4183	0	0	0	0
478	10/2/02	2	0	0	0	0	6.4183	0	0	0	0
478	10/2/02	3	0	0	0	0	6.4183	0	0	0	0
478	10/2/02	4	0	0	0	0	6.4183	0	0	0	0
9 Total		4	0	0	0	0	25.673	0	0	0	0
	Mean (cij)		0	0	0	0					

							Rj	0	0	0	0
							Var Rj	0	0	0	0
481	10/2/02	1	0	0	0	0	5.4643	0	0	0	0
481	10/2/02	2	0	0	0	0	5.4643	0	0	0	0
481	10/2/02	3	0	0	0	0	5.4643	0	0	0	0
10	Total	3	0	0	0	0	16.393	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
484	10/3/02	1	0	0	0	0	5.7883	0	0	0	0
484	10/3/02	2	0	0	0	0	5.7883	0	0	0	0
484	10/3/02	3	0	0	0	0	5.7883	0	0	0	0
484	10/3/02	4	0	0	0	0	5.7883	0	0	0	0
11	Total	4	0	0	0	0	23.153	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
485	10/3/02	1	0	0	0	0	5.4754	0	0	0	0
485	10/3/02	2	0	0	0	0	5.4754	0	0	0	0
485	10/3/02	3	0	0	0	0	5.4754	0	0	0	0
485	10/3/02	4	0	0	0	0	5.4754	0	0	0	0
12	Total	4	0	0	0	0	21.901	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
487	10/3/02	1	0	0	0	0	7.6783	0	0	0	0
487	10/3/02	2	0	0	0	0	7.6783	0	0	0	0
487	10/3/02	3	0	0	0	0	8.6124	0	0	0	0
13	Total	3	0	0	0	0	23.969	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
490	10/3/02	1	0	0	0	0	7.7767	0	0	0	0
490	10/3/02	2	0	0	0	0	7.7767	0	0	0	0
490	10/3/02	3	0	0	0	0	7.7767	0	0	0	0
490	10/3/02	4	0	0	0	0	7.7767	0	0	0	0
14	Total	4	0	0	0	0	31.107	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
492	10/3/02	1	0	0	0	0	6.4401	0	0	0	0
492	10/3/02	2	0	0	0	0	6.4401	0	0	0	0
492	10/3/02	3	0	0	0	0	6.4401	0	0	0	0
492	10/3/02	4	0	0	0	0	6.4401	0	0	0	0
15	Total	4	0	0	0	0	25.76	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
495	10/4/02	1	0	0	0	0	8.0068	0	0	0	0
495	10/4/02	2	0	0	0	0	7.1384	0	0	0	0
495	10/4/02	3	0	0	0	0	7.1384	0	0	0	0
495	10/4/02	4	0	0	0	0	7.1384	0	0	0	0
16	Total	4	0	0	0	0	29.422	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
496	10/4/02	1	0	0	0	0	6.073	0	0	0	0
496	10/4/02	2	0	0	0	0	6.073	0	0	0	0
496	10/4/02	3	0	0	0	0	6.073	0	0	0	0
496	10/4/02	4	0	0	0	0	6.073	0	0	0	0
17	Total	4	0	0	0	0	24.292	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
499	10/4/02	1	0	0	0	0	6.5321	0	0	0	0
499	10/4/02	2	0	0	0	0	6.5321	0	0	0	0
499	10/4/02	3	0	0	0	0	6.5321	0	0	0	0
18	Total	3	0	0	0	0	19.596	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
502	10/4/02	1	0	0	0	0	4.594	0	0	0	0
502	10/4/02	2	0	0	0	0	4.594	0	0	0	0
502	10/4/02	3	0	0	0	0	4.8735	0	0	0	0
502	10/4/02	4	0	0	0	0	4.594	0	0	0	0
19	Total	4	0	0	0	0	18.656	0	0	0	0

Mean (cij)			0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
503	10/4/02	1	0	0	0	0	5.5741	0	0	0	0
503	10/4/02	2	0	0	0	0	5.5741	0	0	0	0
503	10/4/02	3	0	0	0	0	5.5741	0	0	0	0
503	10/4/02	4	0	0	0	0	5.5741	0	0	0	0
20 Total		4	0	0	0	0	22.296	0	0	0	0
Mean (cij)			0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
505	10/5/02	1	0	0	0	0	5.9981	0	0	0	0
505	10/5/02	2	0	0	0	0	5.9981	0	0	0	0
505	10/5/02	3	0	0	0	0	5.9981	0	0	0	0
505	10/5/02	4	0	0	0	0	5.9981	0	0	0	0
21 Total		4	0	0	0	0	23.992	0	0	0	0
Mean (cij)			0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
507	10/5/02	1	0	0	0	0	4.4361	0	0	0	0
507	10/5/02	2	0	0	0	0	4.4361	0	0	0	0
507	10/5/02	3	0	0	0	0	4.4361	0	0	0	0
507	10/5/02	4	0	0	0	0	4.4361	0	0	0	0
22 Total		4	0	0	0	0	17.744	0	0	0	0
Mean (cij)			0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
509	10/5/02	1	0	0	0	0	4.9671	0	0	0	0
509	10/5/02	2	0	0	0	0	4.9671	0	0	0	0
509	10/5/02	3	0	0	0	0	4.9671	0	0	0	0
509	10/5/02	4	0	0	0	0	4.9671	0	0	0	0
23 Total		4	0	0	0	0	19.868	0	0	0	0
Mean (cij)			0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
511	10/5/02	1	0	0	0	0	6.2274	0	0	0	0
511	10/5/02	2	0	0	0	0	6.2274	0	0	0	0
511	10/5/02	3	0	0	0	0	6.2274	0	0	0	0
511	10/5/02	4	0	0	0	0	6.2274	0	0	0	0
24 Total		4	0	0	0	0	24.909	0	0	0	0
Mean (cij)			0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
514	10/5/02	1	0	0	0	0	5.4254	0	0	0	0
514	10/6/02	2	0	0	0	0	5.4254	0	0	0	0
514	10/6/02	3	0	0	0	0	5.4254	0	0	0	0
514	10/6/02	4	0	0	0	0	5.4254	0	0	0	0
25 Total		4	0	0	0	0	21.701	0	0	0	0
Mean (cij)			0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
515	10/6/02	1	0	0	0	0	5.3576	0	0	0	0
515	10/6/02	2	0	0	0	0	5.3576	0	0	0	0
515	10/6/02	3	0	0	0	0	5.3576	0	0	0	0
515	10/6/02	4	0	0	0	0	5.3576	0	0	0	0
26 Total		4	0	0	0	0	21.43	0	0	0	0
Mean (cij)			0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
517	10/6/02	1	0	0	0	0	5.6395	0	0	0	0
517	10/6/02	2	0	0	0	0	5.6395	0	0	0	0
517	10/6/02	3	0	0	0	0	5.6395	0	0	0	0
517	10/6/02	4	0	0	0	0	5.6395	0	0	0	0
27 Total		4	0	0	0	0	22.558	0	0	0	0
Mean (cij)			0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
519	10/6/02	1	0	0	0	0	5.7147	0	0	0	0
519	10/6/02	2	0	0	0	0	5.7147	0	0	0	0
519	10/6/02	3	0	0	0	0	5.7147	0	0	0	0
519	10/6/02	4	0	0	0	0	5.7147	0	0	0	0
28 Total		4	0	0	0	0	22.859	0	0	0	0
Mean (cij)			0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
521	10/6/02	1	0	0	0	0	4.9726	0	0	0	0

521	10/6/02	2	0	0	0	0	4.9726	0	0	0	0
521	10/6/02	3	0	0	0	0	4.9726	0	0	0	0
521	10/6/02	4	0	0	0	0	4.9726	0	0	0	0
29	Total	4	0	0	0	0	19.89	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
522	10/6/02	1	0	0	0	0	4.7516	0	0	0	0
522	10/6/02	2	0	0	0	0	4.7516	0	0	0	0
522	10/6/02	3	0	0	0	0	4.7516	0	0	0	0
522	10/6/02	4	0	0	0	0	4.7516	0	0	0	0
30	Total	4	0	0	0	0	19.006	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
524	10/7/02	1	0	0	0	0	4.8806	0	0	0	0
524	10/7/02	2	0	0	0	0	4.8806	0	0	0	0
524	10/7/02	3	0	0	0	0	4.8806	0	0	0	0
524	10/7/02	4	0	0	0	0	4.8806	0	0	0	0
31	Total	4	0	0	0	0	19.523	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
525	10/7/02	1	0	0	0	0	4.4739	0	0	0	0
525	10/7/02	2	0	0	0	0	4.4739	0	0	0	0
525	10/7/02	3	0	0	0	0	4.4739	0	0	0	0
525	10/7/02	4	0	0	0	0	4.4739	0	0	0	0
32	Total	4	0	0	0	0	17.896	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
527	10/7/02	1	0	0	0	0	5.5538	0	0	0	0
527	10/7/02	2	0	0	0	0	5.5538	0	0	0	0
527	10/7/02	3	0	0	0	0	5.5538	0	0	0	0
527	10/7/02	4	0	0	0	0	5.5538	0	0	0	0
33	Total	4	0	0	0	0	22.215	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
530	10/7/02	1	0	0	0	0	5.3732	0	0	0	0
530	10/7/02	2	0	0	0	0	5.3732	0	0	0	0
530	10/7/02	3	0	0	0	0	5.3732	0	0	0	0
530	10/7/02	4	0	0	0	0	5.3732	0	0	0	0
34	Total	4	0	0	0	0	21.493	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
531	10/7/02	1	0	0	0	0	5.5911	0	0	0	0
531	10/7/02	2	0	0	0	0	5.5911	0	0	0	0
531	10/7/02	3	0	0	0	0	5.5911	0	0	0	0
531	10/7/02	4	0	0	0	0	5.5911	0	0	0	0
35	Total	4	0	0	0	0	22.364	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0
534	10/8/02	1	0	0	0	0	5.8578	0	0	0	0
534	10/8/02	2	0	0	0	0	5.8578	0	0	0	0
534	10/8/02	3	0	0	0	0	5.8578	0	0	0	0
36	Total	3	0	0	0	0	17.573	0	0	0	0
	Mean (cij)		0	0	0	0					
							Rj	0	0	0	0
							Var Rj	0	0	0	0

Total Entrainment by Load **Miller Sands**
WH Pearson and GD Williams **10/1/02 - 10/8/02**

Load # (j)	Total Load Volume (V)	# Samples (b)	Total Sample Volume (v)	Totals by Age Class i				Rij			
				YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
462	5045	4	25.753524	0	0	0	0	0.0000	0.0000	0.0000	0.0000
464	5045	4	18.431067	0	0	0	0	0.0000	0.0000	0.0000	0.0000
465	4810	4	21.605574	0	0	0	0	0.0000	0.0000	0.0000	0.0000
467	4928	4	22.504533	0	0	0	0	0.0000	0.0000	0.0000	0.0000
470	3601	4	22.424409	0	0	0	0	0.0000	0.0000	0.0000	0.0000
473	5903	4	23.106029	0	0	0	0	0.0000	0.0000	0.0000	0.0000
475	5903	4	23.785618	0	0	0	0	0.0000	0.0000	0.0000	0.0000
476	5903	4	20.736179	0	0	0	0	0.0000	0.0000	0.0000	0.0000
478	5903	4	25.673365	0	0	0	0	0.0000	0.0000	0.0000	0.0000
481	5903	3	16.392791	0	0	0	0	0.0000	0.0000	0.0000	0.0000
484	5915	4	23.153	0	0	0	0	0.0000	0.0000	0.0000	0.0000
485	5915	4	21.901486	0	0	0	0	0.0000	0.0000	0.0000	0.0000
487	6053	3	23.969133	0	0	0	0	0.0000	0.0000	0.0000	0.0000
490	6017	4	31.106755	0	0	0	0	0.0000	0.0000	0.0000	0.0000
492	6017	4	25.760281	0	0	0	0	0.0000	0.0000	0.0000	0.0000
495	5940	4	29.422105	0	0	0	0	0.0000	0.0000	0.0000	0.0000
496	5940	4	24.29194	0	0	0	0	0.0000	0.0000	0.0000	0.0000
499	6103	3	19.596352	0	0	0	0	0.0000	0.0000	0.0000	0.0000
502	6103	4	18.655507	0	0	0	0	0.0000	0.0000	0.0000	0.0000
503	6103	4	22.296293	0	0	0	0	0.0000	0.0000	0.0000	0.0000
505	6217	4	23.992366	0	0	0	0	0.0000	0.0000	0.0000	0.0000
507	6217	4	17.744354	0	0	0	0	0.0000	0.0000	0.0000	0.0000
509	6091	4	19.868262	0	0	0	0	0.0000	0.0000	0.0000	0.0000
511	6091	4	24.909463	0	0	0	0	0.0000	0.0000	0.0000	0.0000
514	6257	4	21.701494	0	0	0	0	0.0000	0.0000	0.0000	0.0000
515	6257	4	21.430225	0	0	0	0	0.0000	0.0000	0.0000	0.0000
517	6257	4	22.558132	0	0	0	0	0.0000	0.0000	0.0000	0.0000
519	6257	4	22.858907	0	0	0	0	0.0000	0.0000	0.0000	0.0000
521	6243	4	19.890488	0	0	0	0	0.0000	0.0000	0.0000	0.0000
522	6243	4	19.006467	0	0	0	0	0.0000	0.0000	0.0000	0.0000
524	6270	4	19.5225	0	0	0	0	0.0000	0.0000	0.0000	0.0000
525	6270	4	17.895625	0	0	0	0	0.0000	0.0000	0.0000	0.0000

527	6243	4	22.215351	0	0	0	0	0.0000	0.0000	0.0000	0.0000
530	6040	4	21.492987	0	0	0	0	0.0000	0.0000	0.0000	0.0000
531	6040	4	22.364324	0	0	0	0	0.0000	0.0000	0.0000	0.0000
534	5815	3	17.573272	0	0	0	0	0.0000	0.0000	0.0000	0.0000

Within Load Record **Miller Sands**
WH Pearson and GD Williams **10/1/02 - 10/8/02**

Load Sequence Number (j)	Date	Sample Number (l)	Start Time (h:m)	Sample Load Rate (cu yd/min)	Effective Sample Time (sec)	Sample Volume (CY) (w)	Salinity (ppt)	Number of Crabs (c) by age class (i) YOY 0-50	1+ 51-100	2+ 101-150	3+ >150	UID
462	10/1/02	1	0013	18.017857	21.44	6.43838	nd	0	0	0	0	N
462	10/1/02	2	0039	18.017857	21.44	6.43838	nd	0	0	0	0	N
462	10/1/02	3	0114	18.017857	21.44	6.43838	0	0	0	0	0	N
462	10/1/02	4	0200	18.017857	21.44	6.43838	2	0	0	0	0	N
464	10/1/02	1	0443	16.816667	16.44	4.60777	10	0	0	0	0	N
464	10/1/02	2	0505	16.816667	16.44	4.60777	6	0	0	0	0	N
464	10/1/02	3	0529	16.816667	16.44	4.60777	nd	0	0	0	0	N
464	10/1/02	4	0558	16.816667	16.44	4.60777	12	0	0	0	0	N
465	10/1/02	1	0720	19.713115	16.44	5.40139	15	0	0	0	0	N
465	10/1/02	2	0727	19.713115	16.44	5.40139	15	0	0	0	0	N
465	10/1/02	3	0803	19.713115	16.44	5.40139	15	0	0	0	0	N
465	10/1/02	4	0824	19.713115	16.44	5.40139	15	0	0	0	0	N
467	10/1/02	1	1114	20.533333	16.44	5.62613	15	0	0	0	0	N
467	10/1/02	2	1127	20.533333	16.44	5.62613	16	0	0	0	0	N
467	10/1/02	3	1134	20.533333	16.44	5.62613	nd	0	0	0	0	N
467	10/1/02	4	1153	20.533333	16.44	5.62613	15	0	0	0	0	N
470	10/1/02	1	1740	20.460227	16.44	5.6061	8	0	0	0	0	N
470	10/1/02	2	1801	20.460227	16.44	5.6061	9	0	0	0	0	N
470	10/1/02	3	1817	20.460227	16.44	5.6061	10	0	0	0	0	N
470	10/1/02	4	1826	20.460227	16.44	5.6061	8	0	0	0	0	N
473	10/2/02	1	0126	21.082143	16.44	5.77651	10	0	0	0	0	N
473	10/2/02	2	0136	21.082143	16.44	5.77651	10	0	0	0	0	N
473	10/2/02	3	0151	21.082143	16.44	5.77651	nd	0	0	0	0	N
473	10/2/02	4	0212	21.082143	16.44	5.77651	10	0	0	0	0	N
475	10/2/02	1	0630	21.702206	16.44	5.9464	0	0	0	0	0	N
475	10/2/02	2	0642	21.702206	16.44	5.9464	0	0	0	0	0	N
475	10/2/02	3	0658	21.702206	16.44	5.9464	0	0	0	0	0	N
475	10/2/02	4	0711	21.702206	16.44	5.9464	nd	0	0	0	0	N
476	10/2/02	1	0914	18.919872	16.44	5.18404	0	0	0	0	0	N
476	10/2/02	2	0930	18.919872	16.44	5.18404	0	0	0	0	0	N
476	10/2/02	3	0946	18.919872	16.44	5.18404	0	0	0	0	0	N
476	10/2/02	4	1002	18.919872	16.44	5.18404	4	0	0	0	0	N
478	10/2/02	1	1438	23.424603	16.44	6.41834	8	0	0	0	0	N
478	10/2/02	2	1502	23.424603	16.44	6.41834	nd	0	0	0	0	N
478	10/2/02	3	1511	23.424603	16.44	6.41834	10	0	0	0	0	N
478	10/2/02	4	1534	23.424603	16.44	6.41834	10	0	0	0	0	N
481	10/2/02	1	2132	19.942568	16.44	5.46426	5	0	0	0	0	N
481	10/2/02	2	2151	19.942568	16.44	5.46426	5	0	0	0	0	N
481	10/2/02	3	2223	19.942568	16.44	5.46426	8	0	0	0	0	N
484	10/3/02	1	0412	21.125	16.44	5.78825	2	0	0	0	0	N
484	10/3/02	2	0428	21.125	16.44	5.78825	2	0	0	0	0	N
484	10/3/02	3	0444	21.125	16.44	5.78825	nd	0	0	0	0	N
484	10/3/02	4	0500	21.125	16.44	5.78825	0	0	0	0	0	N
485	10/3/02	1	0632	19.983108	16.44	5.47537	0	0	0	0	0	N
485	10/3/02	2	0641	19.983108	16.44	5.47537	0	0	0	0	0	N

Load # (j)	# Samples (b)	Total Volume	Totals by Age Class i YOY 0-50	1+ 51-100	2+ 101-150	3+ >150
462	4	25.754	0	0	0	0
464	4	18.431	0	0	0	0
465	4	21.606	0	0	0	0
467	4	22.505	0	0	0	0
470	4	22.424	0	0	0	0
473	4	23.106	0	0	0	0
475	4	23.786	0	0	0	0
476	4	20.736	0	0	0	0
478	4	25.673	0	0	0	0
481	3	16.393	0	0	0	0
484	4	23.153	0	0	0	0
485	4	21.901	0	0	0	0
487	3	23.969	0	0	0	0
490	4	31.107	0	0	0	0
492	4	25.76	0	0	0	0
495	4	29.422	0	0	0	0
496	4	24.292	0	0	0	0
499	3	19.596	0	0	0	0
502	4	18.656	0	0	0	0
503	4	22.296	0	0	0	0
505	4	23.992	0	0	0	0
507	4	17.744	0	0	0	0
509	4	19.868	0	0	0	0
511	4	24.909	0	0	0	0
514	4	21.701	0	0	0	0
515	4	21.43	0	0	0	0
517	4	22.558	0	0	0	0
519	4	22.859	0	0	0	0
521	4	19.89	0	0	0	0
522	4	19.006	0	0	0	0
524	4	19.523	0	0	0	0
525	4	17.896	0	0	0	0
527	4	22.215	0	0	0	0
530	4	21.493	0	0	0	0
531	4	22.364	0	0	0	0
534	3	17.573	0	0	0	0

485	10/3/02	3	0656	19.983108	16.44	5.47537	0	0	0	0	0	N
485	10/3/02	4	0712	19.983108	16.44	5.47537	0	0	0	0	0	N
487	10/3/02	1	1152	28.023148	16.44	7.67834	2	0	0	0	0	N
487	10/3/02	2	1228	28.023148	16.44	7.67834	2	0	0	0	0	N
487	10/3/02	3	1249	28.023148	18.44	8.61245	4	0	0	0	0	N
490	10/3/02	1	1728	28.382075	16.44	7.77669	nd	0	0	0	0	N
490	10/3/02	2	1744	28.382075	16.44	7.77669	0	0	0	0	0	N
490	10/3/02	3	1800	28.382075	16.44	7.77669	0	0	0	0	0	N
490	10/3/02	4	1816	28.382075	16.44	7.77669	0	0	0	0	0	N
492	10/3/02	1	2137	23.503906	16.44	6.44007	0	0	0	0	0	N
492	10/3/02	2	2153	23.503906	16.44	6.44007	0	0	0	0	0	N
492	10/3/02	3	2209	23.503906	16.44	6.44007	0	0	0	0	0	N
492	10/3/02	4	2226	23.503906	16.44	6.44007	0	0	0	0	0	N
495	10/4/02	1	0340	26.052632	18.44	8.00684	4	0	0	0	0	N
495	10/4/02	2	0353	26.052632	16.44	7.13842	3	0	0	0	0	N
495	10/4/02	3	0406	26.052632	16.44	7.13842	1	0	0	0	0	N
495	10/4/02	4	0431	26.052632	16.44	7.13842	0	0	0	0	0	N
496	10/4/02	1	0541	22.164179	16.44	6.07299	0	0	0	0	0	N
496	10/4/02	2	0554	22.164179	16.44	6.07299	0	0	0	0	0	N
496	10/4/02	3	0608	22.164179	16.44	6.07299	0	0	0	0	0	N
496	10/4/02	4	0627	22.164179	16.44	6.07299	0	0	0	0	0	N
499	10/4/02	1	1208	23.839844	16.44	6.53212	5	0	0	0	0	N
499	10/4/02	2	1237	23.839844	16.44	6.53212	8	0	0	0	0	N
499	10/4/02	3	1250	23.839844	16.44	6.53212	8	0	0	0	0	N
502	10/4/02	1	1831	16.766484	16.44	4.59402	0	0	0	0	0	N
502	10/4/02	2	1853	16.766484	16.44	4.59402	0	0	0	0	0	N
502	10/4/02	3	1909	16.766484	17.44	4.87346	0	0	0	0	0	N
502	10/4/02	4	1932	16.766484	16.44	4.59402	0	0	0	0	0	N
503	10/4/02	1	2048	20.343333	16.44	5.57407	0	0	0	0	0	N
503	10/4/02	2	2104	20.343333	16.44	5.57407	0	0	0	0	0	N
503	10/4/02	3	2128	20.343333	16.44	5.57407	0	0	0	0	0	N
503	10/4/02	4	2145	20.343333	16.44	5.57407	0	0	0	0	0	N
505	10/5/02	1	0059	21.890845	16.44	5.99809	2	0	0	0	0	N
505	10/5/02	2	0115	21.890845	16.44	5.99809	2	0	0	0	0	N
505	10/5/02	3	0131	21.890845	16.44	5.99809	2	0	0	0	0	N
505	10/5/02	4	0159	21.890845	16.44	5.99809	2	0	0	0	0	N
507	10/5/02	1	0548	16.190104	16.44	4.43609	0	0	0	0	0	N
507	10/5/02	2	0606	16.190104	16.44	4.43609	0	0	0	0	0	N
507	10/5/02	3	0632	16.190104	16.44	4.43609	0	0	0	0	0	N
507	10/5/02	4	0645	16.190104	16.44	4.43609	0	0	0	0	0	N
509	10/5/02	1	1044	18.127976	16.44	4.96707	0	0	0	0	0	N
509	10/5/02	2	1100	18.127976	16.44	4.96707	1	0	0	0	0	N
509	10/5/02	3	1118	18.127976	16.44	4.96707	1	0	0	0	0	N
509	10/5/02	4	1147	18.127976	16.44	4.96707	1	0	0	0	0	N
511	10/5/02	1	1549	22.727612	16.44	6.22737	2	0	0	0	0	N
511	10/5/02	2	1605	22.727612	16.44	6.22737	2	0	0	0	0	N
511	10/5/02	3	1629	22.727612	16.44	6.22737	2	0	0	0	0	N
511	10/5/02	4	1637	22.727612	16.44	6.22737	0	0	0	0	0	N
514	10/5/02	1	2336	19.800633	16.44	5.42537	0	0	0	0	0	N
514	10/6/02	2	0000	19.800633	16.44	5.42537	nd	0	0	0	0	N
514	10/6/02	3	0025	19.800633	16.44	5.42537	nd	0	0	0	0	N
514	10/6/02	4	0105	19.800633	16.44	5.42537	nd	0	0	0	0	N
515	10/6/02	1	0159	19.553125	16.44	5.35756	0	0	0	0	0	N
515	10/6/02	2	0218	19.553125	16.44	5.35756	0	0	0	0	0	N
515	10/6/02	3	0240	19.553125	16.44	5.35756	0	0	0	0	0	N

515	10/6/02	4	0247	19.553125	16.44	5.35756	0	0	0	0	0	N
517	10/6/02	1	0709	20.582237	16.44	5.63953	0	0	0	0	0	N
517	10/6/02	2	0728	20.582237	16.44	5.63953	0	0	0	0	0	N
517	10/6/02	3	0747	20.582237	16.44	5.63953	0	0	0	0	0	N
517	10/6/02	4	0756	20.582237	16.44	5.63953	0	0	0	0	0	N
519	10/6/02	1	1219	20.856667	16.44	5.71473	2	0	0	0	0	N
519	10/6/02	2	1242	20.856667	16.44	5.71473	2	0	0	0	0	N
519	10/6/02	3	1256	20.856667	16.44	5.71473	2	0	0	0	0	N
519	10/6/02	4	1320	20.856667	16.44	5.71473	8	0	0	0	0	N
521	10/6/02	1	1739	18.148256	16.44	4.97262	0	0	0	0	0	N
521	10/6/02	2	1800	18.148256	16.44	4.97262	0	0	0	0	0	N
521	10/6/02	3	1813	18.148256	16.44	4.97262	0	0	0	0	0	N
521	10/6/02	4	1829	18.148256	16.44	4.97262	0	0	0	0	0	N
522	10/6/02	1	2029	17.341667	16.44	4.75162	0	0	0	0	0	N
522	10/6/02	2	2038	17.341667	16.44	4.75162	0	0	0	0	0	N
522	10/6/02	3	2058	17.341667	16.44	4.75162	0	0	0	0	0	N
522	10/6/02	4	2119	17.341667	16.44	4.75162	0	0	0	0	0	N
524	10/7/02	1	0144	17.8125	16.44	4.88063	0	0	0	0	0	N
524	10/7/02	2	0155	17.8125	16.44	4.88063	nd	0	0	0	0	N
524	10/7/02	3	0211	17.8125	16.44	4.88063	0	0	0	0	0	N
524	10/7/02	4	0233	17.8125	16.44	4.88063	0	0	0	0	0	N
525	10/7/02	1	0427	16.328125	16.44	4.47391	0	0	0	0	0	N
525	10/7/02	2	0450	16.328125	16.44	4.47391	0	0	0	0	0	N
525	10/7/02	3	0501	16.328125	16.44	4.47391	0	0	0	0	0	N
525	10/7/02	4	0514	16.328125	16.44	4.47391	0	0	0	0	0	N
527	10/7/02	1	1042	20.269481	16.44	5.55384	0	0	0	0	0	N
527	10/7/02	2	1115	20.269481	16.44	5.55384	0	0	0	0	0	N
527	10/7/02	3	1142	20.269481	16.44	5.55384	0	0	0	0	0	N
527	10/7/02	4	1205	20.269481	16.44	5.55384	0	0	0	0	0	N
530	10/7/02	1	1845	19.61039	16.44	5.37325	0	0	0	0	0	N
530	10/7/02	2	1855	19.61039	16.44	5.37325	0	0	0	0	0	N
530	10/7/02	3	1917	19.61039	16.44	5.37325	0	0	0	0	0	N
530	10/7/02	4	1930	19.61039	16.44	5.37325	nd	0	0	0	0	N
531	10/7/02	1	2117	20.405405	16.44	5.59108	0	0	0	0	0	N
531	10/7/02	2	2139	20.405405	16.44	5.59108	0	0	0	0	0	N
531	10/7/02	3	2156	20.405405	16.44	5.59108	0	0	0	0	0	N
531	10/7/02	4	2215	20.405405	16.44	5.59108	0	0	0	0	0	N
534	10/8/02	1	0424	21.378676	16.44	5.85776	0	0	0	0	0	N
534	10/8/02	2	0439	21.378676	16.44	5.85776	0	0	0	0	0	N
534	10/8/02	3	0502	21.378676	16.44	5.85776	nd	0	0	0	0	N

Load Records And Rates **Miller Sands** **Sample Volume assumes 25% of total load is diverted to sampler; 50% if one drag arm**

WH Pearson and GD Williams **10/1/02 - 10/8/02**

Load Sequence	Sampling Instructions	Date	Load Time		# Passes	Settled Solids Volume (cu yd)	Total Distance Travelled (ft)	No. Basket Samples Taken	Pumping Time (min)	No. Drag Arms in Operation	Ave. Load Rate per Arm (cu yd/min)	Sample Load Rate (cu yd/min)
			Start	End								
462	Sample	10/01/02	0005	0215	5	5045	12500	4	70	2	36.0357143	18.0178571
463	Off	10/01/02	0245	0418	3	5045	7500	0	70	2	36.0357143	18.0178571
464	Sample	10/01/02	0440	0630	5	5045	10000	4	75	2	33.6333333	16.8166667
465	Sample	10/01/02	0710	0831	3	4810	8000	4	61	2	39.4262295	19.7131148
466	Off	10/01/02	0908	1017	3	4928	8000	0	51	2	48.3137255	24.1568627
467	Sample	10/01/02	1053	1203	3	4928	8000	4	60	2	41.0666667	20.5333333
468	Off	10/01/02	1237	1350	4	4928	9000	0	58	2	42.4827586	21.2413793
469	Off	10/01/02	1446	1542	2	5775	4500	0	51	2	56.6176471	28.3088235
470	Sample	10/01/02	1736	1830	3	3601	6000	4	44	2	40.9204545	20.4602273
471	Off	10/01/02	2052	2201	3	5775	6000	0	74	2	39.0202703	19.5101351
472	Off	10/02/02	2256	0015	4	5903	6000	0	69	2	42.7753623	21.3876812
473	Sample	10/02/02	0119	0244	4	5903	9000	4	70	2	42.1642857	21.0821429
474	Off	10/02/02	0331	0457	3	5903	8000	0	71	2	41.5704225	20.7852113
475	Sample	10/02/02	0622	0745	4	5903	9000	4	68	2	43.4044118	21.7022059
476	Sample	10/02/02	0905	1038	4	5903	9000	4	78	2	37.8397436	18.9198718
477	Off	10/02/02	1201	1319	4	5903	9000	0	63	2	46.8492063	23.4246032
478	Sample	10/02/02	1437	1550	3	5903	7500	4	63	2	46.8492063	23.4246032

479	Off	10/02/02	1649	1805	4	5903	10000	0	61	2	48.3852459	24.192623
480	Off	10/02/02	1855	2040	4	5903	10000	0	75	2	39.3533333	19.6766667
481	Sample	10/02/02	2129	2258	4	5903	10000	3	74	2	39.8851351	19.9425676
482	Off	10/03/02	2350	0105	4	5915	10000	0	50	2	59.15	29.575
483	Off	10/03/02	0153	0305	3	5915	7500	0	62	2	47.7016129	23.8508065
484	Sample	10/03/02	0403	0523	3	5915	8000	4	70	2	42.25	21.125
485	Sample	10/03/02	0623	0752	4	5915	10000	4	74	2	39.9662162	19.9831081
486	Off	10/03/02	0854	1050	6	6053	11000	0	96	2	31.5260417	15.7630208
487	Sample	10/03/02	1145	1254	4	6053	9000	3	54	2	56.0462963	28.0231481
488	Off	10/03/02	1340	1439	3	6053	7500	0	49	2	61.7653061	30.8826531
489	Off	10/03/02	1530	1641	4	6017	9000	0	56	2	53.7232143	26.8616071
490	Sample	10/03/02	1727	1835	4	6017	10000	4	53	2	56.7641509	28.3820755
491	Off	10/03/02	1921	2042	4	6017	10000	0	66	2	45.5833333	22.7916667
492	Sample	10/03/02	2136	2255	4	6017	10000	4	64	2	47.0078125	23.5039063
493	Off	10/03/02	2340	0054	3	5940	7500	0	64	2	46.40625	23.203125
494	Off	10/04/02	0143	0245	3	5940	7500	0	52	2	57.1153846	28.5576923
495	Sample	10/04/02	0336	0443	3	5940	7500	4	57	2	52.1052632	26.0526316
496	Sample	10/04/02	0535	0657	4	5940	9000	4	67	2	44.3283582	22.1641791
497	Off	10/04/02	0754	0922	4	6006	10000	0	73	2	41.1369863	20.5684932
498	Off	10/04/02	1005	1145	7	6103	7000	0	64	2	47.6796875	23.8398438

499	Sample	10/04/02	1207	1336	6	6103	6000	3	64	2	47.6796875	23.8398438
500	Off	10/04/02	1354	1521	5	6103	5000	0	62	2	49.2177419	24.608871
501	Off	10/04/02	1546	1755	6	6103	6000	0	99	2	30.8232323	15.4116162
502	Sample	10/04/02	1819	2020	6	6103	6000	4	91	2	33.532967	16.7664835
503	Sample	10/04/02	2047	2227	6	6103	6000	4	75	2	40.6866667	20.3433333
504	Off	10/05/02	2248	0027	7	6217	8000	0	59	2	52.6864407	26.3432203
505	Sample	10/05/02	0058	0234	6	6217	7000	4	71	2	43.7816901	21.8908451
506	Off	10/05/02	0258	0514	6	6217	7000	0	106	2	29.3254717	14.6627358
507	Sample	10/05/02	0539	0745	6	6217	6000	4	96	2	32.3802083	16.1901042
508	Off	10/05/02	0809	1002	6	6217	6000	0	83	2	37.4518072	18.7259036
509	Sample	10/05/02	1035	1229	6	6091	7000	4	84	2	36.2559524	18.1279762
510	Off	10/05/02	1257	1507	5	6091	6000	0	70	2	43.5071429	21.7535714
511	Sample	10/05/02	1540	1727	5	6091	6000	4	67	2	45.4552239	22.7276119
512	Off	10/05/02	1814	2010	5	6091	10000	0	76	2	40.0723684	20.0361842
513	Off	10/05/02	2050	2250	5	6091	10000	0	80	2	38.06875	19.034375
514	Sample	10/05/02	2327	0116	6	6257	6500	4	79	2	39.6012658	19.8006329
515	Sample	10/06/02	0148	0356	7	6257	9000	4	80	2	39.10625	19.553125
516	Off	10/6/02	0437	0624	5	6257	9000	0	72	2	43.4513889	21.7256944
517	Sample	10/6/02	0706	0854	5	6257	9000	4	76	2	41.1644737	20.5822368
518	Off	10/6/02	0934	1134	6	6257	9400	0	85	2	36.8058824	18.4029412

519	Sample	10/6/02	1209	1359	5	6257	6500	4	75	2	41.7133333	20.8566667
520	Off	10/6/02	1431	1658	8	6243	10400	0	82	2	38.0670732	19.0335366
521	Sample	10/6/02	1732	1928	6	6243	9500	4	86	2	36.2965116	18.1482558
522	Sample	10/6/02	2010	2210	6	6243	9000	4	90	2	34.6833333	17.3416667
523	Off	10/6-7/02	2240	0059	6	6270	7500	0	91	2	34.4505495	17.2252747
524	Sample	10/7/02	0130	0353	7	6270	9000	4	88	2	35.625	17.8125
525	Sample	10/7/02	0425	0641	7	6270	8000	4	96	2	32.65625	16.328125
526	Off	10/7/02	0727	0948	6	6270	8000	0	106	2	29.5754717	14.7877358
527	Sample	10/7/02	1033	1252	5	6243	8000	4	77	2	40.538961	20.2694805
528	Off	10/7/02	1325	1527	5	6053	6500	0	87	2	34.7873563	17.3936782
529	Off	10/7/02	1555	1808	7	6040	10000	0	90	2	33.5555556	16.7777778
530	Sample	10/7/02	1845	2037	6	6040	8000	4	77	2	39.2207792	19.6103896
531	Sample	10/7/02	2110	2255	4	6040	5000	4	74	2	40.8108108	20.4054054
532	Off	10/7/02	2327	0119	6	5815	8000	0	96	2	30.2864583	15.1432292
533	Off	10/8/02	0152	0348	6	5815	7000	0	71	2	40.9507042	20.4753521
534	Sample	10/8/02	0419	0537	5	5815	5000	3	68	2	42.7573529	21.3786765
535	Off	10/8/02	0628	0745	4	5815	4000	0	63	2	46.1507937	23.0753968
536	Sample	10/8/02	0827	1010	5	5815	5000	0	68	2	42.7573529	21.3786765

Summary	Total # Loads (H)	# Loads Sampled (h)	Total Load Volume (V)
	75	36	443563

Fish and Invertebrate Catch — **All Upriver Locations**
WH Pearson and GD Williams — **6/10/02 - 10/08/02**

Sampling Area	Load Sequenc e Number	Date	Sample Number	Start Time (h:m)	Fish Spp.															Razor Clams	Crangon Shrimp	Other Inverts - Macoma spp.
					Pacific Sandlance	Eulachon	Stagh. sculpin	Gunnel spp.	UID smelt sp.	Longfin smelt	Starry Flounder	Herring	Pacific tomcod	Shiner surfperch	Dogfish	Lamprey	UID sculpin	Surf smelt	Snake prickleback			
Desdemona	1	06/11/02	1	1535																	3	
Desdemona	1	06/11/02	2	1540																	1	
Desdemona	1	06/11/02	3	1600																		
Desdemona	1	06/11/02	4	1607																1		
Desdemona	1	06/11/02	5	1613																		
Desdemona	1	06/11/02	6	1618																		
Desdemona	1	06/11/02	7	1623																		
Desdemona	1	06/11/02	8	1630																		
Desdemona	2	06/11/02	1	1659																	3	
Desdemona	2	06/11/02	2	1705	2																	
Desdemona	2	06/11/02	3	1710	2																	
Desdemona	2	06/11/02	4	1715																	1	
Desdemona	2	06/11/02	5	1720																		
Desdemona	2	06/11/02	6	1735	9								1								1	
Desdemona	2	06/11/02	7	1758				1														
Desdemona	2	06/11/02	8	1805	1																	
Desdemona	2	06/11/02	9	1812	2								1									
Desdemona	2	06/11/02	10	1820			1															
Desdemona	5	06/11/02	1	2221	1																	
Desdemona	5	06/11/02	2	2225																		
Desdemona	5	06/11/02	3	2230	1																	
Desdemona	5	06/11/02	4	2239	1		2															
Desdemona	5	06/11/02	5	2248	2																	
Desdemona	5	06/11/02	6	2325																	1	
Desdemona	5	06/11/02	7	2333				1														
Desdemona	5	06/11/02	8	2340																		
Desdemona	5	06/11/02	9	2345														1				
Desdemona	5	06/12/02	10	0010																	1	
Desdemona	8	06/12/02	1	0419																		
Desdemona	8	06/12/02	2	0426																		
Desdemona	8	06/12/02	3	0434																		
Desdemona	8	06/12/02	4	0442																		
Desdemona	8	06/12/02	5	0449																		
Desdemona	8	06/12/02	6	0455		1										1					1	
Desdemona	8	06/12/02	7	0502																	3	
Desdemona	8	06/12/02	8	0509																	3	
Desdemona	8	06/12/02	9	0516																	1	
Desdemona	8	06/12/02	10	0523																1	1	
Desdemona	9	06/12/02	1	1533			1	1													1	
Desdemona	9	06/12/02	2	1538		4															1	
Desdemona	9	06/12/02	3	1544																	4	
Desdemona	9	06/12/02	4	1551				2													1	
Desdemona	9	06/12/02	5	1608		6		1							1						3	
Desdemona	9	06/12/02	6	1615		2	1														5	
Desdemona	9	06/12/02	7	1621		2															2	
Desdemona	9	06/12/02	8	1626																	2	
Desdemona	9	06/12/02	9	1641																	2	
Desdemona	9	06/12/02	10	1649																	5	
Desdemona	11	06/12/02	5	2123					1													
Desdemona	11	06/12/02	6	2138	1	2																
Desdemona	11	06/12/02	7	2144	2																	
Desdemona	11	06/12/02	8	2149	1																	
Desdemona	11	06/12/02	9	2155	1																	
Desdemona	11	06/12/02	10	2159	1																	
Desdemona	11	06/12/02	11	2205																		
Desdemona	11	06/12/02	12	2219																		
Desdemona	11	06/12/02	13	2226																		
Desdemona	11	06/12/02	14	2231																		
Desdemona	12	06/12/02	1	2304																		
Desdemona	12	06/12/02	2	2310																		
Desdemona	12	06/12/02	3	2315																		
Desdemona	12	06/12/02	4	2321					2												1	
Desdemona	12	06/12/02	5	2341																		
Desdemona	12	06/12/02	6	2346																		
Desdemona	12	06/13/02	7	0010					2													
Desdemona	12	06/13/02	8	0016																		
Desdemona	12	06/13/02	9	0026	4																	
Desdemona	12	06/13/02	10	0033	1																1	
Desdemona	14	06/13/02	1	1519																	1	
Desdemona	14	06/13/02	2	1527																		
Desdemona	14	06/13/02	3	1532																		
Desdemona	14	06/13/02	4	1538																		
Desdemona	14	06/13/02	5	1549																	2	
Desdemona	14	06/13/02	6	1555			1														1	
Desdemona	14	06/13/02	7	1601			1															
Desdemona	14	06/13/02	8	1611																	1	

Desdemona	15	06/13/02	7	1802																	2	
Desdemona	15	06/13/02	8	1809																	1	
Desdemona	15	06/13/02	9	1816				1														
Desdemona	15	06/13/02	10	1823	1																	
Desdemona	16	06/13/02	1	1909	1																	
Desdemona	16	06/13/02	2	1917	6																	
Desdemona	16	06/13/02	3	1925																		
Desdemona	16	06/13/02	4	1930	1																1	
Desdemona	16	06/13/02	5	1936																		
Desdemona	16	06/13/02	6	1940																		
Desdemona	16	06/13/02	7	1945																		
Desdemona	16	06/13/02	8	2001																		
Desdemona	16	06/13/02	9	2008	1																	
Desdemona	16	06/13/02	10	2015	1																	
Desdemona	17	06/13/02	1	2058	1																	
Desdemona	17	06/13/02	2	2103																		
Desdemona	17	06/13/02	3	2108								1										
Desdemona	17	06/13/02	4	2113	1																	
Desdemona	17	06/13/02	5	2117																		
Desdemona	17	06/13/02	6	2122																		
Desdemona	17	06/13/02	7	2138																		
Desdemona	17	06/13/02	8	2144		9																
Desdemona	17	06/13/02	9	2153																		
Desdemona	17	06/13/02	10	2158	1							1										
Desdemona	17	06/13/02	11	2209																	1	
Desdemona	18	06/13/02	1	2243																		
Desdemona	18	06/13/02	2	2247																		
Desdemona	18	06/13/02	3	2253																		
Desdemona	18	06/13/02	4	2257																		
Desdemona	18	06/13/02	5	2302		2																
Desdemona	18	06/13/02	6	2307																		
Desdemona	18	06/13/02	7	2311																		
Desdemona	18	06/13/02	8	2315																		
Desdemona	18	06/13/02	9	2326	1																	
Desdemona	18	06/13/02	10	2338																		
Desdemona	23	06/14/02	1	1003																		
Desdemona	23	06/14/02	2	1010	1																1	
Desdemona	23	06/14/02	3	1015				1														
Desdemona	23	06/14/02	4	1020																		
Desdemona	23	06/14/02	5	1024																		
Desdemona	23	06/14/02	6	1029																		
Desdemona	23	06/14/02	7	1056																		
Desdemona	23	06/14/02	8	1102								1									1	
Desdemona	23	06/14/02	9	1107																	1	
Desdemona	23	06/14/02	10	1111																		
Desdemona	24	06/14/02	1	1222																		
Desdemona	24	06/14/02	2	1226										2								
Desdemona	24	06/14/02	3	1231																		
Desdemona	24	06/14/02	4	1234																		
Desdemona	24	06/14/02	5	1238																		
Desdemona	24	06/14/02	6	1251																		
Desdemona	24	06/14/02	7	1301	1		1			1											1	
Desdemona	24	06/14/02	8	1308	1		2														2	
Desdemona	24	06/14/02	9	1312																	1	
Desdemona	24	06/14/02	10	1318			1															
Desdemona	27	06/14/02	1	1817																		
Desdemona	27	06/14/02	2	1821																		
Desdemona	27	06/14/02	3	1825			1															
Desdemona	27	06/14/02	4	1830																		
Desdemona	27	06/14/02	5	1845																		
Desdemona	27	06/14/02	6	1853																		
Desdemona	27	06/14/02	7	1859																		
Desdemona	27	06/14/02	8	1904																		
Desdemona	27	06/14/02	9	1909																		
Desdemona	27	06/14/02	10	1922																		
Desdemona	28	06/14/02	1	2013																		
Desdemona	28	06/14/02	2	2018	1																	
Desdemona	28	06/14/02	3	2022																		
Desdemona	28	06/14/02	4	2027	1																	
Desdemona	28	06/14/02	5	2033																		
Desdemona	28	06/14/02	6	2036	1																	
Desdemona	28	06/14/02	7	2041	1																	
Desdemona	28	06/14/02	8	2046	1																	
Desdemona	28	06/14/02	9	2049	1																1	
Desdemona	28	06/14/02	10	2054	1																	
Desdemona	29	06/14/02	1	2216																		
Desdemona	29	06/14/02	2	2220																		
Desdemona	29	06/14/02	3	2224																		
Desdemona	29	06/14/02	4	2227																	1	
Desdemona	29	06/14/02	5	2231																	1	
Desdemona	29	06/14/02	6	2235																	1	
Desdemona	29	06/14/02	7	2240	2					1											2	
Desdemona	29	06/14/02	8	2247	5																	
Desdemona	29	06/14/02	9	2303																		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]			[illegible]											[illegible]	

Desdemona	406	09/17/02	2	2205																		
Desdemona	406	09/17/02	3	2213																		
Desdemona	407	09/17/02	1	2250																		
Desdemona	407	09/17/02	2	2339																		
Desdemona	407	09/17/02	3	2343																		
Upper Sands	453	09/23/02	1	2342																	1	
Upper Sands	453	09/23/02	2	0003															1			
Upper Sands	453	09/23/02	3	nd																		
Upper Sands	454	09/23/02	1	0127																		200
Upper Sands	454	09/23/02	2	0151			1															
Upper Sands	454	09/23/02	3	0215																		
Upper Sands	455	09/23/02	1	0340													1					
Upper Sands	455	09/23/02	2	0356																		
Upper Sands	455	09/23/02	3	0413																		
Upper Sands	456	09/23/02	1	0617																		120
Upper Sands	456	09/23/02	2	0653																		100
Upper Sands	456	09/23/02	3	0712																	1	600
Upper Sands	457	09/23/02	1	0836																		16
Upper Sands	457	09/23/02	2	0855																		38
Upper Sands	457	09/23/02	3	0909																		40
Upper Sands	458	09/23/02	1	1151				5														
Upper Sands	458	09/23/02	2	1207			1															
Upper Sands	458	09/23/02	3	1235																		
Upper Sands	459	09/23/02	1	1532																		27
Upper Sands	459	09/23/02	2	1555																		
Upper Sands	459	09/23/02	3	1607																		50
Upper Sands	460	09/23/02	1	1728																		30
Upper Sands	460	09/23/02	2	1752																		Y
Upper Sands	460	09/23/02	3	1823																		Y
Upper Sands	461	09/23/02	1	1951																		29
Upper Sands	461	09/23/02	2	2016																		
Upper Sands	461	09/23/02	3	2024																		20
Miller Sands	462	10/01/02	1	0013																	2	
Miller Sands	462	10/01/02	2	0039						1												
Miller Sands	462	10/01/02	3	0114																		
Miller Sands	462	10/01/02	4	0200																		
Miller Sands	464	10/01/02	1	0443																		
Miller Sands	464	10/01/02	2	0505																	3	
Miller Sands	464	10/01/02	3	0529																		
Miller Sands	464	10/01/02	4	0558																	1	
Miller Sands	465	10/01/02	1	0720																		
Miller Sands	465	10/01/02	2	0727																		
Miller Sands	465	10/01/02	3	0803																		
Miller Sands	465	10/01/02	4	0824																	2	
Miller Sands	467	10/01/02	1	1114																		
Miller Sands	467	10/01/02	2	1127																	2	
Miller Sands	467	10/01/02	3	1134							1										2	
Miller Sands	467	10/01/02	4	1153			1															
Miller Sands	470	10/01/02	1	1740																		
Miller Sands	470	10/01/02	2	1801																		
Miller Sands	470	10/01/02	3	1817																		
Miller Sands	470	10/01/02	4	1826																		
Miller Sands	473	10/02/02	1	0126																	1	
Miller Sands	473	10/02/02	2	0136																		
Miller Sands	473	10/02/02	3	0151																		
Miller Sands	473	10/02/02	4	0212																		
Miller Sands	475	10/02/02	1	0630																		
Miller Sands	475	10/02/02	2	0642																	3	
Miller Sands	475	10/02/02	3	0658																		
Miller Sands	475	10/02/02	4	0711																		
Miller Sands	476	10/02/02	1	0914																		
Miller Sands	476	10/02/02	2	0930																		
Miller Sands	476	10/02/02	3	0946																	4	
Miller Sands	476	10/02/02	4	1002																		
Miller Sands	478	10/02/02	1	1438																		
Miller Sands	478	10/02/02	2	1502																	1	
Miller Sands	478	10/02/02	3	1511																		
Miller Sands	478	10/02/02	4	1534																		
Miller Sands	481	10/02/02	1	2132							1											
Miller Sands	481	10/02/02	2	2151																		
Miller Sands	481	10/02/02	3	2223																		
Miller Sands	484	10/03/02	1	0412																		
Miller Sands	484	10/03/02	2	0428																		
Miller Sands	484	10/03/02	3	0444																		
Miller Sands	484	10/03/02	4	0500																		
Miller Sands	485	10/03/02	1	0632																	2	
Miller Sands	485	10/03/02	2	0641																		
Miller Sands	485	10/03/02	3	0656																		
Miller Sands	485	10/03/02	4	0712																		
Miller Sands	487	10/03/02	1	1152																		
Miller Sands	487	10/03/02	2	1228																		
Miller Sands	487	10/03/02	3	1249																		
Miller Sands	490	10/03/02	1	1728																		
Miller Sands	490	10/03/02	2	1744																		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																		

Miller Sands	495	10/04/02	3	0406																	2	
Miller Sands	495	10/04/02	4	0431																		
Miller Sands	496	10/04/02	1	0541																		
Miller Sands	496	10/04/02	2	0554																		
Miller Sands	496	10/04/02	3	0608																		
Miller Sands	496	10/04/02	4	0627																		
Miller Sands	499	10/04/02	1	1208																		
Miller Sands	499	10/04/02	2	1237																		
Miller Sands	499	10/04/02	3	1250																		
Miller Sands	502	10/04/02	1	1831																		
Miller Sands	502	10/04/02	2	1853																		
Miller Sands	502	10/04/02	3	1909																		
Miller Sands	502	10/04/02	4	1932																		
Miller Sands	503	10/04/02	1	2048																	1	
Miller Sands	503	10/04/02	2	2104																		
Miller Sands	503	10/04/02	3	2128																	1	
Miller Sands	503	10/04/02	4	2145																		
Miller Sands	505	10/05/02	1	0059																		
Miller Sands	505	10/05/02	2	0115																		
Miller Sands	505	10/05/02	3	0131																	2	
Miller Sands	505	10/05/02	4	0159																		
Miller Sands	507	10/05/02	1	0548																		
Miller Sands	507	10/05/02	2	0606																		
Miller Sands	507	10/05/02	3	0632																		
Miller Sands	507	10/05/02	4	0645																		
Miller Sands	509	10/05/02	1	1044																		
Miller Sands	509	10/05/02	2	1100																		
Miller Sands	509	10/05/02	3	1118																	1	
Miller Sands	509	10/05/02	4	1147																		
Miller Sands	511	10/05/02	1	1549																	2	
Miller Sands	511	10/05/02	2	1605																	3	
Miller Sands	511	10/05/02	3	1629																	2	
Miller Sands	511	10/05/02	4	1637																	1	
Miller Sands	514	10/05/02	1	2336																		
Miller Sands	514	10/06/02	2	0000																	1	
Miller Sands	514	10/06/02	3	0025			1														1	
Miller Sands	514	10/06/02	4	0105																		
Miller Sands	515	10/06/02	1	0159																	6	
Miller Sands	515	10/06/02	2	0218																	8	
Miller Sands	515	10/06/02	3	0240			1														6	
Miller Sands	515	10/06/02	4	0247																	3	
Miller Sands	517	10/06/02	1	0709																	3	
Miller Sands	517	10/06/02	2	0728																		
Miller Sands	517	10/06/02	3	0747																		
Miller Sands	517	10/06/02	4	0756																		
Miller Sands	519	10/06/02	1	1219																		
Miller Sands	519	10/06/02	2	1242																		
Miller Sands	519	10/06/02	3	1256			1															
Miller Sands	519	10/06/02	4	1320																		
Miller Sands	521	10/06/02	1	1739																	1	
Miller Sands	521	10/06/02	2	1800																		
Miller Sands	521	10/06/02	3	1813																		
Miller Sands	521	10/06/02	4	1829																		
Miller Sands	522	10/06/02	1	2029																	1	
Miller Sands	522	10/06/02	2	2038			1															
Miller Sands	522	10/06/02	3	2058			1															
Miller Sands	522	10/06/02	4	2119			1														1	
Miller Sands	524	10/07/02	1	0144																		
Miller Sands	524	10/07/02	2	0155																	5	
Miller Sands	524	10/07/02	3	0211																	2	
Miller Sands	524	10/07/02	4	0233					1													
Miller Sands	525	10/07/02	1	0427																		
Miller Sands	525	10/07/02	2	0450																		
Miller Sands	525	10/07/02	3	0501			1															
Miller Sands	525	10/07/02	4	0514																	2	
Miller Sands	527	10/07/02	1	1042																		
Miller Sands	527	10/07/02	2	1115																		
Miller Sands	527	10/07/02	3	1142							1											
Miller Sands	527	10/07/02	4	1205																	4	
Miller Sands	530	10/07/02	1	1845																		
Miller Sands	530	10/07/02	2	1855																		
Miller Sands	530	10/07/02	3	1917																		
Miller Sands	530	10/07/02	4	1930																		
Miller Sands	531	10/07/02	1	2117																		
Miller Sands	531	10/07/02	2	2139			1															
Miller Sands	531	10/07/02	3	2156																		
Miller Sands	531	10/07/02	4	2215																		
Miller Sands	534	10/08/02	1	0424																		
Miller Sands	534	10/08/02	2	0439																		
Miller Sands	534	10/08/02	3	0502																		
				Total, All Upriver Areas:	70	28	24	14	6	4	3	3	2	2	1	1	1	1	1	4	173	1270

APPENDIX B
EVALUATION REPORT DUNGENESS CRAB (REVISED)

Summary of Projected Entrainment, Adult Equivalent Loss, and Loss to Fishery.
Lower Columbia River
WH Pearson and GD Williams

Variance Estimators (derived from June 2002 field sampling)

	CV %		
E	5.01	Z at 0.975	1.95996
AEL	7.37		
LF	8.11		

Construction Dredging to 40 ft - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	593,812

Results:

Parameter	Projected Value	SE	95% CI
E	132,790	6,653	13,039
AEL	20,078	1,480	2,900
AEL Male	12,052	888	1,741
AEL Female	8,026	592	1,159
Loss to Fishery	3,796	308	603

Construction Dredging to 40 ft - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	593,812

Results:

Parameter	Projected Value	SE	95% CI
E	132,790	6,653	13,039
AEL	9,035	666	1,305
AEL Male	5,423	400	783
AEL Female	3,612	266	522
Loss to Fishery	3,796	308	603

Construction Dredging from 40 to 43 ft - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	473,893

Results:

Parameter	Projected Value	SE	95% CI
E	105,974	5,309	10,406
AEL	16,024	1,181	2,315
AEL Male	9,618	709	1,389
AEL Female	6,405	472	925
Loss to Fishery	3,030	246	482

Construction Dredging from 40 to 43 ft - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	473,893

Results:

Parameter	Projected Value	SE	95% CI
E	105,974	5,309	10,406
AEL	7,211	531	1,042
AEL Male	4,328	319	625
AEL Female	2,882	212	416
Loss to Fishery	3,030	246	482

Annual Maintenance Dredging 40' Year 1 - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	8,945	448	878
AEL	1,353	100	195
AEL Male	812	60	117
AEL Female	541	40	78
Loss to Fishery	256	21	41

Annual Maintenance Dredging 40' Year 1 - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	8,945	448	878
AEL	609	45	88
AEL Male	365	27	53
AEL Female	243	18	35
Loss to Fishery	256	21	41

Annual Maintenance Dredging 40' Year 20 - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	8,945	448	878
AEL	1,353	100	195
AEL Male	812	60	117
AEL Female	541	40	78
Loss to Fishery	256	21	41

Annual Maintenance Dredging 40' Year 20 - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	8,945	448	878
AEL	609	45	88
AEL Male	365	27	53
AEL Female	243	18	35
Loss to Fishery	256	21	41

Annual Maintenance Dredging 43' Year 1 - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	60,000

Results:

Parameter	Projected Value	SE	95% CI
E	13,417	672	1,318
AEL	2,029	150	293
AEL Male	1,218	90	176
AEL Female	811	60	117
Loss to Fishery	384	31	61

Annual Maintenance Dredging 43' Year 1 - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	60,000

Results:

Parameter	Projected Value	SE	95% CI
E	13,417	672	1,318
AEL	913	67	132
AEL Male	548	40	79
AEL Female	365	27	53
Loss to Fishery	384	31	61

Annual Maintenance Dredging 43' Year 20 - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	8,945	448	878
AEL	1,353	100	195
AEL Male	812	60	117
AEL Female	541	40	78
Loss to Fishery	256	21	41

Annual Maintenance Dredging 43' Year 20 - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	8,945	448	878
AEL	609	45	88
AEL Male	365	27	53
AEL Female	243	18	35
Loss to Fishery	256	21	41

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Desdemona, June**	**Construction Dredging to 40 ft**	***593812***

VOLUME OF DREDGED MATERIALS - to 40 ft

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	222412
5		353916
6	Upper Desdem	0
7		0
8		8742
9		8742
10	Flavel Bar	49732
11		298900
12		121292
13		72425
14	Upper Sands	54585
15		51945
16		47557
17		0
18	Tongue Point	14775
19		6976
20		13283
Total		1325282

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **593812** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	3071.8		0.10	0.017	5.07		2.28	
1+	0.19327	114767.6		0.60	0.160	11017.69		4957.96	
2+	0.02429	14425.5		0.86	0.649	8051.43		3623.14	
3+	0.00088	525.5		0.86	2.222	1004.22		451.90	
All		**132790.3**				**20078.41**		**9035.28**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.53		0.50	2.53	
1+	0.50	5508.84		0.50	5508.84	
2+	0.25	2012.86		0.75	6038.57	
3+	0.50	502.11		0.50	502.11	
All		**8026.34**			**12052.06**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

	Proportion of Total AEL	
Age Class	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.14		0.50	1.14	
1+	0.50	2478.98		0.50	2478.98	
2+	0.25	905.79		0.75	2717.36	
3+	0.50	225.95		0.50	225.95	
All		**3611.86**			**5423.43**	
					9035.283	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

	Proportion of Total AEL at 3+	
Age Class	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	132790.3
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	20078.4
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	9035.3
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	5423.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	3611.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
5423.4	0.70	**3796.4**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	3796.4
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Desdemona, June**	**Construction Dredging from 40 to 43 ft**	***473893***

VOLUME OF DREDGED MATERIALS - from 40 to 43 ft

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	94688
5		196724
6	Upper Desdem	66193
7		1039
8		52398
9		62851
10	Flavel Bar	329296
11		535074
12		239608
13		65743
14	Upper Sands	171432
15		271842
16		306717
17		108631
18	Tongue Point	174113
19		162864
20		127219
Total		2966432

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **473893** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	2451.4		0.10	0.017	4.04		1.82	
1+	0.19327	91590.5		0.60	0.160	8792.69		3956.71	
2+	0.02429	11512.3		0.86	0.649	6425.46		2891.46	
3+	0.00088	419.4		0.86	2.222	801.42		360.64	
All		**105973.6**				**16023.62**		**7210.63**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.02		0.50	2.02	
1+	0.50	4396.35		0.50	4396.35	
2+	0.25	1606.37		0.75	4819.10	
3+	0.50	400.71		0.50	400.71	
All		**6405.44**			**9618.17**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.91		0.50	0.91	
1+	0.50	1978.36		0.50	1978.36	
2+	0.25	722.86		0.75	2168.59	
3+	0.50	180.32		0.50	180.32	
All		**2882.45**			**4328.18**	
					7210.628	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	105973.6
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	16023.6
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	7210.6
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	4328.2
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	2882.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
4328.2	0.70	**3029.7**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	3029.7
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Desdemona, June**	**Post Construction Maintenance, 40 ft Yr 1**	***40000***

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40,000
10 to 13	Flavel Bar	400000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		760000

Data from Portland District (4 Dec 2002)

Dredged Yardage (cy) **40,000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	206.9		0.10	0.017	0.34		0.15	
1+	0.19327	7730.9		0.60	0.160	742.17		333.98	
2+	0.02429	971.7		0.86	0.649	542.36		244.06	
3+	0.00088	35.4		0.86	2.222	67.65		30.44	
All		**8944.9**				**1352.51**		**608.63**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.17		0.50	0.17	
1+	0.50	371.08		0.50	371.08	
2+	0.25	135.59		0.75	406.77	
3+	0.50	33.82		0.50	33.82	
All		**540.67**			**811.84**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.08		0.50	0.08	
1+	0.50	166.99		0.50	166.99	
2+	0.25	61.02		0.75	183.05	
3+	0.50	15.22		0.50	15.22	
All		**243.30**			**365.33**	
					608.629	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	8944.9
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	1352.5
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	608.6
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	365.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	243.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
365.3	0.70	**255.7**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	255.7
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	Desdemona, June	Post Construction Maintenance, 40 ft Yr 20	40000

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 20

Volume to be Dredged (cy)			
River Mile	Location Name	Volume (cy)	Data from Portland District (4 Dec 2002)
4 to 9	Desdemona	40000	
10 to 13	Flavel Bar	210000	
14 to 17	Upper Sands	50000	
18 to 20	Tongue Point	270000	
Total		570000	

Dredged Yardage (cy) 40000 Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	206.9		0.10	0.017	0.34		0.15	
1+	0.19327	7730.9		0.60	0.160	742.17		333.98	
2+	0.02429	971.7		0.86	0.649	542.36		244.06	
3+	0.00088	35.4		0.86	2.222	67.65		30.44	
All		**8944.9**				**1352.51**		**608.63**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations

Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.17		0.50	0.17	
1+	0.50	371.08		0.50	371.08	
2+	0.25	135.59		0.75	406.77	
3+	0.50	33.82		0.50	33.82	
All		**540.67**			**811.84**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations

Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.08		0.50	0.08	
1+	0.50	166.99		0.50	166.99	
2+	0.25	61.02		0.75	183.05	
3+	0.50	15.22		0.50	15.22	
All		**243.30**			**365.33**	
					608.629	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	8944.9
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	1352.5
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	608.6
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	365.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	243.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY

(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
365.3	0.70	**255.7**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	255.7
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:

Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Desdemona, June**	**Post Construction Maintenance, 43 ft Yr 1**	***60000***

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	60000
10 to 13	Flavel Bar	500000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		990000

Data from Portland District (4 Dec 2002)

Dredged Yardage (cy) **60000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	310.4		0.10	0.017	0.51		0.23	
1+	0.19327	11596.4		0.60	0.160	1113.25		500.96	
2+	0.02429	1457.6		0.86	0.649	813.53		366.09	
3+	0.00088	53.1		0.86	2.222	101.47		45.66	
All		**13417.4**				**2028.76**		**912.94**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.26		0.50	0.26	
1+	0.50	556.63		0.50	556.63	
2+	0.25	203.38		0.75	610.15	
3+	0.50	50.73		0.50	50.73	
All		**811.00**			**1217.77**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.12		0.50	0.12	
1+	0.50	250.48		0.50	250.48	
2+	0.25	91.52		0.75	274.57	
3+	0.50	22.83		0.50	22.83	
All		**364.95**			**547.99**	
					912.944	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA
Entrainment with Confidence Limits

E	13417.4
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	2028.8
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	912.9
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	548.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	364.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
548.0	0.70	**383.6**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	383.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	Desdemona, June	Post Construction Maintenance, 43 ft Yr 20	40000

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		680000

Data from Portland District (4 Dec 2002)

Dredged Yardage (cy) **40000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	206.9		0.10	0.017	0.34		0.15	
1+	0.19327	7730.9		0.60	0.160	742.17		333.98	
2+	0.02429	971.7		0.86	0.649	542.36		244.06	
3+	0.00088	35.4		0.86	2.222	67.65		30.44	
All		**8944.9**				**1352.51**		**608.63**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.17		0.50	0.17	
1+	0.50	371.08		0.50	371.08	
2+	0.25	135.59		0.75	406.77	
3+	0.50	33.82		0.50	33.82	
All		**540.67**			**811.84**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.08		0.50	0.08	
1+	0.50	166.99		0.50	166.99	
2+	0.25	61.02		0.75	183.05	
3+	0.50	15.22		0.50	15.22	
All		**243.30**			**365.33**	
					608.629	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	8944.9
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	1352.5
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	608.6
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	365.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	243.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
365.3	0.70	**255.7**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	255.7
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

Summary of Projected Entrainment, Adult Equivalent Loss, and Loss to Fishery
Lower Columbia River
WH Pearson and GD Williams

Variance Estimators (derived from Sept 2002 field sampling)

	CV %		
E	29.43	Z at 0.975	1.95996
AEL	20.25		
LF	20.25		

Construction Dredging to 40 ft - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	593,812

Results:

Parameter	Projected Value	SE	95% CI
E	70,955	20,882	40,928
AEL	59,819	12,113	23,742
AEL Male	29,910	6,057	11,871
AEL Female	29,910	6,057	11,871
Loss to Fishery	9,422	1,908	3,739

Construction Dredging to 40 ft - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	593,812

Results:

Parameter	Projected Value	SE	95% CI
E	70,955	20,882	40,928
AEL	26,919	5,451	10,684
AEL Male	13,459	2,726	5,342
AEL Female	13,459	2,726	5,342
Loss to Fishery	9,422	1,908	3,739

Construction Dredging from 40 to 43 ft - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	473,893

Results:

Parameter	Projected Value	SE	95% CI
E	56,626	16,665	32,663
AEL	47,739	9,667	18,947
AEL Male	23,869	4,834	9,474
AEL Female	23,869	4,834	9,474
Loss to Fishery	7,519	1,523	2,984

Construction Dredging from 40 to 43 ft - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	473,893

Results:

Parameter	Projected Value	SE	95% CI
E	56,626	16,665	32,663
AEL	21,482	4,350	8,526
AEL Male	10,741	2,175	4,263
AEL Female	10,741	2,175	4,263
Loss to Fishery	7,519	1,523	2,984

Annual Maintenance Dredging 40' Year 1 - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	4,780	1,407	2,757
AEL	4,030	816	1,599
AEL Male	2,015	408	800
AEL Female	2,015	408	800
Loss to Fishery	635	129	252

Annual Maintenance Dredging 40' Year 1 - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	4,780	1,407	2,757
AEL	1,813	367	720
AEL Male	907	184	360
AEL Female	907	184	360
Loss to Fishery	635	129	252

Annual Maintenance Dredging 40' Year 20 - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	4,780	1,407	2,757
AEL	4,030	816	1,599
AEL Male	2,015	408	800
AEL Female	2,015	408	800
Loss to Fishery	635	129	252

Annual Maintenance Dredging 40' Year 20 - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	4,780	1,407	2,757
AEL	1,813	367	720
AEL Male	907	184	360
AEL Female	907	184	360
Loss to Fishery	635	129	252

Annual Maintenance Dredging 43' Year 1 - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	60,000

Results:

Parameter	Projected Value	SE	95% CI
E	7,169	2,110	4,135
AEL	6,044	1,224	2,399
AEL Male	3,022	612	1,199
AEL Female	3,022	612	1,199
Loss to Fishery	952	193	378

Annual Maintenance Dredging 43' Year 1 - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	60,000

Results:

Parameter	Projected Value	SE	95% CI
E	7,169	2,110	4,135
AEL	2,720	551	1,080
AEL Male	1,360	275	540
AEL Female	1,360	275	540
Loss to Fishery	952	193	378

Annual Maintenance Dredging 43' Year 20 - Age 2+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	4,780	1,407	2,757
AEL	4,030	816	1,599
AEL Male	2,015	408	800
AEL Female	2,015	408	800
Loss to Fishery	635	129	252

Annual Maintenance Dredging 43' Year 20 - Age 3+

Assumptions:

Projected Location	Desdemona
Planned dredged volume (cy)	40,000

Results:

Parameter	Projected Value	SE	95% CI
E	4,780	1,407	2,757
AEL	1,813	367	720
AEL Male	907	184	360
AEL Female	907	184	360
Loss to Fishery	635	129	252

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Desdemona, Sept**	**Construction Dredging to 40 ft**	***593812***

VOLUME OF DREDGED MATERIALS - to 40 ft

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	222412
5		353916
6	Upper Desdem	0
7		0
8		8742
9		8742
10	Flavel Bar	49732
11		298900
12		121292
13		72425
14	Upper Sands	54585
15		51945
16		47557
17		0
18	Tongue Point	14775
19		6976
20		13283
Total		1325282

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **593812** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	12901.0		0.60	0.160	1238.49		557.32	
2+	0.06518	38702.9		0.86	0.649	21601.63		9720.73	
3+	0.03259	19351.4		0.86	2.222	36979.06		16640.58	
All		**70955.3**				**59819.18**		**26918.63**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	619.25		0.50	619.25	
2+	0.50	10800.81		0.50	10800.81	
3+	0.50	18489.53		0.50	18489.53	
All		**29909.59**			**29909.59**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	278.66		0.50	278.66	
2+	0.50	4860.37		0.50	4860.37	
3+	0.50	8320.29		0.50	8320.29	
All		**13459.32**			**13459.32**	
					26918.632	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	70955.3
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	59819.2
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	26918.6
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	13459.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	13459.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
13459.3	0.70	**9421.5**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	9421.5
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Desdemona, Sept**	**Construction Dredging to 40 ft**	***473893***

VOLUME OF DREDGED MATERIALS - from 40 to 43 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	94688
5		196724
6	Upper Desdem	66193
7		1039
8		52398
9		62851
10	Flavel Bar	329296
11		535074
12		239608
13		65743
14	Upper Sands	171432
15		271842
16		306717
17		108631
18	Tongue Point	174113
19		162864
20		127219
Total		2966432

Dredged Yardage (cy) **473893** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	10295.6		0.60	0.160	988.38		444.77	
2+	0.06518	30886.9		0.86	0.649	17239.23		7757.65	
3+	0.03259	15443.5		0.86	2.222	29511.22		13280.05	
All		**56626.0**				**47738.83**		**21482.47**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	494.19		0.50	494.19	
2+	0.50	8619.61		0.50	8619.61	
3+	0.50	14755.61		0.50	14755.61	
All		**23869.42**			**23869.42**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	222.39		0.50	222.39	
2+	0.50	3878.83		0.50	3878.83	
3+	0.50	6640.02		0.50	6640.02	
All		**10741.24**			**10741.24**	
					21482.474	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	56626.0
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	47738.8
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	21482.5
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	10741.2
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	10741.2
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
10741.2	0.70	**7518.9**

Harvest rate of 0.70 is taken from Armstrong et al. (1991).

Loss to Fishery with Confidence Limits

Loss to Fishery	7518.9
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Desdemona, Sept**	**Post Construction Maintenance, 40 ft Yr 1**	***40000***

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40,000
10 to 13	Flavel Bar	400000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		760000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **40,000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	869.0		0.60	0.160	83.43		37.54	
2+	0.06518	2607.1		0.86	0.649	1455.12		654.80	
3+	0.03259	1303.5		0.86	2.222	2490.96		1120.93	
All		**4779.6**				**4029.50**		**1813.28**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	41.71		0.50	41.71	
2+	0.50	727.56		0.50	727.56	
3+	0.50	1245.48		0.50	1245.48	
All		**2014.75**			**2014.75**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.02
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	18.77		0.50	18.77	
2+	0.50	327.40		0.50	327.40	
3+	0.50	560.47		0.50	560.47	
All		**906.64**			**906.64**	
					1813.276	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	4779.6
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	4029.5
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	1813.3
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	906.6
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	906.6
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
906.6	0.70	**634.6**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	634.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Desdemona, Sept**	**Post Construction Maintenance, 40 ft Yr 20**	***40000***

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 20

Volume to be Dredged (cy)			
River Mile	Location Name	Volume (cy)	Data from Portland District (10 Sept 2002)
4 to 9	Desdemona	40000	
10 to 13	Flavel Bar	210000	
14 to 17	Upper Sands	50000	
18 to 20	Tongue Point	270000	
Total		570000	

Dredged Yardage (cy) **40,000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	869.0		0.60	0.160	83.43		37.54	
2+	0.06518	2607.1		0.86	0.649	1455.12		654.80	
3+	0.03259	1303.5		0.86	2.222	2490.96		1120.93	
All		**4779.6**				**4029.50**		**1813.28**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male			
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)	R = Crab Entrainment Rate (crabs/cy)
YOY	0.50	0.00		0.50	0.00		E = Crabs Entrained (number of Crabs)
1+	0.50	41.71		0.50	41.71		M = Post-Entrainment Mortality (proportion)
2+	0.50	727.56		0.50	727.56		S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
3+	0.50	1245.48		0.50	1245.48		AEL = Adult Equivalent Loss
All		**2014.75**			**2014.75**		VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.02
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male			
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)	R = Crab Entrainment Rate (crabs/cy)
YOY	0.50	0.00		0.50	0.00		E = Crabs Entrained (number of Crabs)
1+	0.50	18.77		0.50	18.77		M = Post-Entrainment Mortality (proportion)
2+	0.50	327.40		0.50	327.40		S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
3+	0.50	560.47		0.50	560.47		AEL = Adult Equivalent Loss
All		**906.64**			**906.64**		VAR(AEL) =AEL Variance
					1813.276		

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	4779.6
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	4029.5
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	1813.3
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	906.6
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	906.6
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
906.6	0.70	**634.6**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	634.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Desdemona, Sept**	**Post Construction Maintenance, 43 ft Yr 1**	***60000***

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	60000
10 to 13	Flavel Bar	500000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		990000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **60,000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	1303.5		0.60	0.160	125.14		56.31	
2+	0.06518	3910.6		0.86	0.649	2182.67		982.20	
3+	0.03259	1955.3		0.86	2.222	3736.44		1681.40	
All		**7169.5**				**6044.25**		**2719.91**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	62.57		0.50	62.57	
2+	0.50	1091.34		0.50	1091.34	
3+	0.50	1868.22		0.50	1868.22	
All		**3022.13**			**3022.13**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.01
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	28.16		0.50	28.16	
2+	0.50	491.10		0.50	491.10	
3+	0.50	840.70		0.50	840.70	
All		**1359.96**			**1359.96**	
					2719.915	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	7169.5
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	6044.3
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	2719.9
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	1360.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	1360.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
1360.0	0.70	**952.0**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	952.0
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Desdemona, Sept**	**Post Construction Maintenance, 43 ft Yr 20**	***40000***

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		680000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **40000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	869.0		0.60	0.160	83.43		37.54	
2+	0.06518	2607.1		0.86	0.649	1455.12		654.80	
3+	0.03259	1303.5		0.86	2.222	2490.96		1120.93	
All		**4779.6**				**4029.50**		**1813.28**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	41.71		0.50	41.71	
2+	0.50	727.56		0.50	727.56	
3+	0.50	1245.48		0.50	1245.48	
All		**2014.75**			**2014.75**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.02
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	18.77		0.50	18.77	
2+	0.50	327.40		0.50	327.40	
3+	0.50	560.47		0.50	560.47	
All		**906.64**			**906.64**	
					1813.276	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	4779.6
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	4029.5
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	1813.3
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	906.6
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	906.6
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
906.6	0.70	**634.6**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	634.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

Summary of Projected Entrainment, Adult Equivalent Loss, and Loss to Fishery.
Lower Columbia River
WH Pearson and GD Williams

Variance Estimators (derived from June 2002 field sampling at Desdemona Shoals)

	CV %		
E	5.01	Z at 0.975	1.95996
AEL	7.37		
LF	8.11		

Construction Dredging to 40 ft - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	542,349

Results:

Parameter	Projected Value	SE	95% CI
E	121,282	6,076	11,909
AEL	18,338	1,352	2,649
AEL Male	11,008	811	1,590
AEL Female	7,331	540	1,059
Loss to Fishery	3,467	281	551

Construction Dredging to 40 ft - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	542,349

Results:

Parameter	Projected Value	SE	95% CI
E	121,282	6,076	11,909
AEL	8,252	608	1,192
AEL Male	4,953	365	716
AEL Female	3,299	243	477
Loss to Fishery	3,467	281	551

Construction Dredging from 40 to 43 ft - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	1,169,721

Results:

Parameter	Projected Value	SE	95% CI
E	261,577	13,105	25,685
AEL	39,551	2,915	5,713
AEL Male	23,741	1,750	3,429
AEL Female	15,811	1,165	2,284
Loss to Fishery	7,478	606	1,189

Construction Dredging from 40 to 43 ft - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	1,169,721

Results:

Parameter	Projected Value	SE	95% CI
E	261,577	13,105	25,685
AEL	17,798	1,312	2,571
AEL Male	10,683	787	1,543
AEL Female	7,115	524	1,028
Loss to Fishery	7,478	606	1,189

Annual Maintenance Dredging 40' Year 1 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	400,000

Results:

Parameter	Projected Value	SE	95% CI
E	89,449	4,481	8,783
AEL	13,525	997	1,954
AEL Male	8,118	598	1,173
AEL Female	5,407	398	781
Loss to Fishery	2,557	207	406

Annual Maintenance Dredging 40' Year 1 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	400,000

Results:

Parameter	Projected Value	SE	95% CI
E	89,449	4,481	8,783
AEL	6,086	449	879
AEL Male	3,653	269	528
AEL Female	2,433	179	351
Loss to Fishery	2,557	207	406

Annual Maintenance Dredging 40' Year 20 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	46,961	2,353	4,611
AEL	7,101	523	1,026
AEL Male	4,262	314	616
AEL Female	2,838	209	410
Loss to Fishery	1,343	109	213

Annual Maintenance Dredging 40' Year 20 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	46,961	2,353	4,611
AEL	3,195	235	462
AEL Male	1,918	141	277
AEL Female	1,277	94	185
Loss to Fishery	1,343	109	213

Annual Maintenance Dredging 43' Year 1 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	500,000

Results:

Parameter	Projected Value	SE	95% CI
E	111,812	5,602	10,979
AEL	16,906	1,246	2,442
AEL Male	10,148	748	1,466
AEL Female	6,758	498	976
Loss to Fishery	3,197	259	508

Annual Maintenance Dredging 43' Year 1 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	500,000

Results:

Parameter	Projected Value	SE	95% CI
E	111,812	5,602	10,979
AEL	7,608	561	1,099
AEL Male	4,567	337	660
AEL Female	3,041	224	439
Loss to Fishery	3,197	259	508

Annual Maintenance Dredging 43' Year 20 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	46,961	2,353	4,611
AEL	7,101	523	1,026
AEL Male	4,262	314	616
AEL Female	2,838	209	410
Loss to Fishery	1,343	109	213

Annual Maintenance Dredging 43' Year 20 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	46,961	2,353	4,611
AEL	3,195	235	462
AEL Male	1,918	141	277
AEL Female	1,277	94	185
Loss to Fishery	1,343	109	213

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Construction Dredging to 40 ft**	***542349***

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - to 40 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	222412
5		353916
6	Upper Desdem	0
7		0
8		8742
9		8742
10	Flavel Bar	49732
11		298900
12		121292
13		72425
14	Upper Sands	54585
15		51945
16		47557
17		0
18	Tongue Point	14775
19		6976
20		13283
Total		1325282

Dredged Yardage (cy) **542349** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	2805.5		0.10	0.017	4.63		2.08	
1+	0.19327	104821.2		0.60	0.160	10062.84		4528.28	
2+	0.02429	13175.3		0.86	0.649	7353.65		3309.14	
3+	0.00088	480.0		0.86	2.222	917.19		412.73	
All		**121282.0**				**18338.30**		**8252.24**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.31		0.50	2.31	
1+	0.50	5031.42		0.50	5031.42	
2+	0.25	1838.41		0.75	5515.24	
3+	0.50	458.59		0.50	458.59	
All		**7330.74**			**11007.56**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.04		0.50	1.04	
1+	0.50	2264.14		0.50	2264.14	
2+	0.25	827.29		0.75	2481.86	
3+	0.50	206.37		0.50	206.37	
All		**3298.83**			**4953.40**	
					8252.235	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	121282.0
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	18338.3
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	8252.2
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	4953.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	3298.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
4953.4	0.70	**3467.4**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	3467.4
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Construction Dredging from 40 to 43 ft**	***1169721***

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - from 40 to 43 ft

: and Surface Area to be Dredged (ha)

River Mile	Location Name	Volume (cy)
4	Lower Desdem.	94688
5		196724
6	Upper Desdem	66193
7		1039
8		52398
9		62851
10	Flavel Bar	329296
11		535074
12		239608
13		65743
14	Upper Sands	171432
15		271842
16		306717
17		108631
18	Tongue Point	174113
19		162864
20		127219
Total		2966432

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **1169721** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	6050.9		0.10	0.017	9.98		4.49	
1+	0.19327	226075.0		0.60	0.160	21703.20		9766.44	
2+	0.02429	28416.0		0.86	0.649	15860.12		7137.05	
3+	0.00088	1035.2		0.86	2.222	1978.16		890.17	
All		**261577.1**				**39551.46**		**17798.16**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	4.99		0.50	4.99	
1+	0.50	10851.60		0.50	10851.60	
2+	0.25	3965.03		0.75	11895.09	
3+	0.50	989.08		0.50	989.08	
All		**15810.70**			**23740.76**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.25		0.50	2.25	
1+	0.50	4883.22		0.50	4883.22	
2+	0.25	1784.26		0.75	5352.79	
3+	0.50	445.09		0.50	445.09	
All		**7114.82**			**10683.34**	
					17798.158	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	261577.1
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	39551.5
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	17798.2
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	10683.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
10683.3	0.70	**7478.3**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	7478.3
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 40 ft Yr 1**	*400000*

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40,000
10 to 13	Flavel Bar	400000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		760000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **400,000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	2069.2		0.10	0.017	3.41		1.54	
1+	0.19327	77309.0		0.60	0.160	7421.67		3339.75	
2+	0.02429	9717.2		0.86	0.649	5423.56		2440.60	
3+	0.00088	354.0		0.86	2.222	676.45		304.40	
All		**89449.4**				**13525.09**		**6086.29**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.71		0.50	1.71	
1+	0.50	3710.83		0.50	3710.83	
2+	0.25	1355.89		0.75	4067.67	
3+	0.50	338.23		0.50	338.23	
All		**5406.66**			**8118.44**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.77		0.50	0.77	
1+	0.50	1669.88		0.50	1669.88	
2+	0.25	610.15		0.75	1830.45	
3+	0.50	152.20		0.50	152.20	
All		**2433.00**			**3653.30**	
					6086.292	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	89449.4
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	13525.1
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	6086.3
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	3653.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	2433.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
3653.3	0.70	**2557.3**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	2557.3
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 40 ft Yr 20**	***210000***

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		570000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **210000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	1086.3		0.10	0.017	1.79		0.81	
1+	0.19327	40587.2		0.60	0.160	3896.38		1753.37	
2+	0.02429	5101.5		0.86	0.649	2847.37		1281.32	
3+	0.00088	185.8		0.86	2.222	355.14		159.81	
All		**46960.9**				**7100.67**		**3195.30**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations

Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.90		0.50	0.90	
1+	0.50	1948.19		0.50	1948.19	
2+	0.25	711.84		0.75	2135.53	
3+	0.50	177.57		0.50	177.57	
All		**2838.50**			**4262.18**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations

Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.40		0.50	0.40	
1+	0.50	876.68		0.50	876.68	
2+	0.25	320.33		0.75	960.99	
3+	0.50	79.91		0.50	79.91	
All		**1277.32**			**1917.98**	
					3195.303	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	46960.9
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	7100.7
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	3195.3
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	1918.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	1277.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY

(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
1918.0	0.70	**1342.6**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	1342.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:

Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 43 ft Yr 1**	***500000***

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	60000
10 to 13	Flavel Bar	500000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		990000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **500000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	2586.5		0.10	0.017	4.27		1.92	
1+	0.19327	96636.3		0.60	0.160	9277.08		4174.69	
2+	0.02429	12146.5		0.86	0.649	6779.45		3050.75	
3+	0.00088	442.5		0.86	2.222	845.57		380.51	
All		**111811.8**				**16906.37**		**7607.86**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.13		0.50	2.13	
1+	0.50	4638.54		0.50	4638.54	
2+	0.25	1694.86		0.75	5084.58	
3+	0.50	422.78		0.50	422.78	
All		**6758.32**			**10148.04**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.96		0.50	0.96	
1+	0.50	2087.34		0.50	2087.34	
2+	0.25	762.69		0.75	2288.06	
3+	0.50	190.25		0.50	190.25	
All		**3041.24**			**4566.62**	
					7607.865	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	111811.8
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	16906.4
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	7607.9
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	4566.6
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	3041.2
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
4566.6	0.70	**3196.6**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	3196.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 43 ft Yr 20**	***210000***

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		680000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **210000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	1086.3		0.10	0.017	1.79		0.81	
1+	0.19327	40587.2		0.60	0.160	3896.38		1753.37	
2+	0.02429	5101.5		0.86	0.649	2847.37		1281.32	
3+	0.00088	185.8		0.86	2.222	355.14		159.81	
All		**46960.9**				**7100.67**		**3195.30**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.90		0.50	0.90	
1+	0.50	1948.19		0.50	1948.19	
2+	0.25	711.84		0.75	2135.53	
3+	0.50	177.57		0.50	177.57	
All		**2838.50**			**4262.18**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.40		0.50	0.40	
1+	0.50	876.68		0.50	876.68	
2+	0.25	320.33		0.75	960.99	
3+	0.50	79.91		0.50	79.91	
All		**1277.32**			**1917.98**	
					3195.303	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	46960.9
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	7100.7
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	3195.3
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	1918.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	1277.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
1918.0	0.70	**1342.6**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	1342.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Construction Dredging to 40 ft**	***542349***

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - to 40 ft

Volume to be Dredged (cy) — Data from Portland District (10 Sept 2002)

River Mile	Location Name	Volume (cy)
4	Lower Desdem.	222412
5		353916
6	Upper Desdem	0
7		0
8		8742
9		8742
10	Flavel Bar	49732
11		298900
12		121292
13		72425
14	Upper Sands	54585
15		51945
16		47557
17		0
18	Tongue Point	14775
19		6976
20		13283
Total		1325282

Dredged Yardage (cy) **542349** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	**Female**	**Sexed**	**Male**	**Female**	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	2805.5		0.10	0.017	4.63		2.08	
1+	0.19327	104821.2		0.60	0.160	10062.84		4528.28	
2+	0.02429	13175.3		0.86	0.649	7353.65		3309.14	
3+	0.00088	480.0		0.86	2.222	917.19		412.73	
All		**121282.0**				**18338.30**		**8252.24**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	**AEL**	**VAR(AEL)**	**Proportion**	**AEL**	**VAR(AEL)**
YOY	0.50	2.31		0.50	2.31	
1+	0.50	5031.42		0.50	5031.42	
2+	0.25	1838.41		0.75	5515.24	
3+	0.50	458.59		0.50	458.59	
All		**7330.74**			**11007.56**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	**of AEL**
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	**Female**
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	**AEL**	**VAR(AEL)**	**Proportion**	**AEL**	**VAR(AEL)**
YOY	0.50	1.04		0.50	1.04	
1+	0.50	2264.14		0.50	2264.14	
2+	0.25	827.29		0.75	2481.86	
3+	0.50	206.37		0.50	206.37	
All		**3298.83**			**4953.40**	
					8252.235	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	**of AEL at 3+**
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	**Female**
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	121282.0
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	18338.3
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	8252.2
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	4953.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	3298.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
4953.4	0.70	**3467.4**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	3467.4
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Construction Dredging from 40 to 43 ft**	***1169721***

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - from 40 to 43 ft

: and Surface Area to be Dredged (ha)

River Mile	Location Name	Volume (cy)
4	Lower Desdem.	94688
5		196724
6	Upper Desdem	66193
7		1039
8		52398
9		62851
10	Flavel Bar	329296
11		535074
12		239608
13		65743
14	Upper Sands	171432
15		271842
16		306717
17		108631
18	Tongue Point	174113
19		162864
20		127219
Total		2966432

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **1169721** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	6050.9		0.10	0.017	9.98		4.49	
1+	0.19327	226075.0		0.60	0.160	21703.20		9766.44	
2+	0.02429	28416.0		0.86	0.649	15860.12		7137.05	
3+	0.00088	1035.2		0.86	2.222	1978.16		890.17	
All		**261577.1**				**39551.46**		**17798.16**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	4.99		0.50	4.99	
1+	0.50	10851.60		0.50	10851.60	
2+	0.25	3965.03		0.75	11895.09	
3+	0.50	989.08		0.50	989.08	
All		**15810.70**			**23740.76**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.25		0.50	2.25	
1+	0.50	4883.22		0.50	4883.22	
2+	0.25	1784.26		0.75	5352.79	
3+	0.50	445.09		0.50	445.09	
All		**7114.82**			**10683.34**	
					17798.158	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	261577.1
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	39551.5
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	17798.2
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	10683.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
10683.3	0.70	**7478.3**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	7478.3
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 40 ft Yr 1**	***400000***

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40,000
10 to 13	Flavel Bar	400000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		760000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **400,000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	2069.2		0.10	0.017	3.41		1.54	
1+	0.19327	77309.0		0.60	0.160	7421.67		3339.75	
2+	0.02429	9717.2		0.86	0.649	5423.56		2440.60	
3+	0.00088	354.0		0.86	2.222	676.45		304.40	
All		**89449.4**				**13525.09**		**6086.29**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.71		0.50	1.71	
1+	0.50	3710.83		0.50	3710.83	
2+	0.25	1355.89		0.75	4067.67	
3+	0.50	338.23		0.50	338.23	
All		**5406.66**			**8118.44**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

	Proportion of Total AEL	
Age Class	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.77		0.50	0.77	
1+	0.50	1669.88		0.50	1669.88	
2+	0.25	610.15		0.75	1830.45	
3+	0.50	152.20		0.50	152.20	
All		**2433.00**			**3653.30**	
					6086.292	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

	Proportion of Total AEL at 3+	
Age Class	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	89449.4
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	13525.1
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	6086.3
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	3653.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	2433.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
3653.3	0.70	**2557.3**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	2557.3
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	Flavel Bar	Post Construction Maintenance, 40 ft Yr 20	*210000*

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		570000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **210000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	1086.3		0.10	0.017	1.79		0.81	
1+	0.19327	40587.2		0.60	0.160	3896.38		1753.37	
2+	0.02429	5101.5		0.86	0.649	2847.37		1281.32	
3+	0.00088	185.8		0.86	2.222	355.14		159.81	
All		**46960.9**				**7100.67**		**3195.30**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.90		0.50	0.90	
1+	0.50	1948.19		0.50	1948.19	
2+	0.25	711.84		0.75	2135.53	
3+	0.50	177.57		0.50	177.57	
All		**2838.50**			**4262.18**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.40		0.50	0.40	
1+	0.50	876.68		0.50	876.68	
2+	0.25	320.33		0.75	960.99	
3+	0.50	79.91		0.50	79.91	
All		**1277.32**			**1917.98**	
					3195.303	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	46960.9
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	7100.7
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	3195.3
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	1918.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	1277.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
1918.0	0.70	**1342.6**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	1342.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 43 ft Yr 1**	***500000***

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	60000
10 to 13	Flavel Bar	500000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		990000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **500000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	2586.5		0.10	0.017	4.27		1.92	
1+	0.19327	96636.3		0.60	0.160	9277.08		4174.69	
2+	0.02429	12146.5		0.86	0.649	6779.45		3050.75	
3+	0.00088	442.5		0.86	2.222	845.57		380.51	
All		**111811.8**				**16906.37**		**7607.86**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.13		0.50	2.13	
1+	0.50	4638.54		0.50	4638.54	
2+	0.25	1694.86		0.75	5084.58	
3+	0.50	422.78		0.50	422.78	
All		**6758.32**			**10148.04**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.96		0.50	0.96	
1+	0.50	2087.34		0.50	2087.34	
2+	0.25	762.69		0.75	2288.06	
3+	0.50	190.25		0.50	190.25	
All		**3041.24**			**4566.62**	
					7607.865	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	111811.8
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	16906.4
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	7607.9
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	4566.6
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	3041.2
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
4566.6	0.70	**3196.6**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	3196.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 43 ft Yr 20**	***210000***

**Based on Desdemona June crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		680000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **210000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.50	0.50	* binomial distribution p>0.05; low sample size - assumed to be 1:1.
1+	70	68	138	0.51	0.49	binomial distribution p=0.067 - not sign different from 1:1
2+	12	4	16	0.75	0.25	binomial distribution p<0.05
3+	0	0	0	0.50	0.50	* low sample size - assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00517	1086.3		0.10	0.017	1.79		0.81	
1+	0.19327	40587.2		0.60	0.160	3896.38		1753.37	
2+	0.02429	5101.5		0.86	0.649	2847.37		1281.32	
3+	0.00088	185.8		0.86	2.222	355.14		159.81	
All		**46960.9**				**7100.67**		**3195.30**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.90		0.50	0.90	
1+	0.50	1948.19		0.50	1948.19	
2+	0.25	711.84		0.75	2135.53	
3+	0.50	177.57		0.50	177.57	
All		**2838.50**			**4262.18**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	2.31	0.00
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.40		0.50	0.40	
1+	0.50	876.68		0.50	876.68	
2+	0.25	320.33		0.75	960.99	
3+	0.50	79.91		0.50	79.91	
All		**1277.32**			**1917.98**	
					3195.303	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	2.31	0.03
1+	86.43	54.87
2+	10.86	40.10
3+	0.40	5.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0001	0.0001
1+	0.2744	0.2744
2+	0.3007	0.1002
3+	0.0250	0.0250
ALL	0.60	0.40

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	46960.9
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	7100.7
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	3195.3
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	1918.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	1277.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
1918.0	0.70	**1342.6**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	1342.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

Summary of Projected Entrainment, Adult Equivalent Loss, and Lost Recruits
Lower Columbia River
WH Pearson and GD Williams

Variance Estimators (derived from Sept 2002 field sampling at Desdemona Shoals)

	CV %		
E	29.43	Z at 0.975	1.95996
AEL	20.25		
LF	20.25		

Construction Dredging to 40 ft - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	542,349

Results:

Parameter	Projected Value	SE	95% CI
E	64,806	19,072	37,381
AEL	54,635	11,064	21,684
AEL Male	27,317	5,532	10,842
AEL Female	27,317	5,532	10,842
Loss to Fishery	8,605	1,743	3,415

Construction Dredging to 40 ft - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	542,349

Results:

Parameter	Projected Value	SE	95% CI
E	64,806	19,072	37,381
AEL	24,586	4,979	9,758
AEL Male	12,293	2,489	4,879
AEL Female	12,293	2,489	4,879
Loss to Fishery	8,605	1,743	3,415

Construction Dredging from 40 to 43 ft - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	1,169,721

Results:

Parameter	Projected Value	SE	95% CI
E	139,771	41,135	80,622
AEL	117,835	23,862	46,768
AEL Male	58,917	11,931	23,384
AEL Female	58,917	11,931	23,384
Loss to Fishery	18,559	3,758	7,366

Construction Dredging from 40 to 43 ft - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	1,169,721

Results:

Parameter	Projected Value	SE	95% CI
E	139,771	41,135	80,622
AEL	53,026	10,738	21,045
AEL Male	26,513	5,369	10,523
AEL Female	26,513	5,369	10,523
Loss to Fishery	18,559	3,758	7,366

Annual Maintenance Dredging 40' Year 1 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	400,000

Results:

Parameter	Projected Value	SE	95% CI
E	47,796	14,067	27,570
AEL	40,295	8,160	15,993
AEL Male	20,148	4,080	7,996
AEL Female	20,148	4,080	7,996
Loss to Fishery	6,346	1,285	2,519

Annual Maintenance Dredging 40' Year 1 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	400,000

Results:

Parameter	Projected Value	SE	95% CI
E	47,796	14,067	27,570
AEL	18,133	3,672	7,197
AEL Male	9,066	1,836	3,598
AEL Female	9,066	1,836	3,598
Loss to Fishery	6,346	1,285	2,519

Annual Maintenance Dredging 40' Year 20 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	25,093	7,385	14,474
AEL	21,155	4,284	8,396
AEL Male	10,577	2,142	4,198
AEL Female	10,577	2,142	4,198
Loss to Fishery	3,332	675	1,322

Annual Maintenance Dredging 40' Year 20 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	25,093	7,385	14,474
AEL	9,520	1,928	3,778
AEL Male	4,760	964	1,889
AEL Female	4,760	964	1,889
Loss to Fishery	3,332	675	1,322

Annual Maintenance Dredging 43' Year 1 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	500,000

Results:

Parameter	Projected Value	SE	95% CI
E	59,746	17,583	34,462
AEL	50,369	10,200	19,991
AEL Male	25,184	5,100	9,995
AEL Female	25,184	5,100	9,995
Loss to Fishery	7,933	1,606	3,149

Annual Maintenance Dredging 43' Year 1 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	500,000

Results:

Parameter	Projected Value	SE	95% CI
E	59,746	17,583	34,462
AEL	22,666	4,590	8,996
AEL Male	11,333	2,295	4,498
AEL Female	11,333	2,295	4,498
Loss to Fishery	7,933	1,606	3,149

Annual Maintenance Dredging 43' Year 20 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	25,093	7,385	14,474
AEL	21,155	4,284	8,396
AEL Male	10,577	2,142	4,198
AEL Female	10,577	2,142	4,198
Loss to Fishery	3,332	675	1,322

Annual Maintenance Dredging 43' Year 20 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	25,093	7,385	14,474
AEL	9,520	1,928	3,778
AEL Male	4,760	964	1,889
AEL Female	4,760	964	1,889
Loss to Fishery	3,332	675	1,322

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Construction Dredging to 40 ft**	***542349***

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - to 40 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	222412
5		353916
6	Upper Desdem	0
7		0
8		8742
9		8742
10	Flavel Bar	49732
11		298900
12		121292
13		72425
14	Upper Sands	54585
15		51945
16		47557
17		0
18	Tongue Point	14775
19		6976
20		13283
Total		1325282

Dredged Yardage (cy) **542349** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	11782.9		0.60	0.160	1131.16		509.02	
2+	0.06518	35348.7		0.86	0.649	19729.51		8878.28	
3+	0.03259	17674.3		0.86	2.222	33774.25		15198.41	
All		**64805.9**				**54634.92**		**24585.72**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male			
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)	R = Crab Entrainment Rate (crabs/cy)
YOY	0.50	0.00		0.50	0.00		E = Crabs Entrained (number of Crabs)
1+	0.50	565.58		0.50	565.58		M = Post-Entrainment Mortality (proportion)
2+	0.50	9864.76		0.50	9864.76		S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
3+	0.50	16887.13		0.50	16887.13		AEL = Adult Equivalent Loss
All		**27317.46**			**27317.46**		VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male			
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)	R = Crab Entrainment Rate (crabs/cy)
YOY	0.50	0.00		0.50	0.00		E = Crabs Entrained (number of Crabs)
1+	0.50	254.51		0.50	254.51		M = Post-Entrainment Mortality (proportion)
2+	0.50	4439.14		0.50	4439.14		S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
3+	0.50	7599.21		0.50	7599.21		AEL = Adult Equivalent Loss
All		**12292.86**			**12292.86**		VAR(AEL) =AEL Variance
					24585.715		

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	64805.9
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	54634.9
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	24585.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	12292.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	12292.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
12292.9	0.70	**8605.0**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	8605.0
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Construction Dredging from 40 to 43 ft**	***1169721***

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - from 40 to 43 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	94688
5		196724
6	Upper Desdem	66193
7		1039
8		52398
9		62851
10	Flavel Bar	329296
11		535074
12		239608
13		65743
14	Upper Sands	171432
15		271842
16		306717
17		108631
18	Tongue Point	174113
19		162864
20		127219
Total		2966432

Dredged Yardage (cy) **1169721** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	25413.0		0.60	0.160	2439.65		1097.84	
2+	0.06518	76238.9		0.86	0.649	42551.98		19148.39	
3+	0.03259	38119.5		0.86	2.222	72843.23		32779.45	
All		**139771.3**				**117834.86**		**53025.69**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

<u>**AGE 2+ Calculations**</u>

Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	1219.82		0.50	1219.82	
2+	0.50	21275.99		0.50	21275.99	
3+	0.50	36421.61		0.50	36421.61	
All		**58917.43**			**58917.43**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

<u>**AGE 3+ Calculations**</u>

Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	548.92		0.50	548.92	
2+	0.50	9574.20		0.50	9574.20	
3+	0.50	16389.73		0.50	16389.73	
All		**26512.84**			**26512.84**	
					53025.686	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

<u>**SUMMARY VARIANCE DATA**</u>

Entrainment with Confidence Limits

E	139771.3
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	117834.9
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	53025.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	26512.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	26512.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

<u>**TOTAL LOSS TO MALE FISHERY**</u>
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
26512.8	0.70	**18559.0**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	18559.0
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	Flavel Bar	Construction Dredging to 40 ft	*542349*

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - to 40 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	222412
5		353916
6	Upper Desdem	0
7		0
8		8742
9		8742
10	Flavel Bar	49732
11		298900
12		121292
13		72425
14	Upper Sands	54585
15		51945
16		47557
17		0
18	Tongue Point	14775
19		6976
20		13283
Total		1325282

Dredged Yardage (cy) **542349** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	11782.9		0.60	0.160	1131.16		509.02	
2+	0.06518	35348.7		0.86	0.649	19729.51		8878.28	
3+	0.03259	17674.3		0.86	2.222	33774.25		15198.41	
All		**64805.9**				**54634.92**		**24585.72**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	565.58		0.50	565.58	
2+	0.50	9864.76		0.50	9864.76	
3+	0.50	16887.13		0.50	16887.13	
All		**27317.46**			**27317.46**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	254.51		0.50	254.51	
2+	0.50	4439.14		0.50	4439.14	
3+	0.50	7599.21		0.50	7599.21	
All		**12292.86**			**12292.86**	
					24585.715	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	64805.9
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	54634.9
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	24585.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	12292.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	12292.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
12292.9	0.70	**8605.0**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	8605.0
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	Flavel Bar	Post Construction Maintenance, 40 ft Yr 1	400000

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40,000
10 to 13	Flavel Bar	400000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		760000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **400,000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	8690.3		0.60	0.160	834.27		375.42	
2+	0.06518	26070.8		0.86	0.649	14551.16		6548.02	
3+	0.03259	13035.4		0.86	2.222	24909.61		11209.32	
All		**47796.5**				**40295.03**		**18132.76**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	417.13		0.50	417.13	
2+	0.50	7275.58		0.50	7275.58	
3+	0.50	12454.80		0.50	12454.80	
All		**20147.52**			**20147.52**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	187.71		0.50	187.71	
2+	0.50	3274.01		0.50	3274.01	
3+	0.50	5604.66		0.50	5604.66	
All		**9066.38**			**9066.38**	
					18132.764	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	47796.5
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	40295.0
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	18132.8
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	9066.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	9066.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
9066.4	0.70	**6346.5**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	6346.5
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 40 ft Yr 20**	***210000***

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		570000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **210000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	4562.4		0.60	0.160	437.99		197.10	
2+	0.06518	13687.2		0.86	0.649	7639.36		3437.71	
3+	0.03259	6843.6		0.86	2.222	13077.54		5884.89	
All		**25093.1**				**21154.89**		**9519.70**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	218.99		0.50	218.99	
2+	0.50	3819.68		0.50	3819.68	
3+	0.50	6538.77		0.50	6538.77	
All		**10577.45**			**10577.45**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	98.55		0.50	98.55	
2+	0.50	1718.86		0.50	1718.86	
3+	0.50	2942.45		0.50	2942.45	
All		**4759.85**			**4759.85**	
					9519.701	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	25093.1
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	21154.9
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	9519.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	4759.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	4759.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
4759.9	0.70	**3331.9**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	3331.9
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	Flavel Bar	Post Construction Maintenance, 43 ft Yr 1	500000

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	60000
10 to 13	Flavel Bar	500000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		990000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) 500000 Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	10862.8		0.60	0.160	1042.83		469.27	
2+	0.06518	32588.5		0.86	0.649	18188.95		8185.03	
3+	0.03259	16294.3		0.86	2.222	31137.01		14011.65	
All		**59745.6**				**50368.79**		**22665.95**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	521.42		0.50	521.42	
2+	0.50	9094.47		0.50	9094.47	
3+	0.50	15568.50		0.50	15568.50	
All		**25184.39**			**25184.39**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	234.64		0.50	234.64	
2+	0.50	4092.51		0.50	4092.51	
3+	0.50	7005.83		0.50	7005.83	
All		**11332.98**			**11332.98**	
					22665.954	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	59745.6
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	50368.8
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	22666.0
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	11333.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	11333.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
11333.0	0.70	**7933.1**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	7933.1
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Construction Dredging to 40 ft**	***542349***

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - to 40 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	222412
5		353916
6	Upper Desdem	0
7		0
8		8742
9		8742
10	Flavel Bar	49732
11		298900
12		121292
13		72425
14	Upper Sands	54585
15		51945
16		47557
17		0
18	Tongue Point	14775
19		6976
20		13283
Total		1325282

Dredged Yardage (cy) **542349** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	11782.9		0.60	0.160	1131.16		509.02	
2+	0.06518	35348.7		0.86	0.649	19729.51		8878.28	
3+	0.03259	17674.3		0.86	2.222	33774.25		15198.41	
All		**64805.9**				**54634.92**		**24585.72**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	565.58		0.50	565.58	
2+	0.50	9864.76		0.50	9864.76	
3+	0.50	16887.13		0.50	16887.13	
All		**27317.46**			**27317.46**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	254.51		0.50	254.51	
2+	0.50	4439.14		0.50	4439.14	
3+	0.50	7599.21		0.50	7599.21	
All		**12292.86**			**12292.86**	
					24585.715	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	64805.9
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	54634.9
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	24585.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	12292.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	12292.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
12292.9	0.70	**8605.0**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	8605.0
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 43 ft Yr 20**	***210000***

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		680000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **210000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	4562.4		0.60	0.160	437.99		197.10	
2+	0.06518	13687.2		0.86	0.649	7639.36		3437.71	
3+	0.03259	6843.6		0.86	2.222	13077.54		5884.89	
All		**25093.1**				**21154.89**		**9519.70**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	218.99		0.50	218.99	
2+	0.50	3819.68		0.50	3819.68	
3+	0.50	6538.77		0.50	6538.77	
All		**10577.45**			**10577.45**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

	Proportion of Total AEL	
Age Class	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	98.55		0.50	98.55	
2+	0.50	1718.86		0.50	1718.86	
3+	0.50	2942.45		0.50	2942.45	
All		**4759.85**			**4759.85**	
					9519.701	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

	Proportion of Total AEL at 3+	
Age Class	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	25093.1
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	21154.9
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	9519.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	4759.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	4759.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
4759.9	0.70	**3331.9**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	3331.9
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Construction Dredging from 40 to 43 ft**	***1169721***

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - from 40 to 43 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	94688
5		196724
6	Upper Desdem	66193
7		1039
8		52398
9		62851
10	Flavel Bar	329296
11		535074
12		239608
13		65743
14	Upper Sands	171432
15		271842
16		306717
17		108631
18	Tongue Point	174113
19		162864
20		127219
Total		2966432

Dredged Yardage (cy) **1169721** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	25413.0		0.60	0.160	2439.65		1097.84	
2+	0.06518	76238.9		0.86	0.649	42551.98		19148.39	
3+	0.03259	38119.5		0.86	2.222	72843.23		32779.45	
All		**139771.3**				**117834.86**		**53025.69**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	1219.82		0.50	1219.82	
2+	0.50	21275.99		0.50	21275.99	
3+	0.50	36421.61		0.50	36421.61	
All		**58917.43**			**58917.43**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	548.92		0.50	548.92	
2+	0.50	9574.20		0.50	9574.20	
3+	0.50	16389.73		0.50	16389.73	
All		**26512.84**			**26512.84**	
					53025.686	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	139771.3
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	117834.9
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	53025.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	26512.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	26512.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
26512.8	0.70	**18559.0**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	18559.0
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	**Total Volume Dredged (cy)**
Projected	**Flavel Bar**	**Construction Dredging from 40 to 43 ft**	***1169721***

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - from 40 to 43 ft

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	94688
5		196724
6	Upper Desdem	66193
7		1039
8		52398
9		62851
10	Flavel Bar	329296
11		535074
12		239608
13		65743
14	Upper Sands	171432
15		271842
16		306717
17		108631
18	Tongue Point	174113
19		162864
20		127219
Total		2966432

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **1169721** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from June Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	25413.0		0.60	0.160	2439.65		1097.84	
2+	0.06518	76238.9		0.86	0.649	42551.98		19148.39	
3+	0.03259	38119.5		0.86	2.222	72843.23		32779.45	
All		**139771.3**				**117834.86**		**53025.69**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

<u>AGE 2+ Calculations</u>
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	1219.82		0.50	1219.82	
2+	0.50	21275.99		0.50	21275.99	
3+	0.50	36421.61		0.50	36421.61	
All		**58917.43**			**58917.43**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

<u>AGE 3+ Calculations</u>
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	548.92		0.50	548.92	
2+	0.50	9574.20		0.50	9574.20	
3+	0.50	16389.73		0.50	16389.73	
All		**26512.84**			**26512.84**	
					53025.686	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

<u>SUMMARY VARIANCE DATA</u>

Entrainment with Confidence Limits

E	139771.3
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	117834.9
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	53025.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	26512.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	26512.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

<u>TOTAL LOSS TO MALE FISHERY</u>
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
26512.8	0.70	**18559.0**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	18559.0
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 40 ft Yr 1**	*400000*

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40,000
10 to 13	Flavel Bar	400000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		760000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **400,000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	8690.3		0.60	0.160	834.27		375.42	
2+	0.06518	26070.8		0.86	0.649	14551.16		6548.02	
3+	0.03259	13035.4		0.86	2.222	24909.61		11209.32	
All		**47796.5**				**40295.03**		**18132.76**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	417.13		0.50	417.13	
2+	0.50	7275.58		0.50	7275.58	
3+	0.50	12454.80		0.50	12454.80	
All		**20147.52**			**20147.52**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	187.71		0.50	187.71	
2+	0.50	3274.01		0.50	3274.01	
3+	0.50	5604.66		0.50	5604.66	
All		**9066.38**			**9066.38**	
					18132.764	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	47796.5
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	40295.0
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	18132.8
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	9066.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	9066.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
9066.4	0.70	**6346.5**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	6346.5
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 40 ft Yr 20**	*210000*

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		570000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **210000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	4562.4		0.60	0.160	437.99		197.10	
2+	0.06518	13687.2		0.86	0.649	7639.36		3437.71	
3+	0.03259	6843.6		0.86	2.222	13077.54		5884.89	
All		**25093.1**				**21154.89**		**9519.70**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	218.99		0.50	218.99	
2+	0.50	3819.68		0.50	3819.68	
3+	0.50	6538.77		0.50	6538.77	
All		**10577.45**			**10577.45**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	98.55		0.50	98.55	
2+	0.50	1718.86		0.50	1718.86	
3+	0.50	2942.45		0.50	2942.45	
All		**4759.85**			**4759.85**	
					9519.701	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	25093.1
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	21154.9
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	9519.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	4759.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	4759.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
4759.9	0.70	**3331.9**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	3331.9
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 43 ft Yr 1**	***500000***

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	60000
10 to 13	Flavel Bar	500000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		990000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **500000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	10862.8		0.60	0.160	1042.83		469.27	
2+	0.06518	32588.5		0.86	0.649	18188.95		8185.03	
3+	0.03259	16294.3		0.86	2.222	31137.01		14011.65	
All		**59745.6**				**50368.79**		**22665.95**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	521.42		0.50	521.42	
2+	0.50	9094.47		0.50	9094.47	
3+	0.50	15568.50		0.50	15568.50	
All		**25184.39**			**25184.39**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	234.64		0.50	234.64	
2+	0.50	4092.51		0.50	4092.51	
3+	0.50	7005.83		0.50	7005.83	
All		**11332.98**			**11332.98**	
					22665.954	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	59745.6
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	50368.8
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	22666.0
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	11333.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	11333.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
11333.0	0.70	**7933.1**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	7933.1
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 43 ft Yr 20**	***210000***

**Based on Desdemona September crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		680000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **210000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class, Derived from Desdemona Sept Data

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	2	0	2	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.00000	0.0		0.10	0.017	0.00		0.00	
1+	0.02173	4562.4		0.60	0.160	437.99		197.10	
2+	0.06518	13687.2		0.86	0.649	7639.36		3437.71	
3+	0.03259	6843.6		0.86	2.222	13077.54		5884.89	
All		**25093.1**				**21154.89**		**9519.70**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	218.99		0.50	218.99	
2+	0.50	3819.68		0.50	3819.68	
3+	0.50	6538.77		0.50	6538.77	
All		**10577.45**			**10577.45**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.00		0.50	0.00	
1+	0.50	98.55		0.50	98.55	
2+	0.50	1718.86		0.50	1718.86	
3+	0.50	2942.45		0.50	2942.45	
All		**4759.85**			**4759.85**	
					9519.701	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	0.00	0.00
1+	18.18	2.07
2+	54.55	36.11
3+	27.27	61.82

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0000	0.0000
1+	0.0104	0.0104
2+	0.1806	0.1806
3+	0.3091	0.3091
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	25093.1
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	21154.9
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	9519.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	4759.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	4759.9
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
4759.9	0.70	**3331.9**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	3331.9
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

Summary of Projected Entrainment, Adult Equivalent Loss, and Loss to Fishery.
Lower Columbia River
WH Pearson and GD Williams

Variance Estimators (derived from Sept 2002 field sampling at Upper Sands)

	CV %		
E	70.70	Z at 0.975	1.95996
AEL	98.30		
LF	98.30		

Construction Dredging to 40 ft - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	542,349

Results:

Parameter	Projected Value	SE	95% CI
E	11,136	7,873	15,431
AEL	539	530	1,039
AEL Male	270	265	519
AEL Female	270	265	519
Loss to Fishery	85	83	164

Construction Dredging to 40 ft - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	542,349

Results:

Parameter	Projected Value	SE	95% CI
E	11,136	7,873	15,431
AEL	243	238	467
AEL Male	121	119	234
AEL Female	121	119	234
Loss to Fishery	85	83	164

Construction Dredging from 40 to 43 ft - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	1,169,721

Results:

Parameter	Projected Value	SE	95% CI
E	24,017	16,980	33,280
AEL	1,163	1,143	2,240
AEL Male	581	571	1,120
AEL Female	581	571	1,120
Loss to Fishery	183	180	353

Construction Dredging from 40 to 43 ft - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	1,169,721

Results:

Parameter	Projected Value	SE	95% CI
E	24,017	16,980	33,280
AEL	523	514	1,008
AEL Male	262	257	504
AEL Female	262	257	504
Loss to Fishery	183	180	353

Annual Maintenance Dredging 40' Year 1 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	400,000

Results:

Parameter	Projected Value	SE	95% CI
E	8,213	5,807	11,381
AEL	398	391	766
AEL Male	199	195	383
AEL Female	199	195	383
Loss to Fishery	63	62	121

Annual Maintenance Dredging 40' Year 1 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	400,000

Results:

Parameter	Projected Value	SE	95% CI
E	8,213	5,807	11,381
AEL	179	176	345
AEL Male	89	88	172
AEL Female	89	88	172
Loss to Fishery	63	62	121

Annual Maintenance Dredging 40' Year 20 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	4,312	3,048	5,975
AEL	209	205	402
AEL Male	104	103	201
AEL Female	104	103	201
Loss to Fishery	33	32	63

Annual Maintenance Dredging 40' Year 20 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	4,312	3,048	5,975
AEL	94	92	181
AEL Male	47	46	90
AEL Female	47	46	90
Loss to Fishery	33	32	63

Annual Maintenance Dredging 43' Year 1 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	500,000

Results:

Parameter	Projected Value	SE	95% CI
E	10,266	7,258	14,226
AEL	497	489	958
AEL Male	248	244	479
AEL Female	248	244	479
Loss to Fishery	78	77	151

Annual Maintenance Dredging 43' Year 1 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	500,000

Results:

Parameter	Projected Value	SE	95% CI
E	10,266	7,258	14,226
AEL	224	220	431
AEL Male	112	110	215
AEL Female	112	110	215
Loss to Fishery	78	77	151

Annual Maintenance Dredging 43' Year 20 - Age 2+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	4,312	3,048	5,975
AEL	209	205	402
AEL Male	104	103	201
AEL Female	104	103	201
Loss to Fishery	33	32	63

Annual Maintenance Dredging 43' Year 20 - Age 3+

Assumptions:

Projected Location	Flavel Bar
Planned dredged volume (cy)	210,000

Results:

Parameter	Projected Value	SE	95% CI
E	4,312	3,048	5,975
AEL	94	92	181
AEL Male	47	46	90
AEL Female	47	46	90
Loss to Fishery	33	32	63

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Construction Dredging to 40 ft**	***542349***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - to 40 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	222412
5		353916
6	Upper Desdem	0
7		0
8		8742
9		8742
10	Flavel Bar	49732
11		298900
12		121292
13		72425
14	Upper Sands	54585
15		51945
16		47557
17		0
18	Tongue Point	14775
19		6976
20		13283
Total		1325282

Dredged Yardage (cy) **542349** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	5616.7		0.10	0.017	9.27		4.17	
1+	0.01018	5519.0		0.60	0.160	529.83		238.42	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**11135.7**				**539.09**		**242.59**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	4.63		0.50	4.63	
1+	0.50	264.91		0.50	264.91	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**269.55**			**269.55**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.09		0.50	2.09	
1+	0.50	119.21		0.50	119.21	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**121.30**			**121.30**	
					242.592	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	11135.7
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	539.1
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	242.6
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	121.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	121.3
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
121.3	0.70	**84.9**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	84.9
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	**Total Volume Dredged (cy)**
Projected	**Flavel Bar**	**Construction Dredging from 40 to 43 ft**	***1169721***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - from 40 to 43 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	94688
5		196724
6	Upper Desdem	66193
7		1039
8		52398
9		62851
10	Flavel Bar	329296
11		535074
12		239608
13		65743
14	Upper Sands	171432
15		271842
16		306717
17		108631
18	Tongue Point	174113
19		162864
20		127219
Total		2966432

Dredged Yardage (cy) **1169721** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	12113.9		0.10	0.017	19.99		8.99	
1+	0.01018	11903.3		0.60	0.160	1142.71		514.22	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**24017.2**				**1162.70**		**523.22**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	9.99		0.50	9.99	
1+	0.50	571.36		0.50	571.36	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**581.35**			**581.35**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	4.50		0.50	4.50	
1+	0.50	257.11		0.50	257.11	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**261.61**			**261.61**	
					523.215	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	24017.2
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	1162.7
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	523.2
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	261.6
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	261.6
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
261.6	0.70	**183.1**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	183.1
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 40 ft Yr 1**	***400000***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40,000
10 to 13	Flavel Bar	400000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		760000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **400,000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	4142.5		0.10	0.017	6.84		3.08	
1+	0.01018	4070.5		0.60	0.160	390.76		175.84	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**8213.0**				**397.60**		**178.92**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	3.42		0.50	3.42	
1+	0.50	195.38		0.50	195.38	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**198.80**			**198.80**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.54		0.50	1.54	
1+	0.50	87.92		0.50	87.92	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**89.46**			**89.46**	
					178.920	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	8213.0
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	397.6
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	178.9
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	89.5
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	89.5
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
89.5	0.70	**62.6**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	62.6
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 40 ft Yr 20**	***210000***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		570000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **210000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	2174.8		0.10	0.017	3.59		1.61	
1+	0.01018	2137.0		0.60	0.160	205.15		92.32	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**4311.8**				**208.74**		**93.93**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.79		0.50	1.79	
1+	0.50	102.58		0.50	102.58	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**104.37**			**104.37**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.81		0.50	0.81	
1+	0.50	46.16		0.50	46.16	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**46.97**			**46.97**	
					93.933	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	4311.8
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	208.7
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	93.9
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	47.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	47.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
47.0	0.70	**32.9**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	32.9
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 43 ft Yr 1**	***500000***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	60000
10 to 13	Flavel Bar	500000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		990000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **500000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	5178.1		0.10	0.017	8.54		3.84	
1+	0.01018	5088.1		0.60	0.160	488.46		219.80	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**10266.2**				**497.00**		**223.65**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	4.27		0.50	4.27	
1+	0.50	244.23		0.50	244.23	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**248.50**			**248.50**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.92		0.50	1.92	
1+	0.50	109.90		0.50	109.90	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**111.82**			**111.82**	
					223.650	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	10266.2
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	497.0
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	223.6
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	111.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	111.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
111.8	0.70	**78.3**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	78.3
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Flavel Bar**	**Post Construction Maintenance, 43 ft Yr 20**	***210000***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		680000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **210000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	2174.8		0.10	0.017	3.59		1.61	
1+	0.01018	2137.0		0.60	0.160	205.15		92.32	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**4311.8**				**208.74**		**93.93**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.79		0.50	1.79	
1+	0.50	102.58		0.50	102.58	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**104.37**			**104.37**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

	Proportion of Total AEL	
Age Class	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.81		0.50	0.81	
1+	0.50	46.16		0.50	46.16	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**46.97**			**46.97**	
					93.933	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

	Proportion of Total AEL at 3+	
Age Class	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA
Entrainment with Confidence Limits

E	4311.8
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	208.7
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	93.9
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	47.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	47.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
47.0	0.70	**32.9**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	32.9
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

Summary of Projected Entrainment, Adult Equivalent Loss, and Loss to Fishery.
Lower Columbia River
WH Pearson and GD Williams

Variance Estimators (derived from Sept 2002 field sampling)

	CV %		
E	70.70	Z at 0.975	1.95996
AEL	98.30		
LF	98.30		

Construction Dredging to 40 ft - Age 2+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	154,087

Results:

Parameter	Projected Value	SE	95% CI
E	3,164	2,237	4,384
AEL	153	151	295
AEL Male	77	75	148
AEL Female	77	75	148
Loss to Fishery	24	24	46

Construction Dredging to 40 ft - Age 3+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	154,087

Results:

Parameter	Projected Value	SE	95% CI
E	3,164	2,237	4,384
AEL	69	68	133
AEL Male	34	34	66
AEL Female	34	34	66
Loss to Fishery	24	24	46

Construction Dredging from 40 to 43 ft - Age 2+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	858,622

Results:

Parameter	Projected Value	SE	95% CI
E	17,630	12,464	24,429
AEL	853	839	1,644
AEL Male	427	419	822
AEL Female	427	419	822
Loss to Fishery	134	132	259

Construction Dredging from 40 to 43 ft - Age 3+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	858,622

Results:

Parameter	Projected Value	SE	95% CI
E	17,630	12,464	24,429
AEL	384	378	740
AEL Male	192	189	370
AEL Female	192	189	370
Loss to Fishery	134	132	259

Annual Maintenance Dredging 40' Year 1 - Age 2+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	50,000

Results:

Parameter	Projected Value	SE	95% CI
E	1,027	726	1,423
AEL	50	49	96
AEL Male	25	24	48
AEL Female	25	24	48
Loss to Fishery	8	8	15

Annual Maintenance Dredging 40' Year 1 - Age 3+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	50,000

Results:

Parameter	Projected Value	SE	95% CI
E	1,027	726	1,423
AEL	22	22	43
AEL Male	11	11	22
AEL Female	11	11	22
Loss to Fishery	8	8	15

Annual Maintenance Dredging 40' Year 20 - Age 2+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	50,000

Results:

Parameter	Projected Value	SE	95% CI
E	1,027	726	1,423
AEL	50	49	96
AEL Male	25	24	48
AEL Female	25	24	48
Loss to Fishery	8	8	15

Annual Maintenance Dredging 40' Year 20 - Age 3+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	50,000

Results:

Parameter	Projected Value	SE	95% CI
E	1,027	726	1,423
AEL	22	22	43
AEL Male	11	11	22
AEL Female	11	11	22
Loss to Fishery	8	8	15

Annual Maintenance Dredging 43' Year 1 - Age 2+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	100,000

Results:

Parameter	Projected Value	SE	95% CI
E	2,053	1,452	2,845
AEL	99	98	192
AEL Male	50	49	96
AEL Female	50	49	96
Loss to Fishery	16	15	30

Annual Maintenance Dredging 43' Year 1 - Age 3+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	100,000

Results:

Parameter	Projected Value	SE	95% CI
E	2,053	1,452	2,845
AEL	45	44	86
AEL Male	22	22	43
AEL Female	22	22	43
Loss to Fishery	16	15	30

Annual Maintenance Dredging 43' Year 20 - Age 2+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	100,000

Results:

Parameter	Projected Value	SE	95% CI
E	2,053	1,452	2,845
AEL	99	98	192
AEL Male	50	49	96
AEL Female	50	49	96
Loss to Fishery	16	15	30

Annual Maintenance Dredging 43' Year 20 - Age 3+

Assumptions:

Projected Location	Upper Sands
Planned dredged volume (cy)	100,000

Results:

Parameter	Projected Value	SE	95% CI
E	2,053	1,452	2,845
AEL	45	44	86
AEL Male	22	22	43
AEL Female	22	22	43
Loss to Fishery	16	15	30

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Upper Sands**	**Construction Dredging to 40 ft**	***154087***

VOLUME OF DREDGED MATERIALS - to 40 ft

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	222412
5		353916
6	Upper Desdem	0
7		0
8		8742
9		8742
10	Flavel Bar	49732
11		298900
12		121292
13		72425
14	Upper Sands	54585
15		51945
16		47557
17		0
18	Tongue Point	14775
19		6976
20		13283
Total		1325282

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **154087** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	1595.8		0.10	0.017	2.63		1.18	
1+	0.01018	1568.0		0.60	0.160	150.53		67.74	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**3163.8**				**153.16**		**68.92**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.32		0.50	1.32	
1+	0.50	75.26		0.50	75.26	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**76.58**			**76.58**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

	Proportion of Total AEL	
Age Class	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.59		0.50	0.59	
1+	0.50	33.87		0.50	33.87	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**34.46**			**34.46**	
					68.923	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

	Proportion of Total AEL at 3+	
Age Class	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	3163.8
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	153.2
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	68.9
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	34.5
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	34.5
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
34.5	0.70	**24.1**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	24.1
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Upper Sands**	**Construction Dredging from 40 to 43 ft**	***858622***

VOLUME OF DREDGED MATERIALS - from 40 to 43 ft

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	94688
5		196724
6	Upper Desdem	66193
7		1039
8		52398
9		62851
10	Flavel Bar	329296
11		535074
12		239608
13		65743
14	Upper Sands	171432
15		271842
16		306717
17		108631
18	Tongue Point	174113
19		162864
20		127219
Total		2966432

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **858622** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	8892.1		0.10	0.017	14.67		6.60	
1+	0.01018	8737.5		0.60	0.160	838.80		377.46	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**17629.6**				**853.47**		**384.06**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	7.34		0.50	7.34	
1+	0.50	419.40		0.50	419.40	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**426.73**			**426.73**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	3.30		0.50	3.30	
1+	0.50	188.73		0.50	188.73	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**192.03**			**192.03**	
					384.061	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	17629.6
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	853.5
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	384.1
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	192.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	192.0
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
192.0	0.70	**134.4**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	134.4
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	Upper Sands	Post Construction Maintenance, 40 ft Yr 1	50000

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40,000
10 to 13	Flavel Bar	400000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		760000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **50000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	517.8		0.10	0.017	0.85		0.38	
1+	0.01018	508.8		0.60	0.160	48.85		21.98	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**1026.6**				**49.70**		**22.36**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.43		0.50	0.43	
1+	0.50	24.42		0.50	24.42	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**24.85**			**24.85**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.19		0.50	0.19	
1+	0.50	10.99		0.50	10.99	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**11.18**			**11.18**	
					22.365	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	1026.6
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	49.7
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	22.4
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	11.2
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	11.2
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
11.2	0.70	**7.8**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	7.8
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Upper Sands**	**Post Construction Maintenance, 40 ft Yr 20**	*50000*

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		570000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **50000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	517.8		0.10	0.017	0.85		0.38	
1+	0.01018	508.8		0.60	0.160	48.85		21.98	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**1026.6**				**49.70**		**22.36**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.43		0.50	0.43	
1+	0.50	24.42		0.50	24.42	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**24.85**			**24.85**	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.19		0.50	0.19	
1+	0.50	10.99		0.50	10.99	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**11.18**			**11.18**	
					22.365	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	1026.6
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	49.7
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	22.4
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	11.2
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	11.2
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
11.2	0.70	**7.8**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	7.8
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Upper Sands**	**Post Construction Maintenance, 43 ft Yr 1**	***100000***

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	60000
10 to 13	Flavel Bar	500000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		990000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **100000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	1035.6		0.10	0.017	1.71		0.77	
1+	0.01018	1017.6		0.60	0.160	97.69		43.96	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**2053.2**				**99.40**		**44.73**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male			
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)	R = Crab Entrainment Rate (crabs/cy)
YOY	0.50	0.85		0.50	0.85		E = Crabs Entrained (number of Crabs)
1+	0.50	48.85		0.50	48.85		M = Post-Entrainment Mortality (proportion)
2+	0.50	0.00		0.50	0.00		S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
3+	0.50	0.00		0.50	0.00		AEL = Adult Equivalent Loss
All		**49.70**			**49.70**		VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male			
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)	R = Crab Entrainment Rate (crabs/cy)
YOY	0.50	0.38		0.50	0.38		E = Crabs Entrained (number of Crabs)
1+	0.50	21.98		0.50	21.98		M = Post-Entrainment Mortality (proportion)
2+	0.50	0.00		0.50	0.00		S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
3+	0.50	0.00		0.50	0.00		AEL = Adult Equivalent Loss
All		**22.36**			**22.36**		VAR(AEL) =AEL Variance
					44.730		

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	2053.2
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	99.4
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	44.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	22.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	22.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
22.4	0.70	**15.7**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	15.7
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Upper Sands**	**Post Construction Maintenance, 43 ft Yr 20**	***100000***

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		680000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **100000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	1035.6		0.10	0.017	1.71		0.77	
1+	0.01018	1017.6		0.60	0.160	97.69		43.96	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**2053.2**				**99.40**		**44.73**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male			
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)	R = Crab Entrainment Rate (crabs/cy)
YOY	0.50	0.85		0.50	0.85		E = Crabs Entrained (number of Crabs)
1+	0.50	48.85		0.50	48.85		M = Post-Entrainment Mortality (proportion)
2+	0.50	0.00		0.50	0.00		S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
3+	0.50	0.00		0.50	0.00		AEL = Adult Equivalent Loss
All		**49.70**			**49.70**		VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male			
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)	R = Crab Entrainment Rate (crabs/cy)
YOY	0.50	0.38		0.50	0.38		E = Crabs Entrained (number of Crabs)
1+	0.50	21.98		0.50	21.98		M = Post-Entrainment Mortality (proportion)
2+	0.50	0.00		0.50	0.00		S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
3+	0.50	0.00		0.50	0.00		AEL = Adult Equivalent Loss
All		**22.36**			**22.36**		VAR(AEL) =AEL Variance
					44.730		

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	2053.2
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	99.4
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	44.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	22.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	22.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
22.4	0.70	**15.7**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	15.7
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

Summary of Projected Entrainment, Adult Equivalent Loss, and Loss to Fishery.
Lower Columbia River
WH Pearson and GD Williams

Variance Estimators (derived from Sept 2002 field sampling at Upper Sands)

	CV %		
E	70.70	Z at 0.975	1.95996
AEL	98.30		
LF	98.30		

Construction Dredging to 40 ft - Age 2+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	35,034

Results:

Parameter	Projected Value	SE	95% CI
E	719	509	997
AEL	35	34	67
AEL Male	17	17	34
AEL Female	17	17	34
Loss to Fishery	5	5	11

Construction Dredging to 40 ft - Age 3+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	35,034

Results:

Parameter	Projected Value	SE	95% CI
E	719	509	997
AEL	16	15	30
AEL Male	8	8	15
AEL Female	8	8	15
Loss to Fishery	5	5	11

Construction Dredging from 40 to 43 ft - Age 2+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	464,196

Results:

Parameter	Projected Value	SE	95% CI
E	9,531	6,738	13,207
AEL	461	454	889
AEL Male	231	227	444
AEL Female	231	227	444
Loss to Fishery	73	71	140

Construction Dredging from 40 to 43 ft - Age 3+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	464,196

Results:

Parameter	Projected Value	SE	95% CI
E	9,531	6,738	13,207
AEL	208	204	400
AEL Male	104	102	200
AEL Female	104	102	200
Loss to Fishery	73	71	140

Annual Maintenance Dredging 40' Year 1 - Age 2+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	270,000

Results:

Parameter	Projected Value	SE	95% CI
E	5,544	3,919	7,682
AEL	268	264	517
AEL Male	134	132	259
AEL Female	134	132	259
Loss to Fishery	42	42	81

Annual Maintenance Dredging 40' Year 1 - Age 3+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	270,000

Results:

Parameter	Projected Value	SE	95% CI
E	5,544	3,919	7,682
AEL	121	119	233
AEL Male	60	59	116
AEL Female	60	59	116
Loss to Fishery	42	42	81

Annual Maintenance Dredging 40' Year 20 - Age 2+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	270,000

Results:

Parameter	Projected Value	SE	95% CI
E	5,544	3,919	7,682
AEL	268	264	517
AEL Male	134	132	259
AEL Female	134	132	259
Loss to Fishery	42	42	81

Annual Maintenance Dredging 40' Year 20 - Age 3+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	270,000

Results:

Parameter	Projected Value	SE	95% CI
E	5,544	3,919	7,682
AEL	121	119	233
AEL Male	60	59	116
AEL Female	60	59	116
Loss to Fishery	42	42	81

Annual Maintenance Dredging 43' Year 1 - Age 2+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	330,000

Results:

Parameter	Projected Value	SE	95% CI
E	6,776	4,790	9,389
AEL	328	322	632
AEL Male	164	161	316
AEL Female	164	161	316
Loss to Fishery	52	51	100

Annual Maintenance Dredging 43' Year 1 - Age 3+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	330,000

Results:

Parameter	Projected Value	SE	95% CI
E	6,776	4,790	9,389
AEL	148	145	284
AEL Male	74	73	142
AEL Female	74	73	142
Loss to Fishery	52	51	100

Annual Maintenance Dredging 43' Year 20 - Age 2+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	330,000

Results:

Parameter	Projected Value	SE	95% CI
E	6,776	4,790	9,389
AEL	328	322	632
AEL Male	164	161	316
AEL Female	164	161	316
Loss to Fishery	52	51	100

Annual Maintenance Dredging 43' Year 20 - Age 3+

Assumptions:

Projected Location	Tongue Pt
Planned dredged volume (cy)	330,000

Results:

Parameter	Projected Value	SE	95% CI
E	6,776	4,790	9,389
AEL	148	145	284
AEL Male	74	73	142
AEL Female	74	73	142
Loss to Fishery	52	51	100

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Tongue Pt**	**Construction Dredging to 40 ft**	***35034***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - to 40 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	222412
5		353916
6	Upper Desdem	0
7		0
8		8742
9		8742
10	Flavel Bar	49732
11		298900
12		121292
13		72425
14	Upper Sands	54585
15		51945
16		47557
17		0
18	Tongue Point	14775
19		6976
20		13283
Total		1325282

Dredged Yardage (cy) **35034** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	362.8		0.10	0.017	0.60		0.27	
1+	0.01018	356.5		0.60	0.160	34.23		15.40	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**719.3**				**34.82**		**15.67**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.30		0.50	0.30	
1+	0.50	17.11		0.50	17.11	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**17.41**			**17.41**	
						0.00

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	0.13		0.50	0.13	
1+	0.50	7.70		0.50	7.70	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**7.84**			**7.84**	
					15.671	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	719.3
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	34.8
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	15.7
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution

C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	7.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	7.8
Var(AEL)	0.0
SE AEL	0.0
Z at 0.975	1.95996
95% C. I.	0.0
CV AEL (%)	0.00

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
7.8	0.70	**5.5**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	5.5
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Tongue Pt**	**Construction Dredging from 40 to 43 ft**	***464196***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - from 40 to 43 ft

Data from Portland District (10 Sept 2002)

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4	Lower Desdem.	94688
5		196724
6	Upper Desdem	66193
7		1039
8		52398
9		62851
10	Flavel Bar	329296
11		535074
12		239608
13		65743
14	Upper Sands	171432
15		271842
16		306717
17		108631
18	Tongue Point	174113
19		162864
20		127219
Total		2966432

Dredged Yardage (cy) **464196** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	4807.3		0.10	0.017	7.93		3.57	
1+	0.01018	4723.7		0.60	0.160	453.48		204.07	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**9531.1**				**461.41**		**207.63**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	3.97		0.50	3.97	
1+	0.50	226.74		0.50	226.74	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**230.70**			**230.70**	

0.00

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.78		0.50	1.78	
1+	0.50	102.03		0.50	102.03	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**103.82**			**103.82**	

207.634

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	9531.1
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	461.4
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	207.6
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	103.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	103.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)	
103.8	0.70	**72.7**	Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	72.7
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Tongue Pt**	**Post Construction Maintenance, 40 ft Yr 1**	***270000***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40,000
10 to 13	Flavel Bar	400000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		760000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **270000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	2796.2		0.10	0.017	4.61		2.08	
1+	0.01018	2747.6		0.60	0.160	263.77		118.69	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**5543.7**				**268.38**		**120.77**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.31		0.50	2.31	
1+	0.50	131.88		0.50	131.88	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**134.19**			**134.19**	
						0.00

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.04		0.50	1.04	
1+	0.50	59.35		0.50	59.35	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**60.39**			**60.39**	
					120.771	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	5543.7
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	268.4
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	120.8
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	60.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	60.4
Var(AEL)	0.0
SE AEL	0.0
Z at 0.975	1.95996
95% C. I.	0.0
CV AEL (%)	0.00

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
60.4	0.70	**42.3**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	42.3
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Tongue Pt**	**Post Construction Maintenance, 40 ft Yr 20**	***270000***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 40' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	50000
18 to 20	Tongue Point	270000
Total		570000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **270000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	2796.2		0.10	0.017	4.61		2.08	
1+	0.01018	2747.6		0.60	0.160	263.77		118.69	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**5543.7**				**268.38**		**120.77**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.31		0.50	2.31	
1+	0.50	131.88		0.50	131.88	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**134.19**			**134.19**	
						0.00

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.04		0.50	1.04	
1+	0.50	59.35		0.50	59.35	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**60.39**			**60.39**	
					120.771	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	5543.7
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	268.4
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	120.8
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	60.4
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	60.4
Var(AEL)	0.0
SE AEL	0.0
Z at 0.975	1.95996
95% C. I.	0.0
CV AEL (%)	0.00

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
60.4	0.70	**42.3**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	42.3
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	**Tongue Pt**	**Post Construction Maintenance, 43 ft Yr 1**	***330000***

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 1

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	60000
10 to 13	Flavel Bar	500000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		990000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) **330000** Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	3417.6		0.10	0.017	5.64		2.54	
1+	0.01018	3358.1		0.60	0.160	322.38		145.07	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**6775.7**				**328.02**		**147.61**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.82		0.50	2.82	
1+	0.50	161.19		0.50	161.19	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**164.01**			**164.01**	
						0.00

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.27		0.50	1.27	
1+	0.50	72.54		0.50	72.54	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**73.80**			**73.80**	
					147.609	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	6775.7
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	328.0
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	147.6
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	73.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	73.8
Var(AEL)	0.0
SE AEL	0.0
Z at 0.975	1.95996
95% C. I.	0.0
CV AEL (%)	0.00

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
73.8	0.70	**51.7**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	51.7
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and
thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

MODIFIED DREDGE IMPACT MODEL FOR ESTIMATING HOPPER DREDGE ENTRAINMENT IMPACTS TO COLUMBIA RIVER CRAB

Field Date	Field Location	Projection	Total Volume Dredged (cy)
Projected	Tongue Pt	Post Construction Maintenance, 43 ft Yr 20	330000

**Based on Upper Sands crab entrainment data

VOLUME OF DREDGED MATERIALS - Maintenance 43' Yr 20

Volume to be Dredged (cy)		
River Mile	Location Name	Volume (cy)
4 to 9	Desdemona	40000
10 to 13	Flavel Bar	210000
14 to 17	Upper Sands	100000
18 to 20	Tongue Point	330000
Total		680000

Data from Portland District (10 Sept 2002)

Dredged Yardage (cy) 330000 Amount (cy) dredged during dredging period

Sex Ratios by Age Class

Age Class	Total			Proportion		
	Male	Female	Sexed	Male	Female	
YOY	1	0	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
1+	0	1	1	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
2+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.
3+	0	0	0	0.5*	0.5*	* Sample sizes low; assumed to be 1:1.

Estimates of Crab Entrainment Rate (R), Number of Crabs Entrained (E), Adult Equivalent Loss (AEL), and Variance (AEL)

Age Class	R	E	Var(E)	M	S to 2+	AEL at 2+	VAR(AEL 2+)	AEL at 3+	VAR(AEL 3+)
YOY	0.01036	3417.6		0.10	0.017	5.64		2.54	
1+	0.01018	3358.1		0.60	0.160	322.38		145.07	
2+	0.00000	0.0		0.86	0.649	0.00		0.00	
3+	0.00000	0.0		0.86	2.222	0.00		0.00	
All		**6775.7**				**328.02**		**147.61**	

Note: Entrained 3+ crab are back-calculated to provide AEL at 2+.

AGE 2+ Calculations
Contribution to Adult Equivalent Loss (AEL at 2+) and Variance (AEL at 2+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	2.82		0.50	2.82	
1+	0.50	161.19		0.50	161.19	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**164.01**			**164.01**	
						0.00

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL
YOY	50.44	0.00
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

AGE 3+ Calculations
Contribution to Adult Equivalent Loss (AEL at 3+) and Variance (AEL at 3+) by Sex (MALE/FEMALE) and Age Class

Age Class	Female			Male		
	Proportion	AEL	VAR(AEL)	Proportion	AEL	VAR(AEL)
YOY	0.50	1.27		0.50	1.27	
1+	0.50	72.54		0.50	72.54	
2+	0.50	0.00		0.50	0.00	
3+	0.50	0.00		0.50	0.00	
All		**73.80**			**73.80**	
					147.609	

R = Crab Entrainment Rate (crabs/cy)
E = Crabs Entrained (number of Crabs)
M = Post-Entrainment Mortality (proportion)
S = Natural Survivorship (proportion); survival to 3+ is assumed to be 45% (Armstrong et al. 1987)
AEL = Adult Equivalent Loss
VAR(AEL) =AEL Variance

Age Class Distribution

Age Class	% of Total	
	of Entrained	of AEL at 3+
YOY	50.44	1.72
1+	49.56	98.28
2+	0.00	0.00
3+	0.00	0.00

Age Class	Proportion of Total AEL at 3+	
	Male	Female
YOY	0.0086	0.0086
1+	0.4914	0.4914
2+	0.0000	0.0000
3+	0.0000	0.0000
ALL	0.50	0.50

SUMMARY VARIANCE DATA

Entrainment with Confidence Limits

E	6775.7
Var(E)	
SE E	
Z at 0.975	1.95996
95% C. I.	
CV E (%)	

TOTAL AEL at 2+ with Confidence Limits

AEL at 2+	328.0
Var(AEL2+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

TOTAL AEL at 3+ with Confidence Limits

AEL at 3+	147.6
Var(AEL3+)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

SE = Standard Error
Z = Value of Z from Normal Distribution
C.I. = Confidence Interval
CV = Coefficient of Variation in %

MALE AEL at 3+ with Confidence Limits

AEL at 3+	73.8
Var(AEL)	
SE AEL	
Z at 0.975	1.95996
95% C. I.	
CV AEL (%)	

FEMALE AEL at 3+ with Confidence Limits

AEL at 3+	73.8
Var(AEL)	0.0
SE AEL	0.0
Z at 0.975	1.95996
95% C. I.	0.0
CV AEL (%)	0.00

TOTAL LOSS TO MALE FISHERY
(This total would be distributed over 3-4 years)

Male Age 3+ (number of crab)	Harvest Rate (proportion)	Lost to Fishery (number of crab)
73.8	0.70	**51.7**

Harvest rate of 0.70 is taken from Armstrong et al. (1987).

Loss to Fishery with Confidence Limits

Loss to Fishery	51.7
Var(AEL)	
SE LF	
Z at 0.975	1.95996
95% C. I.	
CV LF (%)	

ADDITIONAL NOTES:
Mortality Rates (M) for crabs collected in June-September are from Armstrong et al. 1987 (Table 3.3, p. 61)
Survival rates (S) to age 2+ for crab collected from June-September are from Wainwright et al. 1992 (Table 6, p. 178), and thereafter survival rate from 2+ to age 3+ is 0.45 (Armstrong et al. 1987).
Sex ratios used were those observed or assumed to be 1:1 where sample size was low.

EXHIBIT K-5

WILDLIFE AND WETLAND MITIGATION (REVISED)

Table of Contents
Exhibit K-5
Wildlife and Wetland Mitigation (Revised)

Wildlife and Wetland Mitigation (Revised)
Columbia River Channel Improvement Project

Introduction

The determination of wildlife (including wetland) mitigation requirements for the Columbia River Channel Improvement project takes into account the impacts to wildlife across a spectrum of habitats impacted by project disposal actions. Mitigation actions associated with the project do not focus only on jurisdictional wetlands as it does for a private party seeking a permit under Section 404 of the Clean Water Act. The mitigation analysis for the channel improvement project addressed wildlife impacts associated with upland habitats (including agricultural lands), riparian forest habitats, and wetland habitats.

The wildlife mitigation plan relied on the Habitat Evaluation Procedures (HEP), a U.S. Fish and Wildlife Service program selected as the analytical means to assess project-related wildlife impacts and mitigation attainment levels. An interagency mitigation team (Corps of Engineers, Washington Departments of Ecology and Fish and Wildlife, U.S. Fish and Wildlife Service, and the Oregon Department of Fish and Wildlife) was formed to determine mitigation levels. The wildlife mitigation plan and updated addendum were presented in the Final Integrated Feasibility Report/Environmental Impact Statement (Final IFR/EIS; August 1999, including Appendix G). Public and agency comments for the draft IFR/EIS were presented in that document.

The resource agencies that participated in the wildlife mitigation planning effort voiced a uniform concern, which centered on resolution of discrepancies, inconsistencies and/or inaccuracies in the HEP analysis for the draft wildlife mitigation plan. Two options to resolve these concerns were offered by the resource agencies. The Corps of Engineers decided to implement Option 1, which is shown below.

> Complete the HEP analysis by collecting data to represent all habitat types and reanalyze current and future conditions based on changes in individual habitat parameters. This re-analysis could be completed during the preconstruction engineering and design (PED) phase of the project.

Subsequent to the decision to implement Option 1, consultation under the Endangered Species Act was reinitiated and concluded with NOAA Fisheries and the U.S. Fish and Wildlife Service. Through this consultation process, the acreage of habitats impacted by the project was reduced further from that reported in the 1999 Final IFR/EIS, Addendum to the Wildlife Mitigation Plan. Currently, 172 acres of agricultural land, 50 acres of riparian forest and 16 acres of wetland habitat are anticipated to be impacted by project-related actions versus 200 agricultural, 67 riparian forest and 20 wetland acres reported in the1999 FIFR/EIS, Addendum to the Wildlife Mitigation Plan. In other words, the revisions made during consultation resulted in a 28 acre reduction in impact to agricultural habitat, a 17 acre reduction in impact to riparian forest habitat, and a 4 acre reduction in impact to wetland habitat.

Further discussions have been held with WDFW and WDOE to resolve their concerns pertaining to the Wildlife Mitigation Plan. To attain a more natural hydrology to the Woodland Bottoms wetland mitigation acreage, the Corps has proposed to remove the levees along Burris Creek that bisects these wetlands to allow natural flooding over the landscape to occur. To resolve Cowlitz County concerns regarding their Shoreline Master Program, it is now proposed to develop approximately 16 acres of tidal marsh habitat in the 32 acre Martin Island lagoon. An 80-acre site on Martin Island, proposed for upland disposal purposes in the 1998 DIFR/EIS would not be developed for mitigation purposes. As a result of these discussions, the Corps has refined the mitigation proposal as described above, and will not be performing the re-analysis previously contemplated.

The present mitigation proposal would see development of 132 acres of agricultural pastureland, 43 acres of riparian forest and 97 acres of wetland habitat at Woodland Bottoms, Washington; 159 acres of riparian forest and 23 acres of wetland habitat would be developed at Martin Island, Washington; and 74 acres of wetland habitat would be developed at Webb, near Westport, Oregon. Wildlife mitigation efforts to develop or enhance wildlife habitat will result in the physical alteration or improved management practices on 528 acres of the 740 acres authorized for wildlife mitigation purposes. Totals thus are 132 acres of agricultural pastureland, 202 acres of riparian forest and 194 acres of wetland habitat. The balance of the 740 acres of the real property acquired for mitigation purposes supports existing habitat, infrastructure (both existing and for mitigation features), or else is undevelopable for mitigation purposes.

Methods

Initial mitigation efforts focused on avoiding or minimizing impacts to wildlife habitat, to the extent practicable, during selection of dredged material disposal sites. Avoidance was accomplished by focusing disposal-siting efforts on existing and previously used disposal sites. Sites with wetland and riparian habitats or important wildlife resources were avoided to the extent practicable. Adjustment of disposal site boundaries to avoid riparian and wetland habitat, based upon site visits and review of aerial photography, also was used. Site boundaries were further adjusted and acreage decreased through the 2001 BA and during development of the Final SEIS.

The wildlife mitigation plan relied on a HEP analysis for evaluating project impacts and mitigation efforts. Detailed discussion of the HEP process as applied for this project is contained in the 1999 Final IFR/EIS, Appendix G. The HEP process used models of habitat variables for selected target species. These species-specific models are based upon habitat suitability indices for each habitat variable. The HEP process assessed both habitat quality and quantity for target species selected by the interagency mitigation team. Target species were selected as representative members of the habitats present in the areas of impact. Habitat variables important to each species, methods to measure these variables, and species models that assign suitability indices (numerical scores) to habitat variables were identified. Existing HEP models were generally used in this process, modified by the interagency team where necessary, along with development of one new model.

The HEP analysis initially focused on determination of impacts from disposal actions. Habitat quantity was determined by mapping habitat acreage for each new upland disposal site. Riparian and wetland habitat that occurred within the boundaries of existing or previously used disposal sites was included in the loss assessment phase of HEP. Habitat quality was determined by field sampling of species-specific habitat variables at representative locations. Field data were summarized and species suitability indices for individual habitat variables were then identified. Mathematical equations were then used to determine habitat suitability indices, a quality value, for each species. Multiplication of habitat quantity and habitat suitability indices on a species-specific basis provided the number of habitat units lost per species. Species losses were reported as average annual habitat units (AAHUs), which is an estimate of the average number of habitat units lost per year over the project life of 50 years.

The mitigation phase of the HEP analysis focused on determination of the level of recovery associated with proposed mitigation actions. Mitigation sites were generally selected on the basis of large tracts of land with potential for habitat development and their nearness to national wildlife refuges or state wildlife management areas. These potential sites were analyzed to determine their baseline value to wildlife and the incremental increase in wildlife habitat value that could be attained through implementation of wildlife mitigation measures.

Existing habitats at potential mitigation sites were identified and quantified to determine the baseline condition. Physical measures that could be employed at each site to develop riparian, wetland or agricultural habitat features were identified and quantified. Habitat quality for target species was determined for mitigation sites as described for disposal sites; projections for future habitat conditions were made for each habitat developed through implementation of mitigation actions. Future projections were based on field sampling of habitat variables in representative habitats and professional judgment. The accumulated information was then analyzed to determine the number of AAHUs generated at each site by the proposed mitigation measures. The Corps will collect additional field data for those habitat types where professional judgment was initially used to estimate habitat suitability indices and thus verify/correct the estimates.

Once information on project-related losses and mitigation gains were identified, a determination of the number of mitigation sites required to offset losses was determined. The selection of which mitigation sites to use was determined by cost efficiency and incremental cost analyses per output.

Results

The mitigation team placed an emphasis on mitigation actions directed toward the development of wetland and riparian forest habitats and not a simple replacement in-kind for the habitat impacted. Habitat acreage impacts identified in the subsequent text reflects changes to the Proposed and Least Cost disposal plans; these changes are also identified in Tables 1 and 2. Agricultural cropland (an upland habitat) was numerically the most impacted habitat (Proposed plan - 172 acres; Least Cost plan – 257 acres), as compared to wetland habitat (Proposed plan – 16 acres; Least Cost plan – 24 acres) and riparian forest habitat (Proposed and Least Cost – 50 acres). However, mitigating for agricultural cropland impacts was minimized in the mitigation plan for the proposed plan (132 acres to be managed as pasturelands); the plan currently calls for development or substantial improvement to 194 acres of wetland habitat and 202 acres of riparian forest habitat. The 202 acres of riparian habitat refers only to early successional riparian forest that would be developed on presently agricultural lands.

The mitigation plan for the Proposed disposal plan calls for development of 159 acres of early successional riparian forest at Martin Island and 43 acres at Woodland Bottoms. Twenty-three acres of wetland habitat, including 16 acres of intertidal emergent marsh habitat would be developed at Martin Island. Ninety-seven acres of wetlands at Woodland Bottoms and an additional 74 acres of wetlands at the Webb location would be developed. Agricultural habitat development (132 acres) would occur at Woodland Bottoms.

The emphasis placed by the mitigation team on implementation of wetland and riparian mitigation actions provided for a substantial acreage ratio for wetland mitigation compared to wetland impacts. The present ratio is approximately 12:1 when including wetland mitigation acreage in both states and 8:1 for Washington wetland mitigation acreage. It is believed that the HEP approach, in conjunction with the emphasis on wetland habitat mitigation, leads to mitigation greater in scope than if jurisdictional wetlands were determined and mitigation was based upon a predetermined ratio predicated upon the nature of the wetland mitigation action.

For wetland mitigation, the HEP process differed substantially from the standard approach used for Section 404 permit applicants. No delineation of jurisdictional wetlands was made for impacted sites (disposal locations). Nor are there established ratios for wetland mitigation efforts that depend upon whether the mitigation effort is based on wetland creation, improvement or restoration. Rather, the HEP evaluation was used to provide data on the scope of the mitigation effort. Impacts, as measured in average annual habitat units (AAHUs), were substantially more than offset by mitigation measures, also evaluated in the terms of AAHUs.

Wetland mitigation siting and implementation also differ from the in-kind, on-site mitigation normally sought under the Section 404 permit process. For the project, large blocks of mitigation acreage were sought rather than to mitigate in-kind and on-site. This mitigation approach allows for the development and/or restoration of large blocks of wildlife habitat with an interspersion of wetland and riparian habitat typically proposed. These large blocks of wetland and riparian habitat offer a more secure and diverse setting for wildlife populations.

If the mitigation approach were restricted to in-kind, on-site requirements, wetland mitigation would occur on small acreage parcels adjacent to lands subject to industrial development or intensive agricultural practices in addition to the disposal operations. Juxtaposition of other habitats such as riparian forest could not be assured. Essentially, we would form islands of habitat within an overall developed area that would lead to local extirpation of some species and reduced populations of other wetland species. Large mitigation areas with an interspersion of wetland and riparian habitats are expected to support a more diverse species assemblage and more stable population of species, including wetland-associated species.

Comments received regarding disposal sites in the 1998 Draft IFR/EIS prompted the Corps and project sponsors to remove several of them from further consideration and add alternate disposal sites for the mitigation plan presented in the 1999 Final IFR/EIS. The 2001 Biological Assessment resulted in additional modifications to disposal sites resulting in reduced impacts to wildlife habitats, particularly riparian forest. Table 1 shows the Proposed disposal plan, as currently configured (i.e., including changes made during the 2001 Biological Assessment process), and the habitat acreage by category for each disposal site. For comparative purposes, the revised least cost disposal plan, as currently configured, is shown in Table 2.

Changes made between the Draft and Final IFR/EIS are as follows. The Morse Brother's Pit (O-80.0) and Peavey Oval (W-73.5) disposal sites were dropped from the plan. The Washington Departments of Fish and Wildlife and Ecology raised concerns that mitigation actions would be required for disposal at Peavy Oval. Disposal sites added to the Proposed plan include W-71.9, W-67.5 and W-33.4. Site W-71.9 (27 acres) and a 12-acre addition to the Cottonwood Island site (for 62 total acres) are proposed to offset the loss of Peavy Oval for disposal purposes.

Changes made during the 2001 Biological Assessment process are as follows. The Mt. Solo disposal site (W-62.0) has been changed in configuration and reduced in acreage (50 to 46.6 acres) in order to avoid more wetland habitat and to meet 2001 BA requirements for a 300-foot setback from ordinary high water. The Gateway 3 (W-101.0) site has been reduced from 69 to 40 acres. The Lord Island disposal site (O-63.5) was reduced from 46 acres to 25 acres, thus avoiding impacts to 17 acres of riparian forest habitat.

As currently configured, the Proposed disposal plan substantially reduces the mitigation requirements compared to the least cost plan because the Proposed disposal plan impacts substantially fewer habitat acres, e.g., 172 acres (Proposed) versus 257 acres (least cost) of agricultural cropland impacts; 50 acres (Proposed) versus 67 acres (least cost) of riparian forest impacts; and 16 acres (Proposed) versus 24 acres (least cost) of wetland habitat impacts. As shown in Table 3, the estimated loss of average annual habitat units (AAHUs) for the Proposed plan (as configured in the 1999 Final IFR/EIS) is 445 AAHUs; losses for the least cost plan (as configured in the 1999 Final IFR/EIS) are estimated at 659 AAHUs. While here loss estimates do not reflect the changes to the Proposed and least cost plans developed as a result of the 2001 Biological Assessment process, all of these changes resulted in <u>reductions</u> in habitat impacts. Specifically, the proposed and least cost plans as currently configured result in a 28-acre reduction in impacts to agricultural habitat, a 17-acre reduction in impact to riparian forest habitat, and a 4-acre reduction in impact to wetland habitat.

The mitigation package for the Proposed disposal plan would be a "balanced" mitigation plan to the extent practicable, with an effort to distribute mitigation actions equitably between Oregon and Washington based upon project-associated losses for each state. Currently, the balanced mitigation plan consists of Martin Island and Woodland Bottoms in Washington and the Webb location in Oregon. This balanced mitigation plan would produce an estimated 608 AAHUs versus a projected loss of 445 AAHUs (Table 3).

The final mitigation plan for the least cost disposal plan would also be comparable to the "balanced" mitigation plan presented for the Proposed plan, except that the mitigation acreage would be increased at the Webb location to 146.5 acres. This mitigation plan would produce an estimated 758 AAHUs versus a projected loss of 659 AAHUs (Table 3).

As noted above, to resolve Cowlitz County concerns regarding their Shoreline Master Program, and after consulting with other members of the interagency team, it is now proposed to develop approximately 16 acres of tidal marsh habitat in the 32 acre Martin Island lagoon rather than the 32 acres initially proposed and evaluated in the 1999 HEP analysis. However, given the substantial reduction in habitat impacts since the 1999 analysis (discussed above) and the already large surplus in AAHUs provided by the mitigation proposal, this change does not alter the conclusion that the mitigation proposed more than compensates for the projected impacts.

Table 1. Habitat Composition and Acreage for the Proposed Disposal Plan as Currently Configured (Final SEIS)

Disposal Site*	Site Acres	Agriculture Cropland (acres)	Wetland (acres)	Riparian (acres)	Existing Dredged Material (acres)	Other Houses, Roads, etc. (acres)
Reach 1 – Columbia River miles 98 to 105						
O-105 W. Hayden Is.	102	0	0	0	102	0
W-101 Gateway 3	40	40	0	0	0	0
Reach 2 – Columbia River miles 84 to 98						
W-97.1 Fazio S&G	27	0	0	0	27	0
W-96.9 Adjacent Fazio	17	8.2	0	0	8.8	0
O-91.5 Lonestar	45	0	0	0	0	45
O-87.8 RR Corridor	12	0	0	0	12	0
W-86.5 Austin Point	26	0	0	3.4	22.6	0
O-86.2 Sand Island	28	0	0	0	28	0
Reach 3 – Columbia River miles 70 to 84						
O-82.6 Reichold	49	0	0	0	49	0
W-82.0 Martin Bar	32	0	0	2.9	29.1	0
W-80.0 Martin Mitig.	16	0	0	0	0	16
O-77.0 Deer Island	28.8	0	0	0	28.8	0
O-75.8 Sandy Is.	30	0	0	0	30	0
W-71.9	27	0	0	0	27	0
W-70.1 Cottonwood Is.	62	0	0	6.2	55.8	0
Reach 4 – Columbia River miles 56 to 70						
W-68.7 Howard Is.	200	0	0	20	180	0
W-67.5 International	29	0	0	0	29	0
O-67.0 Rainier Beach	52	0	0	0	52	0
O-64.8 Rainier Indus.	53	0	0	8.2	44.8	0
O-63.5 Lord Is. Upstrm	24.8	0	0	0	24.8	0
W-63.5 Reynolds Alum	13	0	0	0	13	0
W-62.0 Mt. Solo	46.6	35.8	10.8	0	0	0
W-59.7 Hump Is.	69	0	0	7	62	0
O-57.0 Crims Is.	46	0	0	0	46	0
Reach 5 – Columbia River miles 41 to 56						
O-54.0 Port Westward 1	50	0	0	0	50	0
W-46.3 & W-46.0 Brown Island	72	0	0	0	72	0
W-44.0 Puget Island	100	88.2	5.4	2.6	0	3.8
O-42.9 James River	53	0	0	0	53	0
Reach 6 – Columbia River miles 29 to 41						
O-38.3 Tenasillahe Is.	42	0	0	0	42	0
W-33.4 Skamokawa Pk	11	0	0	0	11	0
O-34.0 Welch Island	42	0	0	0	42	0
Reach 7 – Columbia River miles 3 to 29						
O-27.2 Pillar Rock Is.	55.6	0	0	0	55.6	0
O-23.5 Miller Sands Spt	151	0	0	0	151	0
W-21.0 Rice Island	228	0	0	0	228	0
Totals	**1879.8**	**172.2**	**16.2**	**50.3**	**1576.3**	**64.8**

* “W” and “O” refer to Washington or Oregon shoreline. The number refers to the approximate river mile in the navigation channel.

Table 2. Habitat Composition and Acreage for the Least Cost Disposal Plan as Currently Configured (Final SEIS)

Disposal Site*	Site Acres	Agriculture Cropland (acres)	Wetland (acres)	Riparian (acres)	Existing Dredged Material (acres)	Other Houses, Roads, etc. (acres)
Reach 1 – Columbia River miles 98 to 105						
O-105 W. Hayden Is.	102	0	0	0	102	0
Reach 2 – Columbia River miles 84 to 98						
W-97.1 Fazio S&G	27	0	0	0	27	0
W-96.9 Adjacent Fazio	17	8.2	0	0	8.8	0
W-95.7	25	25	0	0	0	0
O-90.6 Scappoose Dairy	107	99.3	7.7	0	0	0
O-87.8 RR Corridor	12	0	0	0	12	0
W-86.5 Austin Point	26	0	0	3.4	22.6	0
O-86.2 Sand Island	28	0	0	0	28	0
Reach 3 – Columbia River miles 70 to 84						
O-82.6 Reichold	49	0	0	0	49	0
W-82.0 Martin Bar	32	0	0	2.9	29.1	0
W-80.0 Martin Mitig.	16	0	0	0	0	16
O-77.0 Deer Island	28.8	0	0	0	28.8	0
O-75.8 Sandy Is.	30	0	0	0	30	0
W-71.9	27	0	0	0	27	0
W-70.1 Cottonwood Is.	62	0	0	6.2	55.8	0
Reach 4 – Columbia River miles 56 to 70						
W-68.7 Howard Is.	200	0	0	20	180	0
W-67.5 International	29	0	0	0	29	0
O-67.0 Rainier Beach	52	0	0	0	52	0
O-64.8 Rainier Indus.	53	0	0	8.2	44.8	0
O-63.5 Lord Is. Upstrm	24.8	0	0	0	24.8	0
W-63.5 Reynolds Alum	13	0	0	0	13	0
W-62.0 Mt. Solo	46.6	35.8	10.8	0	0	0
W-59.7 Hump Is.	69	0	0	7	62	0
O-57.0 Crims Is.	46	0	0	0	46	0
Reach 5 – Columbia River miles 41 to 56						
O-54.0 Port Westward 1	50	0	0	0	50	0
W-46.3 & W-46.0 Brown Island	72	0	0	0	72	0
W-44.0 Puget Island	100	88.2	5.4	2.6	0	3.8
O-42.9 James River	53	0	0	0	53	0
Reach 6 – Columbia River miles 29 to 41						
O-38.3 Tenasillahe Is.	42	0	0	0	42	0
O-34.0 Welch Island	42	0	0	0	42	0
Reach 7 – Columbia River miles 3 to 29						
O-27.2 Pillar Rock Is.	55.6	0	0	0	55.6	0
O-23.5 Miller Sands Spit	151	0	0	0	151	0
W-21.0 Rice Island	228	0	0	0	228	0
Totals	**1915.8**	**256.5**	**23.9**	**50.3**	**1565.3**	**19.8**

* “W” and “O” refer to Washington or Oregon shoreline. The number refers to the approximate river mile in the navigation channel.

Table 3. Site-specific Wildlife Habitat Losses for the Least Cost and Proposed Disposal Plans as Configured in 1999 Final IFR/EIS

Disposal Site	Least Cost Disposal Plan AAHU Losses	Proposed Disposal Plan AAHU Losses
Reach 1 – Columbia River miles 98 to 105		
W-101 Gateway 3		-28.7
Reach 2 – Columbia River miles 84 to 98		
W-96.9 Adjacent Fazio	-15.6	-15.6
W-95.7	-44	
O-90.6 Scappoose Dairy	-210.1	
W-86.5 Austin Point	-1.8	-1.8
Lonestar Gravel Pit		-9.6
Reach 3 – Columbia River miles 70 to 84		
W-82.0 Martin Bar	-2.1	-2.1
O-77.0 Deer Island*	-26.7	-26.7
W-70.1 Cottonwood Island	-23.6	-23.6
Reach 4 – Columbia River miles 56 to 70		
W-68.7 - Howard Is.	-22.9	-22.9
O-64.8*	-16.1	-16.1
O-63.5*	Correct-40	Correct-40
W-62.0 - Mt. Solo	-82.7	-82.7
W-59.7 - Hump Island	-49.3	-49.3
Reach 5 – Columbia River miles 41 to 56		
W-44.0 - Puget Island	-173.4	-173.4
Total Losses	**Correct-659.3**	**Correct-445.3**
Oregon Losses	Correct-292.9	Correct-92.4
Washington Losses	-366.4	-352.9

Wildlife Mitigation Locations by Site and State	AAHUs	AAHUs
Washington		
Woodland Bottoms	291.9	291.9
Martin Island	223.8	223.8
Oregon		
Webb (74 acres)		92.4
Webb (194 acres)	242	
Mitigation Total	**757.7**	**608.1**

* AAHUs = average annual habitat units
Losses in AAHUs were mathematically adjusted and a 5% contingency factor was added.

Physical Habitat Development at Wildlife Mitigation Sites

Woodland Bottoms: Agricultural, riparian forest and wetland habitat would be developed at this mitigation location. Agricultural habitat development would entail tillage of existing cropland acreage and establishment via seeding and fertilization of permanent pasture on 132 acres. Riparian forest habitat would be established on 43 acres in Woodland Bottoms. Development would occur along the Burris Creek levees, overbuilt areas of the perimeter levees and the perimeter of the mitigation site. Establishment of riparian forest would be accomplished by planting a mix of native trees, principally black cottonwood, willow species, and Oregon white ash. Wetland habitat development would be accomplished by construction of perimeter levees to contain interior drainage and overflow waters from Burris Creek. The levees along Burris Creek would be removed to the extent that soil volume removed matches material requirements for the wetland perimeter levees that would contain waters for the wetlands and maintain the existing level of flood protection as the current Burris Creek levees. The Burris Creek levees would be excavated to an elevation approximately one foot higher than the ground surface such that Burris Creek waters would be maintained in a low flow channel but would overflow the wetland habitat during freshets. This allows for a more natural hydrologic regime in the wetland habitat. An overflow structure and control structure would be incorporated into the perimeter levee at the present pump station to outlet waters during major flood events or to allow dewatering of the wetland for habitat management purposes.

Martin Island: Riparian forest development at Martin Island would occur on the lands currently in unused pastureland and in areas overtaken by blackberry. Pasturelands would be subjected to mowing, herbicide and/or tillage actions to result in bare mineral soil conditions by mid-May in the construction years. Natural seeding by established stands of riparian forest would be relied upon to establish riparian forest species on these lands. Establishment of riparian forest would be supplemented by planting a mix of native trees, principally black cottonwood, willow species, and Oregon white ash, if necessary, to achieve a viable stand. Acreage currently in blackberry thickets would be scarified of blackberries and tilled, again relying upon natural seeding and supplemental planting to establish riparian forest.

Sixteen acres of tidal marsh habitat would be developed in the Martin Island embayment or roughly 50 percent of the lagoon area. Dredged material would be placed via pipeline dredge in this area to bring the bottom elevation to within two feet of the survey elevation at which tidal marsh habitat would develop. Adjacent tidal marsh habitat would be surveyed prior to construction to establish this elevation. Topsoil, obtained during scarification of blackberry thickets on adjacent uplands, would be placed atop the sandy dredged material to complete the construction to design elevation and form a better soil substrate for tidal marsh plant establishment.

Approximately 7 acres of wetland habitat on Martin Island will be enhanced. The present design calls for excavation of approximately one foot of topsoil, to include reed canarygrass above ground vegetation plus roots and rhizomes. This excavation would allow native wetland plants in the soil seed bank to germinate and populate the improved wetland.

Webb Property: Wetland habitat development at this location would primarily consist of construction of a perimeter levee to contain interior drainage and removal of cattle grazing in order to allow wetland plant growth to occur unimpeded. Borrow material for the perimeter levee would come from lands interior to the levee to remove pasture grasses and reed canarygrass, thus providing for a wetland with variable substrate height. An overflow and water control structure would be incorporated into the perimeter levee for water level management. A pump station would also be an element of the infrastructure to assure adequate water can be provided to the wetland during low precipitation periods.

Potential Impacts

Direct

The Proposed disposal plan uses a total of 29 upland disposal sites (i.e., exclusive of shoreline disposal sites and the Lonestar gravel pit), with a total land area of 1630 acres. Material placement would range from 15 to 40 feet high over a 20-year period. The Proposed disposal plan would result in the direct loss of 172 acres of agricultural lands, 50 acres of riparian habitat, and 16 acres of wetland habitat. Wildlife mitigation actions would offset these direct habitat losses. The mitigation plan currently calls for development or substantial improvement to 194 acres of wetland habitat, 132 acres of permanent agricultural lands and 202 acres of riparian forest habitat.

Agricultural lands impacted are principally pasturelands and cereal grain/row crop fields. This habitat is probably most important to wintering waterfowl, but also provides habitat for other species depending upon crop grown, grazing pressure by cattle, management practices, and other factors. Thirty-two acres of riparian habitat losses are early successional stage riparian forest representing cottonwood trees pioneering onto dredged material disposal sites that have been idle for 10 years or more. Eight acres of riparian forest at O-64.8 are represented by cottonwood-dominated forests 25 to 50 plus years in age would be impacted by disposal. The balance of riparian habitat impacted is small inclusions of trees degraded by cattle grazing and located in otherwise agricultural settings. Wetland habitat losses occur at two locations and include wetland habitat associated with drainage ditches, land subject to row crop agriculture, and/or land grazed by livestock.

Using more upland disposal sites rather than the historic shoreline disposal practice would modify aesthetic values from primarily a rural condition to mounds of bare sand. Recreation impacts may result from increased upland disposal and may affect activities such as wildlife viewing although upland disposal sites are often isolated from development and are small in comparison to the overall landscape. Land use at new disposal sites would change land use from agricultural/open space to dredged material disposal. No cultural resources would be impacted by disposal actions.

Indirect

Indirect impacts were assessed for: a) disturbance to wildlife; and b) loss of habitat arising from port and industrial development that are project related. Regarding port and industrial development, the six sponsoring ports, in correspondence attached to the clarification letter for the 2001 BA for NOAA Fisheries, have stated on record that no port/industrial development depending upon channel deepening is foreseen. For ESA listed species, disturbance potential has been described in the original terrestrial BA, and for the 2001 BA plus the associated NOAA Fisheries and US Fish and Wildlife Service Biological Opinions (2002) and is incorporated herein by reference.

For non-ESA species, disturbance is related to location and timing of the specific project associated action. Dredging and shipping actions in the main channel or immediately adjacent open water habitat occur in an environment typically not frequented by large aggregations of wildlife. A notable exception is gull concentrations during the winter smelt run. The response of gull concentrations in open water habitat to dredging and shipping actions in the main channel is minor, brief avoidance or attraction to the ship's wake. Seals and sea lions, western grebes and other diving birds, typically dive and move short distances to avoid the vessel, and then return to their normal activities.

Upland disposal actions are site specific in nature. Only a few upland sites are anticipated to be used concurrently. Further, with disposal occurring primarily on existing or former disposal sites, few wildlife species occur at these locations and these generally at low population levels. Thus disturbance to wildlife at these locations would typically be low. Those few new upland disposal sites proposed for use are typically subject to agricultural operations and thus they generally support few wildlife species and at low population levels. An exception would be wintering waterfowl, particularly Canada geese, which may periodically congregate on these locations.

Disturbance offsite at upland dredged material disposal sites, to wildlife present in adjacent habitats, is projected to be minimal. Disposal related activities, with the potential exception of pipeline placement and removal, are restricted to the site footprint. Associated activities are repetitive in nature and consistent in manner and location, thus wildlife becomes habituated to the actions. Further, upland disposal actions are slated to occur behind berms, which once their construction is completed, will serve as a visual and to a lesser extent, a sound barrier.

Construction actions related to ecosystem restoration features will occur in a number of habitats throughout the project area. Dependent upon the feature to be implemented, these features will take from a few days to 4-plus months to complete with some features taking a number of work seasons scattered over a number of years to complete. The long-term benefits of these features far outweigh any disturbance indirectly incurred by wildlife species. For comparative purposes, such indirect disturbance would be significantly less than that incurred by wildlife resources from human intrusion throughout the project area during waterfowl hunting season or by salmon fisherman during spring and fall fishing seasons. Implementation of ecosystem monitoring and evaluation actions would result in less indirect disturbance to wildlife resources as they are less intrusive into wildlife habitats and do not entail construction activities.

Wildlife mitigation development actions will typically be of short to moderate duration (e.g. approximately 1-4 months per site) and will occur only at three locations. They will occur on lands presently subject to agricultural operations. The benefits of their implementation to wildlife resources far outweigh any short-term disturbance to wildlife associated

Cumulative

Habitat losses from past actions along the lower Columbia and Willamette Rivers have been considerable. The vast majority of these habitat losses are attributed to actions not related to the navigation channel such as diking for agricultural development or filling for urban developments. Studies conducted by Graves et. al. (1995) indicate a total loss of 51,997 acres of wetland/marsh habitat and 27,004 acres of forested wetland habitat since the 1880s. Much of the wetland loss can be attributed to the nearly 84,000 acres encompassed by diking districts and/or a 20,000 acre increase in urban development that has occurred since that time. The combination of diking, urban developments and dredged material disposal practices have essentially contributed to the narrowing of the river and reduced floodplain and floodplain habitats. Port developments and related infrastructure development such as roads and railroads have further contributed to habitat degradation.

Habitat impacts over the past 20 years have been estimated through a review of 1974, 1989 and 1996 aerial photography. This review addressed the 82 upland and/or shoreline disposal sites used for disposal during that time period. Estimates for riparian and/or wetland habitat, shallow water habitat, agricultural lands, industrial sites, existing disposal sites and areas unaffected by disposal were estimated for these 82 sites. Existing disposal sites accounted for an estimated 2,696 acres of the total. Impacts to riparian/wetland habitat were estimated at 898 acres. Port of Kalama industrial development actions, which used dredged material for, fill accounted for 420 acres of the riparian/wetland impacts; mitigation plans were implemented for Port of Kalama development actions. Emergency dredging actions associated with the Mt. St. Helens eruption accounted for an estimated 325 acres of the total riparian/wetland impacts and 220 acres of the total shallow water habitat impact. Impacts to shallow water were estimated at 749 acres. Miller Sands Spit accounted for about 76 acres of shallow water loss post-1975. Otherwise, shallow water impacts were scattered throughout the length of the project and involved relatively small acreage. Agricultural impacts were estimated at 50 acres of pastureland on Hayden Island. Industrial sites accounted for an estimated 114 acres and 88 acres were not impacted.

Future wetland/riparian habitat losses are expected to be reduced because of current state and federal requirements under the Clean Water Act and Endangered Species Act. New programs now in place such as habitat restoration programs by the States of Oregon and Washington, the National Estuary Program, Lower Columbia River Estuary Program and actions implemented under the Corps of Engineers Ecosystem Restoration authorities would potentially lead to restoration of large areas currently diked or filled to wetland/riparian habitat.

Agricultural lands along the lower Columbia River are incurring losses from urban and industrial development plus mining for gravel resources. Either disposal plan would contribute to the cumulative loss that is occurring presently. Clark, Cowlitz, and Wahkiakum Counties in Washington incurred an 11 percent loss (15,618 acres) in all croplands from 1987 to 1992 (U.S. Department of Commerce, 1994). The 172 acres of croplands impacted by the Proposed disposal plan would represent a minor percentage loss of cropland in those three Washington counties. The least cost disposal plan figures are 257 acres of croplands impacted and a similar minor percentage loss. Obviously, urban/industrial development has resulted in additional cropland losses since the *1992 Census of Agriculture* in those Washington counties.

Multnomah and Columbia counties in Oregon experienced a four percent decline in cropland (4,197 acres) from 1987 to 1992 (U.S. Department of Commerce, 1993). No use of new upland (farmland) disposal sites is projected if the Proposed disposal plan is implemented. The 99 acres of Oregon farmland that would be impacted under the least cost plan represent a minor incremental loss. Similar to Washington, urban/industrial development would have resulted in additional losses to croplands since the *1992 Census of Agriculture*.

Riparian forest habitat losses along the lower Columbia River have been estimated by Graves et al. (1995) and the Corps of Engineers (1996) for the period from the 1880s to 1991. An estimated 13,800 acres of riparian forest were lost during that period, principally to agricultural and urban/industrial land development. The loss of 50 acres of riparian forest associated with the Proposed or least cost disposal plan represents an increase of about one-half of one percent to the estimated cumulative loss. The remaining amount of riparian forest downstream of CRM 105.5 along the lower Columbia River is estimated at 2,240 acres. It should be noted that the riparian habitat, e.g., early successional stage riparian forest developing on old dredged material disposal sites, that mitigation is proposed for in this plan would not be currently counted in the cumulative total of riparian habitat present along the lower Columbia River.

Riparian mitigation under the Proposed disposal plan would develop and restore 202 acres of riparian habitat or 4 times the amount impacted. The wildlife mitigation actions proposed to offset disposal impacts for the least cost plan would develop 375 acres of riparian habitat. This is a nearly a seven-fold increase over projected losses from disposal actions. The net result of project-related mitigation under either disposal plan would increase the riparian habitat acreage from existing levels along the lower Columbia River.

Wetland habitat loss is estimated at 16 and 24acres for the Proposed plan and least cost plan, respectively. Historical wetland losses along the lower Columbia River have been estimated by Graves et al. (1995) and the Corps of Engineers (1996) for the period from the 1880s to 1991. An estimated 52,000 acres of wetland/marsh and 27,000 acres of forested wetlands were lost during that period. Mitigation actions for the project would restore and or develop 194 acres (Proposed plan) or 236 (least cost plan) acres of wetland habitat.

These wetland mitigation acreages represent about a 12-fold increase over projected losses and would result in a net gain of wetland habitat, plus securing these sites in the public ownership, along the lower Columbia River.
Cumulative losses of wildlife along the lower Columbia River are directly related to the losses in wetland/marsh, forested wetland, and riparian habitat acres that have occurred over time.

Assessment of Impacts

Disposal of dredged material under the Proposed disposal plan would adversely affect additional upland areas, including 172 acres of agricultural lands, 50 acres of riparian woodlands, and 16 acres of wetlands. These habitat losses would be offset through mitigation actions. The mitigation plan currently calls for development or substantial improvement to 194 acres of wetland habitat and 202 acres of riparian forest habitat plus provision of 132 acres of agricultural pastureland.

Action Plan

The final mitigation plan will be refined in the PED phase. The specific location of structural features and their design detail will be completed. Material quantity requirements for setback levees at Woodland Bottoms will be balanced with borrow requirements from the levees currently encompassing Burris Creek at the Woodland Bottoms mitigation site.

Wetland and riparian habitat development will be the emphasis of mitigation actions as recommended by the interagency team. The Corps' goal will be to develop wetland, riparian, or agricultural (pastureland) habitat acreage to the extent identified at the individual mitigation sites. The Corps' objective will be to replace, overall, the amount of average annual habitat units identified as lost due to project implementation, recognizing that tradeoffs among target species will occur. Focusing mitigation actions on wetland and riparian habitat will lead to tradeoffs among target species. Riparian and wetland oriented target species would be favored over other target species, such as Canada geese, that are more agricultural oriented.

Surveys, design, and construction scenarios including vegetation plantings will be further developed during the PED phase. Engineering analyses will take into account site topography and hydrology; project features will be designed to account for or take advantage of these features. Property boundaries and established infrastructure, such as roads and utilities, will influence individual site development. Mitigation plans and specifications will be prepared and will be suitable for construction bidding and implementation.

Contingency factors have been built in to Corps cost estimates. No specific contingency plans will be developed for individual mitigation sites. Adjustments in the overall mitigation plan will occur if individual sites are not available. It is anticipated that these adjustments will reflect selection of the next incrementally justified site(s) on the basis of cost per wildlife habitat unit that meets the mitigation requirement and provides for a balanced mitigation effort between the states.

In the event Martin Island is acquired in its entirety, the Corps would be agreeable to discussing additional actions on the 80-acre parcel currently not included in the HEP analysis. If the entire balance of the island is not available and additional mitigation is required the Corps would intend to develop additional mitigation acreage on the Webb Site.

Means to establish vegetation on mitigation sites will rely on natural establishment to the extent practicable. Where seeding and/or planting of cuttings, plugs, trees, shrubs or other propagules are necessary, that methodology will be employed. Monitoring and operation and maintenance plans for mitigation habitats were presented in the draft plan (1999 Final IFR/EIS, Appendix G). These plans will be reviewed with the interagency team during the PED phase and revised as necessary.

Operation and maintenance plans identify those actions necessary to maintain developed habitats and site infrastructure at individual mitigation sites. Non-native and invasive plants such as blackberry and reed canarygrass can be expected to occur on mitigation sites. Their presence will be managed to the extent practicable, but as on national wildlife refuges and state wildlife management areas, there will be a presence of these plants on the landscape. Monitoring efforts to assess attainment of HEP objectives will be conducted periodically over the first 10 years of the mitigation sites. Thereafter, such assessments will be solely the responsibility of the land manager.

Implementation of mitigation actions will occur concurrently with construction of channel improvements. The Corps will seek to complete mitigation site construction in 2 years, which matches the project construction schedule.

References

Graves, J.K., J.A. Christy, and P.J. Clinton. 1995. Historic Habitats of the Lower Columbia River. Columbia River Estuary Study Task Force, Astoria, Oregon. 10 pp.

U.S. Army Corps of Engineers. 1996. Lower Columbia River Bi-State Water Quality Program - Fish, Wildlife and Wetlands GIS Habitat Mapping. Prepared for the Oregon Department of Environmental Quality. Portland District, Portland, Oregon.

U.S. Department of Commerce. 1993. 1992 Census of Agriculture. Part 37, Oregon State and County Data.

U.S. Department of Commerce. 1994. 1992 Census of Agriculture. Part 47, Washington State and County Data.

EXHIBIT K-6
ROYALTY FEES FOR STATE-OWNED DREDGED MATERIAL (REVISED)

Table of Contents
Exhibit K-6
Royalty Fees for State-Owned Dredged Material (Revised)
from the
Columbia River Channel Improvement Project

Royalty Fees for State-Owned Dredged Material (Revised) from the Columbia River Channel Improvement Project

Introduction

Washington and Oregon laws require that royalties be paid to the respective state for dredged material (sand) removed from the Columbia River navigation channel and subsequently used for commercial purposes. The Oregon Division of State Lands and the Washington Department of Natural Resources, who administer the sand and gravel program for their respective states, have indicated a need to be able to track the location and volume of dredging, dredged material placement at upland disposal sites, and the sale of the dredged material from the Columbia River Channel Improvement Project. These materials, such as sand taken from the Columbia River channel, are at a premium and are being used for fill material related to construction, roads, filters for city water systems, golf courses, and sand for concrete and all of its many uses.

Background

Oregon Revised Statute (ORS) 274.550 indicates that, “The removal of material from submersible and submerged lands of any navigable stream, owned by the State of Oregon, is authorized when the material is removed for channel or harbor improvement or flood control”. ORS 274.550 further specifies “No payment of royalty shall be required for the material unless it is removed from the place deposited and sold or used as an article of commerce. Before any material may be removed from the place deposited and sold or used as an article of commerce, the division shall be duly notified in writing of the intended removal and sale or use as an article of commerce and payment shall be made to the division of a royalty determined by the Division of State Lands.” Additionally, Oregon Administrative Rule, Division 14, *Rules of Administrative Procedure for Audit of Sand and Gravel Leases* (OAR 141-014-0070 to 141-014-0120) states that, “Unless otherwise specifically exempted, all material removed from state-owned submerged and submersible lands is subject to royalty if it is removed from the place deposited and sold or used as an article of commerce” (141-014-0090). The definition for article of commerce (141-014-0080) reads, “Article of Commerce is any state-owned material which is bought, sold, traded, or bartered for other good or services, or is used for a beneficial purpose and which would otherwise have to be acquired from alternate sources (such as material used for the purpose of ‘surcharging’).”

Washington State Statute, RCW 79.90.150, *Material Removed for Channel or Harbor Improvement or Flood Control - Use for Public Purpose* states that, “When gravel, rock, sand, silt or other material from any aquatic lands is removed by any public agency or under public contract for channel or harbor improvement, or flood control, use of such material may be authorized by the Department of Natural Resources for a public purpose on land owned or leased by the state or any municipality, county, or public corporation: PROVIDED, That when no public land site is available for deposit of such material, its deposit on private land with the landowner's permission is authorized and may be designated by the Department of Natural Resources to be for a public purpose. Prior to removal and use, the state agency, municipality, county, or public corporation contemplating or arranging such use shall first obtain written permission from the Department of Natural Resources. No payment of royalty shall be required for such gravel, rock, sand, silt, or other material used for such public purpose, but a charge will be made if such material is subsequently sold or used for some other purpose: PROVIDED, That the department may authorize such public agency or private landowner to dispose of such material without charge when necessary to implement disposal of material. No charge shall be required for any use of the material obtained under the provisions of this chapter when used solely on an authorized site. No charge shall be required for any use of the material obtained under the provisions of this chapter if the material is used for public purposes by local governments. Public purposes include, but are not limited to, construction and maintenance of roads, dikes, and levies. Nothing in this section shall repeal or modify the provisions of RCW 75.20.100 or eliminate the necessity of obtaining a permit for such removal from other state or federal agencies as otherwise required by law" (RCW 75.20.100 was recodified as RCW 77.55.100 pursuant to 2000 c107 §129).

For the Columbia River Channel Improvement Project, the Sponsor Ports shall be responsible for obtaining all local and state permits and/or authorizations required prior to placement of state-owned dredged materials on sites identified in the selected plan. Such authorizations include appropriate agreements with Oregon Division of State Lands and Washington Department of Natural Resources regarding placement of dredged material on public property, including port property, and subsequent use of such materials.

However, if a private property owner desires to have state-owned dredged materials deposited on their property and said property is not included in the selected plan or considered to be in the best interest of the Government, it is the property owner's responsibility to obtain all required local, state and federal permits and/or authorizations for use as a dredge material disposal site. When the property owner has fulfilled all of the aforementioned obligations, they are allowed to have state-owned dredged materials placed on their property and no royalty fee is due at this point. However, if the owner decides to sell any of the state-owned material for commercial purposes or to use it for their own benefit, such as fill to increase the value or use of the land, then a royalty payment is due to the state for the material sold or used to improve the property. The person that has dredged material placed on their property becomes responsible for the material and must meet all applicable insurance and/or bond requirements specified in the state agreements referenced herein as Attachment A and B. Should a person decide to sell the material, they must obtain approval to do so from either the Oregon Division of State Lands for Oregon property owners by obtaining a "Sand and Gravel License" or from the Washington Department of Natural Resources for Washington property owners by obtaining an "Agreement for Deposit, Sale and Use of State Owned Dredge Material".

Potential Impacts

If the location and volume of dredging, as well as the placement of dredged material at upland disposal sites, are not adequately tracked during dredging and disposal operations for the channel improvement project, Oregon and Washington revenues from royalty fees generated from the sale of dredged material could be reduced.

Assessment of Impacts

The Corps will report verified contractor data to the Oregon Division of State Lands and the Washington Department of Natural Resources (see Implementation Plan, below). Therefore, the ability to track the royalty fees paid to Washington and Oregon from the sale of dredged material should be improved.

Implementation Plan

As part of the reporting procedure for the Columbia River channel improvement project, the Corps will report verified contractor data to the Oregon Division of State Lands and the Washington Department of Natural Resources.

The Corps will meet with representatives from Oregon Division of State Lands and Washington Department of Natural Resources to draft and review construction contract language to address reporting requirements, such as dredging and disposal site locations, depths, volumes, and timeframes for removal and placement of materials, as well as other pertinent information yet to be determined jointly by the aforementioned agencies.

The aforementioned agencies will also discuss, formulate and agree upon notification procedures to transmit information from the Corps to Oregon Division of State Lands and Washington Department of Natural Resources.

References

Oregon Division of State Lands. December 12, 2000. Letter to Eric Braun, U.S. Army Corps of Engineers, Re: Columbia River Maintenance Dredging/Dredge Spoils Placement Sites.

United States Army Corps of Engineers (USACE) – Northwest Division, United States Environmental Protection Agency – Region 10, Oregon Department of Environmental Quality, Washington Department of Ecology, and Washington Department of Natural Resources, 1998. Dredged Material Evaluation Framework, Lower Columbia River Management Area.

STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES
DOUG SUTHERLAND
Commissioner of Public Lands
Olympia, Washington 98504

AGREEMENT FOR DEPOSIT, SALE, AND USE OF STATE-OWNED DREDGED MATERIAL

(For use when material is deposited on land not administered by DNR)
Sept 16, 2002 Draft
TABLE OF CONTENTS

SECTION **PAGE**

STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES
DOUG SUTHERLAND
Commissioner of Public Lands
Olympia, Washington 98504

AGREEMENT FOR DEPOSIT, SALE, AND USE
OF STATE-OWNED DREDGED MATERIAL

AGREEMENT NO. XXXXXX

THIS AGREEMENT is made by and between the STATE OF WASHINGTON, acting through the Department of Natural Resources (the "State"), and <Grantee's Name>, a <Enter> ("Grantee").

BACKGROUND

A. The U.S. Army Corps of Engineers conducts capital and maintenance dredging for public channel or harbor improvements or flood control.

B. Sediments dredged from the Columbia River (“Dredged Material”) may be deposited on public land or private land with the landowner’s permission.

C. These Dredged Materials are “valuable materials” as defined in RCW 79.90.060 and owned by the State of Washington.

D. Under RCW 79.90.150, State must authorize this deposition and subsequent use of the Dredged Material.

E. This agreement provides authorization to deposit Dredged Material on Grantee’s property and for Grantee’s use and sale of this Dredged Material.

THEREFORE, the parties agree as follows:

1. SITE AREA

The U.S. Army Corps of Engineers or its contractors will deposit Dredged Material from the Columbia River at a site designated as W- ***[[insert identification number]]*** and described in more detail in exhibit A, attached (“Site Area”).

2. TERM

This Agreement will remain in effect for as long as Dredged Material remains at the Site Area or until the Dredged Material is used or sold as provided for in this Agreement. ***[[This Agreement shall commence on _________ and will remain in effect until ________ (inclusive) for a term of 30 years.]]***

3. REPORTS

3.1 Deposition Reports. The Grantee will report annually, no later than the 1st of March of each year, the volume of Dredged Material placed within the Site Area between January 1 and December 31 of the previous year, as reported by the U.S. Army Corps of Engineers using the Technical Memorandum for Royalty Fees for State-owned Dredged Material from the Columbia River Channel Improvement Project or Columbia River channel maintenance dredging.

3.2 Sale and Use Reports. Grantee shall report to State the quantity and description of the Dredged Material used, sold, or removed from the Site Area under Sections 4 and 5, below. Unless otherwise provided in this Agreement, Grantee shall submit these reports to State within thirty (30) days of the use, sale or removal of Dredged Material from the Site Area.

4. USE FOR PUBLIC PURPOSE OR ON SITE

This section governs the use of Dredged Material for a public purpose by public entities under RCW 79.90.150 and Grantee's use of the material within the Site Area. Section 5, below, shall govern Grantee's sale of the material and Grantee's use of the material for a non public purpose at a location other than within the Site Area.

4.1 Use for Public Purpose. Any state agency, municipality, county, or public corporation ("Public Entity") may use Dredged Material for a public purpose as defined in RCW 79.90.150 ("Public Purpose") free of charge. A Public Entity shall not sell Dredged Material to another Public Entity, but may charge fees for transportation and storage. Agencies of the federal government or a Tribal governments shall not be deemed Public Entities entitled to free use of Dredged Materials under this Agreement.

4.2. Use in the Site Area. Grantee may use Dredged Material solely within the Site Area without charge subject to the provisions of Section 7 below, and in accordance with RCW 79.90.150.

4.3 Notice and Approval. Grantee shall not use or remove Dredged Material from the Site under this Section 4 without first obtaining the state's prior written verification that the proposed use or removal qualifies for free use under RCW 79.90.150. Prior to removing or using Dredged Material under this Section 4, Grantee shall notify State thirty (30) days in advance of the proposed removal or use of the Dredged Material. This notification shall include a description and volume estimate of the Dredged Material proposed for use or removal, the intended recipient if other than Grantee, and a description of the intended use. State shall verify that the proposed removal or use qualifies for free use under RCW 79.90.150 and State shall then provide Grantee written notice of this verification. If State determines the proposed use or removal is not entitled to free provided in RCW 79.90.150, then the use or removal shall be deemed a sale or off-site use and Section 5, below, shall govern. If Grantee fails to notify State and obtain the State's prior approval, then any use or sale of Dredged Material shall be deemed a sale or off-site use and Section 5, below, shall govern.

5. SALE AND OFF-SITE USE

This section governs Grantee's sale of Dredged Material. This section also governs Grantee's removal of Dredged Material from the Site Area and use for a purpose other than a Public Purpose.

5.1. Sale of Dredged Material

a. Condition of Dredged Material. State does not warrant the volume, grade, quality, merchantability, and condition of the Dredged Material or its fitness for any particular purpose.

b. Quantity of Dredged Material. Except as provided in Section 4, above, Grantee shall have the right sell **<Enter amount>** cubic yards of Dredged Material from the Site Area during the Term. Each one (1) cubic yard of Dredged Material shall be referred to as a "Unit."

c. Royalty Payment. Grantee shall pay to State a monthly Royalty Payment based upon the volume of Dredged Material sold. The Royalty Payment shall be ***[[XXcents ($0.XX) which shall be adjusted on January 31 of each calendar year, using a rate established by the State of Oregon under OAR 141-014-0120, or, if that is not available, the adjustment will be made using the most recently published Producer Price Index ("PPI") for construction sand as published by the US Department of Commerce, Bureau of Labor Statistics, or, if those are not available, as otherwise established through amendment –OR-- ________ percent (_____%)]]of the Fair Market Value ("FMV") established by State. FMV will be determined in January of each calendar year using an average of the local retail sand prices. State shall determine the average local retail sand price by calling each retail distributor selling a like product, in the county of the Site Area, then dividing the total of the prices by the number of prices received. State shall establish the Fair Market Value for each calendar year and adjust the Royalty Payment t no later than January 31 of each year, for each Unit of Dredged Material sold during that calendar year]].***

5.2 Off -Site Use. If Dredged Material is removed from the Site Area, either as raw material or as a component of some other material, and used for a purpose other than a public purpose as provided in RCW 79.90.150, then Grantee shall pay State a Royalty Payment of ***[[XXcents ($0.XX) which shall be adjusted on January 31 of each calendar year, using a rate established by the State of Oregon under OAR 141-014-0120, or, if that is not available, the adjustment will be made using the most recently published Producer Price Index ("PPI") for construction sand as published by the US Department of Commerce, Bureau of Labor Statistics, or, if those are not available, as otherwise established through amendment –OR-- ________ percent (_____%)]]of the Fair Market Value ("FMV") established by State. FMV will be determined in January of each calendar year using an average of the local retail sand prices. State shall determine the average local retail sand price by calling each retail distributor selling a like product, of the Site Area, then dividing the total of the prices by the number of prices received. State shall establish the Fair Market Value and adjust the Royalty Payment no later than January 31 of that same year, for each Unit of Dredged Material used off-site during that calendar year][*.

5.3 Notification. Grantee shall notify State at least thirty (30) days in advance of any proposed sale or off-site use under this Section 5. This notification shall describe the estimated amount of material proposed for sale or use and a description of the proposed use, if known to Grantee.

5.4. Reporting and Payment for Dredged Material Sold or Removed. Grantee shall keep accurate records and accounts of all Dredged Material sold or removed from the Site Area. Grantee shall utilize and maintain consecutively numbered load tickets to record all removal and transporting of Dredged Material from the Site. The load tickets must be prepared by a designated representative of Grantee at the Site at the time any Dredged Material is transported from the Site. The load tickets shall indicate the date of removal of Dredged Material from the Site, the specific source, the amount transported, the equipment number, the trucking or hauling firm, the operator, and the delivery point. The Grantee's designated representative shall attest to the accuracy of information on the load ticket and shall sign the load ticket. Grantee shall provide to State, on or before the fourteenth (14th) day of each month, on a form provided by State, an itemized account of the quantities of Dredged Material removed during the preceding month. At the time of providing the statement or account, Grantee shall pay to State the full amount due for the quantity of Dredged Material removed during the preceding month, computed in accordance with Subsections 5.1 or 5.2, above.

5.5 Audit. State shall be allowed to inspect and audit the books, contracts, and accounts of Grantee to determine whether or not State is being paid the full amount owed to it for the removal of Dredged Material as provided in this Agreement. If the audit discloses that Grantee has underpaid the amount due to State by two percent (2%) or more, Grantee shall pay to State, on demand, the cost of the audit. In addition, because it will be impossible to reliably determine the exact amount of Dredged Material removed but not reported, the Royalty Payment associated with any under-reported Units disclosed by an audit shall be paid to State within thirty (30) days of delivery of the audit to Grantee. Any overpayments by Grantee shall be refunded by State within ninety (90) days of delivery of the audit to Grantee.

5.6 Late Charge. If any payment is not received by State within ten (10) days of the date due, Grantee shall pay to State a late charge equal to four percent (4%) of the amount of the payment, but not less than Fifty Dollars ($50), to defray the overhead expenses of State as a result of the delay.

5.7 Interest for Past Due Payments and Other Sums Owed. If any payment is not received by State within thirty (30) days of the date due, Grantee shall, in addition to paying late charges determined under Subsection 5.6, above, pay interest on the amount outstanding at the rate of one percent (1%) per month until paid. If State advances any amount on behalf of Grantee, Grantee shall reimburse State for the amount advanced and shall pay interest on the amount advanced at the rate of one percent (1%) per month from the date State notifies Grantee of the advance.

5.8 No Counterclaim, Setoff, or Abatement of Fixed Minimum Annual Payments, Royalty Payments, and Other Sums Owed. Except as expressly provided in this Agreement, Royalty Payments and all other sums payable by Grantee pursuant to this Agreement, shall be paid without the requirement of prior notice or demand by State, and shall not be subject to any counterclaim, setoff, deduction, defense, or abatement.

6. NO ASSIGNMENT

The benefits and duties accorded the Grantee under this agreement are personal to the Grantee and shall not be assigned or transferred.

7. SALE OF SITE AREA

7.1 Prior Notification . If Grantee transfers or conveys title, possession or control of the Site Area or any portion of the Site Area ("Conveyed Site Area"), Grantee shall provide State thirty (30) days notice in advance of the transfer or conveyance. Such notice shall contain an estimation of the volume of Dredged Material remaining on the Conveyed Site Area and the identity of the entity that will receive title, possession or control of the Conveyed Site Area.

7.2 Sale to Entity not a Public Entity**.** If Grantee transfers or conveys title, possession, or control of the Conveyed Site Area to an entity other than a Public Entity, then the Dredged Material within the Site Area shall be deemed sold under section 5.1 above. Grantee shall pay to State an amount equal to the Royalty Payment as provided in Section 5.1, above.

7.3 Sale to a Public Entity. If title, possession, or control of the Conveyed Site Area is transferred or conveyed to a Public Entity, then the Grantee shall not be treated as a sale of Dredged Material so long as the receiving Public Entity enters into an Agreement for Deposit, Sale and Use of State-Owned Dredged Material for the Conveyed Site Area with State.

8. INDEMNITY and INSURANCE

8.1 Indemnity. Grantee shall indemnify, defend, and hold harmless State, its employees, officers, and agents from any and all liability (including liability arising from federal and state laws imposing liability for release hazardous waste or hazardous substances), damages (including damages to land, aquatic life, and other natural resources), expenses, causes of action, suites, claims, costs, fees (including attorneys fees), penalties, or judgments, of any nature whatsoever, arising out of the placement, deposition, use, control, or subsequent transfer or use of the Dredged Material, except as may arise solely out of the willful or negligent act of State or States elected officials, employees, or agents. To the extent that RCW 4.24.115 applies, Grantee shall not be required to indemnify, defend, and hold State harmless from States sole or concurrent negligence.

8.2 Insurance. At its own expense, Grantee shall procure and maintain during the Term of this Agreement, the insurance coverages and limits described in Subsections 8.2(a) and (b) below. This insurance shall be issued by an insurance company or companies admitted and licensed by the Insurance Commissioner to do business in the State of Washington. Insurers must have a rating of B+ or better by "Best's Insurance Reports," or a comparable rating by another rating company acceptable to State. If non-admitted or non-rated carriers are used, the policies must comply with Chapter 48.15 RCW.

(a) Types of Required Insurance.

(1) Commercial General Liability Insurance. Grantee shall procure and maintain Commercial General Liability insurance and, if applicable, Marina Operators

Legal Liability insurance covering claims for bodily injury, personal injury, or property damage arising on the Property and/or arising out of Grantee's operations. If necessary, commercial umbrella insurance covering claims for these risks shall be procured and maintained. Insurance must include liability coverage with limits not less than those specified below:

Description	
Each Occurrence	$ 1,000,000.00
General Aggregate Limit	$ 1,000,000.00

State may impose changes in the limits of liability:

(i) Upon a material change in the condition of the Property or any improvements; or,

(ii) Upon a change in the Permitted Use.

New or modified insurance coverage shall be in place within thirty (30) days after changes in the limits of liability are required by State.

(2) Worker's Compensation/Employer=s Liability Insurance. Grantee shall procure and maintain:

(i) State of Washington Worker's Compensation coverage, as applicable, with respect to any work by Grantee's employees on or about the Property and on any improvements;

(ii) Employers Liability or "Stop Gap" insurance coverage with limits not less than those specified below. Insurance must include bodily injury coverage with limits not less than those specified below:

By Accident	Each Employee By Disease	Policy Limit By Disease
$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00

(iii) Longshore and Harbor Worker's Act and Jones Act coverage, as applicable, with respect to any work by Grantee's employees on or about the Property and on any improvements.

(3) Business Auto Policy Insurance. As applicable, Grantee shall procure and maintain a business auto policy. The insurance must include liability coverage with limits not less than those specified below:

Description	Each Accident
Bodily Injury and Property Damage	$1,000,000

(b) Terms of Insurance. The policies required under Subsection 8.2 shall name the State of Washington, Department of Natural Resources as an additional insured (except for State of Washington Worker's Compensation coverage, and Federal Jones' Act and Longshore and Harbor Worker's Act coverages). Furthermore, all policies of insurance described in Subsection 8.2 shall meet the following requirements:

(1) Policies shall be written as primary policies not contributing with and not in excess of coverage that State may carry;

(2) Policies shall expressly provide that such insurance may not be canceled or non-renewed with respect to State except upon forty-five (45) days prior written notice from the insurance company to State;

(3) To the extent of State's insurable interest, property coverage shall expressly provide that all proceeds shall be paid jointly to State and Grantee;

(4) All liability policies must provide coverage on an occurrence basis; and

(5) Liability policies shall not include exclusions for cross liability.

(c) Proof of Insurance. Grantee shall furnish evidence of insurance in the form of a Certificate of Insurance satisfactory to the State accompanied by a checklist of coverages provided by State, executed by a duly authorized representative of each insurer showing compliance with the insurance requirements described in section 8, and, if requested, copies of policies to State. The Certificate of Insurance shall reference the State of Washington, Department of Natural Resources and the lease number. Receipt of such certificates or policies by State does not constitute approval by State of the terms of such policies. Grantee acknowledges that the coverage requirements set forth herein are the minimum limits of insurance the Grantee must purchase to enter into this agreement. These limits may not be sufficient to cover all liability losses and related claim settlement expenses. Purchase of these limits of coverage does not relieve the Grantee from liability for losses and settlement expenses greater than these amounts.

8.3 State's Acquisition of Insurance. If Grantee fails to procure and maintain the insurance described above within fifteen (15) days after Grantee receives a notice to comply from State, State shall have the right to procure and maintain comparable substitute insurance and to pay the premiums. Grantee shall pay to State upon demand the full amount paid by State, together with interest at the rate provided in Subsection 5.7, above, from the date of State's notice of the expenditure until Grantee's repayment.

9. NOTICE

Any notices or reports required under this agreement may be personally delivered, delivered by facsimile machine, or mailed by certified mail, return receipt requested, to the following addresses or to such other places as the parties may direct in writing from time to time:

State: DEPARTMENT OF NATURAL RESOURCES
SOUTHWEST REGION, AQUATIC COORDINATOR
PO BOX 280
CASTLE ROCK, WA 98611

Grantee:

A notice shall be deemed given and delivered upon personal delivery, upon receipt of a confirmation report if delivered by facsimile machine, or three days after being mailed as set forth above, whichever is applicable.

10. MISCELLANEOUS

10.1 Entire Agreement. This Agreement, including the exhibits and addenda, if any, contains the entire agreement of the parties. All prior and contemporaneous agreements, promises, representations and statements relating to this transaction, if any, are merged into this Agreement.

10.2 Applicable Law and Venue. This Agreement is entered into by State pursuant to the authority granted it in Chapters 79.90 to 79.96 RCW and the Constitution of the State of Washington. This Agreement shall be interpreted and construed in accordance with and shall be subject to the laws of the State of Washington. Any reference to a statute enacted by the State of Washington shall mean that statute as presently enacted or hereafter amended or superseded. Venue for any action arising out of or in connection with this Lease shall be in the Superior Court for Thurston County, Washington.

10.3 Modification. Any modification of this Lease must be in writing and signed by the parties. State shall not be bound by any oral representations or statements.

10.4 Authority. Grantee and any and all persons executing this Agreement on behalf of Grantee represent that Grantee is qualified to do business in the State of Washington, that Grantee has full right and authority to enter into this Agreement, and that each and every person signing on behalf of Grantee is authorized to do so. Upon State's request, Grantee will provide evidence satisfactory to State confirming these representations. This Agreement is entered into by State pursuant to the authority granted it in Chapters 79.90 to 79.96 RCW and the Constitution of the State of Washington.

10.5 Survival. Obligations of Grantee to be performed after the Termination Date shall not cease upon the termination of this Agreement, but shall continue as obligations until fully performed.

10.6 Headings. The headings used in this Agreement are for convenience only and in no way define, limit, or extend the scope of this Agreement or the intent of any provision.

10.7 Waiver. The waiver by State of any breach or default of any term, covenant, or condition of this Agreement shall not be deemed to be a waiver of such term, covenant, condition, or any subsequent breach or default of the same or any other term, covenant, or condition of this Agreement. State's acceptance of a Royalty Payment shall not be construed to be a waiver of any preceding or existing breach other than the failure to pay the particular Royalty Payment that was accepted.

10.8 Cumulative Remedies. The rights and remedies of State under this Agreement are cumulative and in addition to all other rights and remedies afforded to State by law or equity.

10.9 Time of Essence. TIME IS OF THE ESSENCE as to each and every provision of this Agreement.

10.10 Invalidity. If any provision of this Agreement shall prove to be invalid, void, or illegal, it shall in no way affect, impair, or invalidate any other provision of this Agreement.

10.11 Language. The word "Grantee" as used in this Agreement shall be applicable to one or more persons, as the case may be, and the singular shall include the plural, and the neuter shall include the masculine and feminine. If there is more than one Grantee, their obligations shall be joint and several. The word "persons" whenever used shall include individuals, firms, associations, and corporations.

THIS AGREEMENT requires the signature of all parties and is executed as of the date of the last signature below.

Dated: ____________________, 20___

By: ____________________________________
Title:
Address:
Phone:

STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES

Dated: ____________________, 20___

By: ____________________________________
Title: ____________________________________
Address: 1234 WADNR Drive Olympia

Standard Authorization for
Deposit of Dredged Material,
Sale, and Use
Approved as to Form by
Christa L. Thompson,
Assistant Attorney General
on August 01, 2002

CORPORATE ACKNOWLEDGMENT

STATE OF WASHINGTON)
) ss
COUNTY OF______________________)

On this _________ day of ______________________, 20___, before me personally appeared ______________________________________to me known to be the ______________________________ of the corporation that executed the within and foregoing instrument, and acknowledged said instrument to be the free and voluntary act and deed of said corporation, for the uses and purposes therein mentioned, and on oath stated that (he/she was) (they were) authorized to execute said instrument.

IN WITNESS WHEREOF, I have hereunto set my hand and affixed my official seal the day and year first above written.

____
Notary Public in and for the State of
______________ residing at ____________.

My appointment expires _______________.

STATE ACKNOWLEDGMENT (Region Mgr.)

STATE OF WASHINGTON)
)ss
County of)

On this _________ day of ________________________, 20___, personally appeared before me ____, to me known to be the ____________________ Region Manager of the Department of Natural Resources, State of Washington, who executed the within and foregoing instrument on behalf of the State of Washington, and acknowledged said instrument to be the free and voluntary act and deed of the State of Washington for the uses and purposes therein mentioned, and on oath stated that [he/she] was authorized to execute said instrument and that the seal affixed is the official seal of the Commissioner of Public Lands for the State of Washington.

IN WITNESS WHEREOF, I have hereunto set my hand and seal the day and year first above written.

____
Notary Public in and for the State of
Washington, residing at _________________.

My appointment expires ________________.

STATE OF OREGON
DIVISION OF STATE LANDS
DREDGE SPOILS EXCLUSIVE LICENSE

SG-INSERT NUMBER

1. PARTIES

The parties to this License are the STATE OF OREGON, acting by and through the Division of State Lands, ("STATE") and INSERT NAME, ("LICENSEE")

2. DESIGNATED REMOVAL SITE

STATE, for the consideration and upon the terms and conditions herein mentioned, does hereby authorize the LICENSEE to remove state-owned sand and silt (dredge spoils) from the following described property:

INSERT LEGAL DESCREPTION
(check page breaks and page #'s)

hereinafter referred to as the Removal Site.

3. LAND OWNER PERMISSION

If the above described lands are not owned by the State of Oregon, the LICENSEE must provide STATE with written permission from the owner to enter upon said lands prior to any removal.

4. PURPOSE

LICENSEE shall have the EXCLUSIVE right to remove dredge spoils from the Removal Site. Removal shall be undertaken in an environmentally appropriate manner, and as stipulated by the terms and conditions of this License.

5. TERM

Subject to compliance with the terms and provisions of this License, the LICENSEE shall be authorized to remove dredge spoils from the Removal Site from INSERT DATE through INSERT DATE.

6. ROYALTIES

a. LICENSEE shall pay a royalty of INSERT $$ AMT cents per cubic yard or INSERT $$ AMT cents per ton for all dredge spoils taken from the Removal Site. STATE reserves the right to redetermine and adjust the royalty rates, in accordance with royalty rates, established by the Land Board.
b. For determining royalty rate per ton, the weight of a cubic yard of dredge spoils is N/A pounds as determined by OAR 141-14-115, and may be adjusted only in accordance with that rule as now in effect or as hereafter amended.

7. PAYMENT

LICENSEE shall make full payment of any royalties due to STATE as herein provided within twenty (20) days after the end of any calendar month in which dredge spoils are removed, and shall provide with such payment a certified true and correct written statement of LICENSEE, on a form provided by STATE, showing the volume of dredge spoils removed. If no dredge spoils are removed, LICENSEE shall still submit said statement, showing no dredge spoils removed. Payment shall be made to STATE at the address listed in paragraph 30, NOTICES.
Any sums due STATE as a result of an audit adjustment under paragraph 9, RECORDS AND AUDITS, shall be paid within ten (10) days of the date the audit report becomes final. Any unpaid amounts shall bear interest pursuant to paragraph 23, INTEREST ON ROYALTIES AND OTHER CHARGES.

8. BOND

LESSEE shall, prior to the issuance of this License furnish to STATE, if required, a surety bond in an amount not less than $INSERT $$ AMT (or cash deposit or certificate of deposit in an amount equal to the amount required for a surety bond, and which names the State of Oregon as co-owner) to ensure that the LICENSEE will perform in accordance with all terms and conditions of the License.

9. RECORDS AND AUDITS

LICENSEE agrees to establish an accounting system for recording and reporting amounts of dredge spoils removed from the Removal Site, and agrees to maintain this system in accordance with generally accepted principles of accounting. LICENSEE further agrees that STATE may at reasonable times and upon reasonable notice examine or audit all such records and supporting documents at

the LICENSEE's office, and that he will keep these records for a period of not less than 6 years from the latest date of removal authorized under paragraph 5 or any extension, or as destruction may be otherwise authorized by audit.
Authorized employees and agents of STATE shall have the right at all reasonable times to enter the Removal Site and/or any other location used or believed to be used for storage of removed dredge spoils to inspect, examine, survey or measure the volume of removed dredge spoils or to ensure compliance with this License, provided that the exercise of said rights shall be conducted in such a way as not to unreasonably interfere with the operations of LICENSEE.
After any such inspection, examination or survey, STATE may issue an audit report which may adjust the amount of royalty owed by LICENSEE and/or any other operational procedure that may not be in compliance with applicable rules and conditions of this License. LICENSEE shall have thirty (30) days from the date of the audit report to review and accept on object to said audit report. If LICENSEE fails to object in writing to the audit report within thirty (30) days from the date of the report, the LICENSEE shall be deemed to have accepted the report and the report shall become final without further notice to LICENSEE.
LICENSEE agrees to, and shall include in any License relating to or in connection with this License, a provision that STATE shall have the right to examine or audit the records and supporting documents of LICENSEE's subcontractors performing work in connection with this License.

10. <u>RESERVATIONS</u>

STATE expressly reserves from the operation of this License all prior and existing grants of rights of way, easements or other rights of use. It shall be the responsibility of LICENSEE to review all matters of record to ascertain the existence of any such grants. STATE further reserves the right to grant such other rights of way, easements or other rights of use as will not unreasonably interfere with the exercise of the rights and privileges herein granted to LICENSEE.

11. <u>PUBLIC RIGHTS</u>

Except as provided in paragraph 15, PUBLIC SAFETY, the rights and privileges granted under this License are subject to all valid rights of the public to engage in recreation, navigation and fishing.

12. <u>COMPLIANCE WITH LAW</u>

LICENSEE shall comply with all applicable federal, state, and local statutes, ordinances, rules and regulations, and permits in its use of the Removal Site. This License does not give LICENSEE permission to conduct any use on the Removal Site which is not in conformance with applicable land use requirements.
LICENSEE shall use the property subject to this license only in a manner, or for such purposes, that assure fair and nondiscriminatory treatment of all persons

without respect to race, creed, color, religion, handicap, disability, age, gender or national origin.

13. TAXES, LIENS, ASSESSMENTS, CHARGES

LICENSEE shall pay as they become due all taxes which result from this License or actions taken under this License, and all assessments, penalties, fines, charges, rates or liens of any nature whatsoever that may be levied, assessed, charged, imposed or claimed on or against the Removal Site or any improvements or fixtures thereon or appurtenances thereto. If LICENSEE fails to pay any taxes, assessments, penalties, fines, charges, rates or liens which result from this License or actions taken under this License, within ten (10) days after notice that such sums are due, STATE may pay such sums. Any such sums paid by STATE shall bear interest at the maximum legal rate from the date of expenditure by STATE until repaid in full.

14. PREVENTION OF WASTE, DAMAGE AND INJURY

LICENSEE shall exercise reasonable diligence in its operation on and from said Removal Site, shall carry on all operations hereunder in a good and workmanlike manner, having due regard for public safety and the prevention of waste, and shall take all reasonable steps to avoid unnecessary damage to soil, timber, fish and fish habitat, wildlife and wildlife habitat, and water quality of both ground water and surface water; shall make all reasonable efforts to minimize interference with existing recreational activities and scenic values; shall minimize alteration to the overall pre-removal contours of the dredge spoils, and not create steep and/or unstable slopes; and shall do all things reasonably necessary to minimize erosion. LICENSEE shall not construct or install any building, fixture, or other permanent improvement on the Removal Site without express written authorization by surface owner.

15. PUBLIC SAFETY

The LICENSEE (upon obtaining written authorization from the property owner, if not the state) may restrict entry to any portion of the Removal Site as may be necessary to protect persons and property from harm arising from or in connection with the LICENSEE's activities upon the Removal Site.

16. ASSIGNMENT

The LICENSEE shall not assign this License or any interest therein without the prior written consent of STATE. STATE may, in its sole discretion, consent to an assignment if LICENSEE has satisfied all conditions of the License to that point in time, and if STATE determines the assignment to be in the best interests of the STATE. LICENSEE and its proposed assignee shall be required to complete a

standard assignment form provided by STATE and to provide assurance that the assignee has the capability to perform on the License.
Any assignment, or attempted assignment, subletting, or attempted subletting, or grant of right of use or attempted grant of right of use without such consent, shall be absolutely null and void and shall, at the option of STATE, terminate all rights of the LICENSEE under or by virtue of this License.

17. DEFAULT

The following shall be events of default:

a. Failure of LICENSEE to pay any royalty or any other charge within ten (10) days after the royalty or other charge is due.
b. Failure of LICENSEE to comply with any term or condition, or to fulfill any obligation of the License within the time allowed, after written notice by STATE specifying the nature of the default with reasonable particularity. The time allowed shall be twenty (20) days, except for defaults governed by subparagraph (a) or (c) of this paragraph, or where STATE agrees in writing to a longer period.
c. Insolvency of LICENSEE; an assignment of LICENSEE for the benefit of creditors; the filing by LICENSEE of a voluntary petition in bankruptcy; an adjudication that LICENSEE is bankrupt or the appointment of a receiver of the properties of LICENSEE; the filing of any involuntary petition of bankruptcy and the failure of LICENSEE to secure a dismissal of the petition within thirty (30) days after filing; attachment of or the levying of execution on the leasehold interest and failure of LICENSEE to secure discharge of the attachment or release of the levy of execution within ten (10) days.

18. STATE'S RIGHT TO CORRECT CONDITIONS OF DEFAULT

If LICENSEE fails to perform any obligation under the License, STATE shall have the option to do so after thirty (30) days' written notice to LICENSEE or within a time frame otherwise specified in this License. All of STATE's expenditures to correct the default shall be reimbursed by LICENSEE on demand with interest at the maximum legal rate from the date of expenditure by STATE until repaid in full.

19. TERMINATION

a. In the event of a default, the License may be terminated at the option of STATE by notice in writing to LICENSEE. If the License is terminated by option of STATE or otherwise, STATE shall be entitled to recover damages from LICENSEE for the default. If the License is terminated, LICENSEE's liability to STATE for damages shall survive such termination. LICENSEE shall have thirty (30) days after date of termination to remove all personal property and equipment from the Removal Site. Failure to remove the above items within the thirty (30) day period will be considered to be abandonment by the LICENSEE and the STATE shall take title to this property after the expiration of thirty (30) days. STATE may enter the Removal Site and remove any persons or property by legal action or by self-help with the use of reasonable force and without liability for damages.

b. In the event of termination on default, STATE shall be entitled to recover immediately, without waiting until the due date of any future payment or until the date fixed for expiration of the License term, the following amounts as damages: the reasonable costs of entry including but not limited to the cost of any clean up, removal of LICENSEE's property, or any other expense occasioned by LICENSEE's failure to quit the Removal Site upon termination and to leave it in the required condition, any restoration and/or reclamation costs, attorneys fees, court costs and advertising costs.

c. This License may also be terminated by mutual written consent of STATE and LICENSEE.

20. <u>DELIVERY OF PREMISES: SURRENDER/DEPARTURE</u>

In the event this License is terminated as herein provided or upon expiration, LICENSEE shall peaceably leave said Removal Site and surrender said License. The Removal Site shall be left insofar as possible in the same condition as that existing as of the commencement of the term of this License except as otherwise approved or ordered by STATE. Upon departure, LICENSEE shall continue to be obligated for the breach of any provision of this License occurring before or simultaneously with termination; for the performance of any restoration or reclamation required; and for the payment of all royalties, taxes, assessments, penalties, fines, charges, rates or liens of any nature accrued on or against the Removal Site, any improvements or fixtures thereon or appurtenances thereto. Departure shall not relieve LICENSEE from the indemnification required under paragraph 25, INDEMNIFICATION.

21. <u>RIGHT TO SUE MORE THAN ONCE</u>

STATE may sue periodically to recover damages during the period corresponding to the remainder of the License term and no action for damages shall bar later action for damages subsequently accruing.

22. <u>REMEDIES CUMULATIVE</u>

The foregoing remedies shall be in addition to, and shall not exclude any other remedy available to STATE under applicable law.

23. <u>INTEREST ON ROYALTIES AND OTHER CHARGES</u>

Any royalty or other sum due from LICENSEE under the terms of this License shall, if not paid within ten (10) days after it is due, bear interest at the maximum legal rate from the due date until paid.

24. <u>INSURANCE</u>

The LICENSEE, if required, agrees to maintain during the terms of this License, comprehensive or commercial general liability insurance covering personal injury and property damage, naming the STATE as additional insured. This insurance shall include contractual liability coverage for the indemnification provided under this Contract. Coverage limits shall not be less than the limits of liability set forth in the provisions of ORS 30.270(1) as now in effect or as hereafter amended. The statute currently provides that the coverage limits shall not be less than $500,000.00 combined single limit per occurrence. The insurance shall be in a form and with companies acceptable to STATE. Such insurance shall be evidenced by certificates or by copies of policies. Such evidence shall be provided to STATE prior to the commencement of any operations or activity under this Contract.

25. <u>INDEMNIFICATION</u>

LICENSEE agrees to indemnify, defend and hold STATE, its officers, employees, and agents harmless from any and all damages, claims, actions, costs and expenses arising in whole or in part out of acts or omissions related to this License. STATE shall have no liability to LICENSEE for any loss or damage caused by third parties, or by any condition of the Removal Site.

26. <u>ATTORNEY FEES</u>

If suit or action is instituted in connection with any controversy arising out of or in connection with this License, the prevailing party shall be entitled to recover all costs and disbursements incurred, including such sum as the court may adjudge reasonable as attorney fees.

27. <u>MODIFICATION</u>

This License may be changed, altered or amended only by mutual written consent of the parties.

28. <u>MERGER</u>

This License constitutes the entire agreement between the parties, and no oral statement, representation or agreement not herein expressed shall be binding upon any party.

29. EFFECT OF WAIVER

Failure of STATE to demand rigid adherence to any of the terms of this License on any occasion shall not be construed as a waiver of any of the terms of this License and such conduct shall not deprive STATE of the right thereafter to insist on strict compliance with any of the terms of this License.

30. NOTICES

Any notices required or permitted under this License shall be in writing and deemed given three (3) days after deposited, postage prepaid, in the United States mail as regular mail and directed to the address provided below or to such other address as may be specified from time to time by either of the parties in writing.

For STATE:

DIVISION OF STATE LANDS
775 Summer Street NE
Salem, OR 97301-1279

For LICENSEE:

____
Name (Print or Type)

____
Title

____
Current Mailing Address

____
City State Zip

____
Area Code Telephone Number

31. EXHIBITS

All exhibits hereto are expressly incorporated herein by reference and made a part hereof.
IN WITNESS WHEREOF the parties have executed this contract.

STATE OF OREGON
DIVISION OF STATE LANDS

____
Authorized Signature

____
Date

LICENSEE

____
Authorized Signature

____
Date

Attorney General Approved 11/98
FO\Forms\Authorization\Dredge Spoils Exclusive License.doc

EXHIBIT K-7
EVALUATION REPORT
FLOODPLAINS
(REVISED)

Table of Contents
Exhibit K-7
Evaluation Report
Floodplains (Revised)

Evaluation Report
Floodplains (Revised)

This evaluation report summarizes floodplain effects for the Proposed and Least Cost Disposal Plans. The Evaluation Report for Consistency with Local Critical Areas Ordinances (CAO) addresses in further detail floodplain effects for Washington locations. This Floodplain Evaluation Report contains all figures depicting floodplain locations for both Washington and Oregon disposal, mitigation and ecosystem restoration sites (Figures 1-17).

Proposed Plan

Nineteen of thirty-four disposal sites for the Proposed plan (Table 1, (Figures 1-17)) lie within FEMA Floodplain Designation A, e.g. within the 100-year floodplain but without a baseflood elevation determination. One of these 19 sites, Port Westward lays only partially within the FEMA "A" zone. Eight disposal locations lie within a FEMA "AE" zone where a baseflood elevation has been determined (Table 1). One of these eight sites (James River) lies partially within an AE zone and partially outside the floodplain. Nine sites lie fully (7) or partially (2) outside the 100-year floodplain (Table 1). The presence of flood control dikes accounts for 6 disposal locations that lie fully (5) or partially outside the 100-yr floodplain. The site elevation at 29 disposal sites has already been historically altered (Table 1) by dredged material placement and 11 of these locations have containment dikes already in place. Four of these 29 previously used disposal sites lie fully outside the floodplain; two previously used disposal sites lie partially outside the floodplain. Another three of the 29 are shoreline disposal sites (Miller Sands, Skamokawa and Sand Island) currently or previously used for 40' channel maintenance where disposal will not alter the topography beyond existing elevations and thus these locations will remain within the floodplain. The FEMA maps likely do not reflect the site elevation alteration that has occurred at the 25 historic disposal locations within the floodplain. The elevation alteration and/or construction of containment dikes are considered of sufficient magnitude to remove 22 (all except shoreline) of these sites from the 100-year floodplain. Letters of Map Revision (LOMR) will be provided to FEMA as detailed site-specific topographic information is obtained for those 22 disposal sites.

Five disposal sites out of the total of 34 have not historically received dredged material. Three sites (Lonestar Gravel Pit, Mt. Solo, and Puget Island) lie outside the FEMA floodplain. Fill at Gateway 3 (W-101.0) will raise the surface elevation in excess of the 100-year flood elevation and will require a LOMR to be prepared in the future. Placement of fill material at the Martin Island embayment location for wildlife mitigation purposes will not elevate the site out of the floodplain.

Wildlife Mitigation Sites

Three wildlife mitigation sites have been identified for habitat development to offset project-related impacts from implementation of either the Proposed or Least Cost Plan.

The Martin Island, Washington mitigation location lays within the FEMA "A" zone (Figure 6). The 16-acres Martin Island embayment fill, for development of tidal marsh habitat, will not raise the surface elevation above ordinary high water. No surface alteration to the remainder of Martin Island will occur that would raise the existing surface topography. Some minor excavation will occur to develop wetland and riparian forest habitat.

The Woodland Bottoms, Washington mitigation location is situated behind a flood control levee within the Cowlitz County Consolidated Diking Improvement District No. 2 and is thus not subject to flooding from the Columbia River. Minimal flooding from internal drainage may occur. The proposed wildlife mitigation features will alter flooding on a portion of the wildlife mitigation site. Levees that currently contain Burris Creek and direct it to the pumping station will be removed either partially or in full and the borrow material used to form setback levees on the perimeter of the 97 acre wetland management unit. These setback levees will afford the same level of flood protection as the levees currently controlling Burris Creek. These setback levees will allow Burris Creek to flood over the wetland management unit during freshets into an area of approximately 97 acres, resulting in a more natural hydrologic regime and effectively increasing available floodplain area. Other than the borrow of material from the levees along Burris Creek and construction of the setback levee, the topography of the Woodland Bottoms wildlife mitigation site will not be altered from the existing condition. No alteration to the FEMA floodplain designation will occur due to implementation of wildlife mitigation features at Woodland Bottoms.

The Webb, Oregon wildlife mitigation site lies within the Webb District Improvement Company near Westport, Oregon and thus behind a flood control dike. However, the FEMA Floodplain Designation for the site is AE (within the 100-year floodplain; Figure 12). A low crest elevation internal levee will be constructed at this site to aid water level management in the 74-acre wetland habitat unit that will be constructed for mitigation purposes. Borrow material for the internal levee will be obtained from within the 74-acre wetland mitigation site. Borrow sites will provide for a varied substrate topography and thus a diverse wetland plant community. No alteration to the main flood control dike or the FEMA Floodplain Designation will result from development of this wildlife mitigation feature.

Ecosystem Restoration Features

The Lois Island and Miller-Pillar ecosystem restoration features will alter the bottom topography of the Columbia River. Dredged material will be placed at these locations to an elevation appropriate for the establishment of tidal marsh habitat. Neither site will increase in elevation sufficient enough to alter their FEMA Floodplain Designation of AE –100-year floodplain (baseflood elevations determined).

The Purple Loosestrife Control Program represents an integrated pest management approach to control this exotic plant in tidal marsh habitat between CRM 18-52. No alteration to topography or the FEMA Floodplain Designation will result from implementation of this feature.

The Tenasillahe Island ecosystem restoration feature consists of three subcomponents. The Interim feature (Figure 13) entails tidegate improvements and construction of inlet channels and control structures to improve flow, circulation and juvenile salmonid access/egress to the interior channels of Tenasillahe Island. The interim feature will not change flooding proneness of Tenasillahe Island or the FEMA Floodplain Designation of AE at this location. The main flood control dike surrounding the island will remain intact and operational. The second component of this feature consists of reintroducing Columbian white-tailed deer to Cottonwood-Howard Island. There will be no topography alteration associated with this action and thus no change to the FEMA Floodplain Designation for the islands. The long-term ecosystem restoration feature at Tenasillahe Island calls for the breaching of the flood control dikes protecting the island and thus restoring the island (approximately 1,778 acres) to the river's influence and effectively increasing available floodplain area. The long-term feature will change flooding proneness of Tenasillahe Island but does not affect the FEMA Floodplain Designation of AE at this location.

The ecosystem restoration feature entitled Tidegate Retrofits is proposed for Burris Creek, Washington (Figure 6), a number of locations along Deep River, Washington (Figure 17), and for the Grizzly Slough (Figure 14), Hall Creek (Figure 14), and Tide Creek (Figure 6) locations in Oregon. Alteration of tidegates will be not result in topography alteration and thus no change to the FEMA Floodplain Designation for these locations is forecast.

The Walker-Lord and Hump-Fisher ecosystem restoration feature to improve embayment circulation (Figure 10) would result in construction of minor channels to connect the embayments to the mainstem Columbia River. The channel excavation at Hump-Fisher would take a portion of the island (approximately 2 acres) currently outside of the 100-year floodplain and return it to the floodplain thus increasing available floodplain area. The Walker-Lord component is already in the 100-year floodplain and the proposed action would not alter that FEMA designation.

The Bachelor Slough ecosystem restoration feature (Figure 4) would entail excavation of approximately 132,000 cy of material from Bachelor Slough and associated deposition of material on adjacent Bachelor Island lands plus excavation of approximately one foot of soil and overburden from 6 acres of Bachelor Slough shoreline. The disposal actions on these adjacent lands would not raise site elevation above the 100-year floodplain elevation.

The Shillapoo Lake ecosystem restoration feature (Figure 2) would entail construction of internal levees for water control purposes in the wetland management units. These internal levees would not exceed the 100-year floodplain elevation or alter the the FEMA Floodplain Designation of A – 100 year floodplain (no baseflood elevation determined).

Least Cost Plan

Nineteen of thirty-three disposal sites for the least cost disposal plan (Table 2) lie within FEMA Floodplain Designation A, e.g. within the 100-year floodplain but without a baseflood elevation determination. One of these 19 sites, Port Westward lays only partially within the FEMA "A" zone. Seven disposal locations lie within a FEMA "AE" zone where a baseflood elevation has been determined (Table 2). One of these seven sites (James River) lies partially within an AE zone and partially outside the floodplain. Nine sites lie fully (7) or partially (2) outside the 100-year floodplain (Table 2). The presence of flood control dikes accounts for 6 disposal locations that lie fully (5) or partially outside the 100-yr floodplain. The site elevation at 28 disposal sites has already been historically altered (Table 2) by dredged material placement and 11 of these locations have containment dikes already in place. Four of these 28 previously used disposal sites lie outside the floodplain; two previously used disposal sites lie partially outside the floodplain. Another two of the 28 are shoreline disposal sites (Miller Sands and Sand Island) currently or previously used for 40' channel maintenance where disposal will not alter the topography beyond existing elevations and thus these locations will remain within the floodplain.

The FEMA maps likely do not reflect the site elevation alteration that has occurred at the 22 historic disposal locations fully or partially within the floodplain. The elevation alteration and/or construction of containment dikes at these locations are considered of sufficient magnitude to remove these sites from the 100-year floodplain. Letters of Map Revision will be provided to FEMA as detailed site-specific topographic information is obtained for those 22 disposal sites. For the remaining 11 disposal sites out of the total of 33, seven sites (Scappoose Dairy, Rainier Beach, IP Rehandle, Reynolds Aluminum, Hump Island, Mt. Solo, and Puget Island) lie outside the FEMA floodplain. Two of the eleven are shoreline disposal sites (Sand Island and Miller Sands) used for 40' channel maintenance where disposal will not alter the topography beyond existing elevations and thus these locations will remain within the floodplain. The Martin Island embayment fill, for development of tidal marsh habitat, will not raise the surface elevation above ordinary high water. Fill at W-95.7 will raise the surface elevation in excess of the 100-year flood elevation and will require a LOMR to be prepared in the future.

Impacts of the wildlife mitigation sites and the ecosystem restoration sites on floodplains are the same as described above in the proposed plan.

Summary: There are three proposed disposal sites in each plan (proposed and least cost) that occur within the floodplain of the Columbia River and that are not historical disposal sites. The Martin Island embayment fill for wildlife (wetland) mitigation purposes would raise the embayments' elevation to the level of intertidal marsh habitat and would not have a significant impact on the floodplain. The proposed plan would impact 48 acres of floodplain habitat (Gateway – 40 acres; Adjacent Fazio – approximately 8 acres of 17 acre site). For the least cost plan, 33 acres of floodplain habitat (W-95.7 – 25 acres;

Adjacent Fazio – approximately 8 acres of 17 acre site) would be impacted. Use of these sites in either plan will not impact the floodplain in any substantial manner. Gateway, Adjacent Fazio and W-95.7 all occur in the Vancouver Lowlands behind flood control dikes that preclude most flood events, but not events comparable to the February 1996 flood events. Practicable alternatives for these disposal sites are not available. Diking districts, State wildlife management areas and a National Wildlife Refuge also occur in this reach of the river. To move dredged material to another upland location outside the floodplain would be impracticable due to distance, logistics, physical (geography) and economical constraints.

The proposed ecosystem restoration features and wildlife mitigation actions, including wetland mitigation, will not have a substantial impact on the floodplain either. An exception would be the Tenasillahe Island long-term (Phase 3) restoration feature, which would restore 1,778 acres of floodplain habitat to the Columbia River when implemented. This would result in a substantial gain of floodplain habitat in the lower Columbia River.

Table 1. Floodplain designation for Proposed Disposal Plan Alternative

				FEMA Floodplain Designation				
Disposal Site *	**Disposal History****	**Site Name**	**Site Acres**	**A**	**AE**	**Outside**	**Flood Control Dike Protects**	**Notes**
O-105.0	DMMS	West Hayden Island	102	X				Site elevation historically raised by dredged material deposition.
W-101.0	New	Gateway 3	40	X			X	No previous disposal.
W-97.1	DMMS	Fazio Sand & Gravel	27	X				Disposal site already has containment dike constructed around portion of perimeter. Site elevation historically raised by dredged material deposition. Resale location (active).
W-96.9	New	Adjacent Fazio	17	X				Site elevation historically raised by dredged material deposition (1/2 site nearest river).
O-91.5	New	Lonestar Gravel Pit	45			X	X	Active Gravel Pit.
O-87.8	Used	RR Corridor	12	X				Site elevation historically raised by dredged material deposition.
W-86.5	Used	Austin Point	26	X				Disposal site already has containment dike constructed around portion of perimeter. Site elevation historically raised by dredged material deposition.
O-86.2	Used	Sand Island (shoreline disposal)	28	X				Beach nourishment site for recreational use. Site elevation historically raised by dredged material deposition but remains w/in floodplain.
O-82.6	Used	Reichold	49	X				Site elevation historically raised by dredged material deposition.
W-82.0	Used	Martin Bar	32	X				Site elevation historically raised by dredged material deposition.
W-80.0	New	Martin Island Embayment	32	X				Mitigation site - emergent marsh development. Site remains subject to tidal inundation.
O-77.0	Used	Lower Deer Island	29	X				Site elevation historically raised by dredged material deposition.
O-75.8	DMMS	Sandy Island	30	X				Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
W-71.9	Used	Northport	27	X				Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition. Resale location (active).

Disposal Site *	Disposal History**		Site Acres	A	AE	Outside	Flood Control Dike Protects	Notes
W-70.1	Used	Cottonwood Island	62	X				Site elevation historically raised by dredged material deposition.
W-68.7	DMMS	Howard Island	200	X				Site elevation historically raised by dredged material deposition.
W-67.5	Used	IP Rehandle	29			X	X	Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
O-67.0	Used	Rainier Beach	52			X		Site elevation historically raised by dredged material deposition.
O64.8	Used	Rainier Indus.	53	X				Site elevation historically raised by dredged material deposition.
O-63.5	DMMS	Lord Island Upstrm.	25	X				Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
W-63.5	Used	Reynolds Aluminum	13			X		Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
W-62.0	New	Mt. Solo	47			X	X	New. No previous disposal.
W-59.7	DMMS	Hump Island	69			X		Site elevation historically raised by dredged material deposition.
O-57.0	DMMS	Crims Island	40	X				Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
O-54.0	Used	Port Westward	50	X (d/s tip)		X	X (upstream 2/3)	Site elevation, other than downstream tip historically raised by dredged material deposition.
W-46.0/ 46.3	DMMS	Brown Island	72		X			Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
W-44.0	New	Puget Island	100			X	X	New. No previous disposal.
O-42.9	DMMS	James River	53		X (southern 1/2)	X (northern 1/2)		Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
O-38.3	DMMS	Tenasillahe Island	42		X			Site elevation historically raised by dredged material deposition.
O-34.0	DMMS	Welch Island	42		X			Site elevation historically raised by dredged material deposition.
W-33.4	Used	Skamokawa	11		X			Shoreline disposal site and resale site. Site elevation historically raised by dredged material deposition.

Disposal Site *	Disposal History**		Site Acres	A	AE	Outside	Flood Control Dike Protects	Notes
O-27.2	DMMS	Pillar Rock Island	56		X			Site elevation historically raised by dredged material deposition.
O-23.5	DMMS	Miller Sands	151		X			Shoreline disposal site; erosive. Site elevation historically raised by dredged material deposition.
W-21.0	DMMS	Rice Island	228		X			Disposal site already has containment dike constructed around portion of perimeter. Site elevation historically raised by dredged material deposition.

* "W" and "O" refer to the Washington or Oregon shoreline, respectively. The number refers to the approximate river mile on the navigation channel.

** DMMS = site is in the no action alternative (existing 40-foot channel maintenance)
New = site is new for this study
Used = site previously used by Corps for disposal

Table 2. Floodplain designation for Least Cost Disposal Plan Alternative

				FEMA Floodplain Designation				
Disposal Site *	**Disposal History****	**Site Name**	**Site Acres**	**A**	**AE**	**Outside**	**Flood Control Dike Protects**	**Notes**
O-105.0	DMMS	West Hayden Island	102	X				Site elevation historically raised by dredged material deposition.
W-97.1	DMMS	Fazio Sand & Gravel	27	X				Disposal site already has containment dike constructed around portion of perimeter. Site elevation historically raised by dredged material deposition. Resale location (active).
W-96.9	New	Adjacent Fazio	17	X				Site elevation historically raised by dredged material deposition (1/2 site nearest river).
W-95.7	New		25	X			X	New. No previous disposal at this location.
O-90.6	New	Scappoose Dairy	107			X	X	New. No previous disposal at this location.
O-87.8	Used	RR Corridor	12	X				Site elevation historically raised by dredged material deposition.
W-86.5	Used	Austin Point	26	X				Disposal site already has containment dike constructed around portion of perimeter. Site elevation historically raised by dredged material deposition.
O-86.2	Used	Sand Island (shoreline disposal)	28	X				Beach nourishment site for recreational use. Site elevation historically raised by dredged material deposition but remains w/in floodplain.
O-82.6	Used	Reichold	49	X				Site elevation historically raised by dredged material deposition.
W-82.0	Used	Martin Bar	32	X				Site elevation historically raised by dredged material deposition.
W-80.0	New	Martin Island Embayment	32	X				Mitigation site - emergent marsh development. Site remains subject to tidal inundation.
O-77.0	Used	Lower Deer Island	29	X				Site elevation historically raised by dredged material deposition.
O-75.8	DMMS	Sandy Island	30	X				Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
W-71.9	Used	Northport	27	X				Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition. Resale location (active).

Disposal Site *	Disposal History**		Site Acres	A	AE	Outside	Flood Control Dike Protects	Notes
W-70.1	Used	Cottonwood Island	62	X				Site elevation historically raised by dredged material deposition.
W-68.7	DMMS	Howard Island	200	X				Site elevation historically raised by dredged material deposition.
O-67.0	Used	Rainier Beach	52			X		Site elevation historically raised by dredged material deposition.
W-67.5	Used	IP Rehandle	29			X	X	Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
O64.8	Used	Rainier Indus.	53	X				Site elevation historically raised by dredged material deposition.
O-63.5	DMMS	Lord Island Upstrm.	25	X				Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
W-63.5	Used	Reynolds Aluminum	13			X		Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
W-62.0	New	Mt. Solo	47			X	X	New. No previous disposal.
W-59.7	DMMS	Hump Island	69			X		Site elevation historically raised by dredged material deposition.
O-57.0	DMMS	Crims Island	40	X				Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
O-54.0	Used	Port Westward	50	X (d/s tip)		X	X (upstream 2/3)	Site elevation, other than downstream tip historically raised by dredged material deposition.
W-46.0/ 46.3	DMMS	Brown Island	72		X			Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
W-44.0	New	Puget Island	100			X	X	New. No previous disposal.
O-42.9	DMMS	James River	53		X (S. 1/2)	X (N. 1/2)		Disposal site already has containment dike constructed around perimeter. Site elevation historically raised by dredged material deposition.
O-38.3	DMMS	Tenasillahe Island	42		X			Site elevation historically raised by dredged material deposition.
O-34.0	DMMS	Welch Island	42		X			Site elevation historically raised by dredged material deposition.

								Site elevation historically raised by dredged material deposition.
Disposal Site *	**Disposal History****		**Site Acres**	**A**	**AE**	**Outside**	**Flood Control Dike Protects**	**Notes**
O-27.2	DMMS	Pillar Rock Island	56		X			Site elevation historically raised by dredged material deposition.
O-23.5	DMMS	Miller Sands	151		X			Site elevation historically raised by dredged material deposition.
W-21.0	DMMS	Rice Island	228		X			Disposal site already has containment dike constructed around portion of perimeter. Site elevation historically raised by dredged material deposition.

* "W" and "O" refer to the Washington or Oregon shoreline, respectively. The number refers to the approximate river mile on the navigation channel.

** DMMS = site is in the no action alternative (existing 40-foot channel maintenance)

New = site is new for this study

Used = site previously used by Corps for disposal

								Site elevation historically raised by dredged material deposition.					
								Site elevation historically raised by dredged material deposition.					
								Site elevation historically raised by dredged material deposition.					

EXHIBIT K-8

CONSISTENCY WITH CRITICAL AREAS ORDINANCES INCLUDING WETLAND MITIGATION (REVISED)

Table of Contents
Exhibit K-8
Consistency With Critical Areas Ordinances Including Wetland Mitigation Plan (Revised) And Wetland Mitigation Plan

PACIFIC INTERNATIONAL ENGINEERING PLLC

Report for the Final Supplemental Environmental Impact Statement

Consistency With Critical Areas Ordinances Including Wetland Mitigation Plan (Revised)

1. Introduction

The Columbia River Channel Improvement Project (Project) takes place within five different local jurisdictions within the state of Washington. This report reviews the Project's consistency with the Critical Areas Ordinance (CAO) of these jurisdictions. This report is prepared for purposes of complying with the Washington State Environmental Policy Act (SEPA), Chapter 43.21C RCW. The level of detail results from the extensive discussions that have occurred between the Washington Ports and state and local agencies and exceeds the amount of information typically found in a SEPA EIS.

Project activities consist of dredging in the Columbia River Federal Navigation Channel, disposal of dredged sand, wetland and wildlife mitigation activities, and ecosystem restoration features. These activities are summarized in Table 1. The CAOs typically do not cover in-water activities, such as dredging and flow-lane disposal. This analysis, therefore focuses on the "upland" disposal sites.

1.1 Wetland and Wildlife Mitigation Plan

The U.S. Army Corps of Engineers (Corps), Portland District has considered the project action area as a whole for assessing impacts to wetland and wildlife resources and their habitats and developing associated wetland and wildlife mitigation efforts. This approach is consistent with the Corps requirements to address impacts to wildlife resources arising from implementation of the Federal project. Further, the Corps' wildlife mitigation effort addresses impacts to wildlife resources in upland (including agricultural lands), riparian forest and wetland habitats rather than focusing only on wetland habitats as would occur for private development actions. An interagency team was established to assess impacts to wildlife resources and develop a mitigation plan (with representatives from the Corps, Ecology, Washington Department of Fish and Wildlife [WDFW], Oregon Dept. of Fish and Wildlife [ODFW], and U.S. Fish and Wildlife Service [USFWS]). The team used the USFWS's Habitat Evaluation Procedure (HEP) to assess wildlife impacts.

Table 1. Upland sand disposal and mitigation sites.

Disposal Site[1]	Location Name	Jurisdiction	SMA Designation	Disposal History[2]	Type of Disposal[3]	Use for Construction/ Maintenance
W-101.0	Gateway 3	City of Vancouver	Urban	New	Upland	Construction and Maintenance
W-97.1	Fazio Sand and Gravel	Clark Co.	Rural	Used 2,3, DMMS	Upland, Resale	Construction and Maintenance
W-96.9	Adjacent to Fazio	Clark Co.	Rural	New, Used 3	Upland, Resale	Maintenance
W-86.5	Austin Point	Cowlitz Co.	Urban	Used 3	Upland, Resale	Construction and Maintenance
W-82.0	Martin Bar	Cowlitz Co.	Urban	Used 3	Upland, Resale	Construction and Maintenance
W-80.0	Martin Island Disposal (Mitigation)	Cowlitz Co.	Conservancy	New	In-water	Mitigation; Construction (2yr)
W-71.9	Northport	Cowlitz Co.	Urban	Used 2, 3	Upland, Resale	Construction and Maintenance
W-70.1	Cottonwood Island	Cowlitz Co.	Urban	Used 2,3	Upland	Construction and Maintenance
W-68.7	Howard Island	Cowlitz Co.	Urban	Used 2,3, DMMS	Upland	Construction and Maintenance
W-67.5	Pt. of Longview/ International Paper	Cowlitz Co.	Urban	Used 1,2	Upland, Resale	Construction and Maintenance
W-63.5	Reynolds Aluminum	Cowlitz Co.	Urban	Used 1,2,3	Upland	Construction
W-62.0	Mt. Solo	City of Longview	Urban	New	Upland	Construction and Maintenance
W-59.7	Hump Island	Cowlitz Co.	Rural	Used 1,2,3, DMMS	Upland	Construction and Maintenance (6 yr)
W-46.3/ W-46.0	Brown Island	Wahkiakum Co.	Conservancy	Used 1,2,3, DMMS	Upland	Construction and Maintenance
W-44.0	Puget Island (Vik Prop.)	Wahkiakum Co.	Rural	New	Upland	Construction and Maintenance
W-33.4	Skamokawa	Wahkiakum Co.	Conservancy /Urban	Used 3	Shoreline, Resale	Maintenance
W-21.0	Rice Island	Wahkiakum Co.	Conservancy	Used 1,2,3, DMMS	Upland	Maintenance
Mitigation Sites						
W-81.0	Woodland Bottoms	Cowlitz Co.	Conservancy	Not Applicable (N/A)	N/A	N/A
W-80.0	Martin Island	Cowlitz Co.	Conservancy	N/A	Mitigation; see W-80.0 above	N/A
Ecosystem Restoration Features						
W-97.0	Shillapoo Lake Restoration	Clark Co.	Rural	N/A	N/A	N/A
W-91.5-87.0	Bachelor Slough Restoration	Clark Co.	Rural	N/A	Upland	Rest. Feature Construction
W-81.0	Burris Creek Tidegate Retrofit	Cowltiz Co.	Rural	N/A	N/A	N/A
W-71.5-68	Cottonwood-Howard Island Deer Reintroduction	Cowlitz Co.	Rural	N/A	N/A	N/A
W-60	Improved Embayment Circulation	Cowlitz Co.	Rural	N/A	Upland	Rest. Feature Construction
W-52-18	Purple Loosestrife Control Program	Wahkiakum Co.	Conservancy/ Natural	N/A	N/A	N/A
W-22.0	Deep River Tidegate Retrofit	Wahkiakum Co.	Conservancy/ Rural	N/A	N/A	N/A

(1) "W-xx.x" means Washington shoreline and the approximate river mile.
(2) "New" means new disposal site; "Used" means site has been previously been used by the Corps for disposal: 1 -Site used within the last 2 years, 2 - Site used within the last 10 years, 3 - Site used more than 10 years ago. DMMS—is listed in the FEIS as being included in the No Action alternative.

(*Table 1 continued*)

Disposal Site	Disposal Site (Acres)/ Habitat[4]	Site Capacity (cy)	Disposal Volume (cy)	Source Material (RM)	Existing Approx. Avg Elevation (Ft CRD)	Estimated Post-Fill Elevation if filled to capacity (Ft CRD)	Final Height (Ft)[5]
W-101.0	40 AG	2,300,000	2,300,000	95-104	21	65	44
W-97.1	27 EUD	650,000	1,200,000	94-95	10	Varies	10
W-96.9	EUD 8.8, AG 8.2; Total 17	475,000	0	--	20	Varies	0
W-86.5	EUD 22.6, RP 3.4; Total 26	1,645,000	1,700,000	88-89	15	Varies	49
W-82.0	EUD 29.1, RP 2.9; Total 32	1,500,000	760,000	81-82	25	51	26
W-80.0	WL 16[5]	550,000	460,000	78-81	–20	–8	12
W-71.9	EUD 27; Total 27	900,000	1,900,000	73-75	15	Varies	26
W-70.1	EUD-55.8, RP 6.2, Total 62	3,200,000	1,500,000	70-73	30	49	19
W-68.7	EUD 180, RP 20, Total 200	6,400,000	600,000	68-70	26	51	25
W-67.5	EUD 29; Total 29	1,000,000	2,900,000	67-68	20	Varies	27
W-63.5	EUD 13	500,000	200,000	63-64	20	Varies	30
W-62.0	AG 35.8, WL 10.8; Total 47.0	2,500,000	2,400,000	62-63	8	49	41
W-59.7	EUD 62, RP 7; Total 69	1,500,000	1,5000,000	58-59	25	42	17
W-46.3/ W-46.0	EUD 72	4,700,000	4,700,000	45-50	15	66	51
W-44.0	AG 88.2, WL 5.4, RP 2.6, Other 3.8; Total 100	3,500,000	3,300,000	43-45	15	41	27
W-33.4	EUD 11	250,000	0	--	0	Varies	Varies
W-21.0	EUD 21 (WA) EUD 207 (OR)	5,500,000	5,500,000	--	13	53	40
Mitigation Sites							
Woodland Bottoms	WL 284 (mit., not disp.)	N/A	N/A	N/A	N/A	N/A	N/A
Martin Island	WL 298-378 (mit., not disp.)	N/A	N/A	N/A	N/A	N/A	N/A
Ecosystem Restoration Features							
Shillapoo Lake Restoration	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bachelor Slough Restoration	EUD 17, NWR 29	N/A	132,000	Bachelor Slough	15	17	2
Burris Creek Tidegate	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cottonwood-Howard Island CWTD	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hump-Fisher Island	EUD 2	24,000	5,800	Old Disposal Site	25	27	2
Purple Loosestrife Control	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Deep River Tidegates	N/A	N/A	N/A	N/A	N/A	N/A	N/A

(3) Existing Conditions - AG = Agricultural Land; EUD = Existing Upland Disposal; RP = Riparian (i.e., shoreline with trees or shrubs); WL = Wetlands; NWR = National Wildlife Refuge lands

(4) In-water disposal is a component of the mitigation proposal.

(5) Difference between final elevation and existing average elevation

"Upland" means landward of the ordinary high water mark of the river; "Beach Nourishment" means below the OHWM of the river.

The HEP evaluation is a modeling tool to quantify impacts to habitat value for specific species. HEP is usually used with a limited range of habitat variables relative to a single species selected as an indicator of ecosystem health (Manlow 2002). In this case, nine target species were used to evaluate project-related impacts to wildlife resources. In order to simplify the analysis, all project impacts were considered to take place within the first year of the project (Corps 1998).

HEP is also used to measure the performance of wildlife mitigation actions, including wetland and riparian habitat restoration and development. The Corp's Wildlife Mitigation Plan was presented in Appendix G of the Final Integrated Feasibility Report and Environmental Impact Statement.

Please refer to the Final SEIS Exhibit K-5, *Wildlife and Wetland Mitigation for the Columbia Channel Improvement Project*, for a more detailed discussion.

In addition, for the purposes of SEPA and compliance with local jurisdiction CAOs and Ecology requirements for wetland mitigation, Appendix B to this report is a Wetland Mitigation Plan consistent with Ecology's *Guidelines for Preparing Freshwater Mitigation Plans and Proposals* (Ecology 1994).

2. Method

The project permitting team (PI Engineering, Anchor Environmental, Preston Gates and Ellis LLP, Ports, and Corps) met with appropriate regulatory personnel from each of the local jurisdictions to discuss permitting requirements, including the application of the local CAO and Shoreline Management Plan (SMP)[1] to project activities under their jurisdiction. The meetings, called Focus Groups, were held with individual jurisdictions (listed in Table 2) in order to ensure that every local entity had the opportunity to ask questions and provide information on their requirements regarding elements of the project occurring within their jurisdiction. The project team also had the opportunity to verify their understanding of the local CAOs and SMPs. For elements of the project that occur within a city and county, meetings with city jurisdictions took place with those of their respective counties in order to identify and clarify similarities and differences in requirements. At least one representative from Ecology attended each meeting. Focus Group meetings are listed in Table 2 below.

[1] An analysis of the application of local SMPs to the project actions within the state of Washington is contained in a separate Exhibit.

Table 2. Focus Group meetings with local jurisdictions.

Date	Jurisdiction	Representatives Present
October 24, 2001	Pacific County[a]	Mike Desimone
October 25, 2001	Wahkiakum County	Chuck Beyer Jack Tobin George Trott
		Steve McClain (Port of Wahkiakum 2)
November 20, 2001	Cowlitz County/City of Longview	Kathy Harnden (Cowlitz County)
		Robb Millspaw (City of Longview)
January 23, 2002	Clark County/City of Vancouver	Terri Brooks Brent Davis (Clark County)
		Marian Lahav Annette Griffy Rich Hines Brian Snodgrass Vicky Ridge-Cooney (City of Vancouver)

a The Focus Group meeting with Pacific County covered Shoreline Management Plan (SMP) and Coastal Zone Management Act (CZM) compliance. No upland sand disposal is proposed in Pacific County.

At the Focus Group meetings, it was determined which sections of the appropriate CAO applied to each of the sand disposal and mitigation sites. The project team checked each provision of the applicable CAO to make sure that all project activities were consistent with the requirements. In cases where activities did not meet requirements, the project was modified to bring it into compliance. The project team communicated with local jurisdiction personnel throughout the consistency analysis. This process is documented in Section 3, Results.

Focus Group meetings were also held to examine project-wide issues, some of which affect the upland sand disposal sites. These meetings were attended by the Ports, consultants, and state agency representatives. Issue-specific meetings are shown in Table 3.

During the HEP meeting on February 15, 2002, WDFW provided preliminary information about designated Priority Habitat and Species (PHS), along with management recommendations to the Corps. These recommendations are addressed for each upland disposal site in Section 3, Results.

Table 3. Focus Group meetings for project-wide issues.

Date(s)	Subject
October 25, 2001, Jan. 23, 2002, Feb. 8, 2002 June 10, 2002 Sept. 5, 2002	Crab
November 13, 2001	SEPA Compliance
November 20, 2001	Wetlands
December 2, 2001, January 30, 2002, February 25, 2002 November 6, 2002	Sediment Supply
February 6, 2002	Fish Stranding
February 7, 2002	Sturgeon/Smelt
February 15, 2002 August 30, 2002 December 2, 2002	Habitat Evaluation Procedure (HEP)

A comparative summary of local CAO requirements is in Table 4.

3. Results

3.1 City of Vancouver

One upland disposal site, Gateway 3, is located within the City of Vancouver. The City of Vancouver does not have a unified CAO. Critical areas are handled within a number of sections of the City of Vancouver Municipal Code (VMC). During a Focus Group meeting with City of Vancouver personnel, it was determined that this project should be reviewed for compliance with the applicable section of the VMC, Chapter 20.50, Wetlands Protection. As discussed below, the Project has been designed to avoid any wetland fill. A review of the FEMA 100-year floodplain map (Exhibit K-7, Figure 1) showed that the project will also need to be reviewed under Chapter 20.51, Flood Plain Combining Districts.

3.1.1 Gateway 3, RM W-101.0

Gateway 3 refers to a 40-acre portion of Parcel 3 of the Port of Vancouver's Gateway property (Appendix A, Figure 1). The land is currently used for agricultural purposes and is designated Urban in the City of Vancouver SMP. The Corps proposes to dispose of dredged sand on these 40 acres over a 20-yr period, during both the construction and maintenance phases of the project.

The 40-acre parcel currently lies at 21 ft CRD. The 2,300,000 cy of sand to be placed at the site will raise it to the level of 65 ft CRD. Sand disposal will be set back 300 ft from the river.

Applicable Requirements of the City of Vancouver Municipal Code

Flood Plain Combining Districts: The Sponsor Ports have complied with the City of Vancouver's rules in Chapter 20.51 governing Floodplain Combining Districts.

Wetlands: Wetlands on the site were delineated by JD White for the Port of Vancouver as part of their work on the SEPA EIS for the Port's Columbia Gateway development project (JD White 2001) (Appendix A, Figure 1). Following JD White's wetland delineation, the Corps revised its site plan to avoid all wetlands on the site and their designated buffers (Appendix A, Figure 1).

Wildlife: The City of Vancouver is in the process of drafting a Habitat Ordinance.

Two bald eagle nests, both within the Buckmire Slough/South Flushing bald eagle territory have been constructed in the riparian stand portion of Parcel adjacent to the Columbia River (Appendix A, Figure 2). The downstream-most nest (0453-3; Isaacs and Anthony 2001) was first reported in 1998 and was apparently blown down, along with the supporting branch in a Fall 2001 windstorm. The second nest in Parcel 3 was constructed upstream of the first nest in Fall 2001 and was occupied by the bald eagle pair in 2002. This latter nest is approximately 1,000 feet upstream of the southwest corner (nearest point) of the 40 acre disposal site.

The disposal area does not contain any riparian forest habitat. The bald eagle nest locations have been avoided in the disposal site plan and the Corps has undergone formal consultation with the USFWS. The BO issued by USFWS on December 6, 1999 permits the incidental take (harassment due to project related disturbance) of one pair (Buckmire/South Flushing territory) of bald eagles at Gateway 3. Harassment of these bald eagles would be associated with construction and O&M dredged material placement. No incursions of equipment or personnel are anticipated within 1,000 ft of the established riparian forest that supports the bald eagle nest site. The Buckmire/South Flushing pair has at least three alternate nest locations to date (Isaacs and Anthony 2001). The Corps currently funds and will continue to fund bald eagle occupancy and productivity surveys for the lower Columbia River per conditions of the DMMP and Channel Improvement BOs. These data will be used to monitor nest site placement of this pair in order to minimize disturbance at the nest site.

Table 4. Comparative summary of Critical Areas Ordinance requirements.

	Clark County	City of Vancouver
Relevant CAO	Clark County	City of Vancouver
Areas Regulated under the CAO	Critical areas are handled within the Clark County Code: Title 20 Environmental Policy Ordinance 18.327 Floodplain Combining Districts 13.29 Stormwater and Erosion Control 13.36 Wetlands Protection 13.51 Habitat Protection	Critical areas are handled within the City of Vancouver Municipal Code. Sections determined relevant to this project: Wetlands Wildlife
Riparian Requirements	Review under Habitat Ordinance required for activities within riparian priority habitat, defined as "areas extending outward from high water mark to the edge of the 100-year floodplain, or the following distances, if greater: DNR Type 1 and 2 waters 250 ft DNR Type 3 waters 200 ft DNR Type 4 and 5 waters 150 ft Approval criteria are listed in Section 3.4 of this Technical Memorandum.	Riparian areas are currently regulated under the state SMP. The City of Vancouver evaluates projects with a focus on critical values and functions. Specific questions should be directed to Vicky Ridge-Cooney.
Wetland Mitigation Requirements	Unenhanced concurrent (within 1 yr) Category 1 6:1 Category 2 3:1 Category 3 (forested) 3:1 Category 3 (scrub-shrub) 2:1 Category 3 (emergent) 1.5:1 Category 4 1.25:1 Unenhanced Pre-Development Category 1 1.5:1 Category 2 1.25:1 Category 3 1:1 Category 4 1:1 Enhanced replacement results in a 20% reduction in area for each category higher (ex., replacing 10 ac of Category 3 wetland with 8 ac of Category 2 wetland, or 6 ac of Category 1 wetland).	<u>Post-Impact</u> Category 1 6:1 Category 2 3:1 Category 3 3:1 Category 4 2:1 Category 5 1.5:1 <u>Pre-Impact</u> Category 1 1.5:1 Category 2 1.25:1 Category 3 1:1 Category 4 1:1 Category 5 1:1
Wetland Buffer Requirements	Category 1 300 ft Category 2 200 ft Category 3 100 ft Category 4 50 ft Adjusted base buffer width based on quality Type A 40% Type B 30% Type C 15% Type D 0%	Category 1 300 ft Category 2 200 ft Category 3 100 ft Category 4 50 ft Category 5 None Reduced width based on buffer quality <u>(see Municipal Code 20.50.399)</u> Quality A 40% Quality B 30% Quality C 15% Quality D None
PHS/State Listed Species	Habitat Ordinance covers areas identified by and consistent with the WDFW PHS criteria, including areas within 1,000 ft of individual species point sites.	Certain sites designated as PHS in the late 1980s were folded into the CAO.

Cowlitz County	City of Longview	Wahkiakum County
Cowlitz County	City of Longview	Wahkiakum County
Wetlands Geologic Hazards Aquifer Recharge Areas Fish and Wildlife Habitat Conservation Areas (including riparian zones) Frequently Flooded Areas.	Wetlands Geologic Hazards Aquifer Recharge Areas Fish and Wildlife Habitat Conservation Areas (including riparian zones)	Frequently Flooded Areas Geologically Hazardous Areas Aquifer Recharge Areas Wetlands Fish and Wildlife Habitat Conservation Areas (including riparian zones).
Depends on water type and stream width. Buffer zone as described in Section 13C of the CAO. In some cases, Habitat Management Plans with BAs are required (see Section 13C of CAO).	Regulated under Fish and Wildlife Habitat Conservation Areas, Sec. 17.10.120. Required setbacks: Type 1 and 2 — 250 ft Type 3, 5-20 ft wide — 200 ft Type 3, less than 5 ft wide — 150 ft Type 4 and 5, low mass wasting potential — 150 ft Type 4 and 5, high mass wasting potential — 225 ft Setbacks subject to revision at the discretion of City personnel	High Intensity Land Use: Type I & II Stream = 100 feet Type III Stream = 75 feet Type IV & V Stream = 50 feet Low Intensity Land Use: Type I, II & III Stream = 50 feet Type IV & V Stream = 25 feet **Areas Adjacent to the Columbia River:** 25 feet, provided the following three circumstances exist: (a) the land consists primarily of dredge spoils or similar degraded habitat; (b) the land lacks any significant woody vegetation (c) there are no associated wetlands present. (Sec. 21.E.4.)
Cowlitz County's classification system is explained in Section 12 of the CAO. Classification 1 Alteration prohibited unless it would maintain or improve existing functions. Classification 2 and 3 At least 1:1 replacement Classification 4 No replacement required	Category I — 6:1 Category II/III Forested — 3:1 Category II/III Shrub/scrub — 2:1 Category II/III Emergent — 1.5:1 Category IV — 1.25:1	Category I = 6:1 Category II or III (forested) = 3:1 Category II or III (scrub-shrub) =2:1 Category II or III (emergent) = 2:1 Category IV = 1.25:1
Dependent on soil type (Table 1 in CAO), and specific buffers for wetlands that provide functions and values for wildlife and fisheries (Table 2 in CAO).	Actual buffer width determined by site visit. (Min / Max) Category I — 200 / 300 Category II — 100 / 200 Category III — 50 / 100 Category IVa — 25 / 50 Category IVb — 25 / 50 There is additional information about averaging and enhancement in the CAO.	High Intensity Land Use: Category I = 200 feet Category II = 150 feet Category III = 75 feet Category IV = 50 feet Low Intensity Land Use: Category I = 150 feet Category II = 100 feet Category III = 50 feet Category IV = 25 feet
Covered in Sec. 13 of the CAO. Critical Area Fish and Wildlife Permit required for eight categories of Fish and Wildlife Habitat Conservation Areas pursuant to WAC 365-190-020(5)(b), plus unintentionally created ponds between 1 and 20 ac in size.	Covered in Sec. 17.10.120 of the CAO. Critical Area Fish and Wildlife Permit required for eight categories of Fish and Wildlife Habitat Conservation Areas pursuant to WAC 365-190-020(5)(b), plus unintentionally created ponds between 1 and 20 ac in size.	Sec. 21 of the CAO addresses WDFW Habitat Conservation areas (areas with state listed species or on PHS list). Critical Areas Permit required.

The Pacific Bald Eagle Recovery Plan (1986) established Habitat Management Goals (HMG) and Recovery Population Goals (RPG) by recovery zone for bald eagles. The Gateway 3 site lies in the Columbia Recovery Zone (RZ-10), which includes portions of both Oregon and Washington. Table 5 (repeated below) summarizes these bald eagle management goals for RZ-10 and observed results for 2001.

Table 5. Habitat Management and Recovery Population Goals

State	Habitat Management Goal[a]	Recovery Population Goal[b]	2001 Breeding Territories Surveyed	2001 Occupied Breeding Territories[c,d]
Washington	18	12	39	38
Oregon	29	19	50	48
Total	47	31	89	86

a This is the target number of breeding territories in order to ensure at least 12 occupied territories per year.
b This is the minimum number of occupied breeding territories to indicate recovering eagle population.
c Data compiled by Isaacs and Anthony (2001).
d Not all existing breeding territories are occupied in any given year.

Data compiled by Isaacs and Anthony (2001) demonstrate that the population of bald eagles in Oregon and Washington, including the RZ-10 population, are exhibiting a continued population growth. Since 1990, the RZ-10 population has expanded from 25 to 89 breeding territories surveyed and 23 to 86 territories occupied and exceeds both the established HMG and RPG. Thus, the incidental take due to harassment of the Buckmire/South Flushing pair would not significantly impact the RZ-10 population.

Sandhill cranes, a state-listed species, have been observed at the site (Manlow 2002). The distribution of sandhill cranes in this region of the Columbia River occurs throughout Sauvie Island and Scappoose Bottoms in Oregon, and the Vancouver Lowlands, Ridgefield National Wildlife Refuge and Woodland Bottoms in Washington.

A strip of riparian vegetation exists between the site and the Columbia River. The temporary pipeline to convey sand from the dredge vessel to the site will be laid over the ground where vegetation is sparse (determined by aerial photo). The pipeline is stationary during sand disposal. Any disturbance to the riparian vegetation will be temporary and minimal.

The Gateway 3 site is set back a minimum of 300 ft from OHW. The strip of riparian vegetation along the river is not included in the disposal site. The weir drainage system will have to cross the riparian zone for dredged material to reach the site and return water to reach the river. The Corps site plan shows the crossings at the most sparsely vegetated point (as identified by aerial photo), near the northernmost corner of the site (Appendix A, Figure 3).

The USFWS has provided an Incidental Take Statement for the Buckmire/South Flushing bald eagle pair (USFWS BO, December 6, 1999); therefore, no BEMP will be prepared for this location. Timing limitations will be complied with to the extent practicable and work outside the disposal site boundary near the active bald eagle nest will not be allowed during the nesting season, provided the nest site is active.

Wintering waterfowl habitat is included in the Wildlife Mitigation Plan for the Federal project at the Woodland Bottoms location (1999 Final IFR/EIS, Appendix G). Approximately 284 acres would be secured in fee title at this location for wildlife mitigation actions. The majority of this acreage would be targeted toward wetland (97 acres) or agricultural (132 acres - long-term pasture) development comparable to management actions at Ridgefield National Wildlife Refuge. These habitat management measures for long-term pasture and wetland habitat should also be suitable for supporting migrant sandhill cranes during their spring and fall stopovers in this area of the lower Columbia River. Littlefield and Ivey (2002) report the species as an opportunistic omnivore. Wetland and pasture management practices at Woodland Bottoms are expected to produce roots, bulbs, berries, earthworms, insects, amphibians, snakes, mice and greens that numerous authors (see Littlefield and Ivey 2002) have reported as constituents of the sandhill crane diet.

The proposed wildlife mitigation is consistent with the Final Washington State Sandhill Crane Recovery Plan (Littlefield and Ivey 2002). As noted above, mitigation at Woodland Bottoms will include 132 acres in long-term pasture and 97 acres in wetland habitat that will benefit sandhill cranes. The wildlife mitigation plan for the project assessed the habitat value of the W-101.0 disposal site and more than compensates for any impact to it. The wildlife mitigation plan provides for securing lands and habitat development in Woodland Bottoms which is documented by WDFW in their final sandhill crane recovery plan as lands used by this crane population.

The Corps will observe timing restrictions for specific activities as listed in the NOAA Fisheries and USFWS Biological Opinions dated May 20, 2002.

3.2 Clark County

There are two sand disposal sites in Clark County, known as Fazio and Adjacent to Fazio. There are also two Ecosystem Restoration Features, Shillapoo Lake and Bachelor Slough, within Clark County.

Clark County does not have a unified CAO. Critical areas are in the Clark County Code in Title 20, Clark County Environmental Policy Ordinance; Title 18, Zoning, Chapter 18.327, Floodplain Combining Districts; Title 13, Public Works, Chapter 13.29, Stormwater and Erosion Control Ordinance, 13.36, Wetland Protection Ordinance, and 13.51, Habitat Protection Ordinance. In the Focus Group meeting with Clark County personnel on January 23, 2002, it was determined that the following areas should be examined:

Floodplain (FP) Combining District
18.327.055:

A. Floodway area. The floodway includes the channel of a river or other watercourse and adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one (1) foot. For areas of special flood hazard studied in detail, the floodway boundary is delineated upon the Flood Insurance Study Maps. In all other areas of special flood hazard, the floodway boundary shall be determined by the use of other base flood data, as described in Section 18.327.070(C-2).

B. Floodway Fringe Area. The floodway fringe is the land area between the boundary of the floodway and the limits of the one hundred (100)-year floodplain. In those special flood hazard areas where the floodway boundary is not delineated upon Flood Insurance Study Maps, the floodway fringe area shall be determined by the use of other base flood data, as described in Section 18.327.070(C-2).

18.327.070(A): *A permit is required before construction of development begins with any area of special flood hazard established in Section 18.327.045.*

18.104.240 (From "Definitions"): *Development. The permit shall be for all structures and development as set forth in the "Definitions." "Development" includes any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation, or drilling operations. Development also includes the commencement of a new use, or the change in existing use of real estate or a structure thereon. (Sec. 3 of Ord. 1982-03-80; amended by Sec. 4 of Ord. 1990-09-04; amended by Sec. 1 of Ord. 1999-03-04)*

18.327.065 Regulation of uses in the Floodplain Combining District. *A. Relationship to Other Requirements. Land uses in the Floodplain Combining District shall be subject to all relevant local, state, or federal regulations including those of the underlying zoning district. Where applicable, permit requirements under the Shoreline Management Act*

(RCW 90.58), or the State Flood Control Zone Act (RCW 86.16) may be substituted for permits required under this chapter, provided that the standards of this chapter are applied.

Wetlands

Wetland mitigation and buffer requirements are shown in Table 4. There are no wetlands on either disposal site.

Habitat Ordinance

The following areas are subject to review under the Habitat Ordinance:

Riparian priority habitat*: Areas extending outward from high water mark to the edge of the 100-year floodplain or the following distances, if greater:*

- *DNR Type 1 and 2 waters, 250 ft*
- *DNR Type 3 waters, 200 ft*
- *DNR Type 4 and 5 waters, 150 ft.*

Clark County Code ("CCC") § 13.51.050, Table 13.51.050.

Other priority habitats and species (PHS)*: Areas identified by and consistent with the WDFW priority habitats and species criteria, including areas within 1,000 ft of individual species point sites. Id.*

Locally important habitats and species*: Areas legislatively designated by Clark County because of unusual or unique habitat warranting protection because of qualitative species diversity or habitat system health indicators, as specified in Section 13.51.055. Id.*

Projects are reviewed with respect to the approval criteria listed in Section 13.51.080 of the Clark County Code:

1. *Intent. Designated habitats are to be protected through an avoidance or reduction of most activities. This section provides standards for the review of proposed nonexempt activities within these designated areas.*
2. *Basic Criteria. Proposed activities subject to this chapter shall demonstrate that the proposal:*
   a. *Substantially maintains the level of habitat functions and values; and*
   b. *Minimizes habitat disruption or alteration beyond the extent required to undertake the proposal.*
3. *Mitigation Measures. Mitigation measures may be established pursuant to the above basic criteria. Subject to individual*

circumstances, potential mitigation measures may include, but are not limited to the following:

a. Avoiding the impact altogether by not taking a certain action or parts of an action;

b. Exploring alternative on-site locations to avoid or reduce impacts of activities;

c. Preservation of important vegetation and natural habitat features through establishment of buffers or other limitations on clearing or alteration;

d. Enhancement, restoration or replacement of vegetation or other habitat features and functions. In riparian areas, this may include buffer averaging as specified in Section 13.51.090(2)(c);

e. Managing the access to habitat areas;

f. Seasonal restriction on construction activities;

g. Implementation of best management practices;

h. Monitoring or review of impacts;

i. Establishment of performance measures or bonding;

j. Establishment of conservation covenants.

4. Clark County shall approve, approve with conditions or if necessary deny proposals based on compliance with the basic criteria and the adequacy of mitigation measures to ensure compliance, and applicable reasonable use assurances of Section 13.51.090. Clark County shall retain final authority for such determination, which shall be issued consistent with the review timelines of Chapter 18.600, and shall be based on best scientific information and analysis available within those timelines. Clark County shall consult with the Department of Fish and Wildlife and shall substantially follow resulting recommendations of WDFW, unless alternative determinations are supported by scientific analysis (Sec. 1 of Ord. 1997-05-30).

3.2.1 Shillapoo Lake, RM W-97.0

This Ecosystem Restoration Feature consists of restoring wetland and riparian habitat on lands purchased by WDFW for inclusion in their Shillapoo Lake Wildlife Management Area. Shillapoo Lake lies behind flood control dikes and currently is drained annually for agricultural use on private lands and for planting of forage crops (mainly corn) to benefit wintering waterfowl.

The proposed ecosystem restoration feature would entail construction of water supply and control structures to ultimately create a total of four diked cells for wetland habitat management purposes. Construction of two cells would not occur unless private lands are acquired. These wetland cells would be hydrologically connected to the Lake River via pipelines, a tidegate and a pumping station in order to manage water levels in the four wetland management units. This will enable WDFW to maintain desired water levels in the wetland management units for optimal habitat management.

Floodplain Combining District

The Shillapoo Lake Wildlife Area lies within the FEMA 100-year floodplain (Exhibit K-7, Figure 1). The proposed water control structures will not alter flood proneness of the floodplain, which is controlled by the existing exterior flood control dikes. Floodwater storage, during major flood events, comparable to February 1996 when the main flood control dikes were overtopped, would incur a negligible impact as borrow areas for levees should offset the fill associated with levee construction. This is consistent with the public safety objective as stated in the Clark County Code, Section 18.327.055.

Wetlands

The Shillapoo Lake site is designated wetland by WDFW. Construction of the water control structures will result in a temporary, minor disturbance to wildlife as construction would occur during summer when most wildlife resources are absent from the area and agricultural tillage and crops are ongoing actions. Operation of the completed project will enhance the wetland characteristics and enhance vegetative productivity, and therefore wildlife use, of the area.

Habitat Ordinance

Shillapoo Lake is used by wintering waterfowl, bald eagles and other raptors, wading birds, shorebirds and sandhill cranes, amongst other species. While construction of the water control structures will result in a temporary disturbance to the area when least populated by wildlife resources, the net benefit of the ecosystem restoration is expected to be significant, based on results of the HEP analysis performed in cooperation with WDFW (Corps 1998). The ecosystem restoration feature will be maintained by WDFW after construction.

Waterfowl concentrations are noted on the WDFW PHS maps for this ecosystem restoration feature (Appendix A, Figure 4). Bald eagle nest locations occur over a mile distant from the area and there are no suitable riparian or coniferous trees in the project vicinity for eagles to use for nesting purposes.

Zoning

Shillapoo Lake is zoned Rural. Restoration activities at the site are consistent with the zoning requirements.

3.2.2 Fazio Sand and Gravel, RM W-97.1

The Fazio site (Appendix A, Figure 4) is owned by Fazio Bros. Sand and Gravel and is used for their sand resale operations. The existing sand pit is surrounded by a berm and drained by a weir system that allows water to clear before it is returned to the river. Current local permits exist for the site's ongoing dredged material receipt from maintenance dredging for the 40-ft channel. Original plans for use of the site for the Channel Improvement Project included expansion of the existing sand pit. The Corps has determined that expansion of the site is not required during the first five years of the project (the two-year construction phase and the first three years of maintenance dredging).

The Fazio sand pit site covers 13.5 acres and current approximate average elevation is 10 ft CRD. The Corps plans to place 112,000 cy of sand at the site during the 2-yr construction dredging phase of the project. The mean elevation of the sand pile will vary depending upon sand resale by Fazio Bros. Sand and Gravel, with the highest elevation likely to be about 19 ft CRD.

Floodplain Combining District
The Fazio site lies within the FEMA 100-year floodplain (Exhibit K-7, Figure 2). Fazio Bros. Sand and Gravel operates their sand pit under an existing Shoreline permit and no expansion to the site is currently proposed.

Wetlands
There are no wetlands on the site.

Habitat Ordinance
Riparian vegetation was planted at the downstream end of the site as part of required mitigation for the current Shoreline permit obtained for Fazio Bros. Sand & Gravel's regular operations. This vegetation will be avoided.

The Corps disposal plan avoids the riparian vegetation as required by the current Shoreline permit for the site.

The WDFW PHS map shows the site falling within a Waterfowl Concentration overlay (Appendix A, Figure 4). The Fazio site itself is bare of vegetation, with the exception of the riparian vegetation mentioned above. The site is developed for sand and gravel mining operations and does not provide any forage or other habitat value to waterfowl.

Zoning
Clark County requires a Surface Mining Overlay to permit sand resale activities. The Fazio site is appropriately zoned.

3.2.3 Adjacent to Fazio, RM W-96.9

The Adjacent to Fazio site (Appendix A, Figure 4) has been used for disposal of dredged sand and a cattle stockyard on 8.8 acres in the past. The balance of the acreage (8.2 acres) continues to be used as a pasture for cattle. The soil of the former disposal portion of the site is unsuitable for intensive use as cropland. The Corps proposes to place sand at the site over a 20-yr period, from the maintenance phase of the project. Fazio Bros. Sand and Gravel will then resell the sand.

The Adjacent to Fazio site covers approximately 17 acres, with an average elevation of 20 ft CRD. A volume of 475,000 cy of sand placed by the Corps would raise the site to 22 ft above the surrounding area, although the crest elevation may be less depending upon resale volumes. No material is presently planned for disposal at this site.

Floodplain Combining District
The site lies within the FEMA 100-yr floodplain (Floodway Fringe Area) (Exhibit K-7, Figure 2) and a floodplain review will be required. Construction standards for flood hazard reduction apply to conventional structures such as buildings. The sand disposal site plan will be reviewed by the Planning Director for assurance that flood hazards have been minimized.

Wetlands
There are no wetlands on the site.

Habitat Ordinance
Sand disposal activities on the previously used disposal portion of the site will avoid riparian habitat that occurs along the shoreline. The riverward portion of the site has been used for sand disposal in the past, and it is of poor value for vegetation and wildlife habitat. The site is currently used as a stockyard for cattle.

The WDFW PHS map shows the site falling within a Waterfowl Concentration overlay (Appendix A, Figure 4). Canada geese occasionally use the 8.2-acre pasture portion of the site.

The project Wildlife Mitigation Plan (1999 Final IFR/EIS, Appendix G) provides for construction of 132 acres of permanent pastureland habitat at Woodland Bottoms, consistent with WDFW recommendations. This habitat will benefit Canada geese, ground-dwelling songbirds, sandhill cranes, reptiles, amphibians and other species.

Zoning
During a meeting between the Corps and Clark County, a question arose if the northernmost portion of the site extended beyond the limit of the surface mining overlay. Subsequent review has determined that there was a difference in scale between the map furnished by the Corps and the

zoning illustration furnished by Clark County. When the illustration is enlarged to match the scale of the Corps map, the Clark County overlay covers the entire Adjacent to Fazio site (Appendix A, Figure 5). When precise site mapping is available, this will be verified with Clark County. If a zone change is in fact required for a portion of the Adjacent to Fazio site, an amendment to the Comprehensive Plan will not be necessary in order to make the zoning change; however, the zoning must be complete before the County can process the Shoreline and Critical Areas Permit applications.

3.2.4 Bachelor Slough, RM W-87-91.5

Implementation of this ecosystem restoration feature is contingent on the Corps' sediment quality evaluation to determine whether material to be dredged from Bachelor Slough is suitable for dredging and/or upland disposal. The action also requires approval from WDNR and the USFWS to dispose of dredged material on their property for riparian habitat development purposes.

The restoration consists of two actions. The first action was proposed by the USFWS, Ridgefield National Wildlife Refuge. Approximately 132,000 cy of material would be dredged from Bachelor Slough to increase water depth and flow, with the result of decreasing water temperatures, which currently exceed the temperature tolerance of salmonids from mid-summer until fall. Improvements in water quality parameters are intended to benefit juvenile salmonids.

The second action involves restoring six acres of riparian habitat on the Bachelor Island shoreline of Bachelor Slough, downstream of the bridge crossing the slough, and restoration of riparian forest on the upland disposal site(s).

Floodplain Combining District
Bachelor Slough lies within the FEMA 100-year floodplain (Exhibit K-7, Figure 3). The proposed upland disposal will result in a negligible reduction in flood storage capacity on 46 acres. Restoration of riparian forest may reduce the risk of erosion from flood flows.

Wetlands
There are no wetlands present on the proposed disposal site(s). The disposal site on WDNR property adjacent to the Columbia River is an old dredged material disposal site for channel maintenance material. The two potential disposal sites on Ridgefield NWR are upland locations. One upland site is managed as a grassland (goose pasture) and the other is an old field habitat. The 6 acres of riparian forest development along the Bachelor Island shoreline of Bachelor Slough would be classified as wetland. The shoreline community is dominated by reed canarygrass and false indigo. The management prescription calls for excavation to a depth

of approximately one foot to remove roots, rhizomes and above-ground vegetation and thus prepare a seed bed for riparian vegetation establishment. Excavated material will be buried in a trench adjacent to the toe of the levee if acceptable, or at an upland location interior to the levee and on the refuge.

Habitat Ordinance
Nests in the Bachelor Island bald eagle territory occur over ½ mile to the west of the Bachelor Slough dredging activity (Isaacs and Anthony 2002). Nests in the Mallard Slough bald eagle territory are a comparable distance south of the Bachelor Slough dredging activity (Isaacs and Anthony 2002). The WDFW PHS maps do not identify any important wildlife resources in the general area (Appendix 1, Figure 6).

Functions of existing riparian habitat will be maintained in accordance with Clark County Code 13.51.050, Table 13.51.050.

Zoning
Bachelor Island is zoned Rural. Restoration activities at the site are consistent with the zoning requirements.

3.3 Cowlitz County

Cowlitz County's CAO covers Wetlands, Geologic Hazards, Aquifer Recharge Areas, Fish and Wildlife Habitat Conservation Areas, and Frequently Flooded Areas (Cowlitz County Draft Critical Areas Ordinance, Section 3 [2000]). The applicant may request that the County conduct a preliminary review of the project site to determine whether any critical areas exist within the site that would trigger the requirement for a CAO permit. *Id.* at Section (9)A.

Request for Determination of Critical Areas: *Staff will conduct an environmental review, based on existing in-house data, to determine if critical areas exist on a parcel, provided that the applicant supplies the following: A completed master application and vicinity map; an assessor's map of the property; the appropriate fee…; and other information as needed. Cowlitz County Draft Critical Areas Ordinance, Section 9(B)(4), (2000).*

Frequently Flooded Areas
All lands identified in the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps, as amended, and approved by the county, as within the 100-year floodplain are designated as frequently flooded areas. Id. at Section 14(A).

All development within designated frequently flooded areas shall comply with the Cowlitz County Floodplain Management Ordinance, Cowlitz County Code 16.25, as now or hereafter amended. Id. at Section 14(B).

Section 16.25 of the Cowlitz County Code requires that a floodplain permit be obtained from the Cowlitz County Department of Building and Planning. Maintenance activities are exempt from this requirement, but placement of dredged material is specifically excluded from the exemption.

The General Development Standards in the Cowlitz County Code Section 16.25.B, states that *no development shall be allowed that, as determined by the Administrator, threatens to: (1) adversely restrict, alter, or increase the flow of floodwaters in the floodway; (2) adversely affect the efficiency or capacity of the floodway or the integrity or stability of flood protection facilities; or (3) increase water surface elevation or the location of the floodway during the regulatory flood.*

Geologic Hazards

For all regulated activities proposed within designated landslide, erosion. and mine hazard areas, a geotechnical assessment or an erosion hazard assessment prepared by a qualified expert shall be submitted and coordinated with the uniform building code requirements. Cowlitz County Critical Areas Ordinance, Section 15(A), (2000).

If the geotechnical assessment indicates an inability of the site to accommodate the proposed activity without special measures or precautions as determined by a qualified expert, the department may require a geotechnical report. Id.

Cowlitz County Wetlands

Wetland mitigation and buffer requirements are shown in Table 4. Project-related actions in wetlands involve the proposed wetland mitigation as part of the mitigation actions at Woodland Bottoms and Martin Island and the two ecosystem restoration features. No disposal activity occurs in sites with wetlands or their buffers, with the exception of the embayment fill at Martin Island for the purpose of developing intertidal marsh habitat, described in detail in the Wetland Mitigation Plan (attached).

Fish and Wildlife Habitat Conservation Areas

Cowlitz County imposes Development Performance Standards, Habitat Protection requirements, and in some cases, Habitat Management Plan requirements for activities within areas identified by WDFW on their PHS maps to support state listed species or designated PHS (Cowlitz County Critical Areas Ordinance, Section 13[B-D]). There are eight different classifications of Fish and Wildlife Habitat Conservation Areas as defined by WAC 365-190-080 (5), plus Cowlitz County's addition of unintentionally created ponds between 1 and 20 acres in size. *Id.* at Section 13(A). This addition at the County's discretion is authorized under WAC 365-190-080(5)(b). Designated Fish and Wildlife Habitat

Conservation Areas are subject to General Development Performance Standards. *Id.* at Section 13(B-D).

Aquifer Recharge Areas
For the purposes of this classification, critical aquifer recharge areas are determined by the combined effects of soil types and hydrogeology (Critical Aquifer Recharge Map, Cowlitz-Wahkiakum Council of Governments, 1993). Id. at Section 16(A).

Classification 1: High susceptibility-areas, identified on the Aquifer Recharge Map, with a very high susceptibility to contamination of the underlying aquifer due to high soil permeability and high water table. Id. None of the Project activities occur in Class 1 Aquifer Recharge Areas.

Id. at Section 16(13)(1-4).

None of the regulated activities are planned as part of the project activities within Cowlitz County.

3.3.1 Austin Point, RM W-86.5

This site, located north of the confluence of the Lewis and Columbia rivers (Appendix A, Figure 7), was used by the Corps for dredged material disposal over ten years ago. Most of the surface is covered with sand. The Port of Woodland owns the site and has been removing the sand for its own use or resale since the Corps discontinued using the site. The Port of Woodland has a current Shoreline permit for sand removal at the site.

The 26-acre site will hold up 1,645,000 cy of sand. The Corps plans to place 1,700,000 cy over a twenty-year period including the construction and maintenance phases of the project. The Port of Woodland will continue to remove sand from the site between disposal events, making room for additional sand. The current average site elevation is 15 ft CRD. When full, the top of the sand pile could potentially reach 64 ft CRD. Sand resale efforts are anticipated to maintain the crest elevation of the disposal site at a lower elevation. A weir system and outfall to handle return water are already in place.

A training school on the site for heavy equipment use will remain in operation, avoiding work areas during disposal events.

Frequently Flooded Areas
The Austin Point site has a FEMA Floodplain Designation A 100-year floodplain (no baseflood elevation determined) (Exhibit K-7, Figure 5). Cowlitz County's floodplain review requirements will be complied with when the site is permitted for use.

Geologic Hazards

The site is not within any designated landslide, erosion, or mine hazard areas.

Aquifer Recharge Areas

The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this project. The Austin Point site is not located in a Classification 1 regulated area.

Wetlands

A site visit was conducted by Ecological Land Services, Inc. on November 30, 2000. No wetlands were found on or immediately adjacent to the berm that defines the limits of the site (ELS 2000).

Fish and Wildlife Habitat Conservation Areas

Riparian vegetation is present in the form of a 3.4-acre grove of cottonwood trees in the northeast corner of the site. The Austin Point site lies within a WDFW PHS area for bald eagles. A bald eagle nest is in the vicinity, about ¾ mi (more than 1,000 ft from the site) downstream of the site (observed by WDFW June 5, 2001) (Appendix A, Figure 7).

The Austin Point site is disturbed over virtually its entire area. Before the heavy-equipment training school operated on the site, it was used as a stockyard for cattle. Some cottonwood trees have colonized the sandy soils at the northeast corner and, based upon the revised site map from the NMFS BA, these pioneering riparian trees will be avoided. A small grove of cottonwoods adjacent to the heavy equipment training school buildings remains within the disposal site. These trees will be removed before sand is deposited on that portion of the site. This 3.4-acre stand of riparian habitat (revised from 2.7 acres after site realignment for the 2001 BA to NMFS) from Austin Point is included as an impact to be mitigated in the Wildlife and Wetland Mitigation Plan (Final SEIS, Exhibit K-5). The plan proposes to develop 202 acres of riparian forest habitat in Washington in the Wildlife and Wetland Mitigation Plan to mitigate a projected impact of approximately 50 acres of riparian forest in both Oregon and Washington.

Because the disposal site is more than 1,000 ft from the nearest bald eagle nest site, a BEMP is not required.

The Biological Assessments and Biological Opinions prepared to date along with the conceptual mitigation plan in Appendix B are intended to satisfy 13D of the CAO.

3.3.2 Martin Bar, RM W-82.0

The Martin Bar site has been covered with dredged sand in the past. The site consists of two parcels with a day-use park and riparian forest inclusion separating the parcels (Appendix A, Figure 8). The two parcels total 32 acres, with an average elevation of 25 ft CRD. The strip between the disposal site parcels will not be impacted by sand disposal activities in order to preserve the park access road and eliminate impacts to the riparian forest stand. The Corps plans to place an additional 760,000 cy of sand on the two parcels, raising the elevation to 51 ft CRD. Disposal will take place as needed during construction and maintenance dredging over a 20-yr period. A weir system will be constructed to allow drainage water to clear before it returns to the river. The Port of Woodland may, at its discretion, use or sell sand from this site.

Frequently Flooded Areas

The Martin Bar site's average elevation is 25 ft CRD. The base flood elevation at the site is 22.1 ft CRD. The site has been raised out of the 100-yr floodplain by previous sand disposal activities, but this is not reflected on the FEMA map (Exhibit K-7, Figure 6). A Letter of Map Revision due to Fill (LOMR-F) will be prepared by the Corps upon attainment of more detailed topographic information for the site.

Geologic Hazards

The site is not within any designated landslide, erosion, or mine hazard areas.

Aquifer Recharge Areas

The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this Project. The Martin Bar site is not located in a Classification 1 regulated area.

Wetlands

One small, forested wetland lies immediately adjacent to the proposed disposal area and the access road to the WDFW property (Appendix A, Figure 8). It is not included within the disposal site boundary. The site has been used for sand disposal in the past and is elevated 10 to 15 ft above the surrounding area.

Fish and Wildlife Habitat Conservation Areas

The site is divided into two parts to avoid a forested wetland and the WDFW access road that runs through the middle of the site. The Martin Bar site is not within any designated PHS habitat (Appendix A, Figure 8). The site supports a few wintering waterfowl and adjacent forested wetlands probably support cavity-nesting ducks.

The Cowlitz County General Development Performance Standards as stated above apply to this site as a Category 1 Habitat Conservation Area. The Cowlitz County Planning Department may, at their discretion, require Development Performance Standards for Salmonids Only or Habitat Management Plans to protect designated Habitat Conservation Areas (Cowlitz County CAO, Section 13B). The Corps in cooperation with Ecology, WDFW, and other state and federal agencies has already met the requirements therein for a BA, Mitigation Plan and Monitoring Plan. Cowlitz County will be furnished with copies of these documents.

3.3.3 Woodland Bottoms Mitigation Site, RM W-81.0

The Woodland Bottoms Mitigation Site (Appendix A, Figure 8) is currently used for agricultural purposes, including row crops, hybrid poplar plantations, and pasture lands. Farmed wetlands (grazed, row crop) exist on the 284-acre wildlife mitigation site (Appendix A, Figure 9). Through mitigation construction activities, 97 acres of wetland habitat and 43 acres of riparian habitat will be developed (Appendix A, Figure 10). A 132-acre portion of the site will be converted to permanent Canada goose forage habitat (Appendix A, Figure 10), similar to that at Ridgefield National Wildlife Refuge.

Construction activities at Woodland Bottoms would include some agricultural tillage. The only grading required would be done in construction of the perimeter levees for the wetland management unit in order to maintain the current level of protection to surrounding lands afforded by the Burris Creek levees (Appendix A, Figure 11). Borrow material for use in constructing the perimeter levees will be obtained by removal of the necessary volume of material from the levees presently encompassing Burris Creek (Appendix A, Figure 11).

Frequently Flooded Areas
The mitigation site lies outside the 100-year floodplain (Exhibit K-7, Figure 6), behind main flood control dikes. An interior drainage system, (e.g., ditches and pump stations) is in place to drain waters from the diking district, including the mitigation site.

Geologic Hazards
The site is not within any designated landslide, erosion, or mine hazard areas.

Aquifer Recharge Areas
The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this project. The Woodland Bottoms site is not located in a Classification 1 regulated area.

Wetlands
Degraded wetlands and hydric soils currently exist in patches at the Woodland Bottoms site. These wetlands will be enhanced by removal of grazing cattle, restoration of native vegetation, and water management.[2] Alteration of all wetland types is permitted under the CAO as long as *"the alteration would improve or maintain the existing wetland function and value, or the alteration would create a higher value or less common wetland type which would improve the function or value of the wetland as*

[2] The Wetland Mitigation Plan for this site is described in more detail in Appendix B.

indicated within the wetland assessment and the mitigation plan." The Wetland Mitigation Plan (Appendix B) clearly demonstrates that the proposed alteration is beneficial and consistent with the intent of the CAO.

The 1999 IFR/EIS, Appendix G states that these mitigation wetlands must be protected in perpetuity. These lands would be obtained in fee title by the sponsoring Washington ports for the Corps. Ownership of the mitigation sites will be turned over to the State of Washington upon their completion. The Wetland Mitigation Plan (Appendix B) outlines how the mitigation wetlands will be maintained.

Fish and Wildlife Habitat Conservation Areas
The area is currently used by wintering waterfowl, principally wintering Canada geese and surface feeding ducks (Appendix A, Figure 8). Wetland, riparian, and permanent pastureland habitat will be developed from existing agricultural land through tillage, construction of water control structures, natural seeding and plantings. This habitat will benefit Canada geese, ground-dwelling songbirds, sandhill cranes, reptiles, amphibians and other species.

3.3.4 Tidegate retrofits at Burris Creek, RM W-81.0

This restoration action entails installation of a new tide gate with a fish slide gate to improve fish passage. The tide gate would be fitted with a panel that has a rectangular opening of approximately 12 by 15 inches (fish slide). The opening can be closed if needed for flood control.

This action will enable salmonids to access spawning and rearing habitat upstream in Burris Creek.

Frequently Flooded Areas
The restoration feature site lies outside the 100-year floodplain (Exhibit K-7, Figure 6). Because the fish slides can be closed, their installation will not affect flood management capabilities within the Diking District.

Geologic Hazards
The site is not within any designated landslide, erosion, or mine hazard areas.

Aquifer Recharge Areas
The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this project. The Burris Creek site is not located in a Classification 1 regulated area.

Wetlands
The tidegate for Burris Creek would be located on the northern edge of the Woodland Bottoms Mitigation Site. The tidegate retrofits are consistent with the goals of the Woodland Bottoms Mitigation Site. Because the fish

slide can be closed if needed, they will not reduce WDFW's ability to regulate flows to the wetlands at Woodland Bottoms.

Fish and Wildlife Habitat Conservation Areas

The adjacent area (Woodland Bottoms) is currently used by wintering waterfowl, principally wintering Canada geese and surface feeding ducks (Appendix A, Figure 8). Installation of the tidegate retrofits will require minimal disturbance because it involves replacement of a portion of an existing structure rather than new construction and is limited in area to the flood control levee. Construction would occur in late summer when wildlife use of the area is minimal. The retrofit will enable salmonids to use spawning habitat upstream that is currently inaccessible.

3.3.5 Martin Island Mitigation Site, RM W-80.0

Martin Island contains a number of habitats, including agricultural pasturelands, riparian forest, and an embayment (Appendix A, Figure 12). Mitigation activities at the Martin Island site consist of two parts; partial filling (16 of 34 acres) of the embayment to create intertidal marsh habitat, and establishment of riparian forest and wetland habitat on a substantial portion of the rest of the island, primarily through conversion of agricultural pasturelands and blackberry thickets (Appendix A, Figure 13).[3]

Lagoon Intertidal Marsh Habitat: The 34-acre lagoon was artificially developed in 1966 when sand was excavated for use in the construction of nearby Interstate Highway 5. The Corps proposes to refill a 16-acre portion of the lagoon (W-80.0; Appendix A, Figure 8) to a level matching the elevation of adjacent, intertidal marsh, in order to create intertidal marsh habitat. The lagoon will be filled during the two-year construction phase. **Riparian Forest Establishment:** Parts of Martin Island have been used for cattle grazing and pastureland. Approximately 159 acres of agricultural habitat (pasture) will be restored to natural riparian forest (riparian early successional; Appendix A, Figure 13). The total may increase to 239 acres if 80 acres of pastureland, located at the south end of the site and no longer considered for an upland disposal site, are used for riparian forest restoration. Establishment of good-quality riparian forest can be accomplished by removing cattle from the island, spot removal of blackberry thickets, and tillage of pasturelands to provide a proper soil condition for seed germination of riparian trees. Riparian forest stands on Martin Island provide an excellent source of seeds for riparian forest development. Tillage operations will be timed to take advantage of natural seed dispersal by riparian tree species. The elevated area where topsoil overburden was dumped during excavation of the embayment, currently overgrown by invasive blackberries, will be removed and a

[3] The wetland mitigation plan for this site is described in more detail in Appendix B.

portion of the topsoil used to cover the sand fill in the embayment to provide a better substrate for emergent wetland plants to develop.

Frequently Flooded Areas

Martin Island is frequently flooded, consistent with its FEMA Floodplain Designation A – 100 year floodplain; no baseflood elevations determined (Exhibit K-7, Figure 6). The 100-year base flood elevation at Martin Island is approximately 22 ft. (CRD). The goal of the mitigation activities on Martin Island is to return the island to a natural condition (e.g., principally riparian forest). Flooding is a natural occurrence in riparian and intertidal marsh habitats and these features often improve flood control. Flooding does not pose a risk to this land use; nor does construction of these habitats increase flood risk to any surrounding areas.

Geologic Hazards

Two small areas of severely erosive soils (old dredged material disposal locations composed of sand) are located on the western edge of the island. These are beaches that will not be disturbed by mitigation activities. The native soil comprising the island proper is less prone to erosion than the sand placed along the shoreline in the past.

Aquifer Recharge Areas

The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this project. The Martin Island Mitigation Site is not located in a Classification 1 regulated area.

Wetlands

The lagoon site is a fully submerged embayment and entrance channel that was initially excavated to provide fill material for Interstate Highway 5. A portion of the embayment will be filled with sand and capped with two feet of topsoil to create 16 acres of intertidal marsh habitat (Appendix A, Figures 13 and 14). As a wetland developed by a mitigation action, the site will be regulated as outlined and approved in the Wetland Mitigation Plan (Appendix B).

The island itself is classified as wetland on the NWI wetland maps. The majority of the land surface is in fact existing riparian forest, cattle pasture and blackberry thickets. Wetland pockets exist on the island where depressions or frequent flooding by the river occur. Establishment of riparian forest on the island, and wetland habitat where elevation is appropriate, is consistent with this NWI characterization.

Alteration of all wetland types is permitted under the CAO as long as *"the alteration would improve or maintain the existing wetland function and value, or the alteration would create a higher value or less common wetland type which would improve the function or value of the wetland as indicated within the wetland assessment and the mitigation plan."* The

Wetland Mitigation Plan (Appendix B) clearly demonstrates that the proposed alteration is beneficial and consistent with the intent of the CAO.

Appendix G of the project EIS states that these mitigation wetlands must be protected in perpetuity. These lands would be obtained in fee title by the sponsoring Washington ports for the Corps. Ownership of the mitigation sites will be turned over to the State of Washington upon their completion. The Wetland Mitigation Plan (Appendix B) outlines how the mitigation wetlands will be maintained.

Fish and Wildlife Habitat Conservation Areas

Although the WDFW PHS maps does not show a bald eagle nest site, a bald eagle nest is located on the west edge of the lagoon (Manlow 2002) (Appendix A, Figure 8). According to WDFW PHS mapping, dusky Canada geese and other waterfowl use the southern tip of the island, ½ mi south of the embayment and forage in the pasturelands present on the island (Appendix A, Figure 8).

Although the WDFW PHS maps do not show great blue heron nesting, a great blue heron rookery occurs north of the lagoon (Manlow 2002).

The Corps evaluated a number of potential measures to address potential impacts. These are discussed below. It is not possible to observe the timing restriction for protection of bald eagle nesting (January 1 to July 15) and great blue herons (February 15 to July 31) at Martin Island. Wildlife mitigation efforts slated for Martin Island are directed toward development of riparian forest and wetland habitats. For successful mitigation, establishment of riparian vegetation requires that work be done on the site in spring (e.g., April 15 – June 15). Dredged material disposal actions in the Martin Island embayment may occur throughout the year. The Corps has undergone formal consultation with USFWS and the BO issued by USFWS on December 6, 1999 permits the incidental take (harassment due to project-related disturbance) of one pair of bald eagles at Martin Island. Harassment of bald eagles, and great blue herons (if nesting birds are present) would be associated with mitigation operations (herbicide application, tillage, removal of invasive blackberry thickets, dredged material and soil placement in the embayment) to develop riparian and wetland habitat at Martin Island. These mitigation operations represent repetitive actions to which bald eagles and great blue herons are anticipated to habituate quickly. No incursions of equipment or personnel are anticipated into the established riparian forest that supports the bald eagle and great blue heron nest sites.

The Pacific Bald Eagle Recovery Plan (1986) established Habitat Management Goals (HMG) and Recovery Population Goals (RPG) by recovery zone for bald eagles. Martin Island lies in the Columbia Recovery Zone (RZ-10), which includes portions of both Oregon and

Washington. Table 5 summarizes these bald eagle management goals for RZ-10 and observed results for 2001.

Table 5. Habitat Management and Recovery Population Goals

State	Habitat Management Goal[a]	Recovery Population Goal[b]	2001 Breeding Territories Surveyed	2001 Occupied Breeding Territories[c,d]
Washington	18	12	39	38
Oregon	29	19	50	48
Total	47	31	89	86

a This is the target number of breeding territories in order to ensure at least 12 occupied territories per year.
b This is the minimum number of occupied breeding territories to indicate recovering eagle population.
c Data compiled by Isaacs and Anthony (2001).
d Not all existing breeding territories are occupied in any given year.

Data compiled by Isaacs and Anthony (2001) demonstrates that the population of bald eagles in Oregon and Washington, including the RZ-10 population, are exhibiting a continued population growth. The RZ-10 population, since 1990, has expanded from 25 to 89 breeding territories surveyed and 23 to 86 territories occupied and exceeds both the established HMG and RPG. Thus, the incidental take due to harassment of the Martin Island pair does not significantly impact the RZ-10 population.

Mitigation actions may result in an expanded, more diversified wildlife use of the site. Waterfowl, principally ducks, will benefit from the intertidal habitat developed at Martin Island. Riparian forest restoration will benefit Neotropical and resident songbirds, and improve Critical Habitat for listed Columbia River salmonids through provision of insects, fauna, and detrital (leaves) debris, and eventually large woody debris export to the Columbia River.

3.3.6 Northport, RM W-71.9

The Northport site has been used for dredged sand disposal in the past. The Port of Kalama is currently removing sand for resale. Sand placed by the Corps during the construction and maintenance phases of the Channel Improvement Project will also be resold.

The Northport site covers 27 acres (Appendix A, Figure 13) and the average elevation is 15 ft CRD. The existing berm will need to be raised over time in order to increase the site's capacity to hold another 900,000 cy of sand. The Corps plans to place 1,900,000 cy of sand at the site. The Port of Kalama will continue to mine sand from the site between disposal events, making room for additional sand. When full, the site elevation will be 41 ft CRD. A weir drainage system is already in place.

Frequently Flooded Areas
The Northport site remains within the 100-yr floodplain, no baseflood elevation determined(Exhibit K-7, Figure 8). The site will undergo FEMA review as required by Cowlitz County to ensure that flood hazards have been minimized.

Geologic Hazards
The site is not within any designated landslide, erosion, or mine hazard areas.

Aquifer Recharge Areas
The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this project. The Northport site is not located in a Classification 1 regulated area.

Wetlands
The PHS map inaccurately identifies wetlands on the site (Appendix A, Figure 15). There are no wetlands on the site. Wetland habitat does immediately abut the site. This is an existing sand disposal and resale site.

Fish and Wildlife Habitat Conservation Areas
An osprey nest was observed ¼ mi south of the site on a steel dock platform, August 14, 2001 and is shown on the PHS map (Appendix A, Figure 15). The Northport site is in a heavily industrialized area and the PHS maps from WDFW show no wildlife use of the site.

3.3.7 Cottonwood-Howard Island Deer Reintroduction, RM W-68-71.5

Approximately 650 acres of Cottonwood and Howard Islands will be acquired for the reintroduction of Columbian white-tailed deer (Appendix A, Figure 15). Approximately 60 acres of tidelands will also be acquired. Columbian white-tailed deer will be translocated to the islands from populations located on the Julia Butler Hansen Columbian White-tailed Deer National Wildlife Refuge, Puget Island or another suitable population determined by the USFWS. The USFWS will be monitor Cottonwood-Howard Island to determine the success of establishing a secure, viable population of Columbian white-tailed deer.

Frequently Flooded Areas
The portions of Howard and Cottonwood islands designated for deer introduction lie within the FEMA 100-year floodplain (Exhibit K-7, Figure 8). The reintroduction of the deer to the riparian forest habitat will not reduce flood storage capacity or increase the risk of erosion during high flows.

Geologic Hazards
The site is not within any designated landslide, erosion, or mine hazard areas. Unstable slopes exist on the southwestern edge of Cottonwood Island, as shown on the Cowlitz County Critical Areas Maps.

Aquifer Recharge Areas
The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this project. The Howard-Cottonwood Island Ecosystem Restoration Feature is not located in a Classification 1 regulated area.

Wetlands
The reintroduction of Columbian white-tailed deer poses not threat to wetlands on the Howard-Cottonwood Island site.

Fish and Wildlife Habitat Conservation Areas
WDFW PHS maps show little wildlife use of the Howard and Cottonwood islands. Concentrations of wintering waterfowl are shown to the east of Cottonwood Island. Implementation of the proposed restoration action would result in use of the site by Columbian white-tailed deer.

3.3.8 Cottonwood Island, RM 70.1

Cottonwood Island was substantially altered in the 1980's by placement of dredged material from the Mt. St. Helens emergency action. Natural riparian forest abutting Carrolls Channel does remain. The land surface is at about 30 ft CRD and steep banks drop off to the Columbia River and Carrolls Channel. The island is undeveloped except for navigational beacons, shoreline protection structures, and a few primitive campsites.

The 62-acre disposal site is located immediately south of the Howard Island disposal site (Appendix A, Figure 15) and can hold up to 3,200,000 cy of sand. The Corps plans to place 1,500,000 cy of sand over a 20-yr period including the construction and maintenance phases of the project. The final site elevation will be 49 ft CRD. A weir drainage system will be constructed to allow return water to clear before it outfalls back to the Columbia River.

Frequently Flooded Areas
The Cottonwood Island site's average elevation is 30 ft CRD. The base flood elevation at the site is 17.7 ft CRD. The site has been raised out of the 100-yr floodplain by previous sand disposal activities, but this is not reflected on the FEMA map (Exhibit K-7, Figure 8). A Letter of Map Revision due to Fill (LOMR-F) will be prepared by the Corps upon attainment of more detailed topographic information for the site.

Geologic Hazards
The site is not within any designated landslide, erosion, or mine hazard areas. Severely erosive soils to the south of the disposal site, as shown on the Cowlitz County Critical Areas Maps, have been avoided.

Aquifer Recharge Areas

The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this project. The Cottonwood Island site is not located in a Classification 1 regulated area.

Wetlands

No wetlands exist on the disposal site. Disposal is limited to the previously designated and used disposal area, thus adjacent wetlands will not be impacted.

Fish and Wildlife Habitat Conservation Areas

There are an estimated 6.2 acres of riparian habitat on the site, consisting of clumps of cottonwoods that have grown since the last deposition of dredged sand (circa 1980s). Impacts to these 6.2 acres have been addressed in the project mitigation plan under the project-wide mitigation approach (Appendix G to the EIS). Riparian impacts for all Washington and Oregon disposal sites are estimated at 50 acres. Approximately 159 acres of riparian habitat will be developed at the Martin Island mitigation site and 43 acres at Woodland Bottoms, for a total of 202 acres (Appendix A, Figures 10 and 13). This yields an average replacement ratio of 4:1. The riparian acreage proposed in the mitigation plan is more than sufficient to replace the anticipated loss of riparian habitat at all Washington and Oregon disposal sites. WDFW's PHS maps show waterfowl nesting adjacent to but not on the site (Appendix A, Figure 15). The site lies outside the PHS area of waterfowl concentration. A great blue heron rookery is present approximately ½ mile north of the disposal site (Appendix A, Figure 13). Waterfowl, primarily Canada geese and mallards, nest on and adjacent to the disposal site. Osprey nest on pile dikes scattered along the shoreline (Appendix A, Figure 15).

The Corps has evaluated a number of potential measures to address potential impacts. These are discussed below.

The disposal site covers only a portion of Cottonwood Island (Appendix A, Figure 15). Corps disposal actions are limited to previously impacted areas and do not intrude into the wetland and riparian forest habitat abutting the disposal site. On the current site map, the heronry is located 970 feet from the nearest portion of the disposal site. The site border will be adjusted to assure that the distance between the site and the rookery is at least 1,000 feet. The rookery is visually screened by intervening riparian forest from the disposal site.

Several osprey nests occur on platforms and structures adjacent to the site (Appendix A, Figure 15). Since osprey nesting and disposal activities have coexisted for years, disposal activities from the Project are not expected to impact the ospreys.

The WDFW PHS maps do not show use of the island by Canada geese; however, a small number of Canada geese utilize Cottonwood Island for nesting activities (WDFW 1996). Loss of a portion of their nesting habitat to disposal activities at Cottonwood Island poses no threat to this population. Nesting activities for Canada geese are virtually fully completed by early May. Some nesting by mallards may occur at this location. However, once the initial construction volumes are placed on the site, no nesting habitat is expected to be available in subsequent years for waterfowl. Thus, the timing restriction is a moot point after the first construction year. Tall, dense vegetative cover suitable for waterfowl nesting would be difficult to establish between annual disposal actions. Planting of vegetation at this location could occur after disposal use of this site has been completed. The 300-foot setback of the disposal site from the Columbia River does provide adequate nesting habitat for the small number of Canada geese and mallards that currently nest at Cottonwood Island.

Columbian white-tailed deer have yet to be translocated to Cottonwood Island. Translocation of deer to the island is proposed as an ecosystem restoration feature to be implemented concurrently with project construction. Provisions for vegetative cover on the disposal site would be relatively futile until site use is discontinued. A deer population translocated to this site would be expected to primarily use the riparian forest habitat that occurs on the undisturbed portions of the island rather than occupy the disposal location on Cottonwood Island.

3.3.9 Howard Island, RM 68.7

The Howard Island site is an existing disposal site used for maintenance of the 40-ft channel. Nearly all of the Howard Island property has been covered with dredged sand over the last 40 years. A 200-acre area is planned for use over the construction and 20-year maintenance phases of the project. This area can hold up to 6,400,000 cy of additional sand, which would raise the average site elevation from 26 ft CRD to 51 ft CRD. The Corps initially plans to utilize only a small amount of this capacity, placing 600,000 cy of sand. A weir drainage system will be constructed to allow return water to clear before it outfalls to the Columbia River.

Frequently Flooded Areas

The Howard Island site's average elevation is 26 ft CRD. The base flood elevation at the site is 17.1 ft CRD. The site has been raised out of the 100-yr floodplain by previous sand disposal activities, but this is not reflected on the FEMA map (Exhibit K-7, Figure 9). A Letter of Map Revision due to Fill (LOMR-F) will be prepared by the Corps upon attainment of more detailed topographic information for the site.

Geologic Hazards

The site is not within any designated landslide, erosion, or mine hazard areas.

Aquifer Recharge Areas

The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this project. The Howard Island site is not located in a Classification 1 regulated area.

Wetlands

There are no wetlands within the 200-acre Howard Island disposal site.

Fish and Wildlife Habitat Conservation Areas

The Howard Island site is not designated as a Fish and Wildlife Habitat Conservation Area for any state-listed species. The PHS designation, as shown on Appendix A, Figure 15, is for "Island" habitat. No regulatory requirements are associated with this designation. The proposed 200-acre disposal site will lie within the footprint of an existing disposal site, resulting primarily from disposal actions associated with Mt. St. Helens dredging activities in the 1980's. The disposal site selected for the Channel Improvement Project has been inactive since the 1980s and some riparian vegetation has established on the site. Placement of dredged material from the Channel Improvement Project will impact an estimated 20 acres of riparian habitat on the site. The Cowlitz County CAO requires that a BA be conducted to determine appropriate mitigation. This has been addressed in the Corps 1999 EIS and associated BA and Mitigation Plan, which will be provided to the County.

Mitigation for riparian impacts is planned under the project-wide mitigation approach as described in the 1999 Final IFR/EIS, Appendix G. Riparian impacts for all Washington and Oregon disposal sites are estimated at 50 acres. Approximately 159 acres of riparian habitat will be developed at the Martin Island mitigation site and 43 acres at Woodland Bottoms, for a total of 202 acres (Appendix A, Figures 10 and 13). This yields an average replacement ratio of 4:1. The riparian acreage proposed in the mitigation plan is more than sufficient to replace the anticipated loss of riparian habitat at all Washington disposal sites.

A great blue heron rookery occurs more than 1,000 ft southeast of the disposal site (Appendix A, Figure 15). Waterfowl nest on and adjacent to the site. Wetlands and a large block of riparian forest are adjacent north and east of the site.

Corps disposal actions are limited to previously impacted areas and do not intrude into the wetland and riparian forest habitat abutting the disposal site. WDFW typically recommends timing restrictions for activities within 1,000 feet of a great blue heron rookery. Disposal will occur beyond 1,000 feet to avoid impacts to the rookery. In addition, the disposal site is screened by intervening riparian forest from the heron rookery.

Several osprey nests occur on platforms and structures adjacent to the site (Appendix A, Figure 15). Since osprey nesting and disposal activities have coexisted for years, disposal activities from the Project are not expected to impact the ospreys.

The WDFW PHS maps do not show use of the island by Canada geese and the area is not a Fish and Wildlife Conservation area for geese; however, a small number of Canada geese utilize Howard Island for nesting activities (WDFW 1996). Loss of a portion of their nesting habitat to disposal activities at Howard Island poses no threat to this population. Nesting activities for Canada geese are almost completed by early May. Some nesting by mallards may occur at this location. However, once the initial construction volumes are placed on the site, no nesting habitat is expected to be available in subsequent years for waterfowl. Tall, dense vegetative cover suitable for waterfowl nesting would be difficult to establish between annual disposal actions. Planting of vegetation at this location could occur after disposal use of this site is completed. The 300-foot setback of the disposal site from the Columbia River provides adequate nesting habitat for the small number of Canada geese and mallards that currently nest at Howard Island.

Columbian white-tailed deer have yet to be translocated to Howard Island. Translocation of deer to the island is proposed as an ecosystem restoration feature to be implemented concurrently with project construction. Provisions for vegetative cover on the disposal site would be relatively futile until site use is discontinued. A deer population translocated to this site would be expected to primarily use the riparian forest habitat that occurs on the undisturbed portions of the island rather than occupy the disposal location on Howard Island. Forage on the undisturbed portions of the island is denser and more palatable because of favorable soil conditions.

3.3.10 Port of Longview, International Paper, RM W-67.5

This site is zoned for heavy manufacturing. It is used as a receiving site for dredged material from maintenance of the 40-ft channel. Sand is currently being sold from the site, and sand placed by the Corps will also be resold. Containment dikes presently surround the 29-acre site (Appendix A, Figure 16). The current average site elevation is 20 ft CRD. When full, the elevation at the top of the sand pile will be 47 ft CRD. The site can accept up to 1,000,000 cy of sand. The Corps plans to place up to 2,900,000 cy of sand over the entire life of the project at this location, using storage capacity created when sand is sold from the site. Because the site has already been used for sand disposal, a weir drainage system is already in place.

Frequently Flooded Areas
The entire International Paper site lies outside the FEMA 100-year floodplain (Exhibit K-7, Figure 14). Flood control levees protect the site.

Geologic Hazards
The site is not within any designated landslide, erosion, or mine hazard areas.

Aquifer Recharge Areas
The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this project. This site is not located in a Classification 1 regulated area.

Wetlands
There are no wetlands on the site. This is an existing, active sand disposal site.

Fish and Wildlife Habitat Conservation Areas
The site is in a heavily industrialized area and the PHS maps from WDFW show no wildlife use of the site (Appendix A, Figure 16). Several osprey nests occur on platforms and other structures in the vicinity of the site. The closest osprey nest is approximately 650 ft from the southern edge of the site. Since osprey nesting and industrial activities have coexisted for years, disposal activities from the Project are not expected to impact the ospreys. A great blue heron rookery occurs approximately 2½ miles from the site, on land across Carrolls Channel, and disposal activities are not expected to adversely affect the heron rookery.

3.3.11 Reynolds Aluminum, RM W-63.5

Reynolds Aluminum has used this 13-acre site in the past for sand disposal from maintenance dredging of the access channel from the river to their aluminum plant, which is now closed (Appendix A, Figure 17). Sand is currently being sold from the site, and sand placed there by the Corps will also be resold. The site lies behind a dike and a weir drainage system for water from pipeline placement of dredged sand is already in place.

The site elevation is currently 20 ft CRD. At full capacity, the top of the sand pile will reach 50 ft CRD. The site can hold up to 500,000 cy of sand. The Corps plans to place 200,000 cy during the first year of the construction phase that would result in a disposal site crest elevation of 32 ft CRD. This sand will probably be resold from the site. The landowner may request additional material to be placed at this location in subsequent years should they sell the sand placed there.

Frequently Flooded Areas
The entire Reynolds Aluminum site lies outside the 100-year floodplain (Exhibit K-7, Figure 10).

Geologic Hazards

The site is not within any designated landslide, erosion, or mine hazard areas.

Wetlands

There are no wetlands on the site. This is an existing, bermed, active sand disposal site.

Aquifer Recharge Areas

The Critical Aquifer Recharge Areas requirements do not apply to activities within the scope of this project. The Reynolds Aluminum site is not located in a Classification 1 regulated area.

Fish and Wildlife Habitat Conservation Areas

The site is in a heavily industrialized area and the PHS maps from WDFW show no wildlife use of the site (Appendix A, Figure 17).

3.3.12 Improved Embayment Circulation, RM W-60

The strip of land connecting Hump and Fisher Islands impedes the flow of water through the embayment. This Ecosystem Restoration Feature proposes to construct a channel between the islands (Appendix A, Figure 17) to allow water to flow through the embayment, reducing water temperature and increasing water quality. Improvements to water quality are expected to benefit juvenile salmonids that use the embayment.

Frequently Flooded Areas

The area designated for channel construction is outside the FEMA 100-year floodplain (Exhibit K-7, Figure 10). The material to be excavated, sand from a historic disposal action, would be placed atop like material immediately adjacent to the channel location that is also outside the FEMA 100-year floodplain.

Geologic Hazards

The site is not within any designated landslide, erosion, or mine hazard areas.

Wetlands

The channel will cut through fringing wetlands on both the river and embayment sides of the feature. The impacted area is minor in nature and fringing wetland habitat is expected to develop along the channel margins post-construction.

Aquifer Recharge Areas

The Critical Aquifer Recharge Areas requirements do not apply to activities at this site. The Hump-Fisher Island site is not located in a Classification 1 regulated area.

Fish and Wildlife Habitat Conservation Areas

Habitat changes as a result of opening the channel between Hump and Fisher Islands are not expected to be detrimental to the heron rookery on Fisher Island. The site is over 2,000 ft from the construction activity and if the forage base is changed at all, the changes are likely to be beneficial.

3.3.13 Hump Island, RM W-59.7

The Hump Island site is an active, existing Corps sand disposal site for maintenance dredging of the 40-ft channel (Appendix A, Figure 17). The site can hold up to 1,500,000 cy of additional sand. The Corps plans to fill the site to capacity during the first six years of the maintenance phase of the Improvement project. The site's current elevation averages 25 ft CRD, with the highest areas adjacent to the navigation channel. When the site is full, the final elevation at the top of the sand pile will be 42 ft CRD. A weir drainage system with outfall to the Columbia River is already in place.

Frequently Flooded Areas

The Hump Island site's average elevation is 25 ft CRD. The base flood elevation at the site is 13.4 ft CRD. The site has been raised out of the 100-yr floodplain by previous sand disposal activities, which is reflected on the FEMA map (Exhibit K-7, Figure 10).

Geologic Hazards

The site is not within any designated landslide, erosion, or mine hazard areas.

Aquifer Recharge Areas

The Critical Aquifer Recharge Areas requirements do not apply to activities at this site. The Hump Island site is not located in a Classification 1 regulated area.

Wetlands

There are no wetlands on the site. This is an active sand disposal site.

Fish and Wildlife Habitat Conservation Areas

The Hump Island site is in a Waterfowl Concentration Area. The PHS maps do not identify eagle, heron, or osprey nests or rookery on the site.

A bald eagle nest is located on Fisher Island, adjacent to the site, and about 1,700 ft north of the northern edge of the site (Appendix A, Figure 17). A great blue heron rookery is present 2,600 ft north of the northern edge of the site on Fisher Island (Appendix A, Figure 17). Three osprey nests occur immediately off the site—one site occurs on a dolphin and the other two are navigation markers (Appendix A, Figure 17). Waterfowl (Canada goose, cavity-nesting ducks) nest on and adjacent to the site. Concentrations of wintering waterfowl feed in the lagoon. Regular small concentrations of cavity nesting ducks utilize the embayment and nest primarily on Fisher Island (Appendix A, Figure 17).

The Corps has evaluated a number of potential measures to address potential impacts. These are discussed below.

A review of WDFW's PHS map of the area shows that the bald eagle nest is more than 1,700 ft from planned disposal and ecosystem restoration activities; therefore, a Bald Eagle Management Plan (BEMP) is not required. The bald eagle nest location is approximately 1,700 feet distant from the nearest portion of the disposal site with riparian forest along both the Hump Island and Fisher Island shoreline providing a visual barrier. Thus, disposal activities are not considered to pose a concern for this nesting pair and timing restrictions are unnecessary.

Sand disposal will take place at least 3,000 ft away from the great blue heron rookery. Riparian forest along both the Hump Island and Fisher Island shoreline will provide a visual barrier between the heronry and the disposal site. Thus, disposal activities are not expected to impact this heronry.

The osprey nests exist on structures adjacent to the site. Past sand disposal has not adversely affected osprey nesting, and disposal activities from the Project are not expected to impact these sites.

An introduced population of Canada geese has nested throughout western Oregon and western Washington since at least the 1970s. This population and the area it uses have increased dramatically since its introduction. A small number of these geese utilize Hump Island for nesting and would be expected to rear their broods in the embayment between Hump and Fisher islands. Loss of a portion of their nesting habitat to disposal activities at Hump Island poses no threat to this population. Nesting activities for Canada geese are almost completed by early May. Some nesting by mallards may occur at this location. However, once the initial construction volumes are placed on the site, no nesting habitat is expected to be available in subsequent years for waterfowl. Thus, the timing restriction would not provide any benefit after the first construction year. Tall, dense vegetative cover suitable for waterfowl nesting would be difficult to establish between annual disposal actions. Planting of vegetation at this location could occur once disposal use of this site has been completed. Mitigation for Canada goose forage habitat is planned in the Wildlife Mitigation Plan (1999 Final IFR/EIS, Appendix G). The 132 acres of permanent pastureland habitat planned for Woodland Bottoms will be of higher quality and more stable than any vegetation that could be established on Hump Island. This pastureland habitat will benefit Canada geese, ground-dwelling songbirds, sandhill cranes, reptiles, amphibians and other species.

Columbian white-tailed deer have yet to be translocated to the Fisher-Hump Island complex by USFWS (David 2002). Translocation of deer to the island complex may occur in approximately February 2003. Provisions for vegetative cover on the disposal site would be relatively futile until site use is discontinued. A deer population translocated to this site would be expected to use the riparian forest habitat that occurs on Fisher Island rather than occupy the disposal location on Hump Island.

Populations of Columbian white-tailed deer naturally occupy Karlson, Price, Hunting, Jackson, Tenasillahe, Wallace, Little Wallace, Puget, Little, Ryan, Jackson, Brown, Whites, Anundes, Kinnunen Cut, and Skull islands in the lower Columbia River (USFWS 1983). Alan Clark, USFWS (Clark 2002) stated that USFWS does not provide crossings for deer to access or egress these islands and that Columbian white-tailed deer are quite capable of swimming between islands and crossing the entire Columbia River. Thus, provision of a crossing at Fisher-Hump Island is unnecessary from a biological standpoint.

The County may require a Habitat Management Plan pursuant to Section 13D of the CAO. The Biological Assessments and Biological Opinions prepared to date along with the conceptual mitigation plan in Appendix B are intended to satisfy 13D of the CAO.

3.4 City of Longview

One disposal site (Mt. Solo) is located within the City of Longview's jurisdiction.

The City of Longview's CAO requirements are the same as Cowlitz County's, except where noted below.

Request for Determination of Critical Areas: *The Director will conduct a preliminary environmental review, based on existing in-house resources and data, to determine if critical areas are known to exist on the applicant's parcel; however, the ultimate burden of proof is on the applicant to provide sufficient data to the Director should the Director suspect critical areas are present. Longview Municipal Code ("LMC") §17.10.080(4).*

A Critical Area permit is required if it is determined that the proposed alteration or development is located within 100 feet of a critical area or associated buffer. LMC §17.10.060.

Wetlands

Wetland categories I through III are nearly identical to Classifications 1 through 3 in the Cowlitz County CAO. Cowlitz County Critical Areas

Ordinance, Section 12(A). Category IV is defined differently from Classification 4. *Id.*; LMC § 17.10.110(A).

Category IV:

a. *Those wetlands which are not category I, II, or III.*

b. Wetlands 2 acres or larger and hydrologically isolated with one vegetation class, and more than 90% ground cover (as assessed by aerial photo) being any combination of non-native, invasive species, are rated Category IV or higher. LMC § 17.10.110(A).

Minimum size for Category IVa and IVb is 2 acres. Id. at (B).

Wetland replacement and buffer requirements are shown in Table 4.

Geologic Hazards

The definition for a Landslide Hazard Area is the same as that for Cowlitz County, except that the City of Longview's Engineer has the discretion to include "*other areas as the City Engineer may conclude present potential slide hazards*." LMC § 17.10.140(B).

Critical Aquifer Recharge Areas

Regulated Aquifer Recharge Areas. All areas with a critical recharging effect on aquifers used for potable water are areas where an aquifer that is a source of drinking water is vulnerable to contamination that would affect the potability of the water supply. LMC § 17.10.150(A).

Fish and Wildlife Habitat Conservation Areas

The City of Longview imposes Development Performance Standards, Habitat Protection requirements, and in some cases, Habitat Management Plan requirements for activities within areas identified by WDFW to support state listed species or designated PHS. LMC § 17.10.120(B, D-I). There are eight different classifications of Fish and Wildlife Habitat Conservation Areas as defined by WAC 365-190-080 (5), plus the City of Longview's addition of unintentionally created ponds between 1 and 20 acres in size (the same as the ninth category adopted by Cowlitz County). LMC § 17.10.120(B). This addition at the City's discretion is authorized under WAC 365-190-080(5)(b). Id.

Frequently Flooded Areas

A. *Classification. All flood hazard areas shall be as identified on the Flood Insurance Rate Maps prepared by FEMA, dated December 20, 2001. These maps are hereby adopted by reference and declared to be part of this ordinance.* LMC § 17.10.130(A).

B. *Designation. Areas of the City of Longview meeting the classification criteria for frequently flooded areas are hereby designated as such under RCW 36.70A.170 Id. at (B).*

C. Development Limitations. All development shall comply with the Longview Municipal Code 17.24, Flood Damage Prevention Ordinance, as now or hereafter amended. Id. at C.

3.4.1 Mt. Solo, RM W-62.0

The 46.6-acre Mt. Solo site (Appendix A, Figure 17) is nearly level at 8 ft CRD. The site can hold up to 2,500,000 cy of dredged sand. The Corps plans to place 2,400,000 cy of sand over a 20-yr period including the construction and maintenance dredging phases of the project, raising the site's elevation to 49 ft CRD. This is a new disposal site with a 2-acre settling/discharge cell. from which a pump station will pump discharge waters over the flood control dike and into the Columbia River (Appendix A, Figure 18). An outfall structure (generally a weir with a pipe riser set at appropriate elevations) will be installed between cells to allow water to flow to the settling/discharge cell adjacent to the flood control dike (Appendix A, Figure 18).

Request for Determination of Critical Areas
The formal Request for Determination, required by the City of Longview, will accompany the Joint Aquatic Resources Permitting Application (JARPA), submitted for Shoreline, Conditional Use, and CAO permits. A preliminary meeting was held with Cowlitz County and City of Longview staff on November 20, 2001. At that time it was determined that the only likely critical area was an approximately 10.8-acre wetland located on the site.

Frequently Flooded Areas
The Mt. Solo site lies outside the FEMA 100-year floodplain, behind a flood control dike maintained by the Cowlitz County Consolidated Diking District (Exhibit K-7, Figure 10). Permission will be secured from the Diking District to lay the temporary pipeline over the dike during sand disposal activities.

Geologic Hazards
The site is not within any designated landslide, erosion, or mine hazard areas.

Aquifer Recharge Areas
The Critical Aquifer Recharge Areas requirements for Cowlitz County do not apply to activities within the scope of this project. The Mt. Solo site is not located in a Classification 1 regulated area.

The Mt. Solo site does not meet the City of Longview's definition of a Regulated Aquifer Recharge Area, as it is hydrologically connected to the Columbia River rather than the Cowlitz River, which is the source of the majority of Longview's potable water resources (LMC Section 17.10.150).

Fish and Wildlife Habitat Conservation Areas

None of the Mt. Solo site matches the descriptions in the City of Longview CAO of Fish and Wildlife Habitat Conservation Areas. The WDFW PHS map does not show any PHS or state-listed species using the site (Appendix A, Figure 17).

Riparian Zones: Development setbacks are required by the City of Longview in areas adjacent to streams. The Columbia River is a Type 1 stream (WAC 222-16-030) and a setback of 250 ft from Ordinary High Water (OHW) is required. The Mt. Solo site lies behind a flood-control dike that effectively limits the boundary of the riparian zone. Distance from OHW to the inland toe of the dike is 191 ft. The riparian zone at the Mt. Solo location consists of the flood control dike, which is annually mowed and maintained as grassland to facilitate dike inspection for damage or leaks. Consequently, no riparian vegetation (trees or shrubs) is allowed to grow on the dike. Nonetheless, the waterward boundary of the disposal site will be set back 300 ft, as agreed to in the 2002 NMFS BO. This setback exceeds that required by the CAO.

Wetlands

The Mt. Solo disposal site is located behind a flood control dike maintained by the Cowlitz County Consolidated Diking District (Corps 2001). Wetland habitat present in the disposal site is detailed in Appendix A, Figure 19.

Using Ecology's information, the wetland on the Mt. Solo site will be classified by the City of Longview personnel according to their classification scheme. It is expected that the wetland will meet the criteria for the fourth level classification under the City CAO, or at best, the third level, and because of its size, it will be considered a Class Three wetland (Ecology 1993). The City of Longview requires mitigation at a 2:1 replacement level. The project-wide mitigation at Martin Island and Woodland Bottoms (Appendix A, Figures 10 and 13) was predicated upon replacement of 20.4 acres of impacted wetlands (revised in 2002 to 16 acres of wetland impacts) with 120 acres, yielding an approximately 8:1 replacement ratio, well above what is required. Further, the wetlands developed by mitigation activities will be of higher quality and greater ecological value than those at the Mt. Solo site due to their larger size, protection, and juxtaposition to riparian forest habitat. Wetlands at Mt. Solo are subject to drainage associated with operation of the diking district and are grazed by cattle. Waste rock was graded over a substantial portion of the site sometime in the past.

Conceptual Mitigation Plan: The Wetland Mitigation Plan (Appendix B) describes the mitigation action using Ecology's *Guidelines for Preparing Freshwater Mitigation Plans and Proposals* (Ecology 1994).

3.5 Wahkiakum County

Wahkiakum County is preparing Critical Areas Maps for adoption. Until the maps are complete, applicants and County staff rely on National Wetlands Inventory (NWI) maps and WDFW PHS maps for use in their environmental review (Beyer 2002).

Critical areas regulated under the Wahkiakum County CAO include:

Frequently Flooded Areas
Flood hazard areas shall be as identified in the scientific and engineering report entitled "the Flood Insurance Study for Wahkiakum County," dated September 28, 1990, with accompanying Flood Insurance Rate Maps prepared by FEMA, and all areas identified within Wahkiakum County's Flood Control Ordinance, Title 86 RCWC, as areas of special flood hazard. Wahkiakum County Ordinance 131-00, Section 17(A), (2000).

Geologically Hazardous Areas
Geologically hazardous areas are defined as designated erosion, seismic, volcanic, and landslide hazard areas. *Id*. at Section 18(A)(1-4).

Aquifer Recharge Areas
Municipal water for Wahkiakum County is pumped directly from the Elochoman River and from ground water adjacent to the Grays River. There are no known critical aquifer recharge areas within the County. Id. at Section 19.

Wetlands
Wetland classifications and mitigation and buffer requirements are shown in Table 4. See *Id*. at Sections 20(B, F and G).

Fish and Wildlife Habitat Conservation Areas
Wahkiakum County imposes Development Standards, Habitat Protection requirements, and in some cases, Habitat Management Plan requirements for activities within areas identified by WDFW to support state listed species or designated PHS. See *Id.* at Section (D). There are eight different classifications of Fish and Wildlife Habitat Conservation Areas (as defined by WAC 365-190-080[5], and standard requirements apply to these areas, as listed in the section following Table 4. *Id.* at Section 21(B).

D. Standards.

1. *The Administrator shall ensure that any development within fish and wildlife habitat conservation areas, as classified in subsection B of this Section, shall be reviewed according to the following performance standards:*
    a. *When impacts to fish and wildlife habitat cannot be avoided, the performance standards contained in this subsection shall*

be used to develop plans for regulated activities. Critical area permits may be conditioned to reflect the following performance standards contained in this Subsection D.

b. *Consider habitat in site planning and design.*

c. *Locate buildings and structures in a manner that preserves the habitat or minimizes adverse impacts.*

d. *Consolidate habitat and vegetated open space in contiguous blocks, and where possible, locate habitat contiguous to other habitat, open space or landscaped areas to contribute to a continuous system or corridor that provides connections to adjacent habitat areas.*

e. *Use native species in any landscaping of disturbed or undeveloped areas and in any enhancement of habitat or buffers.*

f. *Emphasize heterogeneity and structural diversity of vegetation in landscaping.*

g. *Remove and/or control any noxious or undesirable species of plants as identified by the Wahkiakum County Noxious Weed Control Board, but with due attention to possible negative impacts of herbicide sprays to wetlands.*

h. *Preserve trees to the extent possible, preferably in consolidated areas.*

i. *Preserve and introduce native plant species which serve as food, shelter from climatic extremes and predators, and structure and cover for reproduction and rearing of young for critical wildlife.*

j. *Preserve the natural hydraulic and ecological functions of drainage systems.*

k. *Preserve fish and wildlife habitat conservation areas through maintenance of stable channels, adequate low flows, management of stormwater runoff, erosion and sedimentation.*

l. *Manage access to fish and wildlife habitat conservation areas to protect species which are sensitive to human disturbance.*

m. *Maintain or enhance water quality through control of runoff and use of best management practices.*

Wahkiakum Ordinance 131-00, Section 21(D)(1), (2000).

Riparian zones are regulated under Section 21, Fish and Wildlife Habitat Conservation Areas. *Id.* at Section 21(E). Designated riparian zones and mitigation requirements are shown in Table 4.

3.5.1 Purple Loosestrife Control Program, RM W-52-18

Approximately 10,000 acres of tidal marsh in the Columbia River estuary are infested with purple loosestrife, an invasive, non-native plant that displaces native vegetation. If left unchecked, purple loosestrife (sp.) dominates the tidal marsh habitat, resulting in reduced biological diversity and negative impacts to estuarine wildlife.

The Purple Loosestrife Control Program will use an integrated pest management approach to include biological agents (insects), herbicides and mechanical (hand pulling) treatments. The USEPA-approved herbicide Rodeo will be applied from June to October during low tides when the plants are exposed. Fabric treated with the herbicide will be used to wipe herbicide onto purple loosestrife and spot spraying and hand-pulling will be used where appropriate. Release of biological agents would be based upon results from an ongoing action in the estuary (USFWS, Clatsop County and others). These approaches are intended to minimize exposure of non-target plant species.

The success of the program will be monitored and documented over a five-year period, and the results will assist the U.S. Fish and Wildlife Service, the States of Oregon and Washington, and local governments with planning regional control efforts.

Frequently Flooded Areas
The intertidal areas in the estuary targeted for purple loosestrife control all lie within the FEMA 100-year floodplain. No dredging, fill, or construction actions are associated with this restoration activity. Purple loosestrife will only be treated with herbicide at low tides during the summer season (June-October), when the plants are actively growing and leaves, stems and/or flowers are exposed.

Geologically Hazardous Areas
There are no geologically hazardous areas as defined in the CAO on this site.

Wetlands
Activities associated with this restoration action will take place within wetlands. The restoration action is expected to enhance the function of existing wetlands.

Fish and Wildlife Habitat Conservation Areas
The most likely areas for purple loosestrife to occur in Washington include intertidal marsh habitat at Whites, Jackson and Ryan Islands adjacent to Puget Island, the mouth of the Elochoman River, the embayment near Three Tree Point and Grays Bay. These areas all support waterfowl, wading birds such as great blue herons, bald eagles, including nesting pairs at some locations, and shorebirds. Columbian white-tailed

deer occur at Whites, Jackson and Ryan Islands and the mouth of the Elochoman River. Figures 20, 23, 24, and 25 provide PHS information for these locations.

3.5.2 Brown Island, RM W-46.3/46.0

Brown Island (Appendix A, Figure 20 is an existing, active sand disposal site, used routinely by the Corps for maintenance dredging of the 40-ft channel. The site is listed in the Wahkiakum County Dredged Material Management Plan (DMMP). The 72-acre site will be used as needed over a 20-yr period including the construction and maintenance phases of the project. Up to 4,700,000 cy of sand will be placed on Brown Island, raising the elevation from an estimated elevation of 15 ft CRD to 66 ft CRD. A weir drainage system with outfall to the Columbia River is already in place.

Frequently Flooded Areas
The entire Brown Island site lies within the FEMA 100-year floodplain (Exhibit K-7, Figure 12). Brown Island is an established sand disposal site for the 40-foot channel O&M material and a containment berm surrounds the site.

The base flood elevation at the site is 10.3 ft CRD. Portions of the site have been raised out of the 100-yr floodplain by previous sand disposal activities, but this is not reflected on the FEMA map (Exhibit K-7, Figure 12). The containment berm that is in place blocks river flows from entering the remaining area within the disposal area that is lower than the base flood elevation. A Letter of Map Revision due to Fill (LOMR-F) will be prepared by the Corps upon attainment of additional topographic information.

Geologically Hazardous Areas
There are no geologically hazardous areas as defined in the CAO on this site.

Wetlands
There are no wetlands on this site. The site has been routinely used for sand disposal and is raised approximately 10 ft above the natural ground surface level.

Fish and Wildlife Habitat Conservation Areas
Brown Island is almost completely covered by sand. Vegetative cover is sparse due to the virtually sterile, xeric nature of the sand substrate derived from dredged material placement. Wildlife use of the site is limited due to lack of available vegetative forage and cover.

WDFW has expressed concern for waterfowl concentrations, harbor seal haulout areas, and Columbian white-tailed deer at or near the site (Appendix A, Figure 20). Waterfowl concentrations have been observed in the intertidal zone on the north side of the island facing the Cathlamet Channel, north and outside of the sand disposal area. Harbor seals have been observed by WDFW personnel to haulout on sandbars in the intertidal zone north of the island, but are not expected to occur on the disposal site. The disposal activities on Brown Island will not impact the intertidal area frequented by waterfowl or harbor seals. The proposed disposal activity is relatively low intensity, distant from the intertidal area and visually buffered by the containment dike. Some nesting by Canada geese does occur at the location, but disposal operations associated with 40-ft channel O&M have restricted their nesting to the outer toe of the containment dike where debris and/or dense vegetation above the high tide line occurs.

In April 2002, to comply with USFWS requirements in their BO for the Corps' DMMP (O&M dredging of the 40-foot navigation channel), the Corps seeded 57.1 acres of the site with a spring oats/pasture mix and applied approximately 300 lbs of fertilizer/acre (50 percent slow-release formulation) to provide higher-quality forage for Columbian white-tailed deer and to stabilize soil (Dorsey 2002b). The BO requires that the site must be reseeded after each sand disposal event. Once established, the improved vegetation would also provide forage and cover for waterfowl on the disposal site area. The ESA terms and conditions established through the BO for the DMMP will also be implemented during the Channel Improvement Project. The actions the Corps is presently taking, and will continue to implement, as required by USFWS ESA terms and conditions, are sufficient to address Columbian white-tailed deer at Brown Island.

The nearest eagle nest to the site is 1 mile northwest of the western edge, and the nearest great blue heron rookery is ¾ mile northwest of the western edge of the site. Both the nest and the rookery are in the Cut-Off Slough, just off the shore of Whites Island. These nest locations are sufficiently distant from the disposal site that neither will be affected by Project activities.

3.5.3 Puget Island, RM W-44.0

The Puget Island site (Appendix A, Figure 20) is privately owned and currently used as agricultural land. The property is divided into three parcels totaling 100 acres. The landowners have requested that topsoil stripped during the grading process be replaced after sand disposal so they can resume using the land for agricultural purposes. The Corps, in their Biological Assessment (BA) for the USFWS, stated that the site was to be used in three increments, with topsoil to be removed and saved and placed atop the dredged material as each cell was filled. USFWS, in their BO (December 6, 1999) included the Corps incremental disposal plan with topsoil replacement as a non-discretionary reasonable and prudent measure for implementation in order to minimize take of Columbian white-tailed deer.

The current average elevation of the Puget Island site is 15 ft CRD. The Corps disposal plan will raise the elevation to 41 ft CRD by placing 3,300,000 cy of sand. This is a new disposal site and while use of the site is scheduled throughout the construction and 20-yr maintenance phases of the Project, the three parcels will be filled at three different times (Appendix A, Figure 21). Each cell may require multiple years to fill to design height, with the time period dependent upon construction and the O&M volumes available in the nearby navigation channel. A weir, pump station and outfall system for return water will be constructed, to remain in place until all three cells are filled (Appendix A, Figure 20).

The upstream cell would be filled first and the downstream last. The downstream cell contains the 5.4-acre wetland that will ultimately be filled. The Corps estimates that Cell 1 would be filled upon receipt of two years of construction and two years of O&M material. Cells 2 and 3 would each receive approximately 8-10 years of O&M material apiece before they reach design height.

For the purposes of this Critical Areas Ordinance analysis, it is noted that the wetlands at the Puget Island site that are subject to critical areas ordinance are in the part of the site that is scheduled to be used last. Given the projected volumes of sand, the Corps estimates that this would occur more than 12 years after construction. For purposes of mitigation, the Corps assumes that the impact will occur in the first year of the Project. This assumption results in greater mitigation being provided for the project and greater certainty that the mitigation is performing as planned before any fill would occur.

Frequently Flooded Areas
The Puget Island site lies behind flood control dikes, outside the FEMA 100-year floodplain (Exhibit K-7, Figure 12).

Geologically Hazardous Areas
There are no geologically hazardous areas as defined in the CAO on this site.

Wetlands
Wahkiakum County classifies wetlands according to the Washington State Wetland Rating System for Western Washington (2nd Edition) Wahkiakum County Ordinance 131-00, Section 20(B)(2000). The property contains a 5.4-acre wetland (Appendix A, Figures 21 and 22) that meets the functional standards for a Class IV wetland. Under the State Rating System, Class IV wetlands over two acres in size are considered at least a Class III (Ecology 1993). Based on preliminary discussions with Ecology, the wetland will be treated as a Category III shrub wetland.

Section 20(G) requires creation, restoration, or enhancement of wetlands if wetlands are altered. The wetland on the Puget Island site will be filled. Under Section 20(G)3, the County may increase replacement ratios for off-site compensation. Under the project's mitigation approach, 120 acres of wetland habitat, including 16 acres of intertidal marsh, will be restored or enhanced at the Woodland Bottoms and Martin Island mitigation sites (Appendix A, Figures 10 and 13), for an average replacement ratio of 8:1 for the 16.2-acre total impact. This replacement ratio is well beyond what is required, even if the County were to increase the replacement ratio (see Section 9).

Fish and Wildlife Habitat Conservation Areas

A 5.4-acre wetland exists on the site as described above. The site is part of a large agricultural cropland (primarily pasture) area used by Columbian white-tailed deer (Appendix A, Figure 20). The closest bald eagle nest is over a mile east of the site and a great blue heron rookery occurs 1 mile east of the site (Appendix A, Figure 20).

The WDFW PHS map does not show waterfowl use of the Puget Island disposal site properties, though waterfowl do concentrate in the slough areas east of the island. Wintering Canada geese would be expected to forage in these pasturelands. The wildlife mitigation plan includes creation of 132 acres of permanent pastureland habitat at Woodland Bottoms (Appendix A, Figure 10). This habitat will benefit Canada geese, ground-dwelling songbirds, sandhill cranes, reptiles, amphibians and other species. Further, incremental use of the site plus topsoil replacement post-construction also addresses provision of waterfowl (Canada goose) forage comparable to present condition.

The Puget Island subpopulation area used by Columbian white-tailed deer encompasses Puget, Jackson, Brown, and Whites islands. The area to be disturbed during disposal activities is small in relation to the full range of the Puget Island subpopulation of deer. Topsoil will be replaced and the land restored to its existing use after disposal per the Corps disposal plan and non-discretionary requirement of USFWS. The Corps will also provide lands and habitat management on approximately 100 acres for Columbian white-tailed deer at the Webb mitigation site on the Oregon shore opposite and slightly upstream of W-44.0. Potentially, the Woodland Bottoms mitigation site plan that includes the creation of 43 acres of riparian habitat (Appendix A, Figure 10), and the Martin Island mitigation site plan that includes 159 acres of riparian forest could be used to establish populations of Columbian white-tailed deer (Appendix A, Figure 13).

3.5.4 Skamokawa, RM W-33.4

Skamokawa Beach (Appendix A, Figure 23) has had serious erosion problems and sand is routinely placed on the shoreline there to replenish sand lost by erosion. The site is located on the outside of a river bend, and thus is subject to relatively strong river currents. When a sand surplus exists, excess sand is sold from the site to offset operating costs for neighboring Skamokawa Vista Park (a day-use park managed by Port of Wahkiakum 2).

The 11-acre site has a current average elevation of 0 ft CRD. Sand placed at the site will raise the elevation by up to 18 ft. The site capacity is 250,000 cy of sand. No dredged material is currently scheduled for placement at this site <u>during construction</u>. As a beneficial use site, the Port of Wahkiakum 2 may request placement of dredged material (O&M) at the location as it becomes depleted and site capacity becomes available.

Frequently Flooded Areas
The entire Skamokawa Beach site lies within the FEMA 100-year floodplain (Exhibit K-7, Figure 13). This is an existing beach nourishment site and it is expected that the sand may be inundated or carried downstream by erosion. Placement of sand at the site may actually help protect the portion of the park located in the interior of the disposal site from damage due to erosion during flood flows.

Geologically Hazardous Areas
Skamokawa Beach is a highly erosive area. Sand is regularly placed there as shoreline disposal to provide for recreational use and resale by the Port of Wahkiakum 2.

The CAO states that *an erosion control plan shall be submitted to the administrator for approval prior to any clearing, construction or other development in an erosion hazard area. The erosion control plan shall be designed so that the hazard is mitigated such that the site is rendered safe as an area without erosion hazards.*

This site is included in the Corps disposal plan at Wahkiakum County's request as part of the County's erosion control plan.

Wetlands
There are no wetlands on or immediately adjacent to the site.

Fish and Wildlife Habitat Conservation Areas
Bald eagle nesting territories occur approximately 11/4 miles upstream and 1 mile downstream of the Skamokawa Beach disposal site (Appendix A, Figure 23).

3.5.5 Tidegate Retrofits at Deep River, RM W-22

This Ecosystem Restoration Feature entails installation of fish slides in existing tide gates located in levees along Deep River (Appendix A, Figure 24). Where the tide gates now impede fish passage, they will be fitted with panels that have a rectangular opening of approximately 12 by

15 inches. The opening can be closed if needed for flood control purposes. This action will enable salmonids to access spawning and rearing habitat upstream in the Deep River tributaries.

Frequently Flooded Areas

Because the fish slides can be closed if needed, the diking districts ability to regulate flows is not affected.

Geologically Hazardous Areas

The Deep River tidegates are not located in a geologically hazardous area.

Wetlands

The tidegate structures are located within the flood control dikes, thus there is little likelihood of physical damage to adjacent wetland habitat during construction. The combination of lighter tidegate doors and fish slides may result in a more pronounced tidal fluctuation for waters upstream of the tidegate. Fish slides will allow water to flow upstream of the tidegate structure during time periods when the tidegate door is normally closed. Lighter tidegate doors are intended to open sooner and longer to allow for a greater period of time for salmonids to access the stream. This may allow for a more pronounced drawdown of water in the stream above the flood control levee.

Fish and Wildlife Habitat Conservation Areas

The installation of the fish slides does not typically involve new construction; rather, a portion of an existing structure will be replaced. Disturbance to the area is minimal, and the resulting fish passage will benefit salmonids by allowing use of spawning and rearing habitat that is currently inaccessible. Only when the entire tide box structure is in disrepair will a full replacement be considered. Even then, disturbance to adjacent habitat and fish and wildlife resources would be minimal. One bald eagle nesting territory is located in the Deep River project area for this ecosystem restoration feature (Appendix A, Figure 24).

3.5.6 Rice Island, RM W-21.0

Rice Island was created by the Corps as a sand disposal site for the navigation channel beginning around 1962. The 228-acre site lies on the state boundary line and only 21 acres are within the state of Washington (Appendix A, Figure 25). WDNR and the Oregon Division of State Lands (ODSL) own the island. Elevations on the island range from 0 to 40 ft Columbia River Datum (CRD), with an average elevation of 13 ft CRD on the Washington portion of the site. Most of the island is level, with steep 20- to 35-ft banks dropping off from the crest of the dredge pile. Because the island is an existing sand disposal site with containment dikes around the active disposal area, a drainage system is already in place. An additional containment dike and weir would be required when the low elevation portion in the state of Washington is filled. The weir system would be located on the Washington side of the state borderline.

The entire site (encompassing both states) can hold up to 5,500,000 cy of additional sand. The Corps plans to place up to that amount during the maintenance phase of the project, raising the site elevation to 53 ft CRD. The site will be used throughout the entire 20-yr maintenance phase of the project as needed.

Frequently Flooded Areas

The Rice Island site's average elevation is 30 ft CRD. The base flood elevation at the site is 96.9 ft CRD. The site has been raised out of the 100-yr floodplain by previous sand disposal activities, but this is not reflected on the FEMA map (Exhibit K-7, Figure 15). A Letter of Map Revision due to Fill (LOMR-F) will be prepared by the Corps upon attainment of additional topographic information.

Geologically Hazardous Areas

The majority of the island is stabilized by the berm around the sand placement area and does not present an erosion, landslide, or seismic hazard. The balance of the island lies slightly above the high tide line and poses no geologic hazard either.

Wetlands

There are no wetlands on Rice Island.

Fish and Wildlife Habitat Conservation Areas

The WDFW PHS maps show Canada goose, Caspian tern, and double-crested cormorant habitat on the entire island (Appendix A, Figure 25). Glaucous-winged/western gull hybrids, double-crested cormorants, and Caspian terns nest or formerly nested on the western (Oregon) end of the island. Bald eagles and other raptors forage on the site. Two bald eagle nests were observed in 30-ft cottonwoods on the northern edge of the island in 1991 (Appendix A, Figure 25). These nests no longer exist and the eagle pair has relocated to Miller Sands Island, Oregon, more than a mile from the original nest site (Isaacs and Anthony 2001). Concentrations of wintering shorebirds utilize the downstream tip (Oregon) of the island as a winter/high tide roost location.

The Corps has evaluated a number of potential measures (e.g., timing restrictions and revegetation) to address potential impacts. These are discussed below.

Canada geese, the principal waterfowl species that nest on Rice Island, primarily use the debris line or densely vegetated areas for nesting purposes. Disposal actions would remove vegetative cover at the upstream tip where some nesting currently occurs. The Corps has avoided the debris line in the past to the extent practicable to preserve nesting habitat for Canada geese, and this practice would continue with implementation of the Channel Improvement Project. Canada geese have essentially completed their nesting activities (hatched) by May 10. Brood rearing occurs elsewhere (Grays Bay, Miller Sands embayment) as Rice Island does not provide fringing intertidal marsh habitat and protected shorelines that geese with broods seek, nor do the uplands provide an adequate forage base. Construction volumes in this reach of the Columbia River would be placed in either an ecosystem restoration area or the ocean. Typically, Corps maintenance disposal actions at Rice Island would occur after June 1. The Corps would avoid the debris line to the extent practicable during Operations and Maintenance (O&M) actions to maintain Canada goose nesting habitat. These provisions should sufficiently protect nesting Canada geese. In addition, 132 acres of permanent pastureland habitat will be developed at the Woodland Bottoms mitigation site, furnishing the habitat features that Rice Island lacks. This habitat will benefit Canada geese, ground-dwelling songbirds, sandhill cranes, reptiles, amphibians and other species.

Gulls, terns and cormorants nest, or formerly nested, on the downstream tip of the island (Oregon). The Corps, coordinating with USFWS, has used a 1,500-foot separation distance from the nesting colonies when implementing disposal actions concurrent with the nesting seasons for these species. That avoidance measure has been sufficient to protect the colonies from disturbance and would be implemented in the future, if warranted. However, the National Marine Fisheries Service (NMFS) Biological Opinion (BO) for the Columbia River Dredged Material Maintenance Plan (O&M dredging of the 40-foot navigation channel) requires the Corps to prevent Caspian terns from nesting on estuarine islands (Rice Island, Pillar Rock Island and Miller Sands Spit). Further, the settlement agreement between the litigants and plaintiffs for Case No. C00-615R, United States District Court for the Western District of Washington, allows the Corps to place dredged material on Rice Island and other estuarine islands that have not been colonized by Caspian terns in the past. The Corps actions regarding distance setback from bird nesting colonies and compliance with ESA requirements and the Settlement Agreement and Migratory Bird Treaty Act, in addition to continuing coordination with the USFWS, will sufficiently protect colonial nesting birds.

The Corps will implement efforts to establish vegetation on Rice Island when fill activities are completed. Establishment of vegetation is difficult, based upon previous attempts, due to adverse environmental conditions (wind erosion) and the sterile, xeric nature of the sand substrate.

Implementation of these measures to avoid and minimize impacts would meet the Wahkiakum County requirements for habitat protection as stated in Section 21, subsection D, of the CAO.

4. Potential Impacts

4.1 Direct Impacts

Direct impacts as a result of sand disposal activities are the loss of wetland, riparian, and agricultural habitat as shown in Table 6. A summary of upland site floodplain designations is given in Table 7, and PHS habitat designations are summarized in Table 8.

5. Assessment of Impact

Impacts to wetlands and riparian habitat have been discussed in the previous sections. The proposed Wildlife Mitigation Plan for the Project (1999 Final IFR/EIS, Appendix G) exceeds requirements and is expected to yield greater ecosystem benefits than creating more, but smaller mitigation features. In addition, the Wetland Mitigation Plan (Appendix B), prepared to comply with local jurisdiction CAOs and Ecology's *Guidelines for Preparing Freshwater Mitigation Plans and Proposals* (Ecology 1994), demonstrates CAO compliance and functional gains.

6. Action Plan

Wetlands have been avoided wherever possible. At the Mt. Solo and Puget Island sites, total avoidance of wetlands was not feasible and the proposed mitigation exceeds CAO requirements.

The project-wide BAs, Wildlife Mitigation Plan (1999 Final IFR/EIS, Appendix G) and Monitoring Plans will be furnished to the local planning departments. Personnel in these departments should note minor changes in habitat acreage impacts that have arisen due to the 2001 BA and NMFS 2002 BO. All required Critical Areas permits will be applied for. This Consistency Analysis is meant to aid planners in reviewing the permit applications.

Table 9 shows total project mitigation requirements and Table 10 shows proposed project-wide mitigation.

Table 6 Project impacts by habitat type.

River Mile	Location Name	Wetland	Riparian	Agricultural	EUD[a]	Other	Total
101.0	Gateway 3			40.0			40.0
97.1	Fazio Sand and Gravel				27.0		27.0
96.9	Adjacent to Fazio			8.2	8.8		17.0
86.5	Austin Point		3.4		22.6		26.0

River Mile	Location Name	Wetland	Riparian	Agricultural	EUD[a]	Other	Total
82.0	Martin Bar		2.9		29.1		32.0
80.0	Martin Island Mitigation					16.0[b]	16.0
71.9	Northport				27.0		27.0
70.1	Cottonwood Island		6.2		55.8		62.0
68.7	Howard Island		20.0		180.0		200.0
67.5	Pt. of Longview/Int'l. Paper				29.0		29.0
63.5	Reynolds Aluminum				13.0		13.0
62.0	Mt. Solo	10.8		35.8			46.6
59.7	Hump Island		7.0		62.0		69.0
46.3/46.0	Brown Island				72.0		72.0
44.0	Puget Island (Vik Prop.)	5.4	2.6	88.2		3.8[c]	100.0
33.4	Skamokawa				11.0		11.0
21.0	Rice Island				21.0		21.0
	Total	16.2	42.1	172.2	558.3	19.8	808.6

a EUD = Existing Upland Disposal.

b Other habitat type refers to the Martin Island lagoon that will be converted to intertidal marsh habitat.

c Other habitat type refers to houses, driveways, yards, outbuildings, flood control levees and other man-made structures.

Table 7 Floodplain designations for upland sand disposal sites.

Disposal Site *	Disposal History**	Site Name	Site Acres	FEMA Floodplain Designation				Notes
				A	AE	Outside	Protected by Flood Control Dike	
W-101.0	New	Gateway 3	40	X			X	New site.
W-97.1	DMMS	Fazio Sand & Gravel	27	X				Site elevation historically raised by dredged material deposition.
W-96.9	New	Adjacent Fazio	17	X				Site elevation historically raised by dredged material deposition (1/2 site nearest river). Balance new site.
W-86.5	Used	Austin Point	26	X				Site elevation historically raised by dredged material deposition.
W-82.0	Used	Martin Bar	32	X				Site elevation historically raised by dredged material deposition.
W-80.0	New	Martin Island Embayment	16	X				Mitigation site - emergent marsh development.
W-71.9	Used	Northport	27	X				Site elevation historically raised by dredged material deposition.
W-70.1	Used	Cottonwood Island	62	X				Site elevation historically raised by dredged material deposition.
W-68.7	DMMS	Howard Island	200	X				Site elevation historically raised by dredged material deposition.
W-67.5	Used	IP Rehandle	29			X	X	Site elevation historically raised by dredged material deposition.
W-63.5	Used	Reynolds Aluminum	13			X		Disposal site already has containment dike constructed around perimeter.
W-62.0	New	Mt. Solo	47			X	X	New site.
W-59.7	DMMS	Hump Island	69			X		Site elevation historically raised by dredged material deposition.
W-46.0/ 46.3	DMMS	Brown Island	72		X			Disposal site already has containment dike constructed around perimeter.
W-44.0	New	Puget Island	100			X	X	New site.
W-33.4	Used	Skamokawa	11		X			Shoreline disposal.
W-21.0	DMMS	Rice Island	WA-21; OR-207		X			Site elevation exceeds 100-yr floodplain elevation over most of island due to historic dredged material disposal.

* "W" refers to the Washington shoreline, respectively. The number refers to the approximate river mile on the navigation channel.

** DMMS = site is in the no action alternative (existing 40-foot channel maintenance)

New = site is new for this study

Used = site previously used by Corps for disposal

Table 8 WDFW Priority Habitat and Species

Site		Waterfowl Concentration	Dusky Canada Goose	Canada Goose	Bald Eagle	Harbor Seal	Great Blue Heron	Gull Spp.	Caspian Tern	Double-Crested Cormorant	Columbian White-tailed Deer	Osprey	Wetlands	Islands	Notes
W-21.0	Rice Island			♦	♦			♦	♦	♦					
W-33.4	Skamokawa Beach														No PHS polygons assigned.
W-44.0	Puget Island										♦			♦	
W-46.3	Brown Island	♦		♦		♦					♦			♦	
W-59.7	Hump Island	♦		♦	♦							♦		♦	
W-62.0	Mt. Solo														No PHS polygons assigned.
W-63.5	Reynolds Aluminum														No PHS polygons assigned.
W-67.5	International Paper											*			Osprey nests near site. No PHS polygons assigned.
W-68.7	Howard Island						*					*		♦	*Waterfowl concentration and Great Blue Heron PHS polygons adjacent to site.
W-70.1	Cottonwood Island						*					*			*Waterfowl concentration and Great Blue Heron PHS polygons adjacent to site.
W-71.9	Northport											*	*		*Wetland polygon extending onto Northport site is incorrect.
W-80.0	Martin Island Lagoon				*										*Bald eagle nest near site. Waterfowl concentration and Canada goose PHS polygons 0.5 mi upstream.
W-82.0	Martin Bar											*			*Osprey nests near site. Waterfowl concentration and Canada goose PHS polygons adjacent to site.
W-86.5	Austin Point				♦							*			*Osprey nests near site. Waterfowl concentration PHS polygon adjacent to site.
W-96.9	Adjacent to Fazio	♦													Dusky Canada goose PHS polygon adjacent to site.
W-97.1	Fazio	♦													Dusky Canada goose PHS polygon adjacent to site.
W-101	Gateway 3	♦	♦	*											*Eagle nest off disposal site; personal observation, Geoff Dorsey, Corps.

Table 9 Total required mitigation.

Site Requiring Mitigation	Wetland Acres Impacted	Replacement Ratio	Replacement Acreage Required	Riparian Acres Impacted
Austin Point				3.4
Martin Bar				2.9
Cottonwood Island				6.2
Howard Island				20.0
Mt. Solo	10.8	2:1	21.6	
Hump Island				7.0
Puget Island	5.4	2:1	10.8	2.6
Total	16.2		32.4	42.1

Table 10 Habitat creation on mitigation sites.

Site	Wetland (acres)	Riparian (acres)	Agricultural (acres)	
Woodland Bottoms	97	43	132	In addition to Wetland and Riparian habitat, 132 acres of permanent pastureland habitat is provided
Martin Island	23	159		Wetland includes 16 acres of emergent marsh habitat development at Martin Island
Total	120	202	132	

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Wetland Mitigation Plan

Columbia River Channel Improvement Project

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Table of Contents

List of Figures

Figures referenced in this document can be found in Appendix A.

List of Tables

1. Introduction

1.1 Background

The Columbia River Channel Improvement Project takes place within five different local jurisdictions within the state of Washington, including the City of Longview, Cowlitz County, City of Vancouver, Clark County, and Wahkiakum County. The Project activity that results in unavoidable impacts to isolated wetlands is the disposal of dredged material (sand) at the Mt. Solo disposal site (W-62.0) in the City of Longview and on Puget Island (W-44.0) in Wahkiakum County. Both of these sites have not previously been used as dredged material disposal sites. The mitigation actions that will replace lost wetland area and function will occur at Martin Island and Woodland Bottoms, both located in Cowlitz County.

This wetland mitigation plan was developed to address local and Washington Department of Ecology's concerns regarding wetland impacts and mitigation in Washington State, address the impacts to wetlands at Mt. Solo and Puget Island, and present the actions that will occur at Martin Island and Woodland Bottoms to compensate for wetland impacts consistent with the City of Longview, Wahkiakum County, and Cowlitz County Critical Areas Ordinances (CAOs). In addition the wetland mitigation plan follows Washington Department of Ecology's *Guidelines for Developing Freshwater Wetland Mitigation Plans* (Ecology 1994).

1.2 Project Purpose and Description

The overall Project purpose is to provide three additional feet of channel depth to improve safety and efficiency of deep-draft vessel transport of goods on the lower Columbia River. A detailed description of the Project is contained in the Final Integrated Feasibility Report/Environmental Impact Statement (FIFR/EIS, August 1999), and additional project elements are discussed in the Columbia River Channel improvement Project Final SEIS.

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2. Impact Area

2.1 Impact Area Location

The proposed disposal site at Mt. Solo is located at RM W-62.0 within the City of Longview (Appendix A, Figure 17). The proposed Puget Island disposal site is located at the southern tip of the island at River Mile (RM) W-44.0 within Wahkiakum County (Appendix A, Figure 20).

2.2 Project Impact Area Description and Wetland Delineation

2.2.1 Project Impact Area Description

Mt. Solo, RM W-62.0

The 46.6-acre Mt. Solo site (Appendix A, Figure 17) is nearly level at 8 feet CRD. The site can hold up to 2,500,000 cy of dredged sand. The Corps plans to place 2,400,000 cy of sand over a 20-yr period including the construction and maintenance dredging phases of the project, raising the site's elevation to 49 ft CRD. This is a new disposal site with a 2-acre settling/discharge cell from which a pump station will pump discharge waters over the flood control dike and into the Columbia River (Appendix A, Figure 18). An outfall structure (generally a weir with a pipe riser set at appropriate elevations) will be installed between cells to allow water to flow to the settling/discharge cell adjacent to the flood control dike. The Mt. Solo wetland is located behind a flood control dike maintained by the Cowlitz County Consolidated Diking District (Corps 2001).

The initial containment berm will be constructed from topsoil obtained from the disposal site. Dredged material will be placed in each cell using a hydraulic pipeline that transports sand from the dredge to the site. Deposited sand will subsequently be used to build up the height of the perimeter berm and the berm between the cells prior to the next cycle of dredging and disposal at the disposal site.

Using information from Ecology's site visit in January 2002, the wetland on the Mt. Solo site will be classified by the City of Longview personnel according to their classification scheme. It is expected that the wetland will meet the criteria for the fourth level classification under the City CAO, or at best, the third level, and because of its size, it will be considered a Class 3 wetland (Ecology 1993). The disposal of sand on this site will result in the loss of approximately 10.8 acres of a Category 3 shrub wetland. The City of Longview requires mitigation at a 2:1 replacement level.

Puget Island, RM W-44.0

The Puget Island site is privately owned and currently used as agricultural land (see Appendix A, Figures 20, 21 and 22). The property totals 100 acres. The landowners have requested that topsoil stripped during the construction of the initial containment dikes be replaced after sand disposal so they can resume using the land for agricultural purposes. The Corps, in their Biological Assessment (BA) for the USFWS, stated that the site was to be used in three increments, with topsoil to be removed and saved and placed atop the dredged material as each cell was filled. USFWS, in their Biological Opinion (December 6, 1999) included the Corps incremental disposal plan with topsoil replacement as a non-discretionary reasonable and prudent measure for implementation in order to minimize take of Columbian white-tailed deer. To accomplish topsoil replacement, the soil in the initial containment berms will be removed and redistributed atop the disposal site upon completion of fill placement for each cell.

The current elevation of the Puget Island site is 15 ft CRD. The Corps disposal plan will raise the elevation to 41 ft CRD by placing 3,300,000 cy of sand from construction and maintenance dredging activities. This is a new disposal site divided into three cells, and while use of the site is scheduled throughout the construction and 20-yr maintenance phases of the Project, the three parcels will be filled at three different times (Appendix A, Figure 21). Each cell may require multiple years to fill to design height, with the time period dependent upon construction and maintenance volumes available in the nearby navigation channel.

Heavy equipment will be used to strip topsoil from each cell where dredged sand will be placed. The stripped topsoil will be used for the initial containment berms and then mined from these sites for redistribution as topsoil after sand has filled each cell. Dredged material will be placed in each cell using a hydraulic pipeline that transports sand from the dredge to the site. Deposited sand will subsequently be used to build up the height of the perimeter berm and the berm between the cells prior to the next cycle of dredging and disposal at the disposal site.

An outfall structure (generally a weir with pipe riser set at appropriate elevations) will be constructed to convey water between the main portion of the cell and the 2-acre settling/discharge cell and from that cell to the toe drain for outfall water. The toe drain will convey the discharge waters to a pump station from which they will be pumped to the Columbia River.

Wahkiakum County classifies wetlands according to the Washington State Wetland Rating System for Western Washington (2nd Edition) Wahkiakum County Ordinance 131-00, Section 20(B)(2000). The property contains a 5.4-acre wetland (Appendix A, Figures 21 and 22) that meets the functional standards for a Class IV wetland. Under the State Rating System, Class IV wetlands over two acres in size are considered at least a Class III (Ecology 1993). Based on preliminary discussions with Ecology, the wetland will be treated as a Category III shrub wetland.

Section 20(G) requires creation, restoration, or enhancement of wetlands if wetlands are altered. The wetland on the Puget Island site will be filled. Under Section 20(G)3, the County may increase replacement ratios for off-site compensation. Under the project's mitigation approach, 120 acres of wetland habitat, including 16 acres of intertidal marsh, will be restored or enhanced at the Woodland Bottoms and Martin Island mitigation sites (Appendix A, Figures 10 and 13), for an average replacement ratio of 8:1 for the 16.2-acre total impact. This replacement ratio is well beyond what is required, even if the County were to increase the replacement ratio. The wetland occurs in the downstream disposal cell (Cell 3) that will be filled last, thus the wetland impact is not likely to occur for several years (e.g., 15 years) after construction dredging occurs.

2.2.2 Wetland Descriptions

The U.S. Army Corps of Engineers (Corps), Portland District has considered the project action area as a whole for assessing impacts to wetlands and wildlife resources and their habitats and in developing associated wildlife mitigation actions, including a wetland mitigation component. This approach is consistent with the Corps requirements to address impacts to wildlife resources arising from implementation of the Federal project. Further, the Corps' wildlife mitigation effort addresses impacts to wildlife resources in upland (including agricultural lands), riparian forest and wetland habitats rather than focusing only on wetland habitats as would occur for private development actions.

An interagency team was established to assess impacts to wildlife resources and develop a mitigation plan (with representatives from the Corps, Ecology, Washington Department of Fish and Wildlife [WDFW], Oregon Dept. of Fish and Wildlife [ODFW], and U.S. Fish and Wildlife Service [USFWS]). The team used the USFWS's Habitat Evaluation Procedure (HEP) to assess wildlife and wetland impacts.

The HEP evaluation is a modeling tool to quantify impacts to habitat value for specific species. HEP is usually used with a limited range of habitat variables relative to a single species selected as an indicator of ecosystem health (Manlow 2002). In this case, nine target species were used to evaluate project-related impacts to wildlife and wetland resources. In order to simplify the analysis, all project impacts were considered to take place within the first year of the project (Corps 1998).

Impacts to the Puget Island wetland will occur after the wetland mitigation has been implemented. In addition, the amount of wetland impact has been decreased since the HEP analysis was performed from approximately 20 acres to 16 acres as a result of more accurate map analysis (a reduction of approximately 25 percent). HEP is also used to measure the performance of wildlife and wetland mitigation actions, including wetland and riparian habitat restoration and development. The Corp's Wildlife Mitigation Plan was presented in the 1999 Final IFR/EIS, Appendix G. Please refer to Exhibit K-5, *Wildlife and Wetland Mitigation for the Columbia Channel Improvement Project*, for a more detailed discussion.

Because it was determined that HEP was the appropriate tool to use to determine wetland and wildlife impacts, and that rights of entry have not yet been obtained from the property owners of Puget Island and Mt. Solo, wetlands were identified using aerial photographs and by reconnaissance site visits. No formal wetland delineation has been completed on either site, and some detailed information (*i.e.*, soil characteristics from taking soil samples and comparing to the Munsell Soil book) on the wetlands is not available. A formal wetland delineation will be conducted by the Ports for permitting purposes prior to any dredged material being discharged to the wetlands to confirm the wetland acreage, type, and to collect additional baseline information.

Descriptions of the impacted wetlands at the Mt. Solo and Puget Island locations are provided below. Wetland habitat losses occur at two locations and include wetland habitat associated with drainage ditches, swales, land subject to row crop agriculture, and land grazed by livestock.

Mt. Solo Wetland
Classification: A palustrine emergent wetland (PEM).

Size: Approximately 10.8 acres.

Topography: The wetlands are several small, shallow topographic swales (Appendix A, Figures 18 and 19).

Hydrology: The source of water is internal drainage within the flood control dike.

Soils: Soils in this wetland are mapped as Caples, a silty clay loam and Snohomish, also a silty clay loam. These are classified as hydric soils. Their function as hydric soils is compromised by water management implemented by the drainage district (e.g., drainage ditches, pumps).

Vegetation: The wetland swales consist primarily of herbaceous wetland vegetation (e.g., rushes and invasive herbaceous and pasture-type grasses).

Functional Analysis: Based on aerial photography and the reconnaissance site visit, the primary functions of the wetland include habitat for small mammals, waterfowl, passerine birds, and possibly for amphibians. The site provides some internal flood storage during heavy rainfall events for the diking district until water is drained and discharged via a pump to Columbia River. The buffer consists of pasturelands. A formal wetland delineation will be conducted by the Ports for permitting purposes prior to any dredged material being discharged to the wetlands to confirm the wetland acreage, type, and to collect additional baseline information.

The functions of the wetlands will be assessed using Ecology's *Methods for Assessing Wetland Functions on Riverine and Depressional Wetlands in the Lowlands of Western* Washington (Ecology 1999) prior to material being placed in the wetlands.

Puget Island Wetland
Classification: Predominately a palustrine shrub (PSS) wetland community, seasonally flooded/inundated, located within and on the sides of a constructed ditch and adjacent area (Appendix A, Figures 21 and 22).

Size: Approximately 5.4 acres.

Topography: The disposal site is generally flat pastureland and the small wetland is lower in elevation because it is a drainage ditch and immediately associated lands.

Hydrology: Internal drainage (i.e., surface water) of agricultural pasturelands behind the flood control dike of Wahkiakum County Consolidated Diking District No. 1.

Soils: Soils in this wetland are mapped as the Cathlamet series, generally a silt loam.

Vegetation: The majority of the wetland is a PSS wetland consisting of willows and invasive reed canarygrass in and adjacent to the drainage ditch.

Functional Analysis: Based on aerial photography and the reconnaissance site visit, the primary function of the wetland is water conveyance from the adjacent pasturelands. It also appears to provide habitat for some small mammals, passerine birds, and amphibians. It provides some water quality function by trapping sediments as evidenced by landowner's periodic excavation of soil and sediments from these drainage ditches. A formal wetland delineation will be conducted by the Ports for permitting purposes prior to any dredged material being discharged to the wetlands to confirm the wetland acreage, type, and to collect additional baseline information.

The functions of the wetlands will be assessed using Ecology's *Methods for Assessing Wetland Functions on Riverine and Depressional Wetlands in the Lowlands of Western* Washington (Ecology 1999) prior to placement of material into the wetlands.

The buffer consists of pasture grasses that are used for agricultural production (e.g., silage, hay, grazing).

2.2.3 Fauna

The lack of complex habitat structure and lack of vegetative diversity on the sites, and the heavy disturbance from past and current land uses restrict the types of wildlife species that could be present on these sites. The WDFW priority habitat and species (PHS) database indicates that Columbian white-tailed deer are present on the Puget Island disposal location (Appendix A, Figure 20). Small mammals such as voles, wintering Canada and resident geese, small numbers of other waterfowl, passerine birds such as savannah sparrows inhabit the location, often only seasonally Waterfowl, some small mammals, savannah sparrows and some amphibians use the site but are limited by the lack of vegetative structure and diversity.

2.3 Procedural Variation for Wetland Delineations

2.3.1 City of Longview

The City of Longview's CAO indicates that the burden of proof is on the applicant to provide sufficient data to determine whether a wetland exists on a subject property. The City requires that certain information (e.g., master application, assessor's map, critical areas checklist) be provided to the City in an application. The City classifies wetlands in accordance with the *Washington State Wetland Rating System Manual, Western Washington* (Ecology 1996).

A formal wetland delineation will be conducted by the Ports on the site prior to any material being discharged into wetlands.

2.3.2 Wahkiakum County

Wahkiakum County's CAO indicates that wetlands shall be identified and delineated according to the most current edition of Ecology's manual adopted pursuant to RCW 90.58.380, and that they will accept a written determination by the Corps, Ecology, or other qualified critical areas professional as to whether a specific parcel contains a wetland. In lieu of a written determination, the County may also consider other reliable evidence in determining whether a wetland exists. A formal wetland delineation will be conducted by the Ports on the site prior to any material being discharged into wetlands.

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3. Mitigation Approach

3.1 Mitigation Summary

Mitigation will be implemented according to Cowlitz County's CAO because the mitigation sites occur in Cowlitz County. Adverse impacts to existing wetlands on the mitigation sites are not proposed; however, once the sites are acquired, existing wetlands on the mitigation sites will be delineated using Ecology's and the Corps delineation manual and classified based on Cowlitz County's CAO and Ecology's Guidelines for rating wetlands. Additional site data (*i.e.*, baseline topography and hydrology) will also be collected. This mitigation plan is consistent with Cowlitz County's CAO, and the plan will be finalized in coordination with the County when permit applications are prepared to implement the mitigation actions.

Mitigation actions to provide compensatory mitigation for unavoidable impacts to 5.4 acres of wetland on Puget Island and 10.8 acres of wetland at Mt. Solo are proposed at the Woodland Bottoms and Martin Island sites located in Cowlitz County (Appendix A, Figures 10 and 13). Compensation for wetland impacts will be accomplished through the restoration and enhancement of 120 acres of wetland habitat at Woodland Bottoms and Martin Island, including 16 acres of freshwater intertidal emergent marsh restored within the Martin Island embayment, for an average replacement ratio of approximately 8:1 for the 5.4-acre wetland impact and buffer impact at Puget Island and for the 10.8 acres of wetland impact and buffer impact at Mt. Solo.

These replacement ratios are well beyond the required 2:1 replacement ratio for a Category 2 PSS wetland in Wahkiakum County and the required 2:1 replacement ratio for a Category 2 PEM wetland in the City of Longview.

The mitigation plan currently calls for development or substantial improvement to 120 acres of wetland habitat in Washington and 194 wetland acres for the entire project. The Washington wetland mitigation acreages represent an approximately eight-fold increase over projected losses and would result in a net gain of secured wetland habitat along the lower Columbia River.

Wetland development will be the emphasis of mitigation actions as recommended by the interagency HEP team. The Corps' and Sponsor Ports' goal is to develop wetland habitat acreage to the extent identified at the individual mitigation sites. The Corps' and Sponsor Ports' objective will be to replace the wetland acreage and function identified as lost due to placement of dredged sands on Puget Island and Mt. Solo. The mitigation actions will target wetland-oriented species.

The major wetland mitigation actions at Woodland Bottoms include eliminating the existing drainage features and agricultural practices, construction of small perimeter levees that provide internal protection comparable to the present Burris Creek levees, removal of the Burris Creek internal levees to allow water from Burris Creek to naturally flow into the wetland area, and associated water control structures (24-inch-diameter culverts with risers and stop logs), an overflow structure to provide a more natural and appropriate hydrology to the restored wetland areas. Minimal grading associated with levee construction and removal is proposed because the reestablishment of a more natural hydrologic regime is expected to result in emergent wetland establishment within the wetland mitigation unit. Wetland plants that are currently suppressed or lie in the soil seed bank are expected to populate the emergent wetland areas.

Specific features of the mitigation action at Woodland Bottoms include:

- Soil saturation sufficient to support emergent wetland plant communities.
- A hydrologic regime predicated upon the natural flows of Burris Creek dispersing across the wetland management unit
- The establishment of emergent and associated riparian habitat.
- Increased habitat interspersion and diversity.
- Functional replacement.
- A monitoring program that incorporates interim performance standards.
- Maintaining and improving connectivity to adjacent riparian and wetland habitat for amphibians, reptiles, birds, and mammals.

Wetland mitigation activities at Martin Island consist of two parts (Appendix A, Figures 10 and 11). The first action entails fill of 16 acres of the embayment, a former borrow pit for I-5 fill, with dredged material and cap with a 2-feet of topsoil taken from the adjacent upland. The final elevation of the embayment will mimic elevations of adjacent fringe emergent marsh vegetation (Appendix A, Figures 10 and 11). The other wetland development (restoration of 7 acres of emergent marsh) would entail minor grading and removal of invasive reed canarygrass in an existing swale. Removal of reed canarygrass, including soil, in a one-foot increment will remove the roots, rhizomes and seeds of reed canarygrass and increase depth and allow for a longer duration of inundation. Seeds in the soil bank are expected to populate this wetland area. Specific features of the mitigation action at Martin Island include:

- Soil saturation sufficient to support emergent wetland plant communities.
- Placement of dredged material and topsoil in the Martin Island embayment to an elevation level determined by survey of adjacent intertidal marsh habitat to ensure a proper target elevation for emergent marsh establishment and tidal coverage daily
- The establishment of a riparian buffer community.
- Increased habitat interspersion and diversity through development of 159 acres of riparian forest and 23 acres of wetland habitat on Martin Island in addition to natural occurring stands.
- Functional replacement.
- A monitoring program that incorporates interim performance standards.
- Maintaining and improving habitat connectivity to adjacent water bodies that directly support fisheries and wildlife resources such as salmonids, amphibians, reptiles, birds, and mammals.

The mitigation actions will be implemented as a condition of the Wahkiakum County CAO permit, the City of Longview's CAO permit, Cowlitz County's local shoreline permit and CAO permit, and Ecology's 401 water quality certification.

A 10-year performance monitoring period is proposed to evaluate whether mitigation objectives are being achieved. An adaptive management and contingency plan is provided to ensure that interim performance standards are being assessed and that desired results of the mitigation actions are achieved.

3.2 Mitigation Goals, Objectives, and Performance Standards

3.2.1 Goals

The goals for the mitigation actions are to:

1. Achieve no net loss of wetland acreage by establishing 7 acres of emergent marsh and 16 acres of freshwater intertidal emergent

marsh at Martin Island and 97 acres of emergent wetland at Woodland Bottoms;

2. Provide buffer protection/riparian habitat at the mitigation sites;
3. Provide habitat structures (e.g., downed large [> 12 inches in diameter] woody debris and snags) to support wildlife including amphibians; and
4. Provide for an increase in overall habitat functions in the lower Columbia River.

3.2.2 Design Objectives

To achieve these goals, the following objectives have been developed for the mitigation actions:

1. Martin Island Freshwater Intertidal Marsh - Establish suitable site elevations (using the known (surveyed) elevation of immediately adjacent intertidal emergent marsh vegetation) that results in tidal inundation to support freshwater intertidal emergent marsh communities.
2. Martin Island Emergent Wetland and Woodland Bottoms Emergent Wetland – Provide seasonal wetland hydrology to support emergent vegetation. For Woodland Bottoms, the levees encasing Burris Creek will be removed in part to allow flood waters from the stream to spread over the 97-acre wetland mitigation unit. This will allow for a more natural hydrologic regime to influence the wetland mitigation unit. Material borrowed from the Burris Creek levees will be used to construct perimeter levees around the mitigation wetland to ensure that a comparable level of flood protection is maintained for neighboring properties.
3. Provide area and functional replacement for impacts to 5.4 acres of wetland at Puget Island and 10.8 acres of wetland at Mt. Solo.
4. Provide buffer and riparian habitat.
5. Provide freshwater intertidal marsh and emergent wetland habitat and deciduous riparian forest habitat for a diverse array of wildlife species.
6. Provide deciduous riparian forested habitat, including shrub understory buffer, and feeding, rearing and breeding habitat for emergent wetland associated birds, mammals and amphibians.
7. Provide habitat for amphibians.
8. Provide a more diverse aggregate of habitat types.

9. Assure long-term protection of the mitigation sites through acquisition in fee title and transfer to the appropriate State of Washington agency for management.

3.2.3 Performance Standards

The performance standards correspond to the design objectives and define measurable criteria that are evaluated to predict when a mitigation element has been successfully implemented or accomplished and whether overall mitigation goals have been met at the end of the monitoring program (Table 1). Interim performance standards, identified in Chapter 6 – Monitoring Plan, are measurable criteria that are evaluated at periodic intervals during compliance monitoring and serve as indicators of the need for adaptive management or contingency actions.

Table 1. Mitigation goals and associated design objectives, design criteria, and final performance standards.

Design Objective	Design Criteria	Final Performance Standard
Wetland Mitigation Goal 1: Achieve no net loss of wetland acreage and improve wetland function by establishing 7 acres of emergent marsh and 16 acres of freshwater intertidal emergent marsh at Martin Island and 97 acres of emergent wetland at Woodland Bottoms.		
Provide seasonal wetland hydrology to support emergent vegetation.	At Martin Island, excavate to establish an elevation that would increase the duration of inundation to support emergent wetland communities on 7 acres. At Woodland Bottoms, eliminate site drainage ditches, remove agricultural impacts (grazing and tillage), construct water control structures (low levees and pipes with risers) and remove the Burris Creek levees to provide for and maintain site inundation for approximately 8 months of the year for the 97-acre emergent wetland.	Emergent Wetland – Surface water (internal drainage and collection) will be present from 1.0 inches to 1.5 foot depths approximately 8 months of the year with soil saturation typically for the balance of the year. The levees encasing Burris Creek will be removed in part or in total, depending on borrow material requirements to construct perimeter levees for wetland mitigation unit, to within a foot (Appendix A, Figure 11) of typical Burris Creek surface level to ensure freshets overtop bank and flood over 97 acre wetland mitigation unit.
Martin Island Freshwater Intertidal Marsh - Establish suitable site elevations (using the known elevation of immediately adjacent intertidal emergent marsh vegetation) that results in tidal inundation to support freshwater intertidal emergent marsh communities.	Freshwater Intertidal Marsh (Martin Island) – fill embayment with approximately 460,000 of sand and cap with approximately 56,000 cy of topsoil (2-foot cap). Site elevation will mimic immediately adjacent intertidal marsh plant community, and will be at an elevation below that which could support reed canarygrass.	Freshwater Intertidal Marsh: Site will be inundated twice daily by normal tidal fluctuations. Inundation will be assured by matching surface elevation of mitigation site substrate to survey surface elevation of adjacent intertidal marsh habitat.
	Emergent Marsh (Martin Island) – Excavate an existing swale of approximately one foot of topsoil (11,000 cy) to rid area of invasive reed canarygrass roots, rhizomes, and seeds and expose native wetland plant seeds in the soil seed bank.	Emergent Wetland – Surface water (internal drainage and collection) will be present from 1.0 inches to 1.5 foot depths approximately 8 months of the year with soil saturation typically for the balance of the year.

Design Objective	Design Criteria	Final Performance Standard
Provide area and functional replacement for impacts to 5.4 acres of wetland at Puget Island and 10.8 acres of wetland at Mt. Solo.	Martin Island and Woodland Bottoms – Rely on seeds in the soil bank of native emergent wetland plant species that historically occurred on or near these sites prior to human perturbation and that are suited to seasonally flooded and saturated conditions, to repopulate the wetland mitigation sites.	Native emergent wetland species will contribute at least 80% of plant cover in areas restored within 5 years of construction.
Wetland Mitigation Goal 2:	Provide buffer protection/riparian habitat at the mitigation sites.	
Provide buffer and riparian habitat.	Restore 159 acres of deciduous riparian forest at Martin Island, in addition to existing riparian forest stands. Restore 43 acres of riparian forest habitat at Woodland Bottoms. A 132 acre pasture will be developed at Woodland Bottoms too that will provide buffer protection from adjacent land uses.	Establish planting density of approximately 400 cuttings and/or natural seedlings per acre of deciduous riparian forest species that naturally occur on or adjacent to the sites. Species composition will be predominantly willow *spp.*, black cottonwood and Oregon ash. Native species will contribute at least 80% of plant cover in buffer areas and not more than 20% of invasive species.
Wetland Mitigation Goal 3:	Provide habitat structures (e.g., downed large (> 12 inches in diameter) woody debris) to support wildlife including amphibians.	
Provide freshwater intertidal marsh and emergent wetland habitat and deciduous riparian forest habitat for a diverse array of wildlife species.	Provide deciduous riparian forest habitat with a minimum of two species that develop large diameter and height (cottonwood and Oregon ash) and an understory of shrubby willows to 30 ft at project life (50 years).	Deciduous riparian forested habitat will have a shrub understory over 25 to 50% of the area. Evidence of songbird nesting (nest, breeding territories, or observations of breeding behavior) will be present. Amphibians will be locatable in the forest floor litter. Evidence of small mammal use will be present.

Design Objective	Design Criteria	Final Performance Standard
Provide deciduous riparian forested habitat, including shrub understory buffer, and emergent wetland feeding, rearing and breeding habitat for mammals and amphibians.	Large woody debris (stumps and logs of native species) placed throughout the deciduous riparian forested habitat buffer and the emergent wetland to provide year round habitat for smaller mammals and amphibians as an interim measure until the deciduous riparian forest develops and matures to the point where it contributes these materials.	Evidence of small mammal use (nests, feeding) will be present. Presence of habitat structure capable of supporting amphibians (individuals, egg clusters).
Provide habitat for amphibians.	Provide for emergent marsh plant communities that provide attachment substrate for breeding amphibian species consisting of emergent erect vegetation with stem diameter <0.25 inches in emergent zones.	Leaf litter and vegetation debris will be present to provide habitat for invertebrates. Invertebrates will be observed in the ground litter. Presence of habitat structure capable of supporting amphibian egg masses and juveniles (larval form) rearing in the emergent wetlands.
Wetland Mitigation Goal 4:	**Provide for an increase in overall habitat functions in the lower Columbia River.**	
Provide a more diverse aggregate of habitat types (e.g., hummocks and micro excavations).	Restore emergent wetland habitat with associated riparian habitat buffers to provide wildlife habitat features that improve connectivity to adjacent developed or naturally wetland and forested habitats.	See performance standards above.
Assure long-term protection of the mitigation sites.	Legal proof that the land has been acquired in fee title for wetland mitigation purposes.	Title to the land, and permanent deed restrictions for the mitigation sites.

4. Mitigation Sites

4.1 Site Descriptions

There are two mitigation sites – Woodland Bottoms and Martin Island, located in Cowlitz County (Appendix A, Figure 8). Woodland Bottoms is located south of the Martin Island mitigation site, and Burke Slough, Burke Island, and Martin Slough separate the two sites.

4.1.1 Woodland Bottoms, RM W-81.0

The Woodland Bottoms mitigation site is 284 acres in size (see Appendix A, Figure 8). The site is bound by the railroad and I-5 to the east, a tributary slough to Burke Slough on the north, agricultural land and Burke Slough to the west, and agricultural land to the south (Appendix A, Figure 9). The site is currently used for agricultural purposes, including row crops, hybrid poplar plantations, and cattle grazing lands. Existing habitat types including degraded wetlands (grazed, row cropped) exist on the site (Appendix A, Figure 9). Wintering waterfowl, principally wintering Canada geese and surface feeding ducks use the site.

4.1.2 Martin Island, RM W-80.0

Martin Island is 378 acres in size (Appendix A, Figure 8). At least 298 acres of the island would be used for mitigation purposes with the 80-acre balance potentially available for habitat development purposes based on the manner in which the property is acquired. The site is bound by Martin Slough and the railroad and I-5 to the east, north and west by the Columbia River, and Martin Slough to the south (Appendix A, Figure 8). Martin Island has been used for cattle grazing and pastureland. There is a 35-acre lagoon on the east side of the island. The lagoon was artificially created in 1966 when sand was excavated for use in the construction of Interstate 5.

The island itself is classified as wetland on the NWI wetland maps. The majority of the land surface is in fact existing riparian forest, cattle pasture and blackberry thickets. Wetland pockets exist on the island where depressions or frequent flooding by the river occur. A bald eagle nest is located on the west edge of the lagoon and a great blue heron rookery occurs north of the lagoon (Manlow 2002). According to WDFW PHS mapping, dusky Canada geese and other waterfowl use the southern tip of the island, ½ mi south of the embayment (Appendix A, Figure 8). Canada geese forage in the pasturelands present on the island.

4.2 Ownership

The Sponsor Ports will acquire the mitigation sites. These properties will subsequently be conveyed to the WDFW.

4.3 Zoning

The zoning of the Woodland Bottoms and Martin Island mitigation sites is primarily agriculture. The zoning designations should not affect establishing wetlands in the mitigation sites.

4.4 Rationale for Choice of Mitigation Sites

The Corps conducted an extensive evaluation to determine potential mitigation sites during the development of the IFR/EIS. The proposed mitigation sites were selected for the following reasons:

1. The mitigation sites are adjacent to the Columbia River or its side channels and thus provide an opportunity to expand on available fisheries and wildlife habitat.
2. The sites can increase riparian and wetland habitat and provide buffering capacity to protect the integrity of the mitigation wetlands.
3. The mitigation sites will provide habitat connectivity to adjacent habitats and the Columbia River.
4. Acquisition in fee title guarantees preservation of the mitigation sites.
5. Historic photographs of the sites indicate these areas formerly consisted of forested and shrub wetland and riparian habitat prior to human uses.
6. A reliable source of water (internal drainage, Burris Creek at Woodland Bottoms, ground water and/or the Columbia River) will provide water sources necessary to support wetland vegetation.

4.5 Existing Conditions of Mitigation Sites

4.5.1 Vegetation

Woodland Bottoms
Vegetation on the mitigation site consists predominately of pasture grasses, row crops (i.e., corn), and hybrid poplar plantations (Appendix A, Figure 9).

Martin Island

Vegetation on this site consists of pasture grasses, blackberry thickets, and an established willow and cottonwood dominated riparian forest habitat (Appendix A, Figure 12).

4.5.2 Hydrology

Woodland Bottoms

The mitigation site lies behind main flood control dikes and an interior drainage system, (e.g., ditches, pump station and tide gate) is in place to drain waters from the diking district, including the mitigation site. Existing hydrology is from internal drainage and groundwater. The levees along Burris Creek will be removed in part or whole, depending upon borrow requirements to construct the perimeter levees for the wetland mitigation unit, in order to allow freshets to flood over the wetland mitigation unit and thereby affect a natural hydrologic regime.

Martin Island

Martin Island is occasionally flooded by the Columbia River during freshets.

4.5.3 Soils

Woodland Bottoms

The soils at Woodland Bottoms are characterized as Caples and Newberg series.

Martin Island

The soils at Martin Island are characterized as Caples and Newberg series. There is a pocket of riverwash adjacent to the Columbia River.

4.5.4 Fauna

Woodland Bottoms

The site is currently used by wintering waterfowl, principally wintering Canada geese and surface feeding ducks. Small mammals, amphibians, and passerine birds also use the site but the extent of use is limited by the lack of vegetative cover and complexity due to agricultural practices.

Martin Island

A bald eagle nest is located in the riparian forest stand near the west edge of the lagoon and a great blue heron rookery occurs north of the lagoon (Manlow 2002). According to WDFW PHS mapping, dusky Canada geese and other waterfowl use the southern tip of the island, ½ mi south of the embayment (Appendix A, Figure 8). Wintering and resident Canada geese forage in the pasturelands present on the island. Small mammals, amphibians, and passerine birds use the site.

4.5.5 Functions

Woodland Bottoms

This site currently provides some limited wetland functions including foraging habitat for waterfowl and great blue herons. Wetland functions have been compromised by the use of the site for grazing, row-crop agriculture and farming of hybrid poplars.

Martin Island

This site provides wetland functions including some flood storage, forage and rearing habitat for birds, small mammals, and amphibians, nesting habitat for a bald eagle pair, nesting and rearing habitat for great blue herons, and primary production, insect faunal and detrital inputs to the lagoon and surrounding water bodies.

4.5.6 Buffers

Woodland Bottoms

Buffers include a flood control dike on the northern boundary, I-5, including the toe drain and right-of-way to the east, and agricultural lands to the west and south.

Martin Island

Buffers include the Columbia River to the west and Martin Slough to the east and south. Riparian forest stands on the island also buffer much of the area targeted for mitigation development. The island tapers to a point at the northern tip where Martin Slough and the Columbia River join.

4.5.7 Estimate of Wetland Functions After Performance Standards are Met

A functional assessment, using Ecology's *Methods for Assessing Wetland Functions on Riverine and Depressional Wetlands in the Lowlands of Western* Washington (Ecology 1999) will be conducted prior to implementing the mitigation actions to collect baseline information for which subsequent monitoring data can be compared with.

The functional performance level for newly established wetlands on the mitigation sites is estimated using the conceptual site plan and best professional judgment.

Wetland functions anticipated at the mitigation sites after performance standards have been met include:

- Song bird habitat
- Waterfowl foraging, nesting and rearing habitat

- Amphibian habitat
- Mammal habitat
- Fisheries foraging and rearing habitat in Martin Island lagoon
- Plant diversity (although plant diversity is not a function, *per se*, it is a good indicator of overall wetland quality)
- Primary production and nutrient retention and transformation
- Detrital export from wetlands
- Export of leaf liter and woody debris from the deciduous riparian buffer habitat and large woody from the riparian buffer habitat after establishment

4.6 Opportunities and Constraints

The Woodland Bottom and Martin Island sites provide an opportunity to:

1. Provide habitat adjacent to Burke Slough;
2. Remove grazing and agricultural tillage, herbicides and pesticides;
3. Provide deciduous riparian forest buffer habitat;
4. Restore wetland habitats to areas that historically supported this habitat type; and
5. Remove 35+ acres of Himalayan and evergreen blackberry from Martin Island and subsequent restoration of this acreage to riparian forest.
6. Provide for a continuous, large block of secure wetland and riparian forest habitat in the lower Columbia River.

There are no significant constraints on either site to providing wetland mitigation. At Woodland Bottoms, water control structures (low levees, overflow structures) are required to protect immediately adjacent properties from flooding when Burris Creek floods, while maintaining proper hydrologic conditions on the wetland mitigation site to support emergent wetland habitat.

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5. Preliminary Site Grading, Planting Plan, and Hydraulics/Hydrology

The habitat features for the Woodland Bottoms mitigation site are shown in Appendix A, Figures 10 and 11, and for the Martin Island mitigation site are shown in Appendix A, Figures 13 and 14.

5.1 Site Grading

The mitigation objectives for the 7-acre emergent wetland at Martin Island would be achieved by:

1. Grading the 7-acre site to approximately one-foot lower in depth to remove reed canarygrass roots, rhizomes, seeds in the soil and vegetative matter plus allow for native wetland plant seeds in the soil seedbank to germinate and become established; and
2. Establishing hydrology to support the targeted wetland community.

This section discusses the technical considerations, constructability issues, and limitations associated with grading the mitigation site.

The proposed grading potentially involves one earthwork construction step. Surface soil would be excavated one foot below existing grade and removed from the site.

No grading is proposed for restoration of wetland habitat at Woodland Bottoms, with the exception of grading required to remove the Burris Creek levee and construct the perimeter levee for the wetland mitigation unit.

5.2 Excavation

At the 7-acre emergent wetland site on Martin Island, soils would be excavated to a depth of approximately one foot in order to remove invasive reed canarygrass roots, rhizomes, seeds and vegetative matter in order to expose native wetland plant seeds in the soil seed bank, and establish grades appropriate to support proposed wetland communities.

No excavation is proposed for restoration of wetland habitat at Woodland Bottoms other than that required to remove borrow material for levees and associated infrastructure such as an overflow weir.

5.3 Filling

At the Martin Island site, the embayment will be filled with dredged material sand and capped with two feet of topsoil from the adjacent uplands to create 16 acres of intertidal marsh habitat (Appendix A, Figure 10). The entrance channel will not be filled. Fill will be to an elevation based upon surveyed surface elevation of adjacent intertidal marsh habitat.

Portions or all of the Burris Creek levees, based upon borrow requirements for the perimeter levees for the wetland mitigation unit, will be removed to establish a more natural hydrologic regime. Removal of the Burris Creek levees will allow waters from the stream to flood over the wetland management unit during freshets, affecting a more natural hydrologic regime for the area. The wetland mitigation unit perimeter levees are required to protect adjacent properties from flooding and will be constructed to a height comparable to that of the existing Burris Creek levees.

5.4 Planting Plan

At Woodland Bottoms, no formal planting plan is proposed. Rather, natural reestablishment of emergent wetland vegetation is expected once agricultural practices are discontinued and site hydrology is restored via flooding of Burris Creek waters onto the wetland mitigation unit. The existing wetland vegetation is expected to be released upon removal of agricultural practices and provision of a more natural hydrologic regime. At Martin Island, the 7 acre wetland site and emergent marsh in the embayment will rely initially upon natural recruitment to establish the wetland plant community. Emergent wetland plant seeds in the soil seed bank are expected to provide the source material for the 7-acre wetland. Columbia River flows and tidal fluctuation are expected to provide the seed and propagules source for establishment of tidal marsh vegetation in Martin Island embayment.

Deciduous riparian forest buffer habitat will be established through site tillage, planting of cottonwood, willow, and Oregon white ash, plus natural establishment via seeds dispersed from the adjacent riparian forest stands. These riparian forest species are native to the area and currently occur on or adjacent to the mitigation sites. At Woodland Bottoms, approximately 43 acres of riparian forest buffer and habitat would be restored (Appendix A, Figure 10). Species composition per acre would consist of 11,000 black cottonwood cuttings, 4,400 willow cuttings, and 2,200 Oregon ash cuttings and seedlings. The cuttings would be installed in late February – early March. Cuttings and seedlings would be obtained from on-site, Martin and Burkes islands, or other local areas.

At Martin Island, approximately 159 acres of agricultural land would be converted to riparian forest habitat (Appendix A, Figure 13). Deciduous riparian forest buffer habitat will be established through site tillage, planting of cottonwood, willow, and Oregon white ash, plus natural establishment via seeds dispersed from the adjacent riparian forest stands. These riparian forest species are native to the area and currently occur on or adjacent to the mitigation sites. Species composition per acre would be targeted for 250 black cottonwoods, 100 willows, and 50 Oregon ash. The cuttings would be installed in late February – early March. Cuttings and seedlings would be obtained from on-site, Martin and Burkes islands, or other local areas.

5.5 Hydrology

Water for the Woodland Bottoms mitigation site will come from water that floods over the wetland mitigation unit from Burris Creek during freshets and internal drainage of surface water. The sources of water for the wetlands on Martin Island are surface drainage, ground water and surface water from Martin Slough or the Columbia River.

5.6 Habitat Structures

Habitat structures (i.e., logs and woody debris) would be placed in the tidal wetland habitat developed in the embayment at Martin Island and in wetlands at Woodland Bottoms. Logs could be deciduous trees of various species (black cottonwood, red alder, Oregon white ash), western red cedar and/or Douglas fir trees. These species are readily available in the immediate area.. They will be a minimum of 16 inches in diameter and would be in the form of whole logs with several limbs left intact.

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6. Monitoring Plan

Three types of monitoring are proposed.

Construction Monitoring
Oversight of work at the mitigation sites will be needed to ensure that contractors are following requirements identified in the final plans and specifications developed for the site.

As-Built Monitoring
An as-built report would be prepared to define the baseline conditions for measuring progress towards the mitigation goals and final performance standards. The as-built also establishes any permanent sampling locations for future compliance monitoring activity. Any significant deviations between the final site plan and the as-built would be noted, and the significance of these deviations evaluated. Baseline data on hydrology, vegetation, wildlife, topography will be used to evaluate wetland function and compliance with the performance standards summarized in Table 1 and outlined in detail in Table 2. Monitoring would also include photographic documentation of site features and the development of habitat on the site.

Compliance Monitoring
Compliance monitoring would be conducted to determine the degree to which the mitigation action meets performance standards, identifies potential problems and recommends corrective actions, provides a record of site development progress, and reports monitoring protocol effectiveness. The monitoring plan will be developed in consultation with permitting agencies and will be based on the most current and scientifically accepted methods. At least one protocol that could be used includes Ecology's *Methods for Assessing Wetland Functions on Riverine and Depressional Wetlands in the Lowlands of Western* Washington (Ecology 1999).

Monitoring will occur according to the schedule indicated in Table 2. Most monitoring activities would be completed along permanent transects and fixed points established and marked during the as-built survey; however, as determined in the field, additional monitoring may be needed to document unique conditions not present at pre-established sampling locations. All monitoring would use standard ecological techniques to sample, measure, or describe vegetation, hydrologic, and wildlife habitat conditions. These techniques include walk-through surveys, line-intercept sampling along transects (Canfield 1941), plot sampling (Daubenmire 1959), and wetland delineation (FICWD 1989; Environmental Laboratory 1987).

Table 2. Wetland monitoring methods, reporting schedule, and contingencies.

Design Objective	Performance Standard	Method	Month	Frequency	Interim Performance Standards[a]	Contingency Action
Forested Buffer / Riparian Vegetation	Species composition	Walk-through surveys and plot or belt transect sampling to document all plant species present	June-July	As-built and Years 1, 3, 5, 7, and 10	>80% survival of planted stock; density at least 400 stems per acre to include naturally established seedlings	None
	Tree and shrub density	Measure by line-intercept method along transects	June-July	Years 1, 3, 5, 7, and 10	60 – 80% survival; density less than 400 stems per acre; total stems to include naturally established seedlings	Evaluate reason(s) for mortality, and replant to achieve performance standard.
	Plant growth	Walk-through surveys to estimate annual shoot growth and survival rates	June-July	Years 1, 3, 5, 7, and 10	<60% survival; total stems to include naturally established seedlings	Evaluate reason(s) for mortality; consider species suitability for site conditions; replant with the same or alternate species.
	Vegetation structure	Describe from walk-through surveys, incorporating data from above analysis as available	June-July	Years 1, 3, 5, 7, and 10	Presence of seed and/or fruit production on shrub species	None
					Lack of seed and/or fruit production on shrub species	Evaluate potential reasons for lack of seed and/or fruit production; evaluate health and vigor; consider fertilization.
Emergent and Marsh Wetland Vegetation	Species composition	Walk-through surveys to document all plant species present	June-July	As-built and Years 1, 3, 5, 7, and 10	Species composition includes at least 40% of plant species present in adjacent reference wetland	None
	Herbaceous plant coverage/density	Measure by plot sampling method along transects	June-July	Years 1, 3, 5, 7, and 10	Total cover by emergent wetland species at least 70%	None

Design Objective	Performance Standard	Method	Month	Frequency	Interim Performance Standards[a]	Contingency Action
					Total cover by emergent wetland species less than 70%	Consider supplemental plantings. When invasive species (reed canarygrass) represent greater than 20% cover, control of this species by herbicide or other recommended methods would be evaluated.
					Total cover by emergent wetland species less than 20%	Re-evaluate the grades and hydrology of the site and re-establish if necessary. Consider supplemental plantings.
	Plant growth	Walk-through surveys to estimate annual shoot growth and survival rates	June-July	Years 1, 3, 5, 7, and 10	Primary productivity of native emergent wetland species at least 40% of adjacent reference marshes.	None
	Vegetation structure	Describe from walk-through surveys, incorporating data from above analysis, as available	June-July	Years 1, 3, 5, 7, and 10	Height and vegetative density measure on cover boards 40% of adjacent reference marsh	Re-evaluate the grades and hydrology of the site and re-establish if necessary. Consider supplemental plantings.
Wetland Hydrology	Soil saturation	Depth from the soil surface to groundwater measured at permanent sampling stations in forested, shrub, and emergent wetland zones	February, June, September	Years 1, 3, 5, 7, and 10	Comparable to adjacent reference marsh. At Woodland Bottoms, surface water present from 1.0 inch to 1.5 foot depths approximately 8 months of the year. At Martin Island - saturation within 6 inches of surface from December through April (normal rainfall years). At Martin Island intertidal freshwater marsh –tidal inundation twice daily.	Evaluate hydrology and need for supplemental water supply with consideration for seasonal/year weather expression. Possible solutions include modification of water control structures, changing grades.

Design Objective	Performance Standard	Method	Month	Frequency	Interim Performance Standards[a]	Contingency Action
	Surface water depth	Water depths measured at permanent sampling stations in shrub and emergent wetland zones	February, June, September	Years 1, 3, 5, 7, and 10	Comparable to adjacent reference marsh.	Evaluate hydrology and need for supplemental water supply with consideration for seasonal/year weather expression
	Habitat structure	Description of habitat structure from walk-through surveys	February, June	Years 1, 3, 5, 7, and 10	Evaluate based upon results from plant growth and vegetative structure surveys	See vegetative structure proposals.
Wildlife usage		Conduct surveys to record wildlife species and activities on-site.	January, April, June, November	Years 1, 3, 5, 7, and 10	Observations of a variety of wildlife use of the sites	None; or if use limited, evaluate reasons for non-attainment. Possible solutions include modifying water control structures, changing grades, and adding more structure.
Long-term Protection				Years 1	There is no interim performance standard because the Sponsor Port's must provide proof of a deed restriction prior to the site being used for mitigation.	None

General monitoring methods are described below.

6.1 Hydrologic Regime

At Woodland Bottoms and for the 7-acre emergent wetland at Martin Island, surface water elevations would be measured within the wetland itself, and soil saturation would be measured by digging test pits to determine the level of ground water. At the Martin Island freshwater intertidal marsh, surface water elevations would be measured with a measuring rod and calibrated for the tidal elevation.

6.2 Vegetation Structure

Naturally colonizing vegetation will be monitored to measure the species composition and density.

Permanent vegetation sampling and photographic points will be established using lath and rebar within wetland mitigation areas at locations representative of the emergent marsh plant community being sampled. At each sampling point, either a 1.0-m^2 quadrat for emergent, or the line intercept method for shrub and forested vegetation, will be used to measure the following:

- all plant species, in the order of dominance, based on relative percent cover of each species within the vegetative strata;
- the species composition (i.e., percent of each species, exotic or native, planted or colonized); and
- average height and general health of each planted species.

The vegetation data will be correlated with the surface and groundwater water regimes to evaluate the relative success of planted vegetation communities.

6.3 Fauna

A species list of fauna expected and known to occur in wetlands in the project vicinity will be filled out in conjunction with conducting monitoring. The kinds and locations of habitat used by each species will be recorded when observed. Any breeding or nesting activity in the mitigation areas will be documented.

6.4 Assessing Wetland Functions

Functions of the wetland mitigation sites will be assessed prior to construction to establish baseline conditions and after construction as part of the overall monitoring plan using *Methods for Assessing Wetland Functions on Riverine and Depressional Wetlands in the Lowlands of Western* Washington (Ecology 1999).

7. Site Protection

As discussed in Section 4.2, the Sponsor Ports will acquire the mitigation sites in fee title. Legal proof that the land will continue to be adequately protected will be documented through property deed restrictions. The sites will be conveyed to the WDFW.

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8. Adaptive Management and Contingency Plan

Monitoring results will be reported annually, by December 30, to Ecology, Wahkiakum County, City of Longview, and Cowlitz County so that contingency actions, if any, can be implemented before the next winter.

In addition to the annual report, an as-built report will be completed following construction of the mitigation sites (i.e., Year 0) and submitted to Ecology and the local jurisdictions for review and approval. The as-built report will define existing conditions (e.g., topography, water levels, plant communities, infrastructure) in the mitigation areas following construction. It will serve as the baseline from which achievement of mitigation objectives can be measured. Each monitoring report will document project success relative to the mitigation performance standards.

All contingencies cannot be anticipated. The contingency plan needs to be flexible so that modifications can be made if portions of the final design do not produce the desired results. Problems or potential problems will be evaluated by a qualified wetland ecologist, the Corps, Ecology, and Cowlitz County. Specific contingency actions will be developed, agreed to by consensus, and implemented based on all scientifically and economically feasible recommendations.

Contingencies may include the following:

- Modifying grades to correct too low or too high elevations.
- Plantings to correct excessive mortality.
- Monitoring beyond Year 10, or unscheduled monitoring during Years 1 through 10.

Table 2 incorporates contingency measures for the mitigation sites.

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9. Responsible Parties

The mitigation actions will be implemented by the Corps and Sponsor Ports, which include the Port of Longview, the Port of Kalama, the Port of Vancouver, and the Port of Woodland. Tracey McKenzie, Anchor Environmental, and Geoff Dorsey, Corps, Portland District, prepared this mitigation plan.

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Appendix A

Figures

EXHIBIT K-9
CONSISTENCY WITH WASHINGTON LOCAL SHORELINE MASTER PROGRAMS (REVISED)

Table of Contents
Exhibit K-9
Consistency with Washington Local Shoreline Master Programs (Revised)
Columbia River Channel Improvement Project

Table of Contents

Consistency with Washington Local Shoreline Master Programs (Revised) Columbia River Channel Improvement Project

1. Introduction

This report is prepared primarily for the purpose of reviewing consistency of the Project with local shoreline master programs ("SMPs") to comply with the Washington State Environmental Policy Act (SEPA), chapter 43.21C RCW. The level of detail results from the extensive discussions that have occurred between the Washington Ports, the Corps, and State and local agencies. This level of detail exceeds the amount of information often found in an Environmental Impact Statement.

The Project takes place within five different local shoreline jurisdictions in Washington: Wahkiakum County, Clark County, Cowlitz County, the City of Longview and the City of Vancouver. Accordingly, this report demonstrates consistency of all Project activities with statewide shoreline requirements under the Shoreline Management Act ("SMA") as well as the applicable shoreline requirements of those five applicable local jurisdictions.

In addition, the analysis in this report supplements the Coastal Zone Management Consistency analysis in Exhibit F of the Final SEIS. In order to meet the requirements of the federal Coastal Zone Management Act ("CZMA"), all activities must be consistent with the States' Coastal Zone Management Program. Washington's State Coastal Zone Management Program includes Wahkiakum County and Pacific County. Therefore, the analysis, discusses Pacific County's Shoreline Master Program, although no Project activities will occur in Pacific County's shoreline.

This report reviews the specific use activity regulations as well as the more general goals and policies for the proposed activities in each jurisdiction and finds that the Project is not only consistent and in general conformance with these standards, it actually promotes several key goals and policies for circulation and economic development.

2. Method

The Project permitting team met with appropriate regulatory personnel from each of the local jurisdictions to discuss permitting requirements, including the application of local SMPs to Project activities within their jurisdiction. The meetings, called Focus Groups, were held with individual jurisdictions to ensure that each local government had the opportunity to ask questions and express concerns about the Project. The Project team also had the opportunity to verify their understanding of the local requirements and ordinances. Focus group meetings with City jurisdictions took place with those of their respective Counties in order to identify and clarify similarities and differences in requirements. At least one representative from the Department of Ecology attended each meeting. Focus Group meeting dates are listed in Table 1 below.

Table 1 Focus Group meetings with local jurisdictions.

Date	Jurisdiction
October 25, 2001	Wahkiakum County
October 24 2001	Pacific County
November 20, 2001	Cowlitz County/City of Longview
January 23, 2002	Clark County/City of Vancouver

At the Focus Group meetings, it was determined which sections of the appropriate SMP applied to each of the disposal and mitigation sites. The Project team checked each provision of the applicable SMP to make sure that all Project activities were consistent with the requirements. The Project team coordinated with local jurisdiction personnel in completing this consistency analysis. This process is documented in Section 3, Process, and the analysis is provided in Section 4, Results.

In addition, the Project team met with Ecology to discuss the draft consistency analysis. As a result of these meetings, a more detailed analysis of the Ocean Resource Management Act was performed. This analysis resulted in significant revision to the discussion of the Pacific County Shoreline program.

3. Process

The SMA classifies certain shoreline areas as "shorelines of statewide significance." As such, certain state statutory use priorities and policies apply to these "shorelines of statewide significance."

The SMA also requires cities and counties to classify the State's shorelines within their jurisdictions as "types" of shoreline environments (such as urban, rural, conservancy, and so on), encompassing both aquatic environments and upland areas within shoreline jurisdiction. Local SMPs may designate appropriate "uses" for specific shoreline environments, incorporating both regulatory standards and broader policy objectives and guidelines.

The format of this report corresponds with the standards for review of shoreline development proposals. It evaluates the consistency of those project elements with the specific "use" regulations and broader policy objectives and guidelines applicable to that shoreline environment. Because of the way SMPs are written, there are typically numerous policies, guidelines, regulations, and criteria that apply to any given project element, many of which are duplicative. The reader is requested to bear with the repetition inherent in each SMP. Summary statements and cross-references are used as much as possible without making the analysis difficult to follow.

3.1 Summary of Applicable Standards. The report begins by evaluating shoreline consistency of all Project elements with criteria for shorelines of statewide significance:

3.1.1 Shorelines of Statewide Significance Criteria. The Columbia River is a shoreline of statewide significance. Therefore, all Project elements occurring within shoreline jurisdiction are reviewed for consistency with the six criteria for shorelines of statewide significance listed in the Act. These are, in order of priority:

- Recognize and protect the state-wide interest over local interest;
- Preserve the natural character of the shoreline;
- Result in long term over short term benefits;
- Protect the resources and ecology of the shoreline;
- Increase public access to publicly owned areas of the shoreline;
- Increase recreational opportunities for the public in the shoreline;
- Provide for any other element deemed appropriate or necessary.

The report then evaluates shoreline consistency of the Project elements occurring in each jurisdiction, with the provisions of the respective jurisdiction's SMP.

3.1.2 Shoreline Substantial Development Criteria. Each Project activity is also reviewed to determine whether it is permitted in the relevant jurisdiction. Project activities are reviewed under the criteria for a shoreline substantial development permit. The standards are:

- Compliance with Use Regulations and Standards. Each Project activity is reviewed for compliance with the specific regulations and standards governing that type of use or activity. For example, disposal of dredged material is reviewed under the use standards for disposal of dredged material and/or landfill, resale of dredged materials is reviewed under the specific use standards for mining, etc.
- Consistency with Policy Goals, Objectives and Guidelines. Each Project activity is also reviewed for consistency with the general policy goals, objectives and guidelines for that type of use or activity.

3.1.3 Conditional Use Criteria. Certain activities may constitute conditional uses. The Project is reviewed for consistency with the Conditional use criterion in Section 4.1.3.

4. Results –Findings of Shoreline Consistency

4.1 Shorelines of Statewide Significance.

4.1.1 Project Activities within Shorelines of Statewide Significance. The Project includes the following types of activities that will take place within shorelines of statewide significance. Table 1 summarizes information regarding upland disposal and shoreline disposal sites. A potential ocean disposal site was selected after a thorough analysis of alternative disposal sites. The site is located more than 3 miles offshore, and therefore outside the shoreline jurisdiction. The site is also located south of Cape Disappointment. Under the SMA's definition of a shoreline of statewide significance, the site is not in a shoreline of statewide significance.

The ocean disposal site would not be used under the preferred option. Under other alternatives, ocean disposal would only occur following additional site planning and baseline studies.

Columbia River – 43-ft. Channel Improvement Construction and Maintenance Dredging

The Columbia River will be dredged from CRM 3 to CRM 106.5 to deepen the existing 40-foot-deep channel to the newly authorized depth of 43 feet. Once the channel improvements are made, maintenance dredging will be conducted to maintain the 43-foot channel. Dredged material will be disposed in a variety of aquatic and shoreline sites.

Both construction and maintenance of the 43-foot channel will be conducted using a combination of dredging methods currently used for channel maintenance, primarily hopper and pipeline dredges. Overall construction of the 43-foot channel is anticipated to require removing approximately 14.5 mcy of dredged material, as well as 50,500 cubic yards of basalt rock and 440,000 cubic yards of cemented sand, gravel and boulders. Over the first 20 years following completion of the channel improvements, overall annual maintenance dredging is expected to decline from around 8 mcy to about 3 mcy of sand as the new channel reaches equilibrium. Annual maintenance will then continue at an average of about 3 mcy of sand per year for the remaining 30-year life of the Project.

Columbia River - Dredged Material Flowlane Disposal

Flowlane disposal, similar to that which currently occurs for channel maintenance, will be done in selected locations from CRM 3 to CRM 106.5 in or adjacent to the navigation channel, where depths range from 50 to 65 feet, but are typically greater than 50 feet. Flowlane disposal will distribute dredged material in areas within or adjacent to the navigation channel that are at depths greater than the channel, to minimize the potential for material settling back into the channel and causing additional shoaling problems.

Flowlane disposal sites are not specifically designated because they vary according to the condition of the channel and the techniques used by the contractor selected to perform the work. Flowlane disposal is dispersed along the channel to minimize the potential for material settling back into the channel and causing additional shoaling.

Upland Dredged Material Disposal

A number of upland disposal sites will also be used for the disposal of dredged sediments, to reduce the need for in-water disposal. The Project will use existing disposal sites to the extent feasible, as well as three new sites that are located at least 300 feet beyond the River. One site, Adjacent to Fazio in Clark County, would result in disposal on new ground for approximately one-half of the 17-acre site. Upland disposal sites include: Brown Island, Puget Island and Rice Island in Wahkiakum County; Austin Point, Martin Bar, Northport, Cottonwood Island, Howard Island, IP Rehandle, Reynolds Aluminum, and Hump Island in Cowlitz County; Mt. Solo in the City of Longview (Cowlitz County); Fazio and adjacent to Fazio in Clark County; and Gateway in the City of Vancouver (Clark County).

The Rice Island and Hump Island sites will only be used for disposal of maintenance dredge material. Four new sites: Gateway, Adjacent to Fazio (if necessary in the future), Mt. Solo and Puget Island are proposed in the state of Washington. These sites are located at least 300 feet from the Columbia River.

Shoreline Disposal

The Project also includes a shoreline and beneficial use disposal site at Skamokawa in Wahkiakum County. This site will only be used for maintenance dredge material.

Restoration Activities

The Project incorporates a number of ecosystem restoration activities. The following are located in Washington State: a combined pump/gravity water supply for restoring wetland and riparian habitat at Shillapoo Lake (CRM 91); tidegate retrofits with fish slides for salmonid passage at selected locations along the lower Columbia River; connecting channels at Hump-Fisher Islands to improve fish access to embayments and rearing habitat for juvenile salmonids. Additional ecosystem restoration features that are planned include: Purple Loosestrife Control Program, Cottonwood/Howard Island Columbia White-Tailed Deer Introduction, and Bachelor Slough Restoration. Dredged materials will be used to attain target depths for some of these intertidal and/or subtidal habitat restoration efforts. These actions will restore and improve the habitat of native species found in the lower Columbia River ecosystem.

Mitigation Features

The Projects includes a number of mitigation features to address impacts caused by the Project. The following mitigation features are located in Washington State: Martin Island Embayment and Woodland Bottoms. The activities required to implement this mitigation are discussed in Section 4.5.

Dredged Material Resale Activities

The Project also uses a number of disposal sites from which disposed sediments may be sold and reused. These resale sites include the Skamokawa resale site in Wahkiakum County, the Fazio and Adjacent to Fazio sites in Clark County, and the Reynolds Aluminum, International Paper, Northport, Austin Point, and, perhaps, Martin Bar, sites in Cowlitz County. The Adjacent to Fazio site will only be used for maintenance dredge material. These resale activities may be conducted by the Site owner/operator but are not part of the Project.

4.1.2 Shorelines of Statewide Significance Criteria. The Project is consistent with the criteria for activities within shorelines of statewide significance, which are set forth in the SMA in the following order of preference:

1. *Recognize and protect the statewide interest over local interest.*

The Project furthers the interests of Oregon and Washington and recognizes the statewide, regional, and national interests in interstate commerce over local interests. The primary purposes of the Project are to deepen the navigation channel of the Columbia River to a depth of 43 feet and to implement ecosystem restoration features. The Project will enhance the efficiency of navigation on the Columbia River and improve navigational access for goods throughout Oregon, Washington and the region. Navigation is one of the principal public uses recognized and protected under the public trust doctrine and the Washington Shoreline Management Act. (Johnson, The Public Trust Doctrine and Coastal Zone Management in Washington State, Washington Law Review, July 1992).

The Columbia River is an international gateway for waterbourne cargo for the Pacific Northwest region and the United States. More than 35 million tons of cargo are shipped annually on approximately 2,000 ocean-going vessels via the ports of Kalama, Longview and Vancouver in Washington, and Portland and St. Helens in Oregon. In 2000, cargo valued at $14 billion was shipped via lower Columbia River ports. The Columbia River corridor serves as a funnel for cargo moving from more than 40 states, which is then shipped from Columbia River ports.

Since the last improvement to the Columbia River navigation channel, authorized in 1962, the volume of cargo carried by deep-draft vessels to and from Columbia River ports has tripled. During the same period, the average tonnage per vessel has also tripled, while the number of deep-draft vessels calling at Columbia River ports declined slightly. Over the past 20 years, an increasing share of the Columbia River cargo tonnage has been carried on vessels that are Panamax class (the largest size vessels that can transit the Panama Canal) or larger. These larger vessels have design drafts that, after allowing for underkeel clearance requirements, exceed the depth allowed by the 40-foot channel; consequently, these ships must often leave the Columbia River ports "light loaded" (i.e., only partially loaded). Currently, more than 70 percent of the vessels deployed in the transpacific container trade are constrained by the 40-foot channel depth. This would be reduced to 39 percent with a 43-foot channel. By deepening the navigation channel, the Project will continue to support these water-dependent uses that are vital to the economies of Oregon and Washington.

Ecosystem restoration and mitigation also recognize the statewide interest. Proposed restoration focuses on habitat types that have been determined to be important to species listed under the Endangered Species Act, including white-tailed deer and salmonids. This habitat will also benefit a variety of non-listed species. Proposed mitigations focus on habitat types determined to be important resources such as wetlands and riparian habitat that contribute directly and indirectly to aquatic and terrestrial resources. Specific activities needed to implement restoration and mitigation projects are discussed under the appropriate local jurisdiction.

2. *Preserve the natural character of the shoreline.*

The Project includes restoration features to help restore the natural function of shoreline ecosystems and minimize intrusions on shoreline areas. The Project's restoration components responds to a well-demonstrated need for ecosystem restoration and incorporates many restoration actions.

The Project uses dredging and disposal methods similar to those used for maintenance dredging that are designed to minimize impacts on shorelines. Dredging and flowlane disposal will occur at depths to minimize impacts. Dredging will use hopper and pipeline dredges to minimize turbidity. Flowlane disposal uses a "down pipe" with a diffuser plate at its end. The down pipe extends 20 feet below the water surface to avoid impacts to migrating juvenile salmonids. The diffuser and movement of the pipe help prevent mounds from forming on the river bottom. Upland disposal will use temporary pipelines extending from dredges. These temporary pipelines will be removed after dredged material disposal occurs for each event. The Project uses shoreline sites for upland disposal that have been previously used for this purpose for most of the disposal sites. The new sites in Washington State are located at least 300 feet from the Columbia River upland to minimize intrusion on the shoreline.

3. *Plan for long term over short term benefit.*

The Project plans for the long-term benefits of enhanced navigational access. Over the past 20 years, an increasing share of the Columbia River cargo tonnage has been carried by Panamax class vessels or larger. These larger vessels have design drafts that, after allowing for underkeel clearance requirements, exceed the depth allowed by the 40-foot channel; consequently, these ships must often leave the Columbia River ports "light loaded" (i.e., only partially loaded). Currently, more than 70 percent of the vessels deployed in the transpacific container trade are constrained by the 40-foot channel depth. This amount would be reduced to 39 percent with a 43-foot channel. By deepening to 43 feet, the Project will be able to improve navigation infrastructure and maximize the efficiency of the vessels and waterbourne cargo shipments for years to come.

The Project's restoration features also are intended to provide a long-term benefit to the Columbia River. These features include shallow water and intertidal habitat important to salmonids, habitat for white tail deer listed under the Endangered Species Act and to further Lower Columbia River Estuary goals for restoring natural resources in the Columbia River. The Project's mitigation activities are also intended to provide a long-term benefit to the Columbia River, through acquisitions, preservation and long-term protection. The mitigation will provide a net increase in aquatic and riparian habitat.

4. *Protect the resource and ecology of the shoreline.*

Modeling of the Project has shown that it should have only minor, if any effects, on physical parameters such as salinity, stream flows, erosion and accretions. Habitat forming processes and food chain effects have also been determined to be minimal. The Project uses dredging and disposal methods designed to protect the resources and ecology of the shorelines. Dredging will be done at depths of more than 40 feet, while salmonids generally migrate at depths of less than 20 feet. The primary hopper and pipeline dredges generally do not produce large amounts of turbidity during dredging because of the suction action of the dredge pump and the fact that the drag arm or cutter head is buried in the sediment. Turbidity produced by clamshell dredges is minimal

Flowlane disposal generally will also be in depths ranging from 50 to 65 feet. The benthic invertebrates that provide a major food source for some fish are found at depths of less than 20 feet. Therefore, restricting the disposal of dredged materials to depths greater than 20 feet will minimize potential impacts from this activity. To avoid mounding during hopper-dredge disposal, material will be released while the dredge is in motion to disperse material over the flowlane disposal area. During disposal or placement of dredged material by pipeline dredge, the diffuser and movement of the pipe help prevent mounds from forming on the river bottom.

Upland disposal along the Columbia River channel has been reviewed by the NOAA Fisheries and USFWS to avoid adverse impacts on listed fish species or proposed critical habitat. Upland disposal activities will employ measures to minimize potential impacts.

Sand will be placed at upland disposal sites with a temporary pipeline. The pipeline will be removed after the sand is in place, in order to minimize any interference with recreational boating and commercial fishing. Upland disposal sites are designed to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle. Water is allowed to settle and clear through the retention pond drainage system before it runs back into the river. Weirs are used to regulate the return of water to the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance.

Upland sites that have been used for past dredged material disposal are being used again. New upland disposal sites have been located 300 feet beyond ordinary high water. All proposed sites have been located to avoid wetlands to the extent feasible. Impacted wetlands will be mitigated at a ratio of 1:12 or greater.

5. *Increase public access to publicly owned areas of the shorelines.*

The shoreline disposal at Skamokawa Beach helps to maintain a popular public park. A number of the sites that are being acquired for restoration or mitigation are currently planned to focus on their potential to enhance natural resources and help to recover fish and wildlife species, rather than to significantly increase public access because public access can adversely affect natural resources in a manner that would be inconsistent with the basin wide priority for natural resource restoration.

6. Increase recreational opportunities for the public on the shorelines.

The Project will enhance recreational opportunity on the shorelines by restoring the erosive beach at Skamokawa beach. The ecosystem restoration features of the Project will enhance passive recreational opportunities for studying and viewing wildlife on the shorelines. The restoration features located in Washington include restored wetland and riparian habitat at Shillapoo Lake (CRM 91); fish gates for salmonid passage at selected locations along the lower Columbia River; connecting the river to embayments at the upstream end of Hump-Fisher Islands for improved fish access to embayments and rearing habitat for juvenile salmonids; the Purple Loosestrife Control Program; the Cottonwood/Howard Island Columbia White-Tailed Deer Introduction; and the Bachelor Slough Restoration.

4.1.3 Conditional Use Criteria. Each local SMP identifies some of the Project activities as conditional uses in certain areas in its shoreline. The Project activities meet the SMA's conditional use criteria as discussed below.

1. *The use will cause no unreasonable adverse effects on the environment or other uses within the area.*

The Project incorporates numerous best management practices and ecosystem restoration features and is not expected to have an unreasonable adverse effect in the areas where they will take place. Dredging will be done at depths of more than 40 feet, beyond the depths at which salmonids generally migrate. Flowlane disposal generally will be in depths ranging from 50 to 65 feet, beyond the depths at which benthic invertebrates are found. Upland disposal along the Columbia River, is not known to have had any adverse impacts on listed fish species or proposed critical habitat to date. New upland sites are located 300 feet beyond the river to avoid adverse effects.

2. *The use will not interfere with the public use of public shorelines.*

Navigation is a principle public use of the Columbia River, which will be enhanced by this Project. The federal government has dredged the channel for navigation purposes for over 100 years. Such dredging is an activity necessary to enhance and maintain the public's navigational access. Dredging and flowlane disposal will be limited to the navigation channel and adjacent areas will, therefore, not interfere with the other normal public uses of the shorelines. Placement of dredged materials at upland disposal sites will utilize a temporary pipeline extending from the dredge vessel that will be removed after the dredged materials are placed to minimize interference with recreational boating.

Shoreline disposal at Skamokawa Beach in Wahkiakum County also enhances the public use of the day park at that beach. In addition to enhancing the efficiency of the navigation channel, another purpose of this Project is to restore ecosystem function. This Project incorporates a number of ecosystem restoration projects and mitigation features that will enhance passive recreational opportunities for studying and viewing wildlife on the shorelines.

3. *The design of the proposed use will be compatible with the environment in which it will be located.*

The Project is compatible with the existing permitted uses. Dredging and flowlane disposal has historically taken place and is currently ongoing in the navigation channel to maintain the 40-foot channel depth. Additional dredging for the 43-foot channel is, therefore, consistent with existing permitted uses of the navigation channel and the environment in which they will be located. Most of the upland disposal sites have already been used. New sites are being located 300 feet beyond the Columbia River. The upland disposal sites are, therefore compatible with existing uses in the environments for which they are proposed.

a. *Specific performance standards shall be imposed and/or developed for any given use, to make that use compatible to the natural or conservancy environments, in which that use will locate.*

Each activity includes best management practices to make the use compatible with its location.

4. *The proposed use will not be contrary to the goals, policy statements or general intent of the shoreline environments of this master program.*

Most of the activities proposed have occurred in the same or similar locations for maintenance. The new upland disposal sites are sited 300 feet beyond the Columbia River.

4.2 Wahkiakum County

4.2.1 References. Wahkiakum County's shoreline regulations and policies are found in its SMP. References below to the Wahkiakum County SMP (revised 1980) ("WCSMP") are given by page number.

4.2.2 Proposed Shoreline Uses. The Project includes dredging and disposal of dredged material (including flow-lane, upland, and shoreline disposal). Site operators may resell dredged materials, although this activity is not part of the Project. Each of these activities has occurred within Wahkiakum County before in the same general locations as proposed for this Project, except for the upland disposal site on Puget Island. The Puget Island upland disposal site is located 300 feet from the Columbia River and is not within the shoreline jurisdiction. These activities are discussed further below:

Columbia River – 43-ft. Channel Improvement Construction and Maintenance Dredging,

The 600 foot wide navigation channel in the Columbia River will be dredged in specific locations from CRM 20 to CRM 52, in Wahkiakum County. Dredging will deepen the existing 40-foot-deep channel to the newly authorized depth of 43 feet. This dredging will occur in generally the same footprint as past maintenance dredging. Past maintenance dredging has been found to be consistent with the Washington Coastal Management Program. The Department of Ecology most recently determined maintenance dredging in these general areas to be consistent with the Washington Coastal Management Program on June 1, 2000. This Project includes dredging to a new depth within the general footprint for maintenance dredging not previously reviewed.

Columbia River – Dredged Material Flowlane Disposal

Flowlane disposal could be done in selected areas from CRM 20 to CRM 52, in Wahkiakum County. Flowlane disposal will occur where depths range from 50 to 65 feet in or adjacent to the navigation channel, but are typically greater than 50 feet.

Brown Island - Dredged Material Upland, CRM W-46.3/46.0

Size: 72 acres

Elevation: Current surface elevation estimated at +15 feet CRD; surface elevation with total volume placed estimated at +66 feet CRD.

Owner: Washington Department of Natural Resources ("WDNR")

Brown Island is an existing upland disposal site located within 200 feet of the shoreline. The site was included in the maintenance proposal that was subject to the June 1, 2000 consistency determination.

Brown Island is located at the upper end of Puget Island. No improvements are located on the island. Ground surface consists of sand dredged from maintenance of the 40-ft navigation channel. There is no tree cover on the site. Brown Island is bordered by White Island. A low, seasonally inundated swale separates the two.

The site can accept up to 4,700,000 cy of sand. The Corps plans to place up to that amount, raising the elevation up to +66 CRD. Dredged material will be placed with a temporary pipeline extending from the dredge vessel. Water will be allowed to settle and clear through the existing weir system before returning to the river. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

Skamokawa – Dredged Material Shoreline Disposal/ Resale, CRM W-33.4

Size: 11 acres

Elevation: Current surface elevation for the shoreline site averages 0 feet CRD; post-disposal elevation based upon site capacity +18 feet CRD although will vary with resale of materials and beach erosion.

Owner: Port of Wahkiakum 2

Skamokawa is an existing shoreline disposal/resale. The Skamokawa shoreline disposal site will only be used for maintenance dredge material.

The site is zoned an urban shoreland environment above the ordinary high water (OHW) line, and a conservancy aquatic environment below OHW. The property borders a day-use park to the southeast and northeast. The site has been used for material disposal from the Columbia River. The Port of Skamokawa 2 site uses a holding area for sand that the Port sells in order to offset the park's operating costs. The resale activity is not part of this Project and would be separately permitted. The sand and gravel resale operation is focused in the southeast corner of the property. There are no other improvements on the site.

The site can accept up to 250,000 cy of sand. The Corps plans to place 250,000 cy of sand on the beach during the maintenance phases of the Project. Sand has been placed as shoreline disposal at the Skamokawa site to ease severe beach erosion problems in the past, most recently in 2000. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site.

Rice Island - Dredged Material Land Disposal, CRM W-21.0

Size: 228 acres (21 acres, Washington; 207 acres, Oregon)
Elevation: Current surface elevation (average for Washington 21 acres) estimated at +13 feet CRD; surface elevation with total volume placed estimated at +53 feet CRD.

Owners: WDNR and Oregon Division of State Lands ("ODSL")

Rice Island is an existing upland disposal site located within 200 feet of the shoreline. The Rice Island site will only be used for maintenance dredge material. The site was subject to the June 1, 2000 consistency determination.

The property occupies the majority of a roughly northeast-southwest trending bar island. The island was created with material dredged from the Columbia River. The topography of the island interior is relatively level, as the dredged material has been evenly distributed across it. Improvements observed on-site include a retention pond and metal drainage structure for the dredged material dewatering. The downstream end of the island is used by terns and access to the island is limited.

The site can hold up to 5,500,000 cy of sand. The Corps plans to place up to 5,500,000 cy of sand during the maintenance phases of the Project. The site's elevation will be raised up to +53 feet CRD. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

Puget Island (Vik Property), CRM W-44.0

Size: 100 acres
Elevation: Current surface elevation estimated at +15 feet CRD; surface elevation with total volume placed estimated at +41 feet CRD.

Owner: Vik family

Puget Island is a new upland disposal site located at least 300 feet beyond a rural shoreland environment. Because this disposal site is outside the shoreline it is not subject to the WCSMP. The site is bordered on the north, west, and east by other agricultural lands and by private residences to the south. The property is currently used as agricultural land.
The site can accept up to 3,500,000 cy of sand. The Corps plans to place up to 3,300,000 cy of sand at the site, raising the elevation to +41 feet CRD. The topsoil will be replaced so that the property owner can resume using the land for agricultural purposes. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

4.2.3 Permitted Shoreline Uses. The principal WCSMP regulatory use standards that apply to the Project elements that will occur in Wahkiakum County are those governing: dredging, dredged material disposal, mining/mineral extraction, and commercial (sand resale) activities.

Dredging

The WCSMP defines dredging as the removal of earth, sediment or other material from the bottom of a river or other aquatic area for the purpose of deepening a navigation channel or to obtain use of the bottom sediments. In this case, the removal of sand from the Columbia River to deepen the navigational channel to 43 feet constitutes dredging.

- Maintenance dredging is permitted as a substantial development in the urban, rural and conservancy aquatic environments.
- New construction dredging is permitted as a substantial development in urban and rural aquatic environments.
- New construction dredging is permitted as a conditional use in conservancy aquatic environments.

Dredged Material Disposal

Under the WCSMP, the disposal of dredged material encompasses the deposition of dredged material in aquatic areas as well as shorelines, including land disposal, in-water disposal, shoreline disposal, flowlane disposal and ocean disposal. The Project will use three upland sites, one shoreline site, flowlane and in-water fill types of disposal in Wahkiakum County. However, there will be no ocean disposal in Wahkiakum County.

- Land disposal is the deposition of dredged material on land. It will occur at the Brown Island and Rice Island sites. It will also occur beyond shoreline jurisdiction at the Puget Island (Vic property) site.
- Flowlane disposal is the in-water deposition of dredged material in or adjacent to the maintained navigation channel and within the natural channel or the slopes adjacent to the natural channel, in order to avoid permanent deposition and allow the material to continue downstream. This will occur in and adjacent to the navigation channel in the stretch of the Columbia River in Wahkiakum County.
- Shoreline disposal is the deposition of dredged material in shoreline areas where active erosion is occurring, as a way of preventing further erosion of the bankline. This will occur at the Skamokawa shoreline disposal site.

Mining/Mineral Extraction

The WCSMP defines mining and mineral extraction as the removal for economic use of sands, gravels or other naturally occurring materials from the shorelines and/or the bed beneath an aquatic area. In this case, the resale of dredged materials from the Skamokawa site is of material that does not naturally occur at that site and may not constitute mining. The Washington

Department of Ecology has indicated that it would consider these activities to be mining and this analysis will review the resale activities for consistency with these provisions. As noted earlier, this activity is not part of the Project, but may be conducted under a separate permit by the Port of Wahkiakum 2.

Commercial (Sand Resale) Activities

Commercial uses are privately–owned or operated facilities or places of business open to the public for the sale of goods or services. Commercial developments are those uses which are involved in wholesale or retail trade or business activities. In this case, the resale of sand from the Skamokawa resale site is conducted by the Port of Skamokawa 2 and is not privately owned or operated. Therefore, it should not constitute a commercial use. The Washington Department of Ecology has indicated that it considers these activities to be commercial and this analysis will review the resale activities for consistency with the commercial provisions.

4.2.4 Format. The WCSMP is organized into the following areas: general conditions for substantial development, specific regulatory standards for shoreline uses and activities, general policies and objectives for shoreline uses and activities, shoreline environment objectives, element goals and objectives, and conditional use permitting criteria. The analysis below, therefore, follows that same basic structure:

- **Substantial Development Conditions**
- **Master Program Regulatory Standards for Uses and Activities**
  - Dredging
  - Dredged Material Disposal
  - Mining/Mineral Extraction
  - Commercial Activities
- **Master Program Policy Objectives for Uses and Activities**
  - Dredging and Dredged Material Disposal
  - Mining/Mineral Extraction
  - Commercial Activities
- **Master Program Shoreline Environments and Objectives**
  - Urban
  - Rural
  - Conservancy
- **Master Program Element Goals and Objectives**
  - Circulation
  - Conservation
  - Economic Development

4.2.5 Consistency Analysis – Findings. The Project is not only consistent and in general conformance with the WCSMP, it actually promotes several key goals and policies regarding navigation and economic development.

4.2.5.1 Substantial Development Conditions. The Project will adopt and comply with all applicable general permit conditions and best management practices ("BMPs") identified on page "v" of the WCSMP.

4.2.5.2 Dredging. As noted above, the Project's dredging will occur in the navigation channel where dredging has previously occurred. The Project, which involves incrementally deeper dredging, is consistent with the WCSMP's regulatory use standards and general policy objectives for dredging.

4.2.5.2.1 Regulatory Use Standards for Dredging. The Project meets the specific standards for dredging (WCSMP, pp. 51-52):

1. *Dredging in aquatic areas shall be permitted only:*

a. *For navigation or navigational access*.

As discussed in Section 4.1.2, the primary purpose of the Project is to enhance navigation and navigational access. Dredging serves the purposes of navigation and navigational access.

b. *In conjunction with a permitted water-dependent use*.

Marine shipping and related navigational improvements are permitted water-dependent uses.

c. *As part of an approved restoration Project*.

The Project includes restoration features in Wahkiakum County. The Purple Loosestrife Control Program will occur in the county, principally in the vicinity of Puget Island, the mouth of the Elochoman River, the embayment at Three Tree Point and Grays Bay. The installation of tidegate retrofits to improve fish passage through tidegates will occur at Deep River.

d. *As a source of material, or for mining and/or mineral extraction*.

The Project uses disposal sites from which dredged materials can be used beneficially or sold, including the Skamokawa site in Wahkiakum County. The Project will provide materials for the active public port sand and gravel resale operation at the southeast corner of that site. As noted, this resale activity is not part of the Project.

e. *In conjunction with a permitted navigational structure for which there is a public need and no other feasible site or route*.

The dredging will occur in conjunction with construction of the deepened navigational channel. *See* Section 4.1.2 above.

2. *Minimize dredging.*

Construction and maintenance dredging will only remove the material necessary for the authorized 43-foot navigation channel.

3. *Locate dredging in sandy bottom sediments, where biological productivity is low and unwanted shoaling has occurred.*

The amount of dredging that will be necessary in a given location varies depending on the amount and location of shoaling. Most of the dredged materials that are removed during construction of the 43-foot navigation channel will primarily be sand (small quantity of basalt and cobbles), with a low percent (<1%) organic content. These areas are low in benthic productivity when compared to other parts of the river.

4. *Conform to federal and state permits.*

The Project will comply with applicable state and federal permits or approvals.

5. *Avoid destabilization of fine-textured sediments, erosion, siltation, and other undesirable changes in circulation patterns or flushing times.*

The Project will avoid destabilization of fine-textured sediments, erosion and siltation. Most of the dredged materials that are removed during construction of the 43-foot navigation channel will be coarse to medium sand as opposed to fine-textured sediments (silts and clays). Hopper dragheads and pipeline cutter heads will only be lifted to within 3 feet of the river bottom. This minimizes siltation and is normally done by the dredge operators, as it has been required by NOAA Fisheries for maintenance dredging of the 40-foot channel.

6. *Consider adverse effects of initial and maintenance dredging.*

Dredging will be done at depths of more than 40 feet where benthic productivity is low. Because salmonids generally migrate at depths within 20 feet of the surface, entrainment is not expected to occur. No crab are located in the area to be dredged within Wahkiakum County. Upland effects of disposal of dredged materials are discussed below.

7. *New project dredging in conservation aquatic areas shall be limited to shallow draft navigation or acres channels.*

The navigation channel is not located in the Conservation Environment.

4.2.5.2.2 Policy Objectives for Dredging. The Project is also consistent with the WCSMP policy objectives for dredging (WCSMP, p. 20):

1. *Minimize damage to existing ecological systems and natural resources in both the dredging and deposition areas.*

Dredging will be done at depths of more than 40 feet, beyond the depths at which salmonids generally migrate. The primary hopper and pipeline dredges that will be used generally do not produce large amounts of turbidity because of the suction action of the dredge pump and the burial of the drag arm or cutter head in the sediment.

Flowlane disposal generally will also be in depths ranging from 50 to 65 feet. Most benthic invertebrates that serve as a food source for fish are found at depths of less than 20 feet. Therefore, restricting the disposal of dredged materials to depths greater than 20 feet will minimize potential impacts from this activity. Most of the volume of disposal material will be placed in areas in Wahkiakum County that have no crabs. While it has been established that white sturgeon are present in the flowlane disposal areas, the Corps is conducting studies to help avoid and minimize impacts to sturgeon.

The proposed dredging disposal activity along the Columbia River channel has been subject to consultation under the Endangered Species Act to address impacts to listed fish species or proposed critical habitat. Except for the Puget Island site, the upland disposal sites in Wahkiakum County have been used for dredge material disposal. Selection of previously used sites helps to avoid damage to "existing ecological systems" and resources. The new disposal site, Puget Island, in Wahkiakum County is located 300 feet beyond the Columbia River to minimize damage to existing ecological systems and resources of the shoreline. The site is outside of shoreline jurisdiction. The Washington Department of Fish and Wildlife Priority Habitat Survey map does not show waterfowl use of the Puget Island disposal site. Wintering Canada geese would be expected to forage in these pasturelands. The wildlife mitigation plan includes creation of 132 acres of forage habitat at Woodland Bottoms. The disposal site ultimately will be returned to agricultural use and would then provide waterfowl forage compared to the present condition. Exhibit K-8, Consistency with Critical Areas Ordinances Including Wetland Mitigation (Revised). The USFWS Biological Opinion includes the Corps incremental (3 cell)disposal plan with topsoil replacement as a reasonable and prudent measure to minimize impacts on Columbian white-tailed deer.

2. *Restrict dredged material deposition in water areas to improve habitat or to correct material distribution adversely affecting resources.*

Shoreline sites selected for use as shoreline disposal areas are only those that are highly erosive, where replacement of dredged materials will correct the material distribution, such as at the Skamokawa shoreline disposal site in Wahkiakum County. Flowlane disposal will be restricted to the navigation channel and the adjacent areas and will use a diffuser on the down pipe that will be moved continually to prevent mounding on the river bottom.

3. *Local review of dredging to create land or extend property.*

The dredging that will occur in this Project is not being conducted for the purpose of creating land or extending property.

4. *Dredged material disposal in shoreland areas should not impair scenic views of local residents.*

The Project uses existing disposal sites, including Brown Island and Rice Island in Wahkiakum County, in order to minimize visual impacts. The new disposal site is located beyond the shoreline.

5. *Restrict dredging activities in commercial fish drift areas during fishing season.*

Dredging and flowlane disposal will be restricted to the navigation channel and adjacent areas. As noted above, the Project generally uses disposal sites and practices that are being, or have been, used for many years in Wahkiakum County. Dredging and flowlane disposal activities are spatially and temporally restricted and thus would preclude commercial fishing of only a minor portion of the river during dredging operations. Further, dredging operations (O&M) typically occur in the June to September timeframe and would have to coincide with commercial fishing seasons to result in a conflict.

4.2.5.3 Disposal of Dredged Material. The Project is consistent with the WCSMP's regulatory use standards and the policy objectives for the disposal of dredged materials.

4.2.5.3.1 Regulatory Use Standards for Disposal of Dredged Material. The Project is consistent with the WCSMP's standards for the disposal of dredged material (WCSMP, p. 55-57):

1. *Select dredged material disposal sites in accordance with the "Dredged Material Disposal Plan Site Selection and Use Priorities."*

All dredged material disposal sites that are within the shoreline are covered by CREST's Dredged Material Disposal Plan Site Selection and Use Priorities ("DMDP")**.** In addition the CREST DMDP explicitly states that "the Plan is not intended to be an exhaustive list of all possible disposal sites and ***it in no way restricts the disposal of dredged materials to designated sites only."***

2. *Use dikes to protect water quality, and graded slopes of 1½-1 and reseeding to minimize erosion at dredged material disposal sites.*

Upland disposal sites, like Brown Island, Rice Island and Puget Island are designed to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle.

3. *Characterize bottom sediments in the dredging and disposal areas, except for clean Columbia River sands and gravel.*

Sediment quality has been evaluated for dredged materials from the navigation channel. Sediment samples were collected and subjected to physical and chemical analyses. These studies indicate that material to be dredged in the Columbia River navigation channel is suitable for unconfined open water disposal. The bed material of the Columbia River navigation channel is over 99 percent coarse and medium sand. Sediment evaluations of potential maintenance dredging material conducted since the 1970s have consistently found the material to be suitable for unconfined in-water disposal. A recent review of all available sediment and contaminants data from the navigation channel determined that all such data was below current DMEF and NOAA Fisheries thresholds (NOAA Fisheries' Biological Opinion).

4. *Coordinate timing of dredging and disposal with federal, state and local agencies, and private interests to protect biological productivity and minimize interference with fishing activities.*

Year-round dredging is proposed for Project construction because dredging will be restricted to the navigation channel, at depths of more than 40 feet where salmonids and benthic invertebrates are generally not present. Typically, O&M dredging is conducted after the spring freshet, typically from July to October. Dredging and disposal in Wahkiakum County would be limited because the volume of material and number of disposal locations is limited. Restricting dredging and flowlane disposal to the navigation channel and adjacent areas will also minimize interference with commercial and recreational fishing, as will the use of temporary pipelines for placement of sand at upland disposal sites. The NOAA Fisheries and Fish and Wildlife have reviewed the Project and issued Biological Opinions that address the Project's effects on species listed under the Endangered Species Act. The use of existing disposal sites minimizes the impact to terrestrial vegetation, riparian habitat, and aquatic resources. Creation of the upland disposal site at Puget Island will impact farmlands that are located beyond the shoreline.

5. *Minimize adverse short-term effects of dredging and disposal such as turbidity, release of heavy metals, etc., disruption of food chains, loss of benthic productivity, and disturbance of fish runs.*

Dredging will occur at depths of more than 40 feet, beyond the depths at which salmonids generally migrate. Flowlane disposal generally will be in depths ranging from 50 to 65 feet, also beyond the depths at which most benthic invertebrates are found. The Project incorporates dredging methods and BMPs that minimize turbidity. Sediment studies indicate that the quality of sediments that will be dredged from the Columbia River navigation channel is suitable for unconfined open water disposal.

6. *All relevant state and federal water quality standards shall be met by dredging and dredged material disposal activities.*

A Section 401 water quality certification will be obtained for the Project. The Project will comply with all applicable water quality standards.

7. *In-water disposal requirements:*

Flowlane disposal is discussed in response to question 8 below. The only other in-water disposal is at Skamokawa Beach where such activity has occurred for many years.

a. *Consider the need for the proposed disposal, and alternate sites and methods of disposal that might be less damaging to the environment and benthic populations.*

The shoreline disposal site at Skamokawa has been used because of the need to counter highly erosive forces at this area of the shoreline. In addition, the Department of Ecology is generally encouraging in-water disposal.

b. *Consider matching the size and characteristics of dredged material to the disposal site.*

Most of the dredged materials that are removed during construction of the 43-foot navigation channel will be sand, with a low percent organic content, like the sands at the Skamokawa site. Sediment evaluations of potential maintenance dredging material conducted since the 1970s have consistently found this material to be suitable for unconfined in-water disposal.

c. *Avoid erosion, sedimentation, increased flood hazard and other undesirable changes in circulation in dredging and the disposal of the dredged material. Tidal marshes, tidal flats and other wetlands should not be adversely affected.*

The Skamokawa shoreline disposal site was selected specifically to counter erosion. Disposal at this location will neither result in undesirable change nor adversely affect desirable habitat.

d. *No dredged material disposal in the vicinity of a public water supply intake.*

There is no public water supply intake near the Skamokawa shoreline disposal site.

8. *Flowlane disposal requirements:*

a. *No deposit of material upstream from the dredging site or where flows or tidal conditions transport sediments predominantly upriver.*

Flowlane or in-water disposal distributes dredged material downstream of the dredging area, at sites within or adjacent to the navigation channel where depths are greater than the channel. This is done to minimize the potential for material settling back into the channel and causing additional shoaling problems.

b. *No interference with fishing activities by causing major changes in the circulation patterns or bottom configuration of the disposal site.*

Flowlane disposal will be restricted to the navigation channel and the adjacent areas, where fishing activities generally do not take place. Flowlane disposal will be dispersed along the channel to avoid creating mounds that could change circulation patterns or bottom configurations. During hopper-dredge disposal, material will be released while the dredge is in motion to disperse material, during pipeline-dredge disposal, the diffuser on the down pipe will be operated to prevent mounding on the river bottom.

9. *Shoreline disposal disposal requirements:*
a. *[No] erosion or deposition downstream from the disposal site, or erosion that could smother marsh or other shallow productive areas.*

The NOAA Fisheries and USFWS have approved shoreline disposal at Skamakowa after reviewing it to determine that it would not have adverse impacts to listed fish species or their habitat. The area downstream from Skamakawa is not a marsh or other shallow productive area. The site is on the outside bend of the river and, therefore, is unlikely that a stable benthic environment could form.

b. *The volume and frequency of dredged material disposal maintains a stable beach profile, as nearly as possible. Dredged material shall be graded at a uniform slope and contoured to reduce cove and peninsula formation and to minimize stranding of juvenile fish.*

Shoreline disposal will be done primarily with pipeline dredges. Material dredged from the main navigation channel is pumped to a shallow water and beach area. The dredge first pumps a landing on the beach to establish a point from which further material placement occurs. Dredged material is pumped as a sand and water slurry (about 20 percent sand). As it exits the shore pipe, the sand quickly settles out on the beach while the water returns to the river. Once sand begins to accumulate, it is spread to match the elevation of the existing beach. A typical shoreline disposal operation occurs only once at any location during the dredging season. It takes from 5 to 15 days to fill a site, depending on the size of the site and the amount of material to be dredged. The width of the beach that is maintained is approximately 100 to 150 feet riverward. The process continues by adding length to the shore pipe and proceeding longitudinally along the beach. After disposal the beach is groomed to a minimum steepness of 10 to 15 percent to prevent the possibility of creating areas where fish could be stranded by wave action.

10. *Ocean disposal requirements:*

No ocean disposal will occur within Wahkiakum County.

11. *Except for flowlane disposal and shoreline disposal, deposition inside the estuary should be substituted for ocean disposal only when sea or weather conditions are a hazard to navigation for the dredging vessel.*

None of the disposal in Wahkiakum County has been substituted for ocean disposal. In addition, the Washington Department of Ecology has encouraged the Corps to consider alternatives to ocean disposal.

12. *Land disposal requirements:*
a. *Surface discharge must be properly diverted to maintain the integrity of the natural streams, wetlands and drainage ways. Disposal runoff water must exit the waterway through an outfall at a location that maximizes circulation and flushing. Underground springs and aquifers must be identified and protected.*

Upland disposal sites will use weirs to regulate the return of water to the river. Water from the upland disposal sites will be allowed to settle and clear through the retention pond drainage system before it runs back into the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance. The only new upland disposal site is located Puget Island beyond shoreline jurisdiction.

b. *Dikes should be well constructed and large enough to encourage proper "ponding" and to prevent the return of settleable solids into the waterway or estuary. Ponds should be designed to maintain at least one foot of standing water at all times to further encourage proper settling. Weirs should have proper crest heights.*

Upland sites, like Brown Island, Rice Island and Puget Island, in Wahkiakum County, are designed to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle. Sand will be placed in upland disposal sites with a temporary pipeline extending from the dredge vessel. The pipeline will be removed from the sites after sand placement. Sand moves through the pipeline in the form of a slurry mixed with Columbia River water. Water from the upland disposal sites will be allowed to settle and clear through the retention pond drainage system before it runs back into the river. Weirs of appropriate crest height will be used, where necessary, to regulate the return of water to the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance.

13. *Disposal should be comparable with the intended land surface use after disposal and should minimize the quantity of land that is disturbed. Clearing of land should occur in stages on an as-needed basis. Reuse of existing disposal sites is preferable to the creation of new sites.*

Upland disposal sites, like Brown Island and Rice Island, which have been used for past dredged material disposal will continue to be used. Reuse of previous disposal sites minimizes resources impacts as well as the need to obtain new disposal sites. The useful life of these diked disposal sites will be extended by building a series of "lifts" placed on top of the deposited sand after a specified height is reached. This method minimizes the quantity of land that is disturbed. Disposal at Puget Island will occur in stages and topsoil will be replaced to return the land to agricultural use.

14. *Where appropriate, revegetation should occur as soon as possible, using native species, consistent with the interagency seeding manual prepared by the Soil Conservation Service (SCS).*

The Puget Island site will have topsoil replaced and the area will be returned to agricultural use. Sand is not a natural soil base for either upland or beach sites in the project area. Consequently, dredged material disposal sites (sands) are an atypical habitat for the project area. There are no native plant species present in the project area for sandy beach or upland habitats. For upland dredged material sites, particularly downstream of CRM 46, experience has shown the sandy material on disposal sites above the high tide line too dry, sterile and erosive to allow for vegetation establishment.

15. *Height and slope requirements: The final height and slope after each use of a land dredged material site should be such that:*

a. *The site does not enlarge itself by sluffing and erosion.*

Once the water is drained from the upland disposal sites, the sand will be spread around the holding area. After they are no longer used for dredged material disposal, most sites will be regraded to minimize erosion.

b. *Material lost during storms and freshets is minimized.*

Upland sites, like Brown Island, Rice Island and Puget Island will be surrounded by earthen dikes to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle. Return flows of water to the river will be regulated by weirs.

c. View impacts from residences, viewpoints and parks are avoided.

The Project uses existing disposal sites to the extent feasible, like Brown Island and Rice Island, in order to minimize visual impacts. The sites are quite distant from residences view points and parks.

4.2.5.3.2 Policy Objectives for Dredged Material Disposal. The Project is consistent with the WCSMP's standards for dredged material disposal, which are included within its policy objectives for dredging (WCSMP, p. 20). *See* Section 4.1.5.1.2 above.

4.2.5.4 Mining/Mineral Extraction. Although the resale of dredged materials is not part of the Project and does not appear to meet the definition of mining, resale activities that may be conducted by the Port of Wahkiakum 2 would be consistent with the WCSMP's regulatory use standards and general policy objectives for mining/mineral extraction.

4.2.5.4.1 Regulatory Use Standards for Mining/Mineral Extraction. Although not part of the Project, resale activities by the Port of Wahkiakum 2 are consistent with the WCSMP's standards for mining/mineral extraction (WCSMP, p. 71-72):

1. *Submit surface mining plan and a reclamation plan; comply with state and federal standards.*

N/A. Resale activities will comply with all applicable federal and state standards. However, a reclamation plan is typically required to address reclamation of a mine site after mining has finished. The Skamokawa resale site is not a mining site that will need to be reclaimed. Therefore, no reclamation plan should be necessary.

2. *Minimize impacts on fish, bird and wildlife habitats, riparian vegetation, water quality, shoaling, erosion, and circulation.*

The NOAA Fisheries and USFWS have identified the Skamokawa site because of its highly erosive nature and limited habitat value. The Skamokawa site also incorporates a shoreline disposal element specifically designed to correct an erosion problem.

3. *No petroleum extraction or drilling in aquatic areas.*

N/A. The Project does not include any petroleum extraction or drilling.

4. *Stockpiles should be beyond high water so that sediment will not enter or return to the waterway, not within aquatic areas.* Resale materials at the Skamokawa resale site will be placed in areas so that sediment will not enter the waterway. Only shoreline disposal materials will be placed in aquatic areas to restore eroded shorelines.

5. *Submit a surface mining plan or reclamation plan sufficient to protect or restore the shoreline environment.*

See 1 above.

6. *Gravel removal alongside, upstream or downstream from spawning areas shall comply with the technical provisions of the HPA.*

No gravel removal will occur from in-water areas at Skamokawa.

7. *Mining operations shall be strictly controlled or prohibited where historical, cultural, educational, or scientific values will be degraded.*

N/A. There are no known historical or cultural resources at the Skamokawa resale site.

4.2.5.4.2 Policy Objectives for Mining/Mineral Extraction. Resale of materials at Skamokawa resale element of the Project is also consistent with the WCSMP's policy objectives for mining/mineral extraction (WCSMP, p. 27):

1. *When materials are removed form shoreline areas, adequate protection against sediment and silt production should be provided.*

Resale activities at the Skamokawa resale site will take place at the existing sand and gravel removal operations, away from the shoreline to protect against sedimentation and siltation.

2. *Excavations for the production of sand, gravel and minerals should conform with the Washington State Surface Mining Act.*

The Skamokawa resale site will conform with all applicable state laws.

3. *When removal of sand and gravel is permitted, it should be taken from the least sensitive biophysical areas of the beach.*

Resale activities will take place only at the existing sand and gravel removal operation in the southeast corner of the Skamokawa site, upland from the shoreline.

4.2.5.5 Commercial Development. The Project does not include commercial development. Port resale activities, however, would be consistent with the WCSMP's regulatory use standards and general policy objectives for commercial development.

4.2.5.5.1 Regulatory Use Standards for Commercial Activities. Many of the commercial activities standards pertain specifically to commercial structures and developments. Resale, however, is consistent with all applicable WCSMP standards for commercial activities (WCSMP, p. 46-47):

1. *Because shorelines suitable for urban uses are a limited resource, emphasis shall be given to development within already developed areas and particularly to water-dependent commercial uses requiring frontage on navigable waters.*

The Skamokawa resale site is located at an existing sand and gravel resale operation in the southeast corner of the Skamokawa property.

2. *Commercial development may be permitted subject to the following regulations:*

a. *Commercial buildings of more than 35 feet above average ground grade shall be allowed as a conditional use.*

N/A. The Project does not include construction of any buildings. However, the final height of the Skamokawa resale site is not expected to exceed 15 feet.

b. *Commercial structures or facilities shall be set back from the ordinary high water mark by a minimum of 30 feet.*

N/A.

c. *Parking facilities shall be placed as far inland as the topography of the area allows.*

N/A. The Project does not include any parking facilities. The resale site will use the existing parking facilities.

3. *Commercial uses shall be aesthetically compatible with their waterfront location.*

N/A. The Project does not include construction of any buildings. However, the resale site has been operated for years in its current location and provides a revenue source for the day use park.

4. *Visual access to the water shall not be impaired by the placement of signs.*

N/A. The Project does not include any signage.

5. *Off-premise outdoor advertising shall not be allowed in conservancy and rural environments, or in aquatic areas.*

N/A. The Project does not include any off-premise advertising.

6. *Placement of riparian vegetation in shoreline areas to enhance visual attractiveness or assist in bank stabilization may be required.*

N/A. This site is an active eroding site that is used for material resale. Placement of vegetation to enhance visual attractiveness or bank stability is not warranted or feasible.

7. *Commercial uses situated on floating structures shall be located so as not to rest on the bottom at mean high tide and high water.*

N/A.

8. *When the proposed use is situated directly on the waterfront, maximum feasible public access shall be provided.*

N/A. Resale activities are conducted to maintain public access to the beach.

9. *Commercial recreational developments shall not substantially change the character of the environment in which they are located.*

N/A. The Project does not include any commercial recreational developments.

4.2.5.5.2 Policy Objectives for Commercial Activities. Resale activities by the Port of Skamokawa, although not part of the Project, are also consistent with the WCSMP's applicable policy objectives for commercial activities (WCSMP, p. 19):

1. *Prioritize commercial developments that are particularly dependent on location and/or use of the shorelines.*

The dredged materials sold at the Skamokawa resale site will be taken from the Columbia River. Utilizing a resale site close enough to the river to allow for placement of sand by a temporary pipeline extended from the dredge vessel minimizes impacts of moving materials across shorelines.

2. *Locate new commercial developments in those areas where current commercial uses exist.*

The Skamokawa resale site is an existing, rather than new site. It is located at an existing sand and gravel resale operation in the southeast corner of the property.

4.2.5.6 General Policies. The Project is not only consistent with the WCSMP standards and policies discussed above, it also furthers some of the more general master program goals and policy objectives for applicable shoreline environments and elements, as discussed below.

4.2.5.6.1 General Policy Objectives for Shoreline Environments. The Project is consistent with the WCSMP's general policy objectives for the shoreline environments in which Project elements will be located.

1. *Urban: To identify those defined areas which are currently in urban use and potentially capable of urban use to satisfy the socio-economic needs of the present and future population of the County.*

None of the proposed Project uses are urban in nature. The Skamokawa resale activity, although not part of the Project, is consistent with generating revenue to maintain the day use park.

2. *Rural: Establish open spaces which will satisfy positive human needs for recreation, discourage urban sprawl into areas beyond service capabilities and preserve the limited agricultural resource base.*

The only Project elements that will occur in a rural shoreland environment are the temporary pipeline from the dredge vessel to the Puget Island upland disposal site. These less intensive uses are consistent with the rural shoreline goals of establishing open spaces and discouraging urban sprawl.

3. *Conservancy: Maintain these areas for a sustained yield philosophy of resource management, and establish suitable areas for non-intensive agricultural uses, non-intensive recreational uses and limited intensive public access.*

Disposal of dredged material and the Skamokawa shoreline disposal activities will take place in conservancy shoreline areas. Shoreline disposal activities at Skamokawa will restore an eroded shoreline and return sands to the River system consistent with the conservancy shoreline goal of maintaining the Columbia River with a sustained yield philosophy of resource management.

4.2.5.6.2 General Policy Objectives for Shoreline Elements.
The Project is consistent with the WCSMP's general policy objectives for applicable shoreline elements.

1. *Circulation Element:*
Goal: Development of facilities for any of the various modes of travel on County shorelines must not endanger the life, property, or rights, nor debilitate the quality of life of citizens or existing commercial entities.

The dredging and disposal activities related to the navigation channel that are used in Wahkiakum County are similar to those used for many years and have not endangered life, property or the rights of others. The Skamokawa shoreline disposal enhances Wahkiakum County's quality of life by helping maintain the day use park.

Applicable Policy Objectives:

a. *To ensure that the site selected is suitable for the use proposed.*

Dredging and flowlane disposal will be restricted to the navigation channel and the adjacent area. Upland dredged material disposal sites have been chosen so as to avoid and minimize impacts. Sites that have been used for past dredged material disposal, like Brown Island and Rice Island, will continue to be used. Sites from which dredged materials could be used beneficially or sold, like the Skamokawa resale site, were also selected in preference to other locations. The new upland disposal site at Puget Island (Vik), is located outside the 200-foot shoreline jurisdiction. The Skamokawa shoreline disposal site was selected to counter erosive effects to a popular recreation area.

b. *To be introduced to the area with a minimal adverse effect upon the natural features, scenic quality and ecosystems.*

No new circulation activity is being introduced to the shoreline area. Dredging and disposal has occurred in Wahkiakum County for many years. The new Puget Island site is beyond the shoreline jurisdiction.

c. *To fulfill a need which can only be satisfied by such use on the shorelines as opposed to an upland use.*

The Project will use the existing upland disposal sites at Brown Island and Rice Island, and the existing resale site at Skamokawa.

d. *To protect the life, property and rights of others and sustain or improve the quality of life in the area.*

See Goal 1 above.

2. *Conservation Element:*
Goal: Encourage best management practices for the continued sustained yield of replenishable resources of the shorelines and preserve, protect and restore those unique and nonrenewable resources.

The Project incorporates the following BMPs, among others, to protect shoreline resources during dredging:

- During hopper and pipeline dredging, maintain dragheads in the substrate or no more than 3 feet above the bottom with the dredge pumps running.
- The contractor shall not release any trash, garbage, oil, grease, chemicals, or other contaminants into the waterway. The Project also incorporates the following BMPs, among others, to protect shoreline resources during dredged material disposal:

- For flowlane disposal, dispose of material in a manner that prevents mounding of the disposal material.
- Maintain discharge pipe of pipeline dredge at or below 20 feet of water depth during flowlane disposal.
- Berm upland disposal sites to maximize the settling of fines in the runoff water.
- Locate new upland disposal sites 300 feet from the Columbia River.
- Grade shoreline disposal sites to a slope of 10 to 15 percent, with no swales, to reduce the possibility of stranding of juvenile salmonids.

Applicable Policy Objectives:

a. *Preserve the scenic and aesthetic qualities of shorelines and vistas.*

Existing upland disposal sites, like Brown Island and Rice Island, are being used. The new upland disposal site is located outside of the shoreline.

b. *Contribute to a maximum utilization of resources without harming other natural systems or quality of life.*

By deepening the navigation channel to 3 feet in selected locations, the Project will maximize the utility of the navigation channel. At the same time, by incorporating ecosystem restoration components, the Project will further enhance the natural systems and quality of life.

c. *Restore damaged features or ecosystems to a higher quality than may currently exist.*

The Project incorporates a number of ecosystem restoration actions.

d. *Preserve unique and non-renewable resources.*

Restricting dredging and flowlane disposal to depths of more than 20 feet will minimize potential impacts from these activities on threatened and endangered species and their critical habitat.

e. *Consider the total upstream and downstream effect of proposed developments to ensure that no degradation will occur to the shorelines.*

This report includes shoreline consistency analyses for each jurisdiction in which Project activities will take place to consider the total upstream and downstream effects of the proposal.

3. *Economic Development Element:*
Goal: Encourage industry and commercial activities on the shorelines that require the land-water interface for productive efforts.

The Columbia River navigation channel serves the national and regional economy. The lower Columbia River is the second largest grain-shipping waterway in the world, surpassed only by the Mississippi River. Regional growers, producers, and manufacturers use Columbia River ports to transport their goods to world markets. Shippers that use the Columbia River realize lower shipping costs by using Columbia River ports as opposed to more distant alternative ports. Marine shipping is an important industry in the lower Columbia River region. Approximately 40,000 jobs depend on Columbia River port activity, at $46,000 per year per employee on average. Columbia River port activity also generates $2 billion in business revenues and more than $200 million in state and local taxes each year. By lessening or removing the channel depth constraints for Columbia River port activity, the Project will continue to support this vital section of the regional economy for Wahkiakum County citizens and commercial entities.

Applicable Policy Objectives:
a. *Those economic developments proposed must not reduce the quality of life residents.*

The Project involves activities and methods that are well established in Wahkiakum County and will not reduce quality of life.

b. *Effectively operate without debilitating the quality of life or resources of the surrounding and adjacent area selected.*

By deepening the channel depth in selected locations, the Project will enhance the utility of the navigation channel. At the same time, by incorporating ecosystem restoration components, the Project will further enhance quality of life and preserve resources in the surrounding and adjacent areas.

4.2.6. Conditional Use Criteria. See the discussion in Section 4.1.3.

4.3 Pacific County

4.3.1 References. Pacific County's shoreline regulations and policies are found in its SMP. References below to the Pacific County SMP (revised 2000) ("PCSMP") are given by page number.

4.3.2 CZMA Consistency. Federal agency activities are reviewed for consistency with the enforceable policies of the Washington Coastal Management Program. Enforceable policies are legally binding laws, regulations, land use plans, ordinances, or other laws incorporated in an approved management program. A 65 Fed Reg. 77125 (December 8, 2000).

The Deep Water Site is located outside the limits of the Territorial Sea and is not directly within the jurisdiction of Pacific County.

The Pacific County Shoreline Master Program includes a number of provisions that implement the Washington Ocean Resources Management Act. The Ocean Resources Management Act does not apply to the Project because the Deep Water Site is off the coast of Oregon and is south of Cape Disappointment, the southern limit of the area regulated by the Act.

Section 2. Definitions. The Pacific County SMP defines "coastal waters" as "waters of the Pacific Ocean seaward from Cape Flattery south to Cape Disappointment, from mean high tide seaward two hundred miles. For Pacific County, coastal waters include from mean high tide seaward three miles." This definition is similar to the definition in the ORMA, except that it limits Pacific County's definition of coastal waters to within three miles. The Pacific County SMP defines "ocean uses" as "activities or development involving renewable and/or nonrenewable resources that occur on Washington's coastal waters."

Subsection 25.B.9 designates an "Ocean Environment" to which specific regulations apply. This subsection defines the Ocean Environment as being located "between Pacific County and Grays Harbor County; and from mean high tide, seaward three miles."

As noted above, the proposed ocean disposal site is located south of Cape Disappointment and is, therefore, not within the "coastal waters" covered by Pacific County's SMP or in the "Ocean Environment" designated by Pacific County.

4.3.3 CZMA Consistency.

4.3.4 CZMA Findings.

Section 23 Columbia River Estuary Segment. Section 23 of the Pacific County SMP applies to the area defined by the Columbia River Segment of the Pacific County's Shoreline Master Program. Appendix 5 of the SMP defines a part of the Columbia River Segment as including a specific area around Cape Disappointment. Subsection D of Section 23 identifies use and activity regulations for the Columbia River Segment. Subsection D provides tables identifying permitted uses and activities in seven management designations created by Subsection 25.B.1. through Subsection 25.B.8 of this Master Program. None of Subsections 25.B.1-8, cover the ocean. Subsection 25.B.9 designates an "Ocean Environment" and defines it as "waters of the Pacific Ocean from Cape Disappointment north to the border between Pacific County and Grays Harbor County; and from mean high tide, seaward three miles.

Section 23.D. provides use standards for activities in the environments of the Columbia River Segment defined in Subsections 25.B.1-8. As noted above, the project has no activities in any of these environments. Paragraph 23 of Section 23.D provides the use standards for dredge disposal in the Columbia River Segment. As discussed above, these standards only apply to specific environments that do not include the ocean. In addition, the Ocean Environment as defined by the SMP does not include the Ocean Disposal Site. Therefore, the standards in Section 23 do not apply and the use standards are not enforceable policies as defined by the CZMA.

ii. The activity complies with the applicable regulations in Section 27 Ocean Resources.

See following discussion.

Section 27 Ocean
12. Permit Review Criteria. The PCSMP sets forth eight criteria for the County to review ocean and associated upland or coastal uses and activities. By the terms of the PCSMP, these

criteria apply when the County is issuing permits. The County has no authority to issue permits beyond 3 miles, therefore, these criteria do not appear to apply under the plain reading of the PCSMP. In addition, the PCSMP specifically defines the Ocean Environment as the area north of Cape Disappointment.

In this regard, the terms of subsection 12 are not “enforceable policies” of the State Coastal Management Program because they explicitly only pertain to activities subject to the County’s permitting authority.

4.4 Clark County

Clark County is not located in Washington’s Coastal Zone. Therefore, review of the Clark County SMP is presented here for purposes of showing general consistency with local plans, rather than for purposes of demonstrating consistency with the Coastal Zone Management Act.

4.4.1 **References.** Clark County’s shoreline regulations and policies are found in its SMP. References to the Clark County Shoreline Master Program (revised 1974) (“CCSMP”) are given by page number.

4.4.2 **Proposed Shoreline Uses.** The Project, includes the following activities which may occur all or in part within Clark County’s shoreline jurisdiction:

Columbia River – 43-ft. Channel Improvement Construction and Maintenance Dredging
The Columbia River will be dredged in selected areas adjacent to Clark County. Dredging will deepen the existing 40-foot-deep channel to the newly authorized depth of 43 feet.

Columbia River – Dredged Material Flowlane Disposal
Flowlane disposal will be done adjacent to the channel in discrete locations.

The following activities, although not part of the Project, may be conducted by disposal site owners/operators:

Fazio Sand and Gravel - Dredged Material Upland Disposal and Resale/Mining, CRM W-97.1

Size: 27 acres
Elevation: Current surface elevation is approximately +10 feet CRD; surface elevation with total volume in place will go to +20 feet CRD but will vary due to resale.

Owner: Fazio Bros. Sand and Gravel

The Fazio Sand and Gravel site is currently used for sand resale operations. The mining operation is roughly in the center of the site. It is surrounded by a berm and drained by a weir system that allows water to clear before it is returned to the river. The disposal plan includes avoidance of the riparian vegetation.

The north-northwestern portion of the property is currently being used as a feedlot for cattle, and the northeast corner is used as an equipment storage yard. Prior to the mining operation, the property was reportedly used for agricultural purposes.

The site can accept up to 650,000 cy of additional sand. The Corps plans to place 112,000 cy of sand at the site during the 2-yr construction phase of the project. Maintenance dredging is estimated to be up to 1,000,000 cy over 20 years, with the material to be sold from the site as part of the sand resale operation. In the event the capacity is not sufficient to handle maintenance material in any given year, the intent would be to place the material at CRM 96.9, Adjacent to Fazio. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

Adjacent to Fazio - Dredged Material Upland Disposal and Resale/Mining Site, CRM W-96.9

Size: 17 acres
Elevation: Current surface elevation is approximately +20 feet CRD; surface elevation with total volume in place will go to +20 to +30 feet CRD but will vary due to resale.
Owner: Fazio Bros. Sand and Gravel

The Adjacent to Fazio site is an expanded upland disposal site that will be used for the maintenance phase of the project. The site can accept up to 475,000 cy of sand. The Adjacent to Fazio site has previously been used for disposal of dredged sand. The disposal plan will include avoidance of the riparian vegetation.

The Adjacent to Fazio site is currently used as a pasture for cattle. The western and northern portions of the site contain a cattle feedlot, while the eastern portion is open pasture. The soil is sandy and unsuitable for intensive use as cropland. The southern boundary adjoins the Fazio Bros. and New Columbia Garden Co compound. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

4.4.3 Permitted Shoreline Uses. The principal CCSMP regulatory use standards that apply to the Project are those governing dredging.

Dredging

The CCSMP defines dredging as the removal of earth from the bottom of streams, lakes or other water bodies for such purposes as channel improvements or to obtain bottom materials for landfill or resource utilization. (CCSMP, p. 68).

The following CCSMP regulatory use standard would apply to private activities that are not part of the project at the Fazio and Adjacent to Fazio sites:

Mining

The CCSMP defines mining as the removal of naturally occurring materials from the earth for economic use. (CCSMP, p. 67).

Commercial (Sand Resale) Development
The CCSMP defines commercial development as uses which are involved in services, wholesale and retail trade or other business activities. (CCSMP, p. 73).

4.4.4 Format. The CCSMP is organized into the following areas: specific regulatory standards for shoreline uses and activities, general policies and objectives for shoreline uses and activities, shoreline environment objectives, element goals and objectives, and conditional use criteria. The analysis below, therefore, follows that same basic structure:

- **Master Program Regulatory Standards for Uses and Activities**
  Dredging
  Mining
  Commercial Development
- **Master Program Policy Objectives for Uses and Activities**
  Dredging
  Mining
  Commercial Development
- **Master Program Shoreline Environments and Objectives**
  Urban
  Rural
  Conservancy
- **Master Program Element Goals and Objectives**
  Circulation
  Conservation
  Economic Development
  Shoreline Use
  Shoreline Improvement

4.4.5 Consistency Analysis – Findings. The Project is not only consistent and in general conformance with the CCSMP, it actually promotes several key goals and policies regarding navigation and economic development.

4.4.5.1 Dredging. The Project is consistent with the CCSMP's regulatory use standards and general policy objectives for dredging.

4.4.5.1.1 Regulatory Use Standards for Dredging. The Project meets the specific regulations for dredging (CCSMP p. 68):

1. All permits for dredging must be obtained prior to the start of the operation from the appropriate agency or agencies.

The Project will obtain all applicable permits.

2. All dredging proposals which require a shoreline permit must clearly identify the need and purposes of the project; type and volume of dredge material; spoils disposal site; methods of *dredging; time frame of the project; conditions of the dredging site such as water uses and channel characteristics.*

As discussed in Section 4.12, Project dredging is for navigation and navigational access. Construction and maintenance dredging will only remove the material necessary for the authorized 43-foot navigation channel. The amount of dredging that will be necessary in a given location varies depending on the amount and location of shoaling. Most of the dredged materials that are removed during construction of the 43-foot navigation channel will be sand, with a low percent organic content. Dredging will be done at depths of more than 40 feet. The primary hopper and pipeline dredges that will be used generally do not produce large amounts of turbidity because of the suction action of the dredge pump and the burial of the drag arm or cutter head in the sediment. Turbidity produced by mechanical dredging will be reduced by using a closing bucket. Hopper dragheads and pipeline cutter heads will be used only within 3 feet of the river bottom. This minimizes siltation and is normally done by the dredge operators, as it has been required by NOAA Fisheries for maintenance dredging of the 40-foot channel.

4.4.5.1.2 Policy Objectives for Dredging. The Project is also consistent with the CCSMP policy objectives for dredging (CCSMP, p. 68):

1. Dredging of bottom materials for the single purpose of obtaining fill material should be strongly discouraged.
The sole purpose of the Project's dredging is to deepen the navigation channel of the Columbia River to a depth of 43 feet to enhance navigational access.

2. Dredging operations should be conducted in a manner which will minimize degradation of water quality, damage to aquatic life, and to other ecological values.

Dredging will be done at depths of more than 40 feet, beyond the depths at which salmonids generally migrate. The primary hopper and pipeline dredges that will be used generally do not produce large amounts of turbidity because of the suction action of the dredge pump and the burial of the drag arm or cutter head in the sediment. Turbidity produced by mechanical dredging will be reduced by using a closing bucket. Hopper dragheads and pipeline cutter heads will be used only within 3 feet of the river bottom. This further minimizes siltation and is normally done by the dredge operators, as it has been required by NOAA Fisheries for maintenance dredging of the 40-foot channel.

3. Dredge spoils should be deposited only to landward of high water flows, except in cases where deposition of spoils in water areas would result in an improvement of fish habitat, bank erosion; etc., or where depositing material on land would prove to be more detrimental to shoreline resources than a deposit in water areas.

The Project utilizes upland disposal sites, to reduce the amount of in-water disposal consistent with this policy. However, it should be noted the Department of Ecology has recently begun encouraging in-water disposal of dredged materials. Flowlane disposal will be restricted to the navigation channel and the adjacent areas and will utilize a diffuser on the down pipe that will be moved continually to prevent mounding on the river bottom. Flowlane disposal generally will also be in depths ranging from 50 to 65 feet. Most benthic invertebrates that serve as a food source for fish are found at depths of less than 20 feet. Therefore, restricting the disposal of dredged materials to depths greater than 20 feet will minimize potential impacts from this activity. While it has been established that white sturgeon are present in potential flowlane disposal areas, the Corps is conducting studies to help avoid and minimize impacts to sturgeon.

4. All dredging plans should be in conformance with long range plans for the depositing of spoils on land and in water areas to be developed pursuant to the shoreline program.

The dredging in Clark County is consistent with the Corps Dredge Material Management Plan.

4.4.5.2 Mining. Sand resale activities that will be conducted by Fazio Bros. Sand and Gravel are similar to those currently occurring and are consistent with the CCSMP's general policy objectives for mining. There are no specific regulations for mining under the CCSMP. (*See* CCSMP p. 67)

4.4.5.2.1 Policy Objectives for Mining. The Project is also consistent with the CCSMP policy objectives for mining (CCSMP, p. 67):

1. Adequate protection against sediment and silt production should be provided for removal of rock, sand, gravel and minerals from shoreline areas.

Resale activities at the Fazio and Adjacent to Fazio sites will take place beyond the berms, upland from the shoreline to protect against sedimentation and siltation.

2. Operations for the production of sand, gravel, rock and minerals should be done in conformance with the Washington State Surface Mining Act.

The Fazio and Adjacent to Fazio sites will comply with all applicable regulations.

a. Proposals for surface mining should include plans for site reclamation.

Fazio's resale activities will comply with all applicable reclamation requirements.

b. State regulations should be applied to all surface mining in shoreline areas regardless of acreage or duration of the operation.

Fazio's resale activities will comply with all applicable federal and state standards.

3. The removal of sand and gravel from beaches should be prohibited. The Project will not remove sand or gravel from beaches.

Project dredging will be restricted to the navigation channel.

4. Removal of materials from stream banks and channels should be avoided and, when necessary, should be undertaken only with approval of the Departments of Fisheries and Game.

The Project will not remove sand or gravel from stream banks or stream channels. Project dredging will be restricted to the navigation channel of the Columbia River.

5. Surface mining should not occur along wooded shorelines, nor on agriculturally productive lands.

The disposal plans for Fazio and Adjacent to Fazio avoids riparian vegetation. Because these sites have been previously used for disposal of dredged materials, soils are generally sandy and unsuitable for intensive crop use.

4.4.5.3 Commercial Development. Some of the commercial development standards pertain specifically to commercial structures. Although the standards may not apply, Fazio Bros. Sand and Gravel are involved in retail trade, consistent with the CCSMP's regulatory use standards and general policy objectives for commercial development.

4.4.5.3.1 Regulatory Use Standards for Commercial Development. The Project meets the specific regulations for commercial development (CCSMP p. 73):

1. Proposals for commercial developments along the shoreline shall adequately demonstrate that a shoreline location is required.

The dredged materials sold at the Fazio and Adjacent to Fazio sites will be taken from the Columbia River. Utilizing a resale site close enough to the river to allow for placement of sand by a temporary pipeline extended from the dredge vessel minimizes impacts of moving materials across shorelines.

2. Drainage for the development shall be approved by the Clark County Director of Public Works.

The Project will obtain all applicable required approvals. Upland sites, like Fazio and Adjacent to Fazio, in Clark County, are designed to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle. Water from the upland disposal sites will be allowed to settle and clear through the drainage system before it runs back into the river. Weirs of appropriate crest height will be used to regulate the return of water to the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance.

3. Parking facilities shall be placed inland from the shore.

N/A. The Project does not include any parking facilities. The Fazio resale site will utilize the existing parking facilities.

4.4.5.3.2 Policy Objectives for Commercial Development. The Project does not include commercial development; however, Fazio's resale activities are also consistent with the CCSMP policy objectives for commercial development (CCSMP, p. 73):

1. New commercial developments on shorelines should be located in those areas where existing commercial uses are found.

The Fazio site is an existing resale site. The Adjacent to Fazio site is located in the same area, along the northern boundary of the Fazio site.

2. Commercial structures on shorelines should be designed and located so that scenic views from surrounding areas are not degraded.

N/A. The Project does not include construction of any commercial structures.

3. Shoreline frontage of commercial establishments should, to the extent possible, be maintained in its natural condition.

N/A. The Project does not include construction of any commercial establishments or structures.

4. Public access to the shoreline should be provided unless in conflict with the commercial use.

The Project will also enhance recreational opportunity on the shorelines by restoring important ecosystems. The ecosystem restoration features of the Project will enhance passive recreational opportunities for studying and viewing wildlife on the shorelines.

4.4.5.4. General Policy Objectives for Shoreline Elements. The Project is consistent with applicable CCSMP policy goals for applicable shoreline elements (CCSMP, p. 28-29).

1. *Circulation Element:*
Goal: To recognize existing transportation systems of shoreline areas as a means of providing access to other shoreline use activities; and, when additional circulation systems are proposed for shoreline areas, to assure that these facilities require such locations and are developed with minimum disturbance to the natural character of the shoreline.

The Project's in-water activities are located in and adjacent to the existing channel. The navigation channel serves the national and regional economy, including that of businesses located in Clark County. The lower Columbia River is the second largest grain-shipping waterway in the world, surpassed only by the Mississippi River. Regional growers, producers, and manufacturers use Columbia River ports to transport their goods to world markets. Upland dredged material disposal sites have been chosen so as to avoid and minimize impacts. The Project relies heavily on sites that have been used for past dredged material disposal, like the Fazio and Adjacent to Fazio sites. Sites from which dredged materials could be sold, like the Fazio and Adjacent to Fazio sites, were also selected.

2. *Conservation Element:*
Goal: To provide for management of natural resources in shoreline areas by means which will assure the preservation of non-renewable resources, while allowing sound utilization of renewable resources in a manner consistent with the public interest.

Dredging will be done at depths of more than 40 feet, to minimize effects on natural ecosystems. Existing upland disposal sites, like the Fazio site, will be utilized to the extent feasible. Upland disposal at these sites has been reviewed by the NOAA Fisheries and USFWS to address impacts to ESA listed fish species or their critical habitat. Numerous ecosystem restoration features have also been incorporated into the Project.

The Project incorporates the following BMPs, among others, to protect shoreline resources during dredging:

- During hopper and pipeline dredging, maintain dragheads in the substrate or no more than 3 feet above the bottom with the dredge pumps running.
- The contractor shall not release any trash, garbage, oil, grease, chemicals, or other contaminants into the waterway. The Project also incorporates the following BMPs, among others, to protect shoreline resources during dredged material disposal:
- For flowlane disposal, dispose of material in a manner that prevents mounding of the disposal material.
- Maintain discharge pipe of pipeline dredge at or below 20 feet of water depth during flowlane disposal.
- Berm upland disposal sites to maximize the settling of fines in the runoff water.
- Grade shoreline disposal sites to a slope of 10 to 15 percent, with no swales, to reduce the possibility of stranding of juvenile salmonids.

3. *Economic Development Element:*
Goal: To encourage the maintenance and enhancement of existing industrial and commercial activities along the shoreline in such a manner that the land-water interface be utilized for productive purposes while minimizing adverse effects to the environment; and to encourage appropriate shoreline locations for all such new developments of a water-dependent nature.

See above discussions.

4. *Shoreline Use Element:*
Goal: To encourage a pattern of land and water uses compatible with the character of shoreline environments and distributed so as to avoid undesirable concentrations of intense uses, and giving preference to uses which are dependent upon shoreline locations.

The dredging and flow lane disposal occur in, or adjacent to the navigation channel and are compatible with that existing use of the shoreline. Existing upland sites are used. The Gateway 3 site is Port property.

5. *Shoreline Improvement Element:*

Goal: To encourage the restoration of degraded shoreline areas to conditions of natural environmental quality, and promote the revitalization of abandoned shoreline facilities for practical and productive activities.

The Project includes two ecosystem restoration features in Clark County. The Bachelor Slough ecosystem restoration feature would occur on the Ridgefield NWR plus WDNR lands (Bachelor Slough and an old disposal location on the Columbia River shoreline). The Shillapoo Lake ecosystem restoration feature would occur on lands purchased by WDFW for inclusion in their Shillapoo Lake Wildlife Management Area.

Implementation of the Bachelor Slough ecosystem restoration feature is contingent on the Corps' sediment quality evaluation to determine whether material to be dredged from Bachelor Slough is suitable for dredging and/or upland disposal. The action also requires approval from WDNR and the USFWS to dispose of dredged material on their property for riparian habitat development purposes.

The restoration consists of two actions. The first action was proposed by the USFWS, Ridgefield National Wildlife Refuge. Approximately 132,000 cy of material would be dredged from Bachelor Slough to increase water depth and flow, with the result of decreasing water temperatures, which currently exceed the temperature tolerance of salmonids from mid-summer until fall. Improvements in water quality parameters are intended to benefit juvenile salmonids.

The second action involves restoring six acres of riparian habitat on the Bachelor Island shoreline of Bachelor Slough, downstream of the bridge crossing the slough, and restoration of riparian forest on up to 46 acres of upland disposal site(s) for the material dredged from Bachelor Slough.

This Shillapoo Lake ecosystem restoration feature consists of restoring wetland and riparian habitat on lands purchased by WDFW for inclusion in their Shillapoo Lake Wildlife Management Area. Shillapoo Lake lies behind flood control dikes and currently is drained annually for agricultural use on private lands and for planting of forage crops (mainly corn) to benefit wintering waterfowl.

The proposed ecosystem restoration feature would entail construction of water supply and control structures to ultimately create a total of four diked cells for wetland habitat management purposes. Construction of two cells would not occur unless private lands are acquired. These wetland cells would be hydrologically connected to the Lake River via pipelines, a tidegate and a pumping station in order to manage water levels in the four wetland management units. This will enable WDFW to maintain desired water levels in the wetland management units for optimal habitat management.

4.4.6. Conditional Use Criteria. See the discussion in Section 4.1.3.

4.5 Cowlitz County Cowlitz County is not located in Washington's Coastal Zone. Therefore, review of the Cowlitz County SMP is presented here for purposes of showing general consistency with local plans, rather than for purposes of demonstrating consistency with Washington's Coastal Program under the Coastal Zone Management Act. All of the upland disposal sites in Cowlitz County are existing disposal sites. Therefore, the level of detail of analysis for Cowlitz County reflects that sand disposal at these sites is an established, rather than a new use. The new Mt. Solo upland disposal site is in the City of Longview and is reviewed for consistency with the City of Longview Shoreline Master Program. Section 4.6. Dredging and flow lane disposal in the general locations for this Project are also currently occurring in Cowlitz County's shoreline waters.

4.5.1 References. References to the Cowlitz County Shoreline Master Program (revised 1977) ("CSMP") are given by page number.

4.5.2 Proposed Shoreline Uses. The Project, includes the following activities which may occur all, or in part, within Cowlitz County's shoreline jurisdiction:

Columbia River – 43-ft. Channel Improvement Construction and Maintenance Dredging
The Columbia River will be dredged in selected areas within Cowlitz County's shoreline jurisdiction in the location of the current navigation channel. Dredging will deepen the existing 40-foot-deep channel to the newly authorized depth of 43 feet.

Columbia River – Dredged Material Flowlane Disposal -
Flowlane disposal will be done in selected areas within Cowlitz County's shoreline jurisdiction. These areas are similar to those currently used for maintenance dredging. Flowlane disposal will occur where depths range from 35 to 65 feet, but are typically greater than 50 feet.

Hump Island - Dredged Material Upland Disposal, CRM W-59.7

Size: 69 acres

Elevation: Current surface elevation is +25 feet CRD; surface elevation with total volume in place estimated at +42 feet CRD

Owners: Washington Department of Fish and Wildlife and Washington Department of Natural Resources

Hump Island is an active, existing upland sand disposal site for maintenance dredging of the 40-ft channel. It is located within 200 feet of the shoreline, in a rural environment. It will only be used for construction and six years of maintenance of the Project.

Hump Island can hold up to 1,500,000 cy additional sand. The Corps plans to place 1,500,000 cy during the construction and maintenance of the Project. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

Reynolds Aluminum - Dredged Material Upland Disposal, Mining/Resale, CRM W-63.5

Size: 13 acres

Elevation: Current surface elevation is +20 feet CRD; surface elevation with total volume in place estimated at +50 feet CRD

Owner: Reynolds Aluminum

The Reynolds Aluminum site has been used in the past as an upland sand disposal site for maintenance dredging of the 40-ft channel. The Reynolds Aluminum site is in a heavily industrialized area. Sand is currently being sold from the site, and sand placed by this Project may also be resold. The site is diked and a drainage system for dredged sand is already in place. The Reynolds Aluminum site can hold up to 500,000 cy of sand. The Corps plans to place 180,000 cy during the construction phase. At full capacity, the top of the sand will reach +50 feet CRD, however that elevation is unlikely as the site is used for resale purposes. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

Port of Longview/International Paper - Dredged Material Upland Disposal, Mining/Resale, CRM W-67.5

Size: 29 acres

Elevation: Current surface elevation is +20 feet CRD; surface elevation with total volume in place estimated at +47 feet CRD

Owner: Port of Longview

The International Paper site has been used in the past as an upland sand disposal site for maintenance dredging of the 40-ft channel. The International Paper site is in a heavily industrialized area. Sand placed by this Project will be resold. A weir drainage system for dredged sand is already in place.

The site can accept up to 1,000,000 cy of sand. The Corps plans to place up to 2,900,000 cy of sand over the life of the project, using storage capacity created when sand is sold from the site. When full, the elevation at the top of the sand will be +47 feet CRD. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

Howard Island - Dredged Material Upland Disposal, CRM W-68.7

Size: 200 acres

Elevation: Current surface elevation is +26 feet CRD; surface elevation with total volume in place estimated at +29 feet CRD (at site capacity surface elevation is +51 feet CRD)

Owners: Washington Department of Natural Resources, Dr. Gene Davis, and Delta Trust

Howard Island is an existing disposal site used for maintenance of the 40-ft channel. The disposal site is setback 300 feet of the shoreline, and is outside shoreline jurisdiction, and in an urban environment. Nearly all of the Howard Island property has been covered with dredged sand over the last 40 years. A 200-acre area is planned for use for the construction and maintenance phases of the Project.

Howard Island can hold up to 6,400,000 cy of additional sand. The Corps plans to place 600,000 cy of sand and raising the site elevation to +28 feet CRD. Ultimately, the site could receive 6,400,000 cy of material raising the site elevation to +51 feet CRD. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

Cottonwood Island – Temporary Pipeline and Return Weir for Upland Dredged Material Upland Disposal, CRM W-70.1

Size: 62 acres

Elevation: Current surface elevation is +30 feet CRD; surface elevation with total volume in place estimated at +49 feet CRD

Owners: Washington Department of Natural Resources, Dr. Gene Davis, and Delta Trust

Cottonwood Island has been used in the past as an upland sand disposal site for maintenance dredging of the 40-ft channel. The Disposal Site is set back 300 feet from the Columbia River and is outside shoreline jurisdiction. Only the temporary pipeline used to place sand at, and the return weir used to drain water from, the upland disposal site will be located within the 200-foot shoreline jurisdiction.

Cottonwood Island has been almost completely covered in the past by dredged material. The land surface is +30 feet CRD. Cottonwood Island is undeveloped except for navigational beacons, shoreline protection structures, and a few primitive campsites.

The 62-acre site can hold up to 3,200,000 cy of sand. The Corps plans to place 1,500,000 cy of sand during the construction and maintenance phases of the project. The final site elevation will be +49 feet CRD. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

Northport - Dredged Material Upland Disposal, Resale CRM W-71.9

Size: 27 acres

Elevation: Current surface elevation is +15 feet CRD; surface elevation with total volume in place estimated at +41feet CRD (will vary with resale)

Owner: Port of Kalama

Northport has been used for dredged sand disposal in the past. The Port of Kalama is currently selling sand from this site. Sand placed by this Project will also be resold.

The Corps plans to place 1,900,000 cy of sand at the site. When full, the site elevation will be +41 feet CRD. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

Martin Island Mitigation, CRM W-80.0

Size: 16 acres

Elevation: Current surface elevation is -20 feet CRD; surface elevation with total volume in place estimated at -8 feet CRD (dependent on adjacent tidal marsh elevation)

Owners: Robert and Richard Colf

Martin Island is a mitigation site. Mitigation activities at the Martin Island site consist of two parts: shoreline disposal/partial filling of the embayment to create intertidal marsh habitat, and establishment of riparian forest on the rest of the island. The goal of these mitigation activities on Martin Island is to return the island to a natural condition.

Martin Island's 32-acre embayment was artificially created in 1966 when sand was excavated for use in the construction of nearby Interstate Highway 5. A 16-acre portion of the lagoon will be filled to a surveyed elevation that matches the surveyed elevation for adjacent intertidal marsh in order to create a wetland/intertidal marsh. The Corps will use approximately 460,000 cy of sand, capped with two feet of top soil, to develop intertidal marsh habitat. The balance of the lagoon, 16+ acres, would be left in its current state.

Parts of Martin Island have been used for cattle grazing and crop land. The approximately 85 acres of degraded riparian forest and associated habitat and the approximately 159 aces of agricultural and associated habitat will be reverted to natural riparian forest.

Woodland Bottoms – Mitigation Site, CRM W-81.0

Size: 284 acres

The Woodland Bottoms Mitigation Site (Appendix A, Figure 8) is currently used for agricultural purposes, including row crops, hybrid poplar plantations, and pasture lands. Farmed wetlands (grazed, row crop) exist on the 284-acre wildlife mitigation site (Appendix A, Figure 9). Through mitigation construction activities, 97 acres of wetland habitat and 43 acres of riparian habitat will be developed (Appendix A, Figure 10). A 132-acre portion of the site will be converted to permanent Canada goose forage habitat (Appendix A, Figure 10), similar to that at Ridgefield National Wildlife Refuge.

Construction activities at Woodland Bottoms would include some agricultural tillage. The only grading required would be done in construction of the perimeter levees for the wetland management unit in order to maintain the current level of protection to surrounding lands afforded by the Burris Creek levees (Appendix A, Figure 11). Borrow material for use in constructing the perimeter levees will be obtained by removal of the necessary volume of material from the levees presently encompassing Burris Creek (Appendix A, Figure 11). Removal of the Burris Creek levees will allow for freshets to flood over the wetland management unit thus providing for a natural hydrologic regime.

Martin Bar - Dredged Material Upland Disposal Resale, CRM W-82.0

Size: 32 acres
Elevation: Current surface elevation is +25 feet CRD; surface elevation with total volume in place estimated at +51 feet CRD Owner: Port of Woodland and Washington Department of Fish and Wildlife

Martin Bar has been used in the past as an upland sand disposal site. The site consists of two parcels with a day-use park in between. The site has been configured to avoid the day-use park. A weir system will be constructed to allow draining water to clear before it returns to the river.

The Corps plans to place an additional 760,000 cy of sand on the two parcels, raising the elevation to +51 feet CRD. The Port of Woodland may, at its discretion, use or sell sand from this site. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

Austin Point - Dredged Material Upland Disposal, Mining/Resale, CRM W-86.5

Size: 26 acres
Elevation: Current surface elevation is +15 feet CRD; surface elevation with total volume in place estimated at +64 feet CRD (without resale)

Owner: Port of Woodland

Austin Point has been used in the past as an upland sand disposal site. Most of the surface is covered with sand. The Port of Woodland owns the site and has been mining the sand for its own use or resale since the Corps discontinued using the site.

The 26-acre site will hold up 1,645,000 cy of sand. The Corps plans to place 1,700,000 cy over a twenty year period including the construction and maintenance phases of the project. The Port of Woodland will continue to remove sand from the site between disposal events, making room for additional sand. When full, the top of the sand will reach +64 feet CRD if no resale occurs.

Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

4.5.3 Permitted Shoreline Uses. The principal CSMP regulatory use standards that apply to the Project are those governing dredging and dredged material disposal.

Dredging
The CSMP defines dredging as the removal of earth from the bottom of a stream, river, lake, bay, or other water body for the purposes of deepening a navigational channel or to obtain use of the bottom materials for landfill. (CSMP, p. 18).

Landfill
The CSMP defines landfill as the creation of dry upland area by the filling or depositing of sand, soil, or gravel into a wetland area. (CSMP, p. 18).

The following activities, although not part of the Project, may be conducted by disposal site owners/operators:

Mining
The CSMP defines mining as the removal of naturally occurring materials from the earth for economic use. (CSMP, p. 10). The sand disposed of as part of the Project is not naturally occurring at the disposal sites and may not constitute mining under the CSMP definitions. This analysis reviews resale for consistency with the mining standards. Mining is a permitted use in urban environments.

Ports and Water-Related Industries
The CSMP defines Ports and water-related industries as centers for water-borne traffic and, as such, it recognizes that Ports are centers for industrial/manufacturing firms.

Commercial (Sand Resale) Development
The CSMP defined commercial uses as those uses which are involved in wholesale and retail trade or business activities.

4.5.4 Format. The CSMP is organized into the following areas: general criteria for substantial development, specific regulatory standards for shoreline uses and activities, general policies and objectives for shoreline uses and activities, element goals and objectives. The analysis below, therefore, follows that same basic structure:

- **Substantial Development Conditions**
- **Master Program Regulatory Standards for Uses and Activities**
  - Dredging
  - Landfill
  - Mining
  - Ports and Water-Related Industries
  - Commercial Development

- **Master Program Policy Objectives for Uses and Activities**
  - Dredging
  - Landfill
  - Mining
  - Ports and Water-Related Industries
  - Commercial Development
- **Master Program Shoreline Environments and Objectives**
  - Urban
  - Rural
  - Conservancy
- **Master Program Element Goals and Objectives**
  - Circulation
  - Conservation
  - Economic Development
  - Public Access
  - Other Shoreline Uses

4.5.5 Consistency Analysis – Findings. The Project is not only consistent and in general conformance with the CSMP, it promotes several key goals and policies regarding navigation and economic development.

4.5.5.1 Substantial Development Conditions. The Project will comply with the general construction practices for substantial development that are set forth on page 27 of the CSMP.

4.5.5.2 Dredging. The Project is consistent with the CSMP's regulatory use standards and general policy objectives for dredging.

4.5.5.2.1 Regulatory Use Standards for Dredging. The Project meets the specific regulations for dredging (CSMP p. 44-45):

1. *Dredging and landfills are prohibited on conservancy shorelines, except where they do not substantially change the character of that district along navigable waters deemed necessary for adequate navigation as determined by U.S. Army Corps of Engineers, and where they are necessary accessory to a project which is dependent on a location near or adjacent to a body of water. Dredging and landfills are permitted on rural, and natural shorelines subject to the regulations below, if they do not substantially change the character of the environment or are accessory to a project which is dependent on a location near a body of water.*

A principal purpose of this Project is to deepen the navigation channel of the Columbia River to enhance navigational access. The navigation channel that is the subject of this project has been authorized by Congress to provide adequate navigation on the Columbia River. Marine shipping and navigational improvements are permitted water-dependent public uses of the shoreline. Dredging and disposal of dredged sediments are necessary to maintaining these permitted water-dependent public uses of the shoreline. Disposal of dredge materials for proposed mitigation sites is for a project (channel deepening) that is water dependent.

Dredging and flowlane disposal will be restricted to the navigation channel and the adjacent area, which will preserve the existing character of the existing shoreline environment. Using existing upland disposal sites also helps to preserve the existing character of the shorelines.

2. *All dredging or spoils disposal shall confirm to the following:*
a. *Dredging shall conform to the operating standards specified on any required federal and state permits.*

The Project will comply with applicable state and federal permits or approvals.

b. *Dredge spoils exceeding the Department of Ecology criteria for toxic sediments shall be disposed of on land.*

Sediment quality has been evaluated for dredged materials from the navigation channel. Sediment samples were collected and subjected to physical and chemical analyses. These studies indicate that material to be dredged in the Columbia River navigation channel is suitable for unconfined open water disposal.

c. *Dredge disposal sites shall be completely enclosed by dikes to allow sediment to settle before water leaves the diked area.*

Upland disposal sites, like Hump Island, Reynolds Aluminum, International Paper, Howard Island, Cottonwood Island, Northport, Martin Bar and Austin Point are designed with earthen dikes to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle. Sand is placed with a temporary pipeline extending from the dredge vessel, which is removed from the site after sand placement. Sand moves through the pipeline in the form of a slurry mixed with Columbia River water and the water is allowed to settle and clear through the retention system before it runs back into the river. Weirs are used to regulate the return of water to the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance. Once the water is drained, the sand is "drifted" or spread evenly around the holding area.

d. *Dikes shall be sloped at 1-1/2 to 1 or flatter and seeded with grass or otherwise protected to prevent erosion. Outlets shall be placed so that water will take the longest time to reach the outlet and so that only the clearest water is allowed to return to the receiving waters.*

Weirs are used as needed to regulate the return of water to the river. Water from the upland disposal sites will be allowed to settle and clear through the retention pond drainage system before it runs back into the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance. After they are no longer used for dredged material disposal, these sites will be regraded at the required slope and seeded to prevent erosion.

4.5.5.2.2 Policy Objectives for Dredging. The Project is also consistent with the CSMP policy objectives for dredging (CSMP, p. 18):

a. *Dredging shall minimize damage to existing ecological values and natural resources of the area to be dredged and the area for deposit of dredged materials.*

Dredging will be done at depths of more than 40 feet, beyond the depths at which salmonids generally migrate. The hopper and pipeline dredges that will be used generally do not produce large amounts of turbidity because of the suction action of the dredge pump and the burial of the drag arm or cutter head in the sediment. Turbidity produced by mechanical dredging will be reduced by using a closing bucket.

Flowlane disposal generally will also be in depths ranging from 50 to 65 feet. Most benthic invertebrates that serve as a food source for fish are found at depths of less than 20 feet. Therefore, restricting the disposal of dredged materials to depths greater than 20 feet will minimize potential impacts from this activity. While it has been established that white sturgeon are present in potential flowlane disposal areas, the Corps is conducting studies to help avoid and minimize impacts to sturgeon.

Upland disposal sites in Cowlitz County have been previously used and were selected to avoid impacts to new areas and their resources.

Upland disposal proposed in Cowlitz County has been the subject of a consultation under the Endangered Species Act to address potential impacts to ESA listed species and their critical habitat. Measures are included to minimize the potential for impact from this activity, such as maintaining minimum buffer widths between disposal sites and the river, avoiding the riparian edge along the shoreline, whenever possible, and avoiding wetlands.

b. *Deposit sites in water areas shall be identified by local government in cooperation with the state departments of natural resources, game, and fisheries. Depositing of dredge material in water areas shall be allowed only for habitat improvement, to correct problems of material distribution adversely affecting fish and shellfish resources, or where the alternatives of depositing material on land is more detrimental to shoreline resources.*

As in the case with the current flow lane disposal for maintenance dredging, flowlane disposal for the Project will be restricted to the navigation channel and the adjacent area. The only other in-water disposal proposed in Cowlitz County is for mitigation at Martin Island. The purpose of this mitigation is for habitat improvement.

c. *Dredging of bottom materials for the single purpose of extending ones property shall be discouraged.*

N/A. Project dredging is not for the purpose of extending property. It serves the purpose of enhancing the navigation channel.

d. *Navigation channels, turning and moorage basins shall be identified. Future channel and basin areas which would be used in conjunction with potential future ports and marinas should be identified as non-deposit areas for spoils from other dredging operations.*

N/A. Dredging and flowlane disposal for the Project will be limited to the navigation channel and adjacent areas.

4.5.5.3 Landfill. The Project is consistent with the CSMP's regulatory use standards and general policy objectives for landfill. The purpose of upland disposal for this Project is not to create dry upland areas, as dredged materials are being placed on areas that are already dry upland. Therefore, upland disposal does not meet the definition of landfill under the CSMP. Cowlitz County and WDOE, as a matter of practice, broadly interpret the definition to cover placement of dredged materials at upland disposal sites. As discussed below, however, even if the fills were considered to be landfill, they meet the requirements for such activities. Some fill activities will occur in the Martin Island Embayment and Woodland Bottoms Mitigation features. These fills are consistent with the SMP.

4.5.5.3.1 Regulatory Use Standards for Landfill. *See* Section 4.5.6.2.1 above.

4.5.5.3.2 Policy Objectives for Landfill. Although the disposal sites do not meet the definition of a landfill, the Project is also consistent with the CSMP policy objectives for landfill (CSMP, p. 18):

1. *Landfill*

a. Shoreline fills or cuts shall be designed and located so that significant damage to existing ecological values or natural resources, or alteration of local currents will not occur, creating a hazard to adjacent life, property, natural resources systems, and aesthetics.

All of the upland disposal sites in Cowlitz County have been used for past dredged material disposal. Continued use of these sites minimizes damage to existing ecological values and natural resources. Fills at Woodland Bottoms and Martin Island are intended to enhance habitat functions and values. Significant damage to existing ecological values is not anticipated.

b. All perimeters of fills shall be provided with vegetation, retaining walls, or other mechanisms for erosion prevention.

Upland disposal sites, like Hump Island, the Reynolds Aluminum and International Paper sites, Howard Island, Cottonwood Island, Northport, Martin Bar and Austin Point, are or will be surrounded by dikes as needed to avoid and prevent erosion.

Fill at Woodlands Bottom will be designed to prevent erosion. The goal at the Martin Island Embayment is to create intertidal marsh which will be vegetated.

c. Fill materials shall be of such quality that it will not cause problems of state water quality standards established by the Department of Ecology. Shoreline areas are not to be considered for sanitary landfills or the disposal of solid waste.

Sediment evaluations of potential maintenance dredging material conducted since the 1970s have consistently found the material to be suitable for unconfined in-water disposal. Water returned to the river from upland disposal sites through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance.

d. Priority shall be given to landfills for water-dependent uses and for public uses.

A principal purpose of this Project is to deepen the navigation channel of the Columbia River to enhance navigational access. Marine shipping and navigational improvements are permitted water-dependent public uses of the shoreline. Dredging and disposal of dredged sediments and fill for mitigation features are necessary to maintaining these water-dependent public uses of the shoreline.

e. In evaluating fill projects and in designating areas appropriate for fill, such factors as total water surface reduction, navigation restriction, impediment to water flow and circulation, reduction of water quality, and destruction of habitat shall be considered.

Upland disposal should have no impact on water surface, navigation, water flow or circulation different than the current disposal.

Upland disposal sites are designed to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle. Sand will be placed in upland disposal sites with a temporary pipeline extending from the dredge vessel. The pipeline will be removed from the sites after sand placement. Sand moves through the pipeline in the form of a slurry mixed with Columbia River water. Water is allowed to settle and clear through the drainage system before it runs back into the river. Water returned to the river from upland disposal sites through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance.

Fill associated with mitigation and Woodland Bottoms and Martin Island are not anticipated to restrict navigation, impede water flow and circulation or reduce water quality. This mitigation should enhance habitat functions and values.

f. All landfill materials and erosion control methods shall be subject to approval of the program administrator or his designee.
The program administrator will review Project materials, specifications and the proposed erosion control methods.

4.5.5.4 Mining. As discussed in Section 4.4.4, sand removal for resale involves restoring materials that do not naturally occur at the disposal sites and does not appear to meet the definition of mining. In practice, Cowlitz County and WDOE interpret the code provision to include sand removal for resale. Resale activities are not part of the Project, but are expected to be conducted by disposal site owners or operators. As discussed below, such resale is consistent with the CSMP's regulatory use standards and general policy objectives for mining.

4.5.5.4.1 Regulatory Use Standards for Mining. The Project meets the specific regulations for mining (CSMP p. 47):

1. *Mining that does not substantially change the character of the environment shall be permitted.*

Removal for resale of sand deposited will occur at some upland disposal sites. Reuse of upland disposal/mining sites, like the Reynolds Aluminum site, Northport, and Austin Point, helps to preserve the existing character of the shorelines.

2. *Any person proposing to undertake or engage in a mining operation shall apply for a permit.*

Site operators/owners will obtain all applicable permits.

3. *A permit for mining operation may be granted subject to the following regulations:*

a. *Operators of surface mines subject to the 1970 Surface Mine Land Reclamation Act shall present to the County a surface mining plan and a reclamation plan.*

The sand resale sites are not surface mines subject to the 1970 Surface Mine Land Reclamation Act.

b. *A surface mining plan or a reclamation plan judged by the County to be insufficient for the protection or restoration of the shoreline environment shall be grounds for denial of a permit.*

N/A. This provision applies to surface mines subject to the 1970 Surface Mine Land Reclamation Act. The sand resale sites are not such sites.

c. *Any gravel removal alongside, upstream or downstream from spawning areas shall be in conformance with the technical provisions of the hydraulics project approval by WDFW.*

The removal of gravel from the resale sites is not occurring upstream or downstream from spawning areas. The removal is occurring behind dikes which will prevent any impact on the river.

d. *Mining operations shall be strictly controlled or prohibited where historical, cultural, educational, or scientific value will be degraded.*

No mining is proposed in areas with historical, cultural, educational, or scientific value.

4.5.5.4.2 Policy Objectives for Mining. As noted above, WDOE and Cowlitz County broadly interpret the term "mining" to include resale. Although sand resale is not part of the Project, resale activities are also consistent with the CSMP policy objectives for mining (CSMP, p. 10):

a. *When rock, sand, gravel, and minerals are removed, adequate protection against sediment and silt production should be provided.*

Removal of sand from the mining/resale sites will occur behind dikes that will prevent sediment or silt from reaching the river.

b. *Excavations for the production of sand, gravel, and minerals should be done in conformance with the Washington State surface mining Act, and from the least sensitive biophysical areas.*
Project dredging is not for the purpose of production and sale of sand, it serves the purpose of enhancing navigational access. Dredging, therefore, will be limited to the navigation channel. However, the resale sites will comply with all applicable regulations.

c. *Since mining developments may have lasting effect on the visual quality of the shorelines, prudent judgment should be exercised in permitting areas to be developed for this particular use.*

Removal of sand from upland disposal resale sites, like the Reynolds Aluminum site, Northport, and Austin Point will not affect the visual quality of the shorelines as would occur from removing materials from their original location.

d. *Removal of rock, sand, gravel, and minerals shall be strictly controlled or prohibited where the scenic and aesthetic qualities of the shorelines will be degraded and in areas having historical, geological, cultural, educational, and/or scientific values.*

No resale is proposed in areas with historical, cultural, educational, or scientific value. Use of upland disposal, like the International Paper, Reynolds Aluminum, Northport, and Austin Point sites helps to preserve the aesthetic qualities of the shorelines.

4.5.5.5 Commercial Development. The Project does not include commercial development. However, disposal site operations may conduct resale activities.

4.5.5.5.1 Regulatory Use Standards for Commercial Development. Resale activities are consistent with the CSMP policy objectives for commercial development in urban environments (CSMP, p. 32):

1. *Because shorelines suitable for urban uses are a limited resource, emphasis should be given to development within already developed areas and particularly on water-dependent industrial and commercial uses requiring frontage on navigable waters.*

All of the upland disposal/resale sites in Cowlitz County are being used or, have been previously used. Disposal of dredged material is necessary to maintaining marine shipping and navigational improvements are permitted water-dependent public uses of the shoreline.

2. *A permit for commercial development may be granted subject to the following regulations:*

a. *Commercial buildings of more than 35 feet above average ground grade shall be allowed as a conditional use.*

N/A. The Project does not include any commercial buildings.

b. *Any commercial structure or facility except on which requires or is dependent on direct, contiguous access to the water shall be set back from the ordinary high water mark by a minimum of ten feet, as measured on a horizontal plane.*

N/A. Resale sites do not require structures or facilities.

c. *Parking facilities shall not be located within ten (10) feet of the ordinary high water mark, as measured on a horizontal plane.*

N/A. The Project does not include any parking facilities.

4.5.5.5.2 Policy Objectives for Commercial Development. The resale activities are consistent with the applicable policy objectives for commercial development (CSMP, p. 6-7):

a. *Although many commercial developments benefit by a shoreline location, priority should be given to those commercial developments, which are particularly dependent on their location and/or use of the shorelines.*

Disposal of dredged material is necessary to maintaining marine shipping and navigational improvements are permitted water-dependent public uses of the shoreline.

b. *New commercial developments on shorelines should be encouraged to locate in those areas where current commercial uses exist.*

Upland disposal/resale sites in Cowlitz County, Northport, and Austin Point, are existing reuse sites.

c. *An assessment should be made of the effect a commercial structure will have on a scenic view significant to a given area or enjoyed by a significant number of people.*

N/A. The resale sites do not require a commercial structure.

d. *Commercial developments must be aesthetically compatible with the site or so buffeted as to lessen the visual impact of such development.*

Reuse of sand has occurred at these sites in the past.

4.5.5.6 Ports and Water-Related Industry. The Project is consistent with the CSMP's the specific regulations for Ports and water-related industry.

4.5.5.6.1 Regulatory Use Standards for Ports and Water-Related Industry. The Project is consistent with the CSMP policy objectives for Ports and water-related industry in urban environments (CSMP, p. 49-50):

1. Ports and Water-Related Industry:

2. Any person proposing a development which constitutes a Port facility or water-related industry shall apply for a permit.

The Project will obtain all applicable permits or approvals.

3. Permits may be granted upon:

a. Demonstration of compliance with the regulations specified on any federal and state permits required for such facilities and operations.

The Project will comply with the conditions of all applicable state and federal permits or approvals.

b. Compliance with other applicable use regulations in the SMP.

The Project will comply with applicable regulations as discussed in this memorandum.

4.5.5.6.2 Policy Objectives for Ports and Water-Related Industry. The Project is also consistent with the applicable policy objectives for Ports and water-related industry (CSMP, p. 7-8):

h. *Ports and water-related industries are encouraged to locate in urban environments, but in exceptional cases may locate under natural, conservancy, and rural environments, subject to conditional use and specific performance standards.*

All of the upland disposal sites and resale sites, except Hump Island, are located in urban environments. Although Hump Island is located in a rural environment, it has previously been used as a disposal site and is already covered with sand from maintenance dredging of the 40-foot channel.

4.5.6.7. General Policy Objectives for Shoreline Elements. The Project is consistent with the applicable CSMP general policies objectives for applicable shoreline elements.
Circulation: When necessary to develop facilities for any of the various modes of travel on the shorelines of Cowlitz County, these features must not endanger the life, property, or rights of others, nor debilitate the quality of life enjoyed by the public.

It is not clear that upland disposal sites are "facilities" under this Section. However, the Project meets this standard. The existing sites do not endanger life, property, or rights of others.

1. *Ensure that the site selected is suitable for the proposed use.*

Dredging and flowlane disposal for the project, as is the case for current maintenance activities, will be restricted to the navigation channel and the adjacent area. The Project uses upland dredged material disposal. The Project also uses locations in the urban environment for resale sites.

2. *Introduce development to the areas with a minimal adverse effect upon the natural features, scenic quality, and ecosystems existing in the shorelines.*

No new development is being introduced to the Cowlitz County shoreline. The Project's dredging and disposal activities are occurring in areas where such activities have occurred on a routine basis.

3. *The use should fulfill a need which can only be satisfied by such use on the shorelines as opposed to an upland use.*

A principal purpose of this Project is to deepen the navigation channel of the Columbia River to enhance navigational access. Marine shipping and navigational improvements are permitted water-dependent public uses of the shoreline. Dredging and disposal of dredged sediments are necessary to maintain these water-dependent public uses of the shoreline.

4. *New development should protect the life, property, and rights of others, and sustain or improve the quality of lift existing in the area.*

See Discussion of Circulation Goal above.

Conservation: To encourage the best management practices for the continued sustained yield or replenishable resources of the shorelines and preserve, protect, and restore those unique and non-renewable resources.

The Project incorporates the following BMPs, among others, to protect shoreline resources during dredging:

- During hopper and pipeline dredging, maintain dragheads in the substrate or no more than 3 feet above the bottom with the dredge pumps running.
- The contractor shall not release any trash, garbage, oil, grease, chemicals, or other contaminants into the waterway. The Project also incorporates the following BMPs, among others, to protect shoreline resources during dredged material disposal:
- For flowlane disposal, dispose of material in a manner that prevents mounding of the disposal material.
- Maintain discharge pipe of pipeline dredge at or below 20 feet of water depth during flowlane disposal.
- Berm upland disposal sites to maximize the settling of fines in the runoff water.
- Grade shoreline disposal sites to a slope of 10 to 15 percent, with no swales, to reduce the possibility of stranding of juvenile salmonids.

1. *Preserve the scenic and aesthetic qualities of shorelines and vistas.*

Existing upland disposal sites are used in Cowlitz County to minimize aesthetic impacts.

2. *Contribute to a maximum utilization of the resources without harming other natural systems or the quality of life.*

By deepening the Columbia River channel in selected locations, the Project will improve the utility of the navigation channel. At the same time, by incorporating ecosystem restoration components, the Project will further enhance the natural systems.

3. *Restore damaged features or ecosystems to a higher quality than may currently exist.*

The Project incorporates a number of ecosystem restoration actions.

4. *Preserve unique and non-renewable resources.* Restricting dredging and flowlane disposal to depths of more than 40 feet will minimize potential impacts from these activities on threatened and endangered species and their critical habitat.

5. *Consider the total upstream, and downstream effect of proposed developments to ensure that no degradation will occur on the shoreline.*

This report includes shoreline consistency analyses for each jurisdiction in which Project activities will take place to consider the total upstream and downstream effects of the proposal.

Economic Development: To encourage the establishment and development of industrial and commercial activities in Cowlitz County on shorelines that require the land-water interface for productive efforts.

The Columbia River navigation channel serves the national and regional economy, including shippers located in Cowlitz County. The lower Columbia River is the second largest grain-shipping waterway in the world, surpassed only by the Mississippi River. Regional growers, producers, and manufacturers use Columbia River ports to transport their goods to world markets. These shippers realize lower shipping costs by using Columbia River ports as opposed to more distant alternative ports. Marine shipping is an important industry in the lower Columbia River region. Approximately 40,000 jobs depend on Columbia River port activity, at $46,000 per year per employee on average. Columbia River port activity also generates $2 billion in business revenues and more than $200 million in state and local taxes each year.

1. *Those economic developments proposed on the shorelines must effectively operate without reducing the environmental quality of the surrounding shoreline area, or the quality of life of County residents.*

By deepening the navigation channel by three feet in selected locations, the Project will improve the utility of the navigation channel. At the same time, by incorporating ecosystem restoration components, the Project will further enhance quality of life and preserve resources in the surrounding and adjacent areas.

Public Access: To assure the safe and reasonable access for the public to public property in the shorelines of Cowlitz County.

1. *To retain existing public access and develop additional access where such will not endanger life or property nor interfere with the rights inherent with private property.*

A number of boaters use the Martin Island Embayment for mooring. This embayment is currently private property. Developing 16 acres of the embayment for intertidal marsh habitat to improve its natural functions may limit the use of this private land for boating. However, the balance of the embayment (16+ acres) would be left in its current state. The restoration proposed for this area is an important activity under the Shoreline Management Act and other laws such as the Endangered Species Act. Coordination with Cowlitz County has occurred to modify the initial proposal from a 32 acre mitigation development to the proposed 16 acre mitigation development in order to maintain boater access associated with the current use of the Martin Island embayment.

2. *Such access should not have an adverse effect on unique or fragile natural features, nor alter ecological systems of the area.*

Other Shoreline Uses: *Development within the shorelines of Cowlitz County must be for the betterment of the lifestyle of the citizens of Cowlitz County, and so located as to prevent ecological debilitation.*

By deepening the channel by three feet in selected locations, the Project will ensure that the navigation channel and continues to support marine shipping, a vital section of the regional economy for Cowlitz County citizens.

1. *To encourage those uses which are necessary to maintain or improve the health, safety, and welfare of the citizens when such uses must occupy shorelines.*

By deepening the channel in selected locations, the Project will improve the utility of the navigation channel.

2. *To locate those necessary uses and design facilities on the shorelines in such a manner as to retain or improve the physical and aesthetic quality of the natural environment.*

Existing upland disposal sites are used.

3. *To encourage multiplicities of use in proposed shoreline area developments.*

The Project will facilitate marine shipping and maximize public use of the navigation channel. The Project will also enhance passive recreational opportunities for studying and viewing wildlife on the shorelines.

4. *To retain or improve the degree of public access to shorelines.*

By deepening the channel, the Project will facilitate marine shipping and public use of the navigation channel.

4.5.6. Conditional Use Criteria. See the discussion in Section 4.1.3.

4.6 City of Longview

The City of Longview is not located in Washington's Coastal Zone. Therefore, review of the applicable SMP provisions is presented here for purposes of showing general consistency with local plans, rather than for purposes of demonstrating consistency with the Coastal Zone Management Act. The Mt. Solo disposal site is located outside the shoreline area. Dredging and flowlane disposal are well-established uses in the channel near the City of Longview.

4.6.1 References. The City of Longview uses Cowlitz County's SMP. Therefore, this section frequently references the analysis for Cowlitz County presented in the preceding section. References to the Cowlitz County Shoreline Master Program (revised 1974) ("CSMP") are given by page number.

4.6.2 Proposed Shoreline Uses. The Project, includes the following activities which may occur all or in part within the City of Longview's 200-foot shoreline jurisdiction:

Columbia River – 43-ft. Channel Improvement Construction and Maintenance Dredging
The Columbia River navigation channel will be dredged in selected locations within the City of Longview's shoreline jurisdiction. This dredging will typically occur in locations dredged for maintenance of the channel. Dredging will deepen the existing 40-foot-deep channel to the newly authorized depth of 43 feet

Columbia River – Dredged Material Flowlane Disposals
Flowlane disposal will be done in areas similar to those for maintenance dredging with the City of Longview's shoreline jurisdiction. Flowlane disposal will occur where depths range from 35 to 65 feet, but are typically greater than 50 feet.

Mt. Solo - Temporary Pipeline and Weir for Upland Dredged Material Disposal Site, CRM W-62.0

Size: 47 acres
Elevation: Current surface elevation is +8 feet CRD; surface elevation with total volume in place estimated at +49 feet CRD Owner: Radakovich family

Mt. Solo is a new upland disposal site located more than 300 feet beyond the ordinary high water mark. Because this disposal site is outside the shoreline it is not subject to the CSMP. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

The site is nearly level at +8 feet CRD. The site can hold up to 2,500,000 cy of dredged sand. The Corps plans to place 2,400, 000 cy of sand over a 20-yr period including the construction and maintenance dredging phases of the project, raising the site's elevation to +49 feet CRD.

4.6.3. Permitted Shoreline Uses. The principal CSMP regulatory use standards that apply to the Project elements that will occur in the City of Longview are those governing dredging

Dredging
The CSMP defines dredging as the removal of earth from the bottom of a stream, river, lake, bay, or other water body for the purposes of deepening a navigational channel or to obtain use of the bottom materials for landfill. (CSMP, p.18)

4.6.4. Format. The CSMP is organized into the following areas: general criteria for substantial development, specific regulatory standards for shoreline uses and activities, general policies and objectives for shoreline uses and activities, shoreline environment objectives, element goals and objectives, and conditional use permitting criteria. The analysis below, therefore, follows that same basic structure:

- **Substantial Development Conditions**
- **Master Program Regulatory Standards for Uses and Activities**
  Dredging
- **Master Program Policy Objectives for Uses and Activities**
  Dredging
- **Master Program Shoreline Environments and Objectives**
  Urban
  Rural
  Conservancy
  Natural
- **Master Program Element Goals and Objectives**
  Circulation
  Conservation
  Economic Development
  Public Access
  Other Shoreline Uses

4.6.5. Consistency Analysis – Findings. The Project is not only consistent and in general conformance with the CSMP, it actually promotes several key goals and policies regarding navigation and economic development.

4.6.6.1 Substantial Development Criteria. The Project will comply with the general construction practices for substantial development that are set forth on page 27 of the CSMP.

4.6.6.2 Dredging. The Project is consistent with the regulatory use standards and general policy objectives for dredging. *See* discussion in Section 4.6.5.6.2 above.

4.6.6.3. General Policy Objectives for Shoreline Environments. The Project is consistent with the CSMP's general policy objectives for the shoreline environments in which Project elements will be located. *See* Section 4.5.6.7 above.

4.6.6.4. General Policy Objectives for Shoreline Elements. The Project is consistent with the applicable CSMP's general policy objectives for shoreline elements. *See* Section 4.5.6.8 above.

4.6.6.5. Conditional Use Criteria. See the discussion in Section 4.1.3.

4.7 City of Vancouver

The City of Vancouver is not located in Washington's Coastal Zone. Therefore, review of Vancouver's SMP is presented here for purposes of showing general consistency with local plans, rather than for purposes of demonstrating consistency with the Coastal Zone Management Act.

4.7.1 References. The City of Vancouver's shoreline regulations and policies are both found in its SMP. References to the City of Vancouver Shoreline Management Master Program (revised 1997) ("VSMMP") are given by page number.

4.7.2 Proposed Shoreline Uses. The Project, includes the following activities which may occur all or in part within the City of Vancouver's shoreline jurisdiction:

Columbia River – 43-ft. Channel Improvement Construction and Maintenance Dredging

The Columbia River will be dredged in selected areas adjacent to the City of Vancouver. Dredging will deepen the existing 40-foot-deep channel to the newly authorized depth of 43 feet.

Columbia River – Dredged Material Flowlane Disposal

Flowlane disposal may be done in selected areas adjacent to the City of Vancouver. Flowlane disposal will occur where depths range from 35 to 65 feet, but are typically greater than 50 feet.

Gateway 3 - Upland Dredged Material Disposal Site, CRM W-101.0

Size: 40 acres
Elevation: Current surface elevation is +21 feet CRD; surface elevation with total volume in place estimated at +65 feet CRD

Owner: Port of Vancouver

Gateway 3 is a new upland disposal site within the City's shoreline. A temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river.

Gateway 3 refers to Parcel 3 of the Port of Vancouver's Gateway property. The land is currently used for agricultural purposes. The Corps proposes to dispose of dredged sand on a portion of this parcel over a 20-yr period, during both the construction and maintenance phases of the project. The strip of riparian vegetation along the river will be avoided. The drainage weir is designed to cross at the most sparsely vegetated point, near the southernmost corner of the site.

The site is relatively level with an average elevation of +21 feet CRD. The disposal site has a capacity of 2,300,000 cy of dredged material. The Corps plans to place 2,300,000 cy of sand over a 20-year period including the construction and 20-year maintenance dredging phases of the project raising the site's elevation to +65 feet CRD. Within the 200-foot shoreland environment, only a temporary pipeline will be used for placement of dredged materials at the site, and a return weir will be constructed for water drainage from the site back to the river, if it does not already exist.

4.7.3 Permitted Shoreline Uses. The principal VSMMP regulatory use standards that apply to the Project are those governing: dredging, dredged material disposal, mining/mineral extraction, and commercial (sand resale) activities.

Dredging and Dredged Material Disposal. The VSMMP defines dredging as the removal or displacement of earth or sediments such as gravel, sand, mud or silt and/or other materials or debris from any stream, river, lake or marine water body and associated shorelines and wetlands. Under the VSMMP, landfill is defined as the placement of soil, sand, rock, gravel, or existing sediment or other material to create new land, tideland or bottom land area waterward of the OHWM, or in upland areas to raise elevations. The purpose of flowlane disposal is not to create new bottomland area. Therefore, flowlane disposal does not appear to meet the definition of a landfill; however, the use is analyzed for consistency with this provision.

4.7.4 Format. The VSMMP is organized into the following areas: general conditions for substantial development permits, specific regulatory standards for shoreline uses and activities, general policies and objectives for shoreline uses and activities, shoreline environment objectives, and element goals and objectives.

- **Substantial Development Permit Conditions**
- **Master Program Regulatory Standards for Uses and Activities**
  - Dredging and Dredged Material Disposal
  - Landfill
- **Master Program Policy Objectives for Uses and Activities**
  - Dredging and Dredged Material Disposal
  - Landfill
- **Master Program General Policies**
- **Master Program Shoreline Environments and Objectives**
  - Aquatic Environment
  - Upland Environment, Urban High-Density
- **Master Program Element Goals and Objectives**
  - Circulation
  - Conservation

Economic Development

4.7.5 Consistency Analysis – Findings. The Project is not only consistent and in general conformance with the VSMMP, it actually promotes several key goals and policies regarding navigation and economic development.

4.7.6.1 Substantial Development Permit Conditions. The Project will comply with all applicable general permit conditions and best management practices ("BMPs") identified.

4.7.6.2 Dredging. The Project is consistent with the VSMMP's regulatory use standards and general policy objectives for dredging. (VSMMP, p. 5-12 to 5-14).

77. *Policy: Dredging operations should be planned and conducted to minimize interference with navigation and adverse impacts to other shorelines uses, properties and values. Long-range regional plans should be developed for the disposal and use of dredged material on land, particularly in areas where maintenance of navigation channels is routine and continuous. When dredge material has suitable organic and physical properties, dredging operations should be encouraged to recycle dredged material for beneficial use in beach enhancement, habitat creation, aggregate or clean cover material at a landfill.*

As discussed in Section 4.1.2, a principal purpose of Project dredging is to enhance navigation and navigational access. The other purpose of the Project is ecosystem restoration. Dredging is occurring in locations where dredging has historically occurred, although at deeper depths in selected areas. Most of the dredged materials that are removed during construction will be sand, with a low percent organic content. Sediment evaluations of potential maintenance dredging material conducted since the 1970s have consistently found this material to be suitable for unconfined in-water disposal.

231. Regulation: *In evaluating permit applications for any dredging project, the adverse effects of the initial dredging, subsequent maintenance dredging and dredge disposal that will be necessary shall be considered. Dredging and dredge disposal shall be permitted only where it is demonstrated that the proposed actions will not result in significant or ongoing adverse impacts to water quality, fish and wildlife habitat, flood holding capacity, natural drainage and water circulation patterns, significant plant communities, prime agricultural land, and public access to shorelines. When such impacts are unavoidable, they shall be minimized and otherwise mitigated.*

Dredging will occur in locations that have been subject to dredging on a routine basis. The dredging to attain the new depth will occur deeper than 40 feet, beyond the depths at which salmonids generally migrate. The hopper and pipeline dredges that will be used generally do not produce large amounts of turbidity because of the suction action of the dredge pump and the burial of the drag arm or cutter head in the sediment. Turbidity produced by mechanical dredging will be reduced by using a closing bucket.

Flowlane disposal generally will also be in depths ranging from 50 to 65 feet. Most benthic invertebrates that serve as a food source for fish are found at depths of less than 20 feet.

Therefore, restricting the disposal of dredged materials to depths greater than 20 feet will minimize potential impacts from this activity. While it has been established that white sturgeon are present in the three potential flowlane disposal areas, the Corps is conducting studies to help avoid and minimize impacts to sturgeon.

Upland disposal along the Columbia River channel has been reviewed by the NOAA Fisheries and USFWS to address impacts, if any to ESA listed fish species or proposed critical habitat. The Gateway site is the only upland disposal site in the City of Vancouver. It has been located 300 feet beyond the ordinary high water to avoid impacts to shoreline resources. The site has been reduced in size since the 1999 Final IFR/EIS to further reduce impacts to riparian habitat. Impacts and proposed mitigation are discussed in detail in K-5, Wildlife and Wetland Mitigation (Revised) and K-8, Consistency with Critical Areas Ordinances Including Wetland Mitigation (Revised) of the Final SEIS. This exhibit demonstrates that proposed mitigation exceeds that required under local critical areas ordinances.

232. Regulation: *Only the minimum amount of dredging necessary shall be permitted. Dredging techniques that cause minimum dispersal and broadcast of bottom material shall be used.*

Construction and maintenance dredging will only remove the material necessary for the authorized 43-foot navigation channel.

233. Regulation: *Dredging waterward of the OHWM shall be permitted only:*

a. for navigation or navigational access;

b. in conjunction with a water-dependent use of water bodies or adjacent shorelands;

c. as part of an approved habitat improvement project;

d. to improve water flow or water quality, provided that all dredged material shall be contained and managed so as to prevent it from reentering the water;

e. in conjunction with a bridge, navigational structure or waste water treatment facility for which there is a documented public need and where other feasible sites or routes do not exist. to acquire only from within the Columbia River sand and gravel for commercial purposes.

The dredging for the Project is for navigation and navigation access.

234. Regulation: *Dredged material shall be disposed of on land only at contained sites approved by the USACOE and the City of Vancouver. Disposal shall be limited to the smallest possible land area, unless dispersed disposal is authorized as a condition of permit approval for soil enhancement or other purposes. Dredged material may be used for beach creation, expansion, restoration, or enhancement projects, PROVIDED the policies and regulations of this Master Program pertaining to such activities are fulfilled.*

The Gateway 3 site has been selected by the USACOE. It is anticipated that the City will review its use.

235. <u>Regulation</u>: *The following conditions shall apply to land disposal sites:*

a. Containment dikes and adequate settling basins shall be built and maintained so that the water discharged from the site carries a minimum of suspended sediment. Required basins shall be designed to maintain at least one foot of standing water at all times to encourage proper settling;

b. Proper diversion of surface discharge shall be provided to maintain the integrity of the natural streams, wetlands, and drainage ways;

c. There shall be a single point of ingress and egress for removal of the de-watered material;

d. Runoff shall be directed through grassy swales or other treatment features to a location that maximizes circulation and fishing; and sites shall be adequately screened from view. Dredge disposal in shoreline areas shall not impair scenic views.

f. Sites shall be revegetated with native species as soon as possible to retard erosion and restore wildlife habitat value;

The site is designed to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle. Sand will be placed in upland disposal sites with a temporary pipeline extending from the dredge vessel. The pipeline will be removed from the sites after sand placement. Sand moves through the pipeline in the form of a slurry mixed with Columbia River water. Water from the upland disposal sites will be allowed to settle and clear through the drainage system before it runs back into the river. Weirs of appropriate crest height will be used, as necessary, to regulate the return of water to the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance. Perimeter dike erosion protection will be provided.

78. <u>Policy</u>: *Dredge material disposal in water bodies should be discouraged, except for habitat improvement where depositing dredge material on land would be more detrimental to shoreline resources than deposition in water areas. Dredge disposal sites in water areas should be identified by local governments in cooperation with the USACOE, EPA, and the State Departments of Ecology, Natural Resources, and Fish and Wildlife. Dredged material containing chemicals at concentrations high enough to cause significant harm to resident biota should not be placed at unconfined open-water disposal sites.*

Flowlane disposal will be restricted to the navigation channel and adjacent areas and will be similar to flow lane disposal that has been used by the Corps for maintenance dredge material disposal. Sediment quality has been evaluated for dredged materials from the navigation channel. Sediment samples were collected and subjected to physical and chemical analyses. These studies indicate that material to be dredged in the Columbia River navigation channel is suitable for unconfined open water disposal. The bed material of the Columbia River navigation channel is medium to coarse grained sand with less than 1% fines. Sediment evaluations of potential maintenance dredging material conducted since the 1970s have consistently found the material to be suitable for unconfined in-water disposal.

236. Regulation: *The deposition of dredged materials in water shall be permitted only:*

a. to improve wildlife habitat;

b. to correct material distribution problems adversely affecting fish habitat;

c. to create, expand, rehabilitate, or enhance a beach when permitted under this Master Program; or

d. when land deposition is demonstrated to be more detrimental to shoreline resources than water deposition.

Flowlane disposal distributes dredged material downstream of the dredging area, at sites within or adjacent to the navigation channel where depths are greater than the channel. This is done to minimize the potential for material settling back into the channel and causing additional shoaling problems. The Washington Department of Ecology has recently begun encouraging the Corps to dispose of dredged materials in the river where possible.

237. Regulation: *Dredged material shall be disposed of in water only at sites approved by the USACOE and the City of Vancouver. Disposal techniques that cause minimum dispersal and broadcast of bottom material shall be used, unless dispersal of material is specifically approved.*

Flowlane disposal, similar to that which would be used for the Project, was approved by the Corps in the November 3, 1998 Record of Decision for the 40-foot navigation channel. During hopper-dredge disposal, material will be released while the dredge is in motion to disperse material; during pipeline-dredge disposal, the diffuser on the down pipe will be moved continually to prevent mounding on the river bottom.

238. Regulation: *Flow-lane disposal shall be conducted so that:*
a. disposal shall not occur under fresh-water flow and tidal conditions where the predominant sediment transport at a site is upriver; and

Flowlane disposal distributes dredged material downstream of the dredging area, at sites within or adjacent to the navigation channel where depths are greater than the channel. This is done to minimize the potential for material settling back into the channel and causing additional shoaling problems.
b. use of the disposal site does not interfere with fishing activities by causing major changes in the circulation patterns or bottom configuration of the disposal site.

Flowlane disposal will be dispersed adjacent to the channel in a manner that should not interfere with fishing activities.

79. *Policy: Dredging of bottom materials for the primary purpose of obtaining fill material is strongly discouraged.*

Project dredging is not for the purpose of obtaining fill material. As discussed in Section 4.1.2, Project dredging is for the purpose of increasing navigation and enhancing navigational access.

239. *Regulation: Dredging for the primary purpose of obtaining material for landfill shall be prohibited. Dredging and dredge material disposal shall be prohibited in wetlands, EXCEPT when these activities have been approved by a wetland permit as required under the Wetland Protection Ordinance, Dredging and dredge disposal shall be prohibited on or in archaeological sites which are listed on the Washington State Register of Historic Places until such time that they have been released by the State Archaeologist. Dredging to construct land canals or small basins for boat moorage or launching, water ski landings, swimming holes, or other similar recreational activities shall be prohibited. Dredging shall be prohibited between the OHWM and - 15 feet CRD, unless shallow water habitat will be created to mitigate for the dredging project.*

Project dredging is not for the purpose of obtaining fill material. As discussed in Section 4.1.2, Project dredging is for the purpose of increasing navigation and enhancing navigational access. The Gateway disposal site was designed so that it is outside the shoreline. The site avoids wetlands and their buffers.

4.7.6.3 Landfill. *The Project is consistent with the VSMMP's regulatory use standards and general policy objectives for landfill. (VSMMP, p. 5-15 to 5-16).*

80. *Policy: Shoreline fills shall be designed and located so that there will be no significant damage to existing ecological systems or natural resources, and no alteration of local currents, surface water drainage of flood waters which would result in a hazard to adjacent life, property, and natural resource systems. Their perimeters should be designed to avoid or eliminate erosion and sedimentation impacts, both during initial landfill activities and over time. In evaluating fill projects, such factors as conflict with potential and current public use of the shoreline and water surface area, total water surface reduction, navigation restriction, impediment to water flow and drainage, reduction of water quality, and destruction of habitat should be considered. Further, the City of Vancouver should assess the overall value of the landfill site in its present state versus the proposed shoreline use to be created to ensure consistency with the SMA and this Master Program.*

See answer to 242.

241. *Regulation: Environmental review of proposed landfills shall be accomplished concurrently with review of the intended use, and the threshold determination concerning the need for an environmental impact statement shall be based on this combined project review.*

The Corps has already issued a 1999 Final IFR/EIS for this Project as well as a Final SEIS to incorporate additional information.

242. Regulation: *Landfills shall be designed, constructed and maintained to prevent, minimize, and control all material movement, erosion and sedimentation from the affected area. Perimeters of permitted landfill projects shall be designed and constructed with silt curtains, vegetation, retaining walls, or other mechanisms and appropriately sloped to prevent erosion and sedimentation both during initial landfill activities and afterwards. Such containment practices shall occur during the first growing season following completion of the landfill.*

The Gateway 3 upland site is designed to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle. Sand will be placed in upland disposal sites with a temporary pipeline extending from the dredge vessel. The pipeline will be removed from the sites after sand placement, to minimize interference with recreational boating. Sand moves through the pipeline in the form of a slurry mixed with Columbia River water. Water from the upland disposal sites will be allowed to settle and clear through the drainage system before it runs back into the river. Weirs will be used, as necessary to regulate the return of water to the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance. Sites will be graded to avoid erosion.

243. Regulation: *Fill materials shall be sand, gravel, soil, rock or other similar material. Use of polluted dredge spoils or sanitary landfill materials is prohibited. Landfill construction shall be timed to minimize damage to water quality and aquatic life. Pile or pier supports shall be utilized instead of landfills whenever feasible, particularly for permitted development in floodways or wetlands.*

Sediments placed at Gateway 3 will be primarily sand, with low organic content. Sediment quality has been evaluated for dredged materials from the navigation channel. Sediment samples were collected and subjected to physical and chemical analyses. These studies indicate that material to be dredged in the Columbia River navigation channel is suitable for unconfined open water disposal.

244. Regulation: *Landfill on dry land shall not result in substantial changes to surface water drainage patterns off the project site and onto adjacent properties. Landfills shall be designed to allow surface water penetration into groundwater supplies where such conditions existed prior to filling.*

Water from the upland disposal sites will be allowed to settle and clear through the drainage system before it runs back into the river. Weirs will be used to regulate the return of water to the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance.

81. Policy: *Landfills should be permitted only when necessary for a specific development proposal that is permitted by this Master Program. They should be the of the minimum size necessary to provide for the proposed use. Speculative landfill activity should be prohibited. Solid waste landfills should not be located in shoreline jurisdiction. Landfills waterward of the OHWM should be prohibited except in conjunction with a water-dependent or public access use* *when such fill is necessary and unavoidable and complies with all other policies and regulations of this Master Program.*

The Primary purpose of the Project is to enhance navigation and navigational access for marine shipping. Marine shipping and related navigational improvements are permitted water-dependent uses. Flowlane and upland disposal are necessary for dredging. The Gateway 3 site does not constitute a speculative landfill because the fill is not being placed in speculation that the site will later be used for development. Rather, the site is a dedicated upland disposal site that is being used in conjunction with channel deepening and maintenance.

245. *Regulation: Landfills shall be permitted only in conjunction with a permitted use, and shall be of the minimum size necessary to support that use. Speculative landfills are prohibited.*

A principle purpose of the Project is to enhance navigation and navigational access for marine shipping. Marine shipping and related navigational improvements are permitted water-dependent uses. Flowlane and upland disposal are necessary for the Project. Construction and maintenance dredging will only remove the material necessary for the authorized 43-foot navigation channel. In this regard, the fill occurring at the Gateway 3 site is in conjunction with the permitted dredging activities.

246. *Regulation: Landfills shall be permitted only where it is demonstrated that the proposed action will not (1) result in significant damage to water quality, or fish and wildlife habitat, nor (2) adversely alter natural drainage and circulation patterns, currents, river and tidal flows, or significantly reduce flood water capacities. In addition, any such damage, alteration, or reduction not considered significant must be mitigated.*

Water from the upland disposal sites will be allowed to settle and clear through the drainage system before it runs back into the river. Weirs will be used to regulate the return of water to the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance. Impacts to habitat from the Gateway 3 site are being mitigated by habitat creation in the mitigation sites, including Woodland Bottoms and Martin Island.

247. *Regulation: Landfill waterward of OHWM shall be prohibited, except it may be permitted as a conditional use (1) when it is necessary to support a water-dependent or public access use, or (2) in accordance with the provisions of a wetland permit pursuant to the Wetland Protection Ordinance, as amended (VMC 20.50). In the Columbia River, landfills shall be prohibited between the OHWM and -15 feet CRD unless shallow water habitat will be created as mitigation.*

A principle purpose of the Project is to enhance navigation and navigational access for marine shipping. Marine shipping and related navigational improvements are permitted water-dependent uses. Flowlane disposal is necessary to support a water-dependent activity and will occur beyond the 15 feet CRD. Flowlane disposal generally will also be in depths ranging from 50 to 65 feet. Most benthic invertebrates that serve as a food source for fish are found at depths of less than 20 feet. Therefore, restricting the disposal of dredged materials to depths greater than 20 feet will minimize potential impacts from this activity. While it has been established that white sturgeon are present in potential flowlane disposal areas, the Corps is conducting studies to help avoid and minimize impacts to sturgeon.

248. Regulation: *Solid and hazardous waste landfills shall be prohibited in shoreline jurisdiction.*

N/A. The Project includes no solid or hazardous waste landfills.

4.7.6.4 Master Program General Regulations and Policies. The Project is consistent with the applicable general regulations and policies under the VSMMP.

General:

1. *Policy: All shoreline uses and modification activities should further the intent of the SMA and related federal, state, and local statutes and ordinances.*

As discussed in Section 4.1.2, the Project is consistent with the SMA's priorities for Shorelines of Statewide Significance. The Project will comply with all applicable regulations.

1. *Regulation: All shoreline uses and modification activities including those that do not require a Shoreline Substantial Development Permit shall (a) further the intent of the goals and policies of this Master Program; and (b) fulfill the requirements of all applicable sections of this Master Program as well as any other applicable federal, state, or local statutes ordinances, or codes.*

As discussed in this memorandum, the Project is consistent with the VSMMP.

5. *Policy: Water-dependent uses and water-enjoyment uses should have the closest physical relationship with the water, followed by water-related uses. Non-water-oriented uses should not generally be located within shoreline jurisdiction, although they may be permitted under certain circumstances. When they are permitted, they should be located upland of water-oriented uses and as far upland as possible.*

A principle purpose of the Project is to enhance navigation and navigational access for marine shipping. Marine shipping and related navigational improvements are permitted water-dependent uses. Flowlane and upland disposal are necessary for the Project.

9. *Policy: Adverse impacts to the environment and its natural processes should be avoided. When unavoidable, they should be minimized or otherwise mitigated.*

Dredging will be done at depths of more than 40 feet, beyond the depths at which salmonids generally migrate. The primary hopper and pipeline dredges that will be used generally do not produce large amounts of turbidity because of the suction action of the dredge pump and the burial of the drag arm or cutter head in the sediment. Turbidity produced by mechanical dredging will be reduced by using a closing bucket.

Flowlane disposal generally will also be in depths ranging from 50 to 65 feet. Most benthic invertebrates that serve as a food source for fish are found at depths of less than 20 feet. Therefore, restricting the disposal of dredged materials to depths greater than 20 feet will minimize potential impacts from this activity. While it has been established that white sturgeon are present in potential flowlane disposal areas, the Corps is conducting studies to help avoid and minimize impacts to sturgeon.

Upland disposal along the Columbia River channel has been reviewed by the NOAA Fisheries and USFWS to address impacts, if any, to ESA listed fish species and their critical habitat to date. The upland Gateway 3 disposal site has been located 300 feet beyond the river and avoids wetlands and their buffers.

16. Regulation: *All new shoreline uses and modification activities and their associated structures and equipment shall be located, designed, installed, constructed, conducted, managed, operated, and maintained using the best available technology and best management practices for the purpose of (1) protecting and enhancing all forms of aquatic, littoral, or terrestrial life, and their spawning, nesting, and rearing grounds, habitats, and migratory routes; and (2) avoiding probable significant adverse impact to the environment and its natural processes. When such impact cannot be entirely avoided, it shall be minimized or otherwise mitigated. For residents of the shoreline area, this regulation shall be construed to mean that hazardous materials be disposed of pursuant to federal, state, and local laws and ordinances, and that other steps be taken to protect the ecology of the shoreline area in accordance with the other policies and regulations of this Master Program.*

The Project incorporates the following BMPs, among others, to protect shoreline resources during dredging:

- During hopper and pipeline dredging, maintain dragheads in the substrate or no more than 3 feet above the bottom with the dredge pumps running.
- The contractor shall not release any trash, garbage, oil, grease, chemicals, or other contaminants into the waterway. The Project also incorporates the following BMPs, among others, to protect shoreline resources during dredged material disposal:
- For flowlane disposal, dispose of material in a manner that prevents mounding of the disposal material.
- Maintain discharge pipe of pipeline dredge at or below 20 feet of water depth during flowlane disposal.
- Berm upland disposal sites to maximize the settling of fines in the runoff water.
- Grade shoreline disposal sites to a slope of 10 to 15 percent, with no swales, to reduce the possibility of stranding of juvenile salmonids.

36. Policy: *The quantity and quality of surface and groundwater should be preserved and protected through treatment of stormwater, erosion control, restoration of degraded water discharge systems, and other appropriate actions.*

Water from the Gateway 3 upland disposal site will be allowed to settle and clear through the drainage system before it runs back into the river. Weirs will be used as necessary to regulate the return of water to the river. Water returned to the river through weirs is subject to applicable state water quality standards, after dilution, at an appropriate point of compliance.

4.7.4.6. Master Program Element Goals and Objectives. The Project is consistent with the VSMMP's goals and objectives for shoreline elements.

Circulation Element:

1. *Provide safe, convenient, and diversified circulation systems to and within shoreline areas to assure efficient movement of goods and people where routes will have the least possible adverse effect on the shoreline environment, while contributing to the functional and visual enhancement of the shoreline.*

A principle purpose of the Project is to improve navigation and enhance navigational access for marine shipping. The Columbia River navigation channel benefits the national and regional economy and serves shippers located in Vancouver County and throughout the Pacific Northwest. The lower Columbia River is the second largest grain-shipping waterway in the world, surpassed only by the Mississippi River. Regional growers, producers, and manufacturers use Columbia River ports to transport their goods to world markets. By deepening the channel by three feet in selected locations, the Project will continue to support this vital section of the national and regional economy. By incorporating ecosystem restoration elements, the Project will further enhance the quality of life for residents.

4. *Protect, manage and enhance those characteristics of shoreline circulation corridors that are unique or have historic significance or great aesthetic quality, for the benefit and enjoyment of the public.*

Dredging and flowlane disposal will be restricted to the navigation channel and the adjacent area where similar activities have occurred in the past. The new upland disposal site at Gateway 3, will be located 300 feet beyond the river to minimize impacts to shoreline aesthetics.

Conservation/Restoration Element

5. *Manage, conserve, protect, and restore those shoreline areas necessary for the support of wild and aquatic life and those identified as having geological, hydrological or biological significance.*

In addition to maintaining the existing trade base, another purpose of the Project is to restore ecosystem function. This Project responds to a well-demonstrated need for ecosystem restoration and incorporates many restoration actions. These Project features include restored wetland and riparian habitat at Shillapoo Lake (CRM 91); fish gates for salmonid passage at selected locations along the lower Columbia River; connecting channels at the upstream end of Walker-Lord and Hump-Fisher Islands for improved fish access to embayments and rearing habitat for juvenile salmonids; the Lois Island Embayment Habitat Restoration; the Purple Loostrife Control Program, Miller/Pillar Habitat Restoration; the Tenasillahe Island Tidegate/Inlet Improvements and Dike Beach; the Cottonwood/Howard Island Columbia White-Tailed Deer Introduction; and the Bachelor Slough Restoration.

6. *Ensure that utilization of a resource takes place with the minimum adverse impact to natural systems and quality of the shoreline environment.*

Dredging and flowlane disposal will be done at depths of more than 40 feet, to minimize effects on natural systems.

7. *Ensure mitigation of adverse impacts to the greatest extent possible.*

The Project incorporates the following BMPs, among others, to protect shoreline resources during dredging:

- During hopper and pipeline dredging, maintain dragheads in the substrate or no more than 3 feet above the bottom with the dredge pumps running.
- The contractor shall not release any trash, garbage, oil, grease, chemicals, or other contaminants into the waterway. The Project also incorporates the following BMPs, among others, to protect shoreline resources during dredged material disposal:
- For flowlane disposal, dispose of material in a manner that prevents mounding of the disposal material.
- Maintain discharge pipe of pipeline dredge at or below 20 feet of water depth during flowlane disposal.
- Berm upland disposal sites to maximize the settling of fines in the runoff water.
- Grade shoreline disposal sites to a slope of 10 to 15 percent, with no swales, to reduce the possibility of stranding of juvenile salmonids.

The Project includes mitigation for lost riparian, agricultural and wetland habitat.

Economic Development Element

11. *Encourage the maintenance, operation, and enhancement of existing industrial and commercial activities along the shoreline in such a manner that the land-water interface is utilized for productive purposes while minimizing adverse effects to the environment.*

Project activities will occur in and adjacent to the channel in the same or similar locations as have been used previously.

12. *Ensure healthy, orderly economic growth by encouraging new economic activities which will be an asset to the economy of the area and which will result in the least possible adverse effect on the quality of the shoreline, the surrounding environment and downstream water.*

By deepening the channel by three feet in selected locations, the Project will improve the utility of the navigation channel.

14. *Protect economic activity that is consistent with the objectives of the Shoreline Management Master Program.*

A principle purpose of the Project is to enhance navigation and navigational access for marine shipping. Marine shipping and related navigational improvements are permitted water-dependent uses. Flowlane and upland disposal are necessary for the Project as discussed elsewhere in this analysis.

15. *Develop, as an economic asset, the recreational industry along shorelines in a manner that will enhance the public enjoyment of the shorelines.*

16. *Encourage new shoreline industrial and commercial development which is water-dependent, water-related, or water-enjoyment.*

A principle purpose of the Project is to enhance navigation and navigational access for marine shipping. Marine shipping and related navigational improvements are permitted water-dependent uses. Flowlane and upland disposal are necessary for the Project.

4.7.6. Conditional Use Criteria. See the discussion in Section 4.1.3.