Biological Assessment

The Effects of the Proposed Action to Operate the Klamath Project from April 1, 2008 to March 31, 2018 On Federally-Listed Threatened and Endangered Species

Appendix 1-A - USFWS Listed Species and Critical Habitat Concurrence Letter

Klamath Basin Area Office
Mid Pacific Region

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Klamath Falls Fish and Wildlife Office
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Klamath Falls, Oregon 97601
(541) 885-8481 FAX (541)885-7837

In Reply Refer To: 1-10-07-I-0070

JUL 26 2007

Memorandum

To: Area Manager, Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon

From: Field Supervisor, Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon Curt Mullis

Subject: Request for concurrence regarding species and critical habitat within the Klamath Project

This responds to your July 16, 2007 letter requesting concurrence on species and critical habitat that occur within the Klamath Project. We concur with your conclusion that the endangered Lost River sucker (*Deltistes luxatus*) and shortnose suckers (*Chasmistes brevirostris*) occur with the action area. However, please note that critical habitat for these species has not been finalized and thus it is still proposed. Another listed species known to be present in the action area that was not mentioned in your letter is the endangered Applegate's milk-vetch (*Astragalus applegatei*). It is represented by several populations between the Klamath Falls airport and Lake Ewauna, and on both sides of the Keno Reservoir near Miller Island. The Oregon spotted frog (*Rana pretiosa*), a candidate species, may also be present at Agency Lake Ranch because it is known from the nearby Wood River Wetlands. A complete list of Federally-protected species in Klamath, Modoc, and Siskiyou counties can be found on our website at: http://www.fws.gov/klamathfallsfwo/office/kffwo.html.

As you are likely aware, the threatened bald eagle (*Haliaeetus leucocephalus*), which occurs in the action area, will be officially delisted on August 8, 2007. Although Federal agencies will no longer need to consult under section 7 of the Endangered Species Act, the bald eagle is still protected under The Bald and Golden Eagle Protection Act and a permit will be required for take under this Act. The Service is in the process of promulgating regulations for these permits. In the interim, to avoid take, we ask that you follow the enclosed National Bald Eagle Management Guidelines. If you have any questions regarding the delisting of the bald eagle, please Trish Roninger of my staff at 541/885-2505 or see the U.S. Fish and Wildlife Service, bald eagle website at: http://www.fws.gov/migratorybirds/baldeagle.htm.

If you have any questions regarding our response, please contact Ron Larson of my staff, at 541/885-2506.

NATIONAL BALD EAGLE MANAGEMENT GUIDELINES

U.S. Fish and Wildlife Service

May 2007

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INTRODUCTION

The bald eagle (*Haliaeetus leucocephalus*) is protected by the Bald and Golden Eagle Protection Act (Eagle Act) and the Migratory Bird Treaty Act (MBTA). The MBTA and the Eagle Act protect bald eagles from a variety of harmful actions and impacts. The U.S. Fish and Wildlife Service (Service) developed these National Bald Eagle Management Guidelines to advise landowners, land managers, and others who share public and private lands with bald eagles when and under what circumstances the protective provisions of the Eagle Act may apply to their activities. A variety of human activities can potentially interfere with bald eagles, affecting their ability to forage, nest, roost, breed, or raise young. The Guidelines are intended to help people minimize such impacts to bald eagles, particularly where they may constitute "disturbance," which is prohibited by the Eagle Act.

The Guidelines are intended to:

(1) Publicize the provisions of the Eagle Act that continue to protect bald eagles, in order to reduce the possibility that people will violate the law,

(2) Advise landowners, land managers and the general public of the potential for various human activities to disturb bald eagles, and

(3) Encourage additional nonbinding land management practices that benefit bald eagles (see Additional Recommendations section).

While the Guidelines include general recommendations for land management practices that will benefit bald eagles, the document is intended primarily as a tool for landowners and planners who seek information and recommendations regarding how to avoid disturbing bald eagles. Many States and some tribal entities have developed state-specific management plans, regulations, and/or guidance for landowners and land managers to protect and enhance bald eagle habitat, and we encourage the continued development and use of these planning tools to benefit bald eagles.

Adherence to the Guidelines herein will benefit individuals, agencies, organizations, and companies by helping them avoid violations of the law. However, the Guidelines themselves are not law. Rather, they are recommendations based on several decades of behavioral observations, science, and conservation measures to avoid or minimize adverse impacts to bald eagles.

The U.S. Fish and Wildlife Service strongly encourages adherence to these guidelines to ensure that bald and golden eagle populations will continue to be sustained. The Service realizes there may be impacts to some birds even if all reasonable measures are taken to avoid such impacts. Although it is not possible to absolve individuals and entities from liability under the Eagle Act or the MBTA, the Service exercises enforcement discretion to focus on those individuals, companies, or agencies that take migratory birds without regard for the consequences of their actions and the law, especially when conservation measures, such as these Guidelines, are available, but have not been implemented. The Service will prioritize its enforcement efforts to focus on those individuals or entities who take bald eagles or their parts, eggs, or nests without implementing appropriate measures recommended by the Guidelines.

The Service intends to pursue the development of regulations that would authorize, under limited circumstances, the use of permits if "take" of an eagle is anticipated but unavoidable. Additionally, if the bald eagle is delisted, the Service intends to provide a regulatory mechanism to honor existing (take) authorizations under the Endangered Species Act (ESA).

During the interim period until the Service completes a rulemaking for permits under the Eagle Act, the Service does not intend to refer for prosecution the incidental "*take*" of any bald eagle under the MBTA or Eagle Act, if such take is in full compliance with the terms and conditions of an incidental take statement issued to the action agency or applicant under the authority of section 7(b)(4) of the ESA or a permit issued under the authority of section 10(a)(1)(B) of the ESA.

The Guidelines are applicable throughout the United States, including Alaska. The primary purpose of these Guidelines is to provide information that will minimize or prevent violations only of *Federal* laws governing bald eagles. In addition to Federal laws, many states and some smaller jurisdictions and tribes have additional laws and regulations protecting bald eagles. In some cases those laws and regulations may be more protective (restrictive) than these Federal guidelines. If you are planning activities that may affect bald eagles, we therefore recommend that you contact both your nearest U.S. Fish and Wildlife Service Field Office (see the contact information on p.16) and your state wildlife agency for assistance.

LEGAL PROTECTIONS FOR THE BALD EAGLE

The Bald and Golden Eagle Protection Act

The Eagle Act (16 U.S.C. 668-668c), enacted in 1940, and amended several times since then, prohibits anyone, without a permit issued by the Secretary of the Interior, from "taking" bald eagles, including their parts, nests, or eggs. The Act provides criminal and civil penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle ... [or any golden eagle], alive or dead, or any part, nest, or egg thereof." The Act defines "take" as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb." "Disturb" means:

> "Disturb means to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior."

In addition to immediate impacts, this definition also covers impacts that result from human-induced alterations initiated around a previously used nest site during a time when eagles are not present, if, upon the eagle=s return, such alterations agitate or bother an eagle to a degree that injures an eagle or substantially interferes with normal breeding, feeding, or sheltering habits and causes, or is likely to cause, a loss of productivity or nest abandonment.

A violation of the Act can result in a criminal fine of $100,000 ($200,000 for organizations), imprisonment for one year, or both, for a first offense. Penalties increase substantially for additional offenses, and a second violation of this Act is a felony.

The Migratory Bird Treaty Act

The MBTA (16 U.S.C. 703-712), prohibits the taking of any migratory bird or any part, nest, or egg, except as permitted by regulation. The MBTA was enacted in 1918; a 1972 agreement supplementing one of the bilateral treaties underlying the MBTA had the effect of expanding the scope of the Act to cover bald eagles and other raptors. Implementing regulations define "take" under the MBTA as "pursue, hunt, shoot, wound, kill, trap, capture, possess, or collect."

Copies of the Eagle Act and the MBTA are available at: http://permits.fws.gov/ltr/ltr.shtml.

State laws and regulations

Most states have their own regulations and/or guidelines for bald eagle management. Some states may continue to list the bald eagle as endangered, threatened, or of special concern. If you plan activities that may affect bald eagles, we urge you to familiarize yourself with the regulations and/or guidelines that apply to bald eagles in your state. Your adherence to the Guidelines herein does not ensure that you are in compliance with state laws and regulations because state regulations can be more specific and/or restrictive than these Guidelines.

NATURAL HISTORY OF THE BALD EAGLE

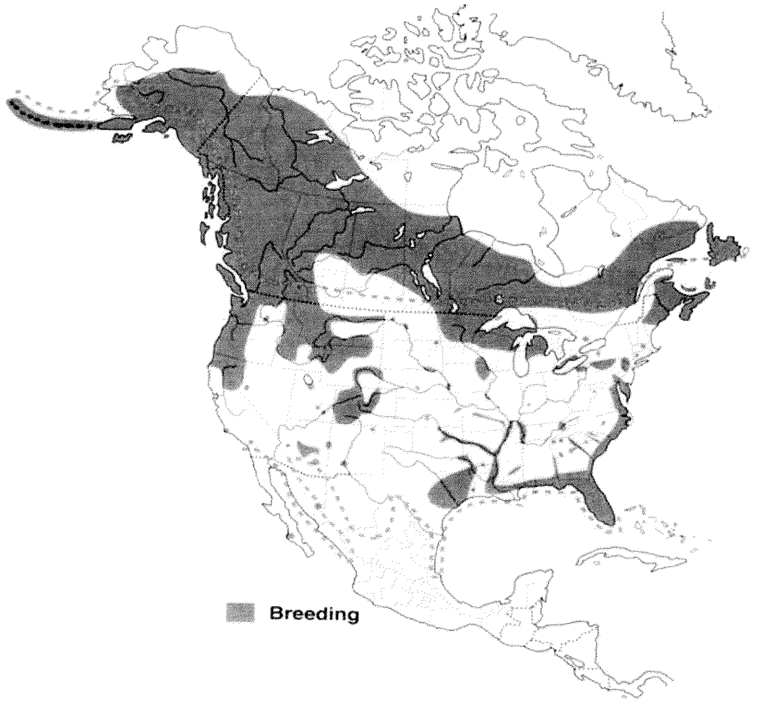
Bald eagles are a North American species that historically occurred throughout the contiguous United States and Alaska. After severely declining in the lower 48 States between the 1870s and the 1970s, bald eagles have rebounded and re-established breeding territories in each of the lower 48 states. The largest North American breeding populations are in Alaska and Canada, but there are also significant bald eagle populations in Florida, the Pacific Northwest, the Greater Yellowstone area, the Great Lakes states, and the Chesapeake Bay region. Bald eagle distribution varies seasonally. Bald eagles that nest in southern latitudes frequently move northward in late spring and early summer, often summering as far north as Canada. Most eagles that breed at northern latitudes migrate southward during winter, or to coastal areas where waters remain unfrozen. Migrants frequently concentrate in large numbers at sites where food is abundant and they often roost together communally. In some cases, concentration areas are used year-round: in summer by southern eagles and in winter by northern eagles.

Juvenile bald eagles have mottled brown and white plumage, gradually acquiring their dark brown body and distinctive white head and tail as they mature. Bald eagles generally attain adult plumage by 5 years of age. Most are capable of breeding at 4 or 5 years of age, but in healthy populations they may not start breeding until much older. Bald eagles may live 15 to 25 years in the wild. Adults weigh 8 to 14 pounds (occasionally reaching 16 pounds in Alaska) and have wingspans of 5 to 8 feet. Those in the northern range are larger than those in the south, and females are larger than males.

Where do bald eagles nest?

Breeding bald eagles occupy "territories," areas they will typically defend against intrusion by other eagles. In addition to the active nest, a territory may include one or more alternate nests (nests built or maintained by the eagles but not used for nesting in a given year). The Eagle Act prohibits removal or destruction of both active and alternate bald eagle nests. Bald eagles exhibit high nest site fidelity and nesting territories are often used year after year. Some territories are known to have been used continually for over half a century.

Bald eagles generally nest near coastlines, rivers, large lakes or streams that support an adequate food supply. They often nest in mature or old-growth trees; snags (dead trees); cliffs; rock promontories; rarely on the ground; and with increasing frequency on human-made structures such as power poles and communication towers. In forested areas, bald eagles often select the tallest trees with limbs strong enough to support a nest that can weigh more than 1,000 pounds. Nest sites typically include at least one perch with a clear view of the water where the eagles usually forage. Shoreline trees or snags located in reservoirs provide the visibility and accessibility needed to locate aquatic prey. Eagle nests are constructed with large sticks, and may be lined with moss, grass, plant stalks, lichens, seaweed, or sod. Nests are usually about 4-6 feet in diameter and 3 feet deep, although larger nests exist.



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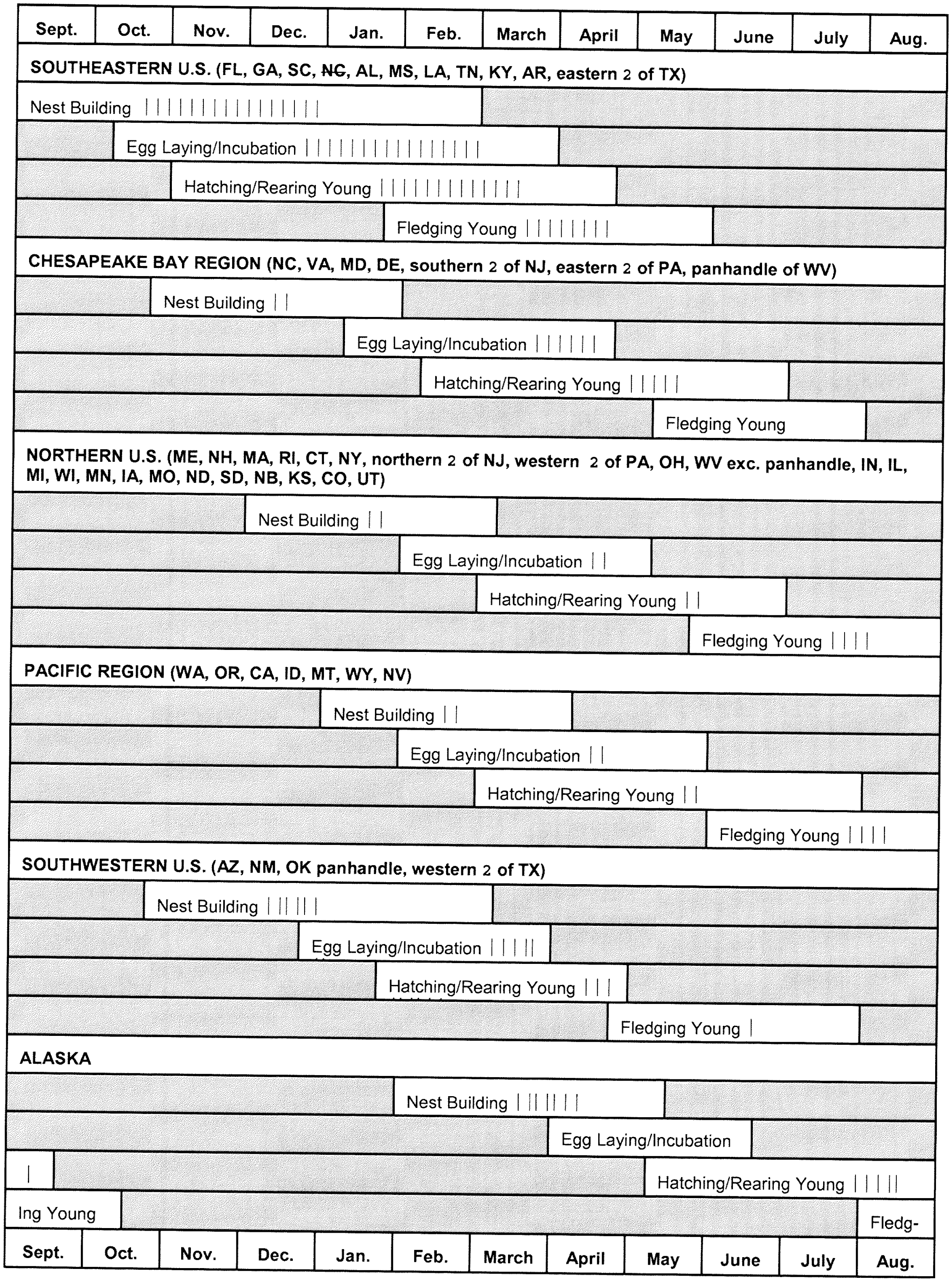
The range of breeding bald eagles in 2000 (shaded areas). This map shows only the larger concentrations of nests; eagles have continued to expand into additional nesting territories in many states. The dotted line represents the bald eagle's wintering range.

When do bald eagles nest?

Nesting activity begins several months before egg-laying. Egg-laying dates vary throughout the U.S., ranging from October in Florida, to late April or even early May in the northern United States. Incubation typically lasts 33-35 days, but can be as long as 40 days. Eaglets make their first unsteady flights about 10 to 12 weeks after hatching, and fledge (leave their nests) within a few days after that first flight. However, young birds usually remain in the vicinity of the nest for several weeks after fledging because they are almost completely dependent on their parents for food until they disperse from the nesting territory approximately 6 weeks later.

The bald eagle breeding season tends to be longer in the southern U.S., and re-nesting following an unsuccessful first nesting attempt is more common there as well. The following table shows the timing of bald eagle breeding seasons in different regions of the country. The table represents the range of time within which the majority of nesting activities occur in each region and does not apply to any specific nesting pair. Because the timing of nesting activities may vary within a given region, you should contact the nearest U.S. Fish and Wildlife Service Field Office (see page 16) and/or your state wildlife conservation agency for more specific information on nesting chronology in your area.

Chronology of typical reproductive activities of bald eagles in the United States.



How many chicks do bald eagles raise?

The number of eagle eggs laid will vary from 1-3, with 1-2 eggs being the most common. Only one eagle egg is laid per day, although not always on successive days. Hatching of young occurs on different days with the result that chicks in the same nest are sometimes of unequal size. The overall national fledging rate is approximately one chick per nest, annually, which results in a healthy expanding population.

What do bald eagles eat?

Bald eagles are opportunistic feeders. Fish comprise much of their diet, but they also eat waterfowl, shorebirds/colonial waterbirds, small mammals, turtles, and carrion. Because they are visual hunters, eagles typically locate their prey from a conspicuous perch, or soaring flight, then swoop down and strike. Wintering bald eagles often congregate in large numbers along streams to feed on spawning salmon or other fish species, and often gather in large numbers in areas below reservoirs, especially hydropower dams, where fish are abundant. Wintering eagles also take birds from rafts of ducks at reservoirs and rivers, and congregate on melting ice shelves to scavenge dead fish from the current or the soft melting ice. Bald eagles will also feed on carcasses along roads, in landfills, and at feedlots.

During the breeding season, adults carry prey to the nest to feed the young. Adults feed their chicks by tearing off pieces of food and holding them to the beaks of the eaglets. After fledging, immature eagles are slow to develop hunting skills, and must learn to locate reliable food sources and master feeding techniques. Young eagles will congregate together, often feeding upon easily acquired food such as carrion and fish found in abundance at the mouths of streams and shallow bays and at landfills.

The impact of human activity on nesting bald eagles

During the breeding season, bald eagles are sensitive to a variety of human activities. However, not all bald eagle pairs react to human activities in the same way. Some pairs nest successfully just dozens of yards from human activity, while others abandon nest sites in response to activities much farther away. This variability may be related to a number of factors, including visibility, duration, noise levels, extent of the area affected by the activity, prior experiences with humans, and tolerance of the individual nesting pair. The relative sensitivity of bald eagles during various stages of the breeding season is outlined in the following table.

Nesting Bald Eagle Sensitivity to Human Activities

Phase	Activity	Sensitivity to Human Activity	Comments
I	Courtship and Nest Building	Most sensitive period; likely to respond negatively	Most critical time period. Disturbance is manifested in nest abandonment. Bald eagles in newly established territories are more prone to abandon nest sites.
II	Egg laying	Very sensitive period	Human activity of even limited duration may cause nest desertion and abandonment of territory for the breeding season.
III	Incubation and early nestling period (up to 4 weeks)	Very sensitive period	Adults are less likely to abandon the nest near and after hatching. However, flushed adults leave eggs and young unattended; eggs are susceptible to cooling, loss of moisture, overheating, and predation; young are vulnerable to elements.
IV	Nestling period, 4 to 8 weeks	Moderately sensitive period	Likelihood of nest abandonment and vulnerability of the nestlings to elements somewhat decreases. However, nestlings may miss feedings, affecting their survival.
V	Nestlings 8 weeks through fledging	Very sensitive period	Gaining flight capability, nestlings 8 weeks and older may flush from the nest prematurely due to disruption and die.

If agitated by human activities, eagles may inadequately construct or repair their nest, may expend energy defending the nest rather than tending to their young, or may abandon the nest altogether. Activities that cause prolonged absences of adults from their nests can jeopardize eggs or young. Depending on weather conditions, eggs may overheat or cool too much and fail to hatch. Unattended eggs and nestlings are subject to predation. Young nestlings are particularly vulnerable because they rely on their parents to provide warmth or shade, without which they may die as a result of hypothermia or heat stress. If food delivery schedules are interrupted, the young may not develop healthy plumage, which can affect their survival. In addition, adults startled while incubating or brooding young may damage eggs or injure their young as they abruptly leave the nest. Older nestlings no longer require constant attention from the adults, but they may be startled by loud or intrusive human activities and prematurely jump from the nest before they are able to fly or care for themselves. Once fledged, juveniles range up to ¼ mile from the nest site, often to a site with minimal human activity. During this period, until about six weeks after departure from the nest, the juveniles still depend on the adults to feed them.

The impact of human activity on foraging and roosting bald eagles

Disruption, destruction, or obstruction of roosting and foraging areas can also negatively affect bald eagles. Disruptive activities in or near eagle foraging areas can interfere with feeding, reducing chances of survival. Interference with feeding can also result in reduced productivity (number of young successfully fledged). Migrating and wintering bald eagles often congregate at specific sites for purposes of feeding and sheltering. Bald eagles rely on established roost sites because of their proximity to sufficient food sources. Roost sites are usually in mature trees where the eagles are somewhat sheltered from the wind and weather. Human activities near or within communal roost sites may prevent eagles from feeding or taking shelter, especially if there are not other undisturbed and productive feeding and roosting sites available. Activities that permanently alter communal roost sites and important foraging areas can altogether eliminate the elements that are essential for feeding and sheltering eagles.

Where a human activity agitates or bothers roosting or foraging bald eagles to the degree that causes injury or substantially interferes with breeding, feeding, or sheltering behavior and causes, or is likely to cause, a loss of productivity or nest abandonment, the conduct of the activity constitutes a violation of the Eagle Act's prohibition against disturbing eagles. The circumstances that might result in such an outcome are difficult to predict without detailed site-specific information. If your activities may disturb roosting or foraging bald eagles, you should contact your local Fish and Wildlife Service Field Office (see page 16) for advice and recommendations for how to avoid such disturbance.

RECOMMENDATIONS FOR AVOIDING DISTURBANCE AT NEST SITES

In developing these Guidelines, we relied on existing state and regional bald eagle guidelines, scientific literature on bald eagle disturbance, and recommendations of state and Federal biologists who monitor the impacts of human activity on eagles. Despite these resources, uncertainties remain regarding the effects of many activities on eagles and how eagles in different situations may or may not respond to certain human activities. The Service recognizes this uncertainty and views the collection of better biological data on the response of eagles to disturbance as a high priority. To the extent that resources allow, the Service will continue to collect data on responses of bald eagles to human activities conducted according to the recommendations within these Guidelines to ensure that adequate protection from disturbance is being afforded, and to identify circumstances where the Guidelines might be modified. These data will be used to make future adjustments to the Guidelines.

To avoid disturbing nesting bald eagles, we recommend (1) keeping a distance between the activity and the nest (distance buffers), (2) maintaining preferably forested (or natural) areas between the activity and around nest trees (landscape buffers), and (3) avoiding certain activities during the breeding season. The buffer areas serve to minimize visual and auditory impacts associated with human activities near nest sites. Ideally, buffers would be large enough to protect existing nest trees and provide for alternative or replacement nest trees.

The size and shape of effective buffers vary depending on the topography and other ecological characteristics surrounding the nest site. In open areas where there are little or no forested or topographical buffers, such as in many western states, distance alone must serve as the buffer. Consequently, in open areas, the distance between the activity and the nest may need to be larger than the distances recommended under Categories A and B of these guidelines (pg. 12) if no landscape buffers are present. The height of the nest above the ground may also ameliorate effects of human activities; eagles at higher nests may be less prone to disturbance.

In addition to the physical features of the landscape and nest site, the appropriate size for the distance buffer may vary according to the historical tolerances of eagles to human activities in particular localities, and may also depend on the location of the nest in relation to feeding and roosting areas used by the eagles. Increased competition for nest sites may lead bald eagles to nest closer to human activity (and other eagles).

Seasonal restrictions can prevent the potential impacts of many shorter-term, obtrusive activities that do not entail landscape alterations (e.g. fireworks, outdoor concerts). In proximity to the nest, these kinds of activities should be conducted only outside the breeding season. For activities that entail both short-term, obtrusive characteristics and more permanent impacts (e.g., building construction), we recommend a combination of both approaches: retaining a landscape buffer *and* observing seasonal restrictions.

For assistance in determining the appropriate size and configuration of buffers or the timing of activities in the vicinity of a bald eagle nest, we encourage you to contact the nearest U.S. Fish and Wildlife Service Field Office (see page 16).

Existing Uses

Eagles are unlikely to be disturbed by routine use of roads, homes, and other facilities where such use pre-dates the eagles' successful nesting activity in a given area. Therefore, in most cases *ongoing* existing uses may proceed with the same intensity with little risk of disturbing bald eagles. However, some *intermittent, occasional, or irregular* uses that pre-date eagle nesting in an area may disturb bald eagles. For example: a pair of eagles may begin nesting in an area and subsequently be disturbed by activities associated with an annual outdoor flea market, even though the flea market has been held annually at the same location. In such situations, human activity should be adjusted or relocated to minimize potential impacts on the nesting pair.

ACTIVITY-SPECIFIC GUIDELINES

The following section provides the Service=s management recommendations for avoiding bald eagle disturbance as a result of new or intermittent activities proposed in the vicinity of bald eagle nests. Activities are separated into 8 categories (A – H) based on the nature and magnitude of impacts to bald eagles that usually result from the type of activity. Activities with similar or comparable impacts are grouped together.

In most cases, impacts will vary based on the visibility of the activity from the eagle nest and the degree to which similar activities are already occurring in proximity to the nest site. Visibility is a factor because, in general, eagles are more prone to disturbance when an activity occurs in full view. For this reason, we recommend that people locate activities farther from the nest structure in areas with open vistas, in contrast to areas where the view is shielded by rolling topography, trees, or other screening factors. The recommendations also take into account the existence of similar activities in the area because the continued presence of nesting bald eagles in the vicinity of the existing activities indicates that the eagles in that area can tolerate a greater degree of human activity than we can generally expect from eagles in areas that experience fewer human impacts. To illustrate how these factors affect the likelihood of disturbing eagles, we have incorporated the recommendations for some activities into a table (categories A and B).

First, determine which category your activity falls into (between categories A – H). If the activity you plan to undertake is not specifically addressed in these guidelines, follow the recommendations for the most similar activity represented.

If your activity is under A or B, our recommendations are in table form. The vertical axis shows the degree of visibility of the activity from the nest. The horizontal axis (header row) represents the degree to which similar activities are ongoing in the vicinity of the nest. Locate the row that best describes how visible your activity will be from the eagle nest. Then, choose the column that best describes the degree to which similar activities are ongoing in the vicinity of the eagle nest. The box where the column and row come together contains our management recommendations for how far you should locate your activity from the nest to avoid disturbing the eagles. The numerical distances shown in the tables are the closest the activity should be conducted relative to the nest. In some cases we have included additional recommendations (other than recommended *distance* from the nest) you should follow to help ensure that your activity will not disturb the eagles.

Alternate nests

For activities that entail permanent landscape alterations that may result in bald eagle disturbance, these recommendations apply to both active and alternate bald eagle nests. Disturbance becomes an issue with regard to alternate nests if eagles return for breeding purposes and react to land use changes that occurred while the nest was inactive. The likelihood that an alternate nest will again become active decreases the longer it goes unused. If you plan activities in the vicinity of an alternate bald eagle nest and have information to show that the nest has not been active during the preceding 5 breeding seasons, the recommendations provided in these guidelines for avoiding disturbance around the nest site may no longer be warranted. The nest itself remains protected by other provisions of the Eagle Act, however, and may not be destroyed.

If special circumstances exist that make it unlikely an inactive nest will be reused before 5 years of disuse have passed, and you believe that the probability of reuse is low enough to warrant disregarding the recommendations for avoiding disturbance, you should be prepared to provide all the reasons for your conclusion, including information regarding past use of the nest site. Without sufficient documentation, you should continue to follow these guidelines when conducting activities around the nest site. If we are able to determine that it is unlikely the nest will be reused, we may advise you that the recommendations provided in these guidelines for avoiding disturbance are no longer necessary around that nest site.

This guidance is intended to minimize disturbance, as defined by Federal regulation. In addition to Federal laws, most states and some tribes and smaller jurisdictions have additional laws and regulations protecting bald eagles. In some cases those laws and regulations may be more protective (restrictive) than these Federal guidelines.

Temporary Impacts

For activities that have temporary impacts, such as the use of loud machinery, fireworks displays, or summer boating activities, we recommend seasonal restrictions. These types of activities can generally be carried out outside of the breeding season without causing disturbance. The recommended restrictions for these types of activities can be lifted for alternate nests within a particular territory, including nests that were attended during the current breeding season but not used to raise young, after eggs laid in another nest within the territory have hatched (depending on the distance between the alternate nest and the active nest).

In general, activities should be kept as far away from nest trees as possible; loud and disruptive activities should be conducted when eagles are not nesting; and activity between the nest and the nearest foraging area should be minimized. If the activity you plan to undertake is not specifically addressed in these guidelines, follow the recommendations for the most similar activity addressed, or contact your local U.S. Fish and Wildlife Service Field Office for additional guidance.

If you believe that special circumstances apply to your situation that increase or diminish the likelihood of bald eagle disturbance, or if it is not possible to adhere to the guidelines, you should contact your local Service Field Office for further guidance.

Category A:
Building construction, 1 or 2 story, with project footprint of ½ acre or less.
Construction of roads, trails, canals, power lines, and other linear utilities.
Agriculture and aquaculture – new or expanded operations.
Alteration of shorelines or wetlands.
Installation of docks or moorings.
Water impoundment.

Category B:
Building construction, 3 or more stories.
Building construction, 1 or 2 story, with project footprint of more than ½ acre.
Installation or expansion of marinas with a capacity of 6 or more boats.
Mining and associated activities.
Oil and natural gas drilling and refining and associated activities.

	If there is no similar activity within 1 mile of the nest	***If there is similar activity closer than 1 mile from the nest***
If the activity will be visible from the nest	660 feet. Landscape buffers are recommended.	660 feet, or as close as existing tolerated activity of similar scope. Landscape buffers are recommended.
If the activity will not be visible from the nest	Category A: 330 feet. Clearing, external construction, and landscaping between 330 feet and 660 feet should be done outside breeding season. Category B: 660 feet.	330 feet, or as close as existing tolerated activity of similar scope. Clearing, external construction and landscaping within 660 feet should be done outside breeding season.

The numerical distances shown in the table are the closest the activity should be conducted relative to the nest.

Category C. Timber Operations and Forestry Practices

- Avoid clear cutting or removal of overstory trees within 330 feet of the nest at any time.

- Avoid timber harvesting operations, including road construction and chain saw and yarding operations, during the breeding season within 660 feet of the nest. The distance may be decreased to 330 feet around alternate nests within a particular territory, including nests that were attended during the current breeding season but not used to raise young, after eggs laid in another nest within the territory have hatched.

- Selective thinning and other silviculture management practices designed to conserve or enhance habitat, including prescribed burning close to the nest tree, should be undertaken outside the breeding season. Precautions such as raking leaves and woody debris from around the nest tree should be taken to prevent crown fire or fire climbing the nest tree. If it is determined that a burn during the breeding season would be beneficial, then, to ensure that no take or disturbance will occur, these activities should be conducted only when neither adult eagles nor young are present at the nest tree (i.e., at the beginning of, or end of, the breeding season, either before the particular nest is active or after the young have fledged from that nest). Appropriate Federal and state biologists should be consulted before any prescribed burning is conducted during the breeding season.

- Avoid construction of log transfer facilities and in-water log storage areas within 330 feet of the nest.

Category D. Off-road vehicle use (including snowmobiles). No buffer is necessary around nest sites outside the breeding season. During the breeding season, do not operate off-road vehicles within 330 feet of the nest. In open areas, where there is increased visibility and exposure to noise, this distance should be extended to 660 feet.

Category E. Motorized Watercraft use (including jet skis/personal watercraft). No buffer is necessary around nest sites outside the breeding season. During the breeding season, within 330 feet of the nest, (1) do not operate jet skis (personal watercraft), and (2) avoid concentrations of noisy vessels (e.g., commercial fishing boats and tour boats), except where eagles have demonstrated tolerance for such activity. Other motorized boat traffic passing within 330 feet of the nest should attempt to minimize trips and avoid stopping in the area where feasible, particularly where eagles are unaccustomed to boat traffic. Buffers for airboats should be larger than 330 feet due to the increased noise they generate, combined with their speed, maneuverability, and visibility.

Category F. Non-motorized recreation and human entry (e.g., hiking, camping, fishing, hunting, birdwatching, kayaking, canoeing). No buffer is necessary around nest sites outside the breeding season. If the activity will be visible or highly audible from the nest, maintain a 330-foot buffer during the breeding season, particularly where eagles are unaccustomed to such activity.

Category G. Helicopters and fixed-wing aircraft.
Except for authorized biologists trained in survey techniques, avoid operating aircraft within 1,000 feet of the nest during the breeding season, except where eagles have demonstrated tolerance for such activity.

Category H. Blasting and other loud, intermittent noises.
Avoid blasting and other activities that produce extremely loud noises within 1/2 mile of active nests, unless greater tolerance to the activity (or similar activity) has been demonstrated by the eagles in the nesting area. This recommendation applies to the use of fireworks classified by the Federal Department of Transportation as Class B explosives, which includes the larger fireworks that are intended for licensed public display.

RECOMMENDATIONS FOR AVOIDING DISTURBANCE AT FORAGING AREAS AND COMMUNAL ROOST SITES

1. Minimize potentially disruptive activities and development in the eagles' direct flight path between their nest and roost sites and important foraging areas.

2. Locate long-term and permanent water-dependent facilities, such as boat ramps and marinas, away from important eagle foraging areas.

3. Avoid recreational and commercial boating and fishing near critical eagle foraging areas during peak feeding times (usually early to mid-morning and late afternoon), except where eagles have demonstrated tolerance to such activity.

4. Do not use explosives within ½ mile (or within 1 mile in open areas) of communal roosts when eagles are congregating, without prior coordination with the U.S. Fish and Wildlife Service and your state wildlife agency.

5. Locate aircraft corridors no closer than 1,000 feet vertical or horizontal distance from communal roost sites.

ADDITIONAL RECOMMENDATIONS TO BENEFIT BALD EAGLES

The following are additional management practices that landowners and planners can exercise for added benefit to bald eagles.

1. Protect and preserve potential roost and nest sites by retaining mature trees and old growth stands, particularly within ½ mile from water.
2. Where nests are blown from trees during storms or are otherwise destroyed by the elements, continue to protect the site in the absence of the nest for up to three (3) complete breeding seasons. Many eagles will rebuild the nest and reoccupy the site.
3. To avoid collisions, site wind turbines, communication towers, and high voltage transmission power lines away from nests, foraging areas, and communal roost sites.
4. Employ industry-accepted best management practices to prevent birds from colliding with or being electrocuted by utility lines, towers, and poles. If possible, bury utility lines in important eagle areas.
5. Where bald eagles are likely to nest in human-made structures (e.g., cell phone towers) and such use could impede operation or maintenance of the structures or jeopardize the safety of the eagles, equip the structures with either (1) devices engineered to discourage bald eagles from building nests, or (2) nesting platforms that will safely accommodate bald eagle nests without interfering with structure performance.
6. Immediately cover carcasses of euthanized animals at landfills to protect eagles from being poisoned.
7. Do not intentionally feed bald eagles. Artificially feeding bald eagles can disrupt their essential behavioral patterns and put them at increased risk from power lines, collision with windows and cars, and other mortality factors.
8. Use pesticides, herbicides, fertilizers, and other chemicals only in accordance with Federal and state laws.
9. Monitor and minimize dispersal of contaminants associated with hazardous waste sites (legal or illegal), permitted releases, and runoff from agricultural areas, especially within watersheds where eagles have shown poor reproduction or where bioaccumulating contaminants have been documented. These factors present a risk of contamination to eagles and their food sources.

CONTACTS

The following U.S. Fish and Wildlife Service Field Offices provide technical assistance on bald eagle management:

Alabama	Daphne	(251) 441-5181
Alaska	Anchorage	(907) 271-2888
	Fairbanks	(907) 456-0203
	Juneau	(907) 780-1160
Arizona	Phoenix	(602) 242-0210
Arkansas	Conway	(501) 513-4470
California	Arcata	(707) 822-7201
	Barstow	(760) 255-8852
	Carlsbad	(760) 431-9440
	Red Bluff	(530) 527-3043
	Sacramento	(916) 414-6000
	Stockton	(209) 946-6400
	Ventura	(805) 644-1766
	Yreka	(530) 842-5763
Colorado	Lakewood	(303) 275-2370
	Grand Junction	(970) 243-2778
Connecticut	(See New Hampshire)	
Delaware	(See Maryland)	
Florida	Panama City	(850) 769-0552
	Vero Beach	(772) 562-3909
	Jacksonville	(904) 232-2580
Georgia	Athens	(706) 613-9493
	Brunswick	(912) 265-9336
	Columbus	(706) 544-6428
Idaho	Boise	(208) 378-5243
	Chubbuck	(208) 237-6975
Illinois/Iowa	Rock Island	(309) 757-5800
Indiana	Bloomington	(812) 334-4261
Kansas	Manhattan	(785) 539-3474
Kentucky	Frankfort	(502) 695-0468
Louisiana	Lafayette	(337) 291-3100
Maine	Old Town	(207) 827-5938
Maryland	Annapolis	(410) 573-4573
Massachusetts	(See New Hampshire)	
Michigan	East Lansing	(517) 351-2555
Minnesota	Bloomington	(612) 725-3548
Mississippi	Jackson	(601) 965-4900
Missouri	Columbia	(573) 234-2132
Montana	Helena	(405) 449-5225
Nebraska	Grand Island	(308) 382-6468
Nevada	Las Vegas	(702) 515-5230
	Reno	(775) 861-6300
New Hampshire	Concord	(603) 223-2541
New Jersey	Pleasantville	(609) 646-9310
New Mexico	Albuquerque	(505) 346-2525
New York	Cortland	(607) 753-9334
	Long Island	(631) 776-1401
North Carolina	Raleigh	(919) 856-4520
	Asheville	(828) 258-3939
North Dakota	Bismarck	(701) 250-4481
Ohio	Reynoldsburg	(614) 469-6923
Oklahoma	Tulsa	(918) 581-7458
Oregon	Bend	(541) 383-7146
	Klamath Falls	(541) 885-8481
	La Grande	(541) 962-8584
	Newport	(541) 867-4558
	Portland	(503) 231-6179
	Roseburg	(541) 957-3474
Pennsylvania	State College	(814) 234-4090
Rhode Island	(See New Hampshire)	
South Carolina	Charleston	(843) 727-4707
South Dakota	Pierre	(605) 224-8693
Tennessee	Cookeville	(931) 528-6481
Texas	Clear Lake	(281) 286-8282
Utah	West Valley City	(801) 975-3330
Vermont	(See New Hampshire)	
Virginia	Gloucester	(804) 693-6694
Washington	Lacey	(306) 753-9440
	Spokane	(509) 891-6839
	Wenatchee	(509) 665-3508
West Virginia	Elkins	(304) 636-6586
Wisconsin	New Franken	(920) 866-1725
Wyoming	Cheyenne	(307) 772-2374
	Cody	(307) 578-5939

National Office
U.S. Fish and Wildlife Service
Division of Migratory Bird Management
4401 North Fairfax Drive, MBSP-4107
Arlington, VA 22203-1610
(703) 358-1714
http://www.fws.gov/migratorybirds

State Agencies

To contact a state wildlife agency, visit the Association of Fish & Wildlife Agencies' website at http://www.fishwildlife.org/where_us.html

GLOSSARY

The definitions below apply to these National Bald Eagle Management Guidelines:

Communal roost sites – Areas where bald eagles gather and perch overnight – and sometimes during the day in the event of inclement weather. Communal roost sites are usually in large trees (live or dead) that are relatively sheltered from wind and are generally in close proximity to foraging areas. These roosts may also serve a social purpose for pair bond formation and communication among eagles. Many roost sites are used year after year.

Disturb – To agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior.

In addition to immediate impacts, this definition also covers impacts that result from human-caused alterations initiated around a previously used nest site during a time when eagles are not present, if, upon the eagle=s return, such alterations agitate or bother an eagle to a degree that injures an eagle or substantially interferes with normal breeding, feeding, or sheltering habits and causes, or is likely to cause, a loss of productivity or nest abandonment.

Fledge – To leave the nest and begin flying. For bald eagles, this normally occurs at 10-12 weeks of age.

Fledgling – A juvenile bald eagle that has taken the first flight from the nest but is not yet independent.

Foraging area – An area where eagles feed, typically near open water such as rivers, lakes, reservoirs, and bays where fish and waterfowl are abundant, or in areas with little or no water (i.e., rangelands, barren land, tundra, suburban areas, etc.) where other prey species (e.g., rabbit, rodents) or carrion (such as at landfills) are abundant.

Landscape buffer – A natural or human-made landscape feature that screens eagles from human activity (e.g., strip of trees, hill, cliff, berm, sound wall).

Nest – A structure built, maintained, or used by bald eagles for the purpose of reproduction. An **active** nest is a nest that is attended (built, maintained or used) by a pair of bald eagles during a given breeding season, whether or not eggs are laid. An **alternate** nest is a nest that is not used for breeding by eagles during a given breeding season.

Nest abandonment – Nest abandonment occurs when adult eagles desert or stop attending a nest and do not subsequently return and successfully raise young in that nest for the duration of a breeding season. Nest abandonment can be caused by altering habitat near a nest, even if the alteration occurs prior to the breeding season. Whether the eagles migrate during the non-breeding season, or remain in the area throughout the non-breeding season, nest abandonment can occur at any point between the time the eagles return to the nesting site for the breeding season and the time when all progeny from the breeding season have dispersed.

Project footprint – The area of land (and water) that will be permanently altered for a development project, including access roads.

Similar scope – In the vicinity of a bald eagle nest, an existing activity is of similar scope to a new activity where the types of impacts to bald eagles are similar in nature, and the impacts of the existing activity are of the same or greater magnitude than the impacts of the potential new activity. Examples: (1) An existing single-story home 200 feet from a nest is similar in scope to an additional single-story home 200 feet from the nest; (2) An existing multi-story, multi-family dwelling 150 feet from a nest has impacts of a greater magnitude than a potential new single-family home 200 feet from the nest; (3) One existing single-family home 200 feet from the nest has impacts of a lesser magnitude than three single-family homes 200 feet from the nest; (4) an existing single-family home 200 feet from a communal roost has impacts of a lesser magnitude than a single-family home 300 feet from the roost but 40 feet from the eagles' foraging area. The existing activities in examples (1) and (2) are of similar scope, while the existing activities in example (3) and (4) are not.

Vegetative buffer – An area surrounding a bald eagle nest that is wholly or largely covered by forest, vegetation, or other natural ecological characteristics, and separates the nest from human activities.

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Biological Assessment

The Effects of the Proposed Action to Operate the Klamath Project from April 1, 2008 to March 31, 2018 On Federally-Listed Threatened and Endangered Species

Appendix 1-B - NMFS Listed Species and Critical Habitat Concurrence Letter

Klamath Basin Area Office
Mid Pacific Region

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region Arcata Area Office
1655 Heindon Road
Arcata, California 95521
Tel (707) 825-5163; Fax (707) 825-4840

AUG 20 2007

In response refer to:
151422SWR2007AR00148

Official File Copy
Received
Date Received: 8/31/2007
Date of Letter: 8/20/2007
Control Number: 07075245
File Code: ENV 7.0
Folder I.D.: 360-0 Endangered Species
Project: KLAMATH

Code	Initial	Date
100	GG	8/30/07
700 Williams		
700 Karsen		

HoDl, +
Karas

Mr. Pablo Arroyave
Area Manager
Bureau of Reclamation
Klamath Basin Area Office
6600 Washburn Way
Klamath Falls, Oregon 97603-9365

Dear Pablo:

Thank you for your July 16, 2007, request for information regarding the presence of Federally-listed species and designated critical habitat that may be affected by the proposed Klamath Project Operations. Available information indicates the following threatened listed species and critical habitat may occur in the action area.

- Southern Oregon/Northern California Coast (SONCC) coho salmon (*Oncorhynchus kisutch*) Evolutionarily Significant Unit (June 28, 2005, 70 FR 37160); and
- Critical habitat for SONCC coho salmon (May 5, 1999, 64 FR 24049).

Watercourses within this area are also designated Essential Fish Habitat (EFH), pursuant to the Magnuson-Stevens Fisheries Conservation and Management Act for Chinook salmon (*O. tschawytscha*) and coho salmon under the Pacific Coast Salmon Species Fishery Management Plan. For more information on EFH, see our website (http://swr.nmfs.noaa/efh.htm).

If you have any questions concerning this letter, please contact Mr. Jim Simondet at (707) 825-5171.

Sincerely,

Irma Lagomarsino
Irma Lagomarsino
Supervisor, Arcata Area Office

cc: Copy to file- ARN 151422SWR2007AR00148

Biological Assessment

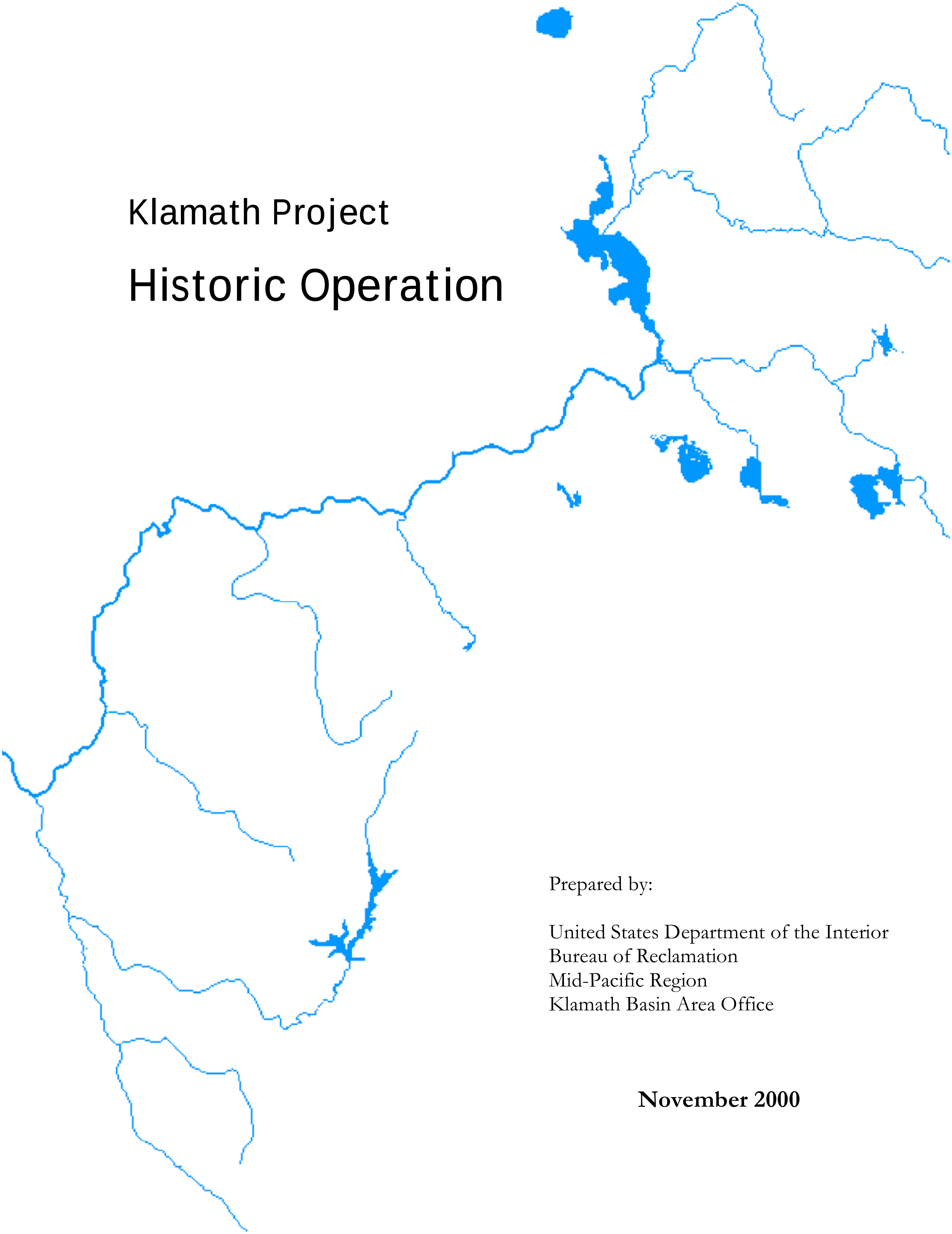
The Effects of the Proposed Action to Operate the Klamath Project from April 1, 2008 to March 31, 2018 On Federally-Listed Threatened and Endangered Species

Appendix 1-C - Klamath Project Historic Operation November 2000. Prepared by the Bureau of Reclamation

Klamath Basin Area Office
Mid Pacific Region

Klamath Project

Historic Operation



Prepared by:

United States Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
Klamath Basin Area Office

November 2000

Klamath Project

Historic Operation

MARCH 3, 1849

Prepared by:

United States Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
Klamath Basin Area Office

November 2000

MISSION STATEMENTS

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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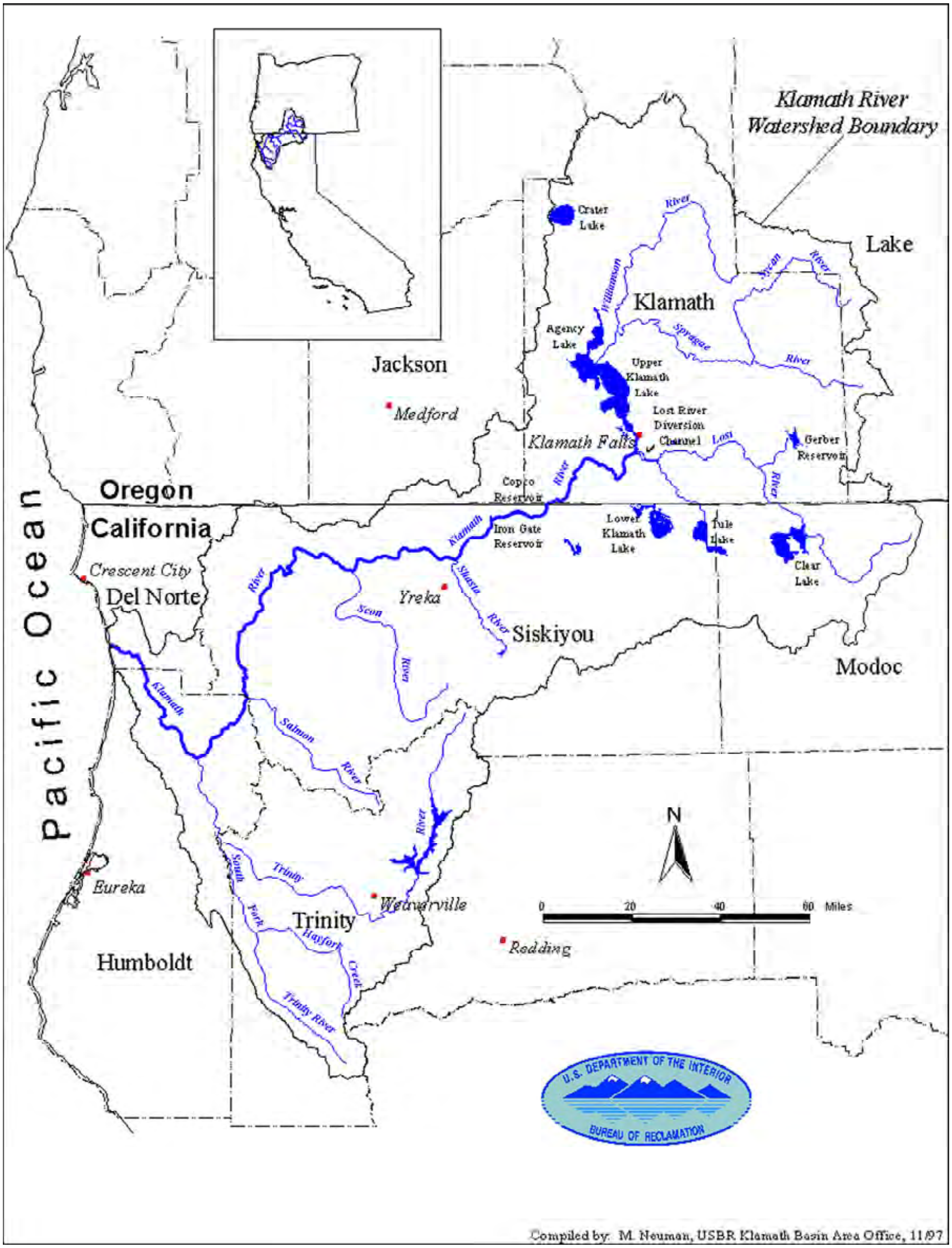
INTRODUCTION

This report describes the features and facilities of the Klamath Project (Project), a federal reclamation project developed and operated by the U.S. Department of the Interior's Bureau of Reclamation (Reclamation). This report also describes Project operation. This information is needed for the Klamath Project Long-Term Operations Plan Environmental Impact Statement (EIS). It provides a benchmark description of project operation needed to properly assess the long-term changes in effects resulting from project operation in the future. This report focuses on Project operation from 1961 to 1999. This period is used, because all major Project features and facilities were operational and documented. This period is also the base period used in the Klamath Project Operations Simulation Model (KPOPSIM).

The Klamath Project is located in the upper portion of the Klamath River basin in southern Oregon and northern California (fig. 1). The total drainage area in the upper basin encompasses about 5,700 square miles. The project lands and facilities are located within Klamath County in Oregon, and Siskiyou and Modoc Counties in California (fig. 2). It also includes the Clear Lake-Lost River watershed, which is a closed basin within the larger Klamath River basin.



Compiled by: M. Neuman, USBR Klamath Basin Area Office, 11/97

Figure 1.—Geographic scope of the Klamath Project.

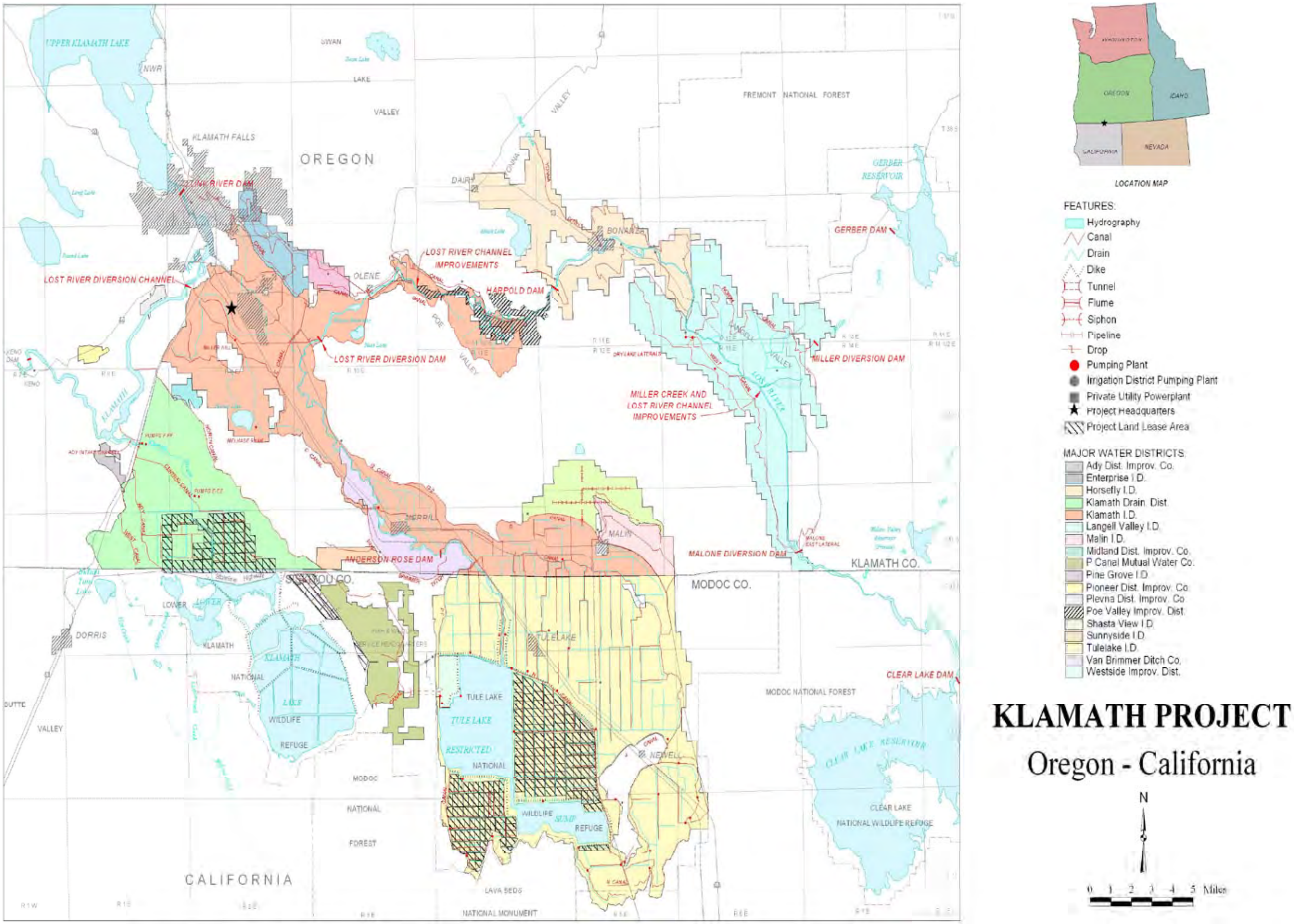


Figure 2.—Klamath Project.

BACKGROUND[1] AND HISTORY

The Klamath Project provides irrigation water for both agricultural and national wildlife refuge lands in the Klamath Basin of south-central Oregon and north-central California, and also provides flood control along the Klamath River in and downstream of the Project area. The Klamath Project is located in the Klamath River and Lost River Basins in southern Oregon and northern California. Prior to development of the Project, agriculture in the surrounding area was limited.

Four watersheds comprise the Project area: the Klamath River watershed, which is the largest, and the Lost River watershed, collectively comprised of the Clear Lake, Malone and Gerber watersheds. Prior to development of the Project, the two major watersheds were linked by a flood channel that allowed water from the Klamath River to enter the Lost River and flow to Tule Lake during high runoff conditions. The two watersheds are still linked, but in a manner that facilitates the use of water by the Klamath Project for domestic, wildlife, and irrigation uses.

The Klamath Project is one of the earliest federal reclamation projects. The Oregon and California legislatures, on January 20 and February 3, 1905, respectively, passed legislation ceding certain lands in Lower Klamath and Tule Lakes to the United States for use by the Klamath Project for project development under provisions of the Reclamation Act of 1902. The Act of February 9, 1905, 33 Stat. 714, authorized the Secretary of the Interior (Secretary) to change the level of several lakes and to dispose of certain lands in the area that were later included in the Klamath Project.

Project construction was authorized by the Secretary on May 15, 1905, in accordance with the Reclamation Act (43 U.S.C. S 372 *et seq*, Act of June 17, 1902, 32 Stat. 388) for project works to drain and reclaim lake bed lands of the Lower Klamath and Tule Lakes, to store water of the Klamath and Lost Rivers, including storage of water in Lower Klamath and Tule Lakes, to divert irrigation supplies, and to control flooding of the reclaimed lands. Under provisions of the Reclamation Act, Project costs were to be repaid through by the beneficiaries on the reclaimed Project lands.

In 1905, Reclamation filed a notice of intent to appropriate all of the then unappropriated waters of the Klamath Basin to support the Project. Reclamation also purchased various water rights and facilities existing prior to the Project. Work on the Project began in 1906 with the construction of the Main or A Canal. In 1907, the California Northeastern Railway Company, by virtue of an agreement with the United States, constructed a railroad line between the Klamath River and Lower Klamath Lake, which also served as a dike to control

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[1] The information presented here was taken from the *Klamath Project Water Rights Data*, dated February 27, 1988, the *Klamath Basin* Report prepared by the Oregon State Water Resources Board, dated June 1971, and personal communication with Bureau of Reclamation, Klamath Project staff.

the Klamath River overflow into Lower Klamath Lake.[2] In addition, the Lower Klamath Lake Wildlife Refuge was established in 1908, the Clear Lake Wildlife Refuge was established in 1911, the Upper Klamath Lake Wildlife Refuge was established in 1928, and the Tule Lake Wildlife Refuge was established in 1928.

Work continued with the construction of Clear Lake Dam in 1910 to hold back flood waters from Tule Lake and provide irrigation to the lands within Langell Valley. Various project facilities were built between 1906 and 1966. Major project facilities include Link River Dam (completed 1921), Clear Lake Dam (completed 1910), and Gerber Dam (completed 1925). Clear Lake and Gerber Dams provide flood protection and irrigation benefits to Lost-River-dependent lands.

The lands formerly inundated by Tule and Lower Klamath Lakes were dewatered as a result of flood control measures and were homesteaded by farmers as late as 1949. The Oregon and California legislation, which relinquished state title to project lands in 1905, and congressional action which directed the project undertaking, provided for disposition of the reclaimed lands in accordance with the 1902 Reclamation Act. Under provisions of the Act, the reclaimed public lands were to be opened for homesteading, subject to charges designed to repay project costs.

The first public lands were homesteaded in March 1917, for 3,250 acres of private lands and 2,700 acres of public lands. The 1917 land opening notice announced a construction charge of $39 per irrigable acre for land already in private ownership and $45 per irrigable acre for unentered public land. Reclaimed lands in the Tule Lake area were opened for homestead entry under 10 different public notices—the first in 1922 and the last in 1948. A total of about 44,000 acres, making up 614 farm units, were homesteaded in the Tule Lake area. The 1922 homestead notice, later recalled, included a construction charge of $90 per irrigable acre. Subsequent land openings in the Tule Lake Division included a construction charge of $88.35 per acre, contingent on the landowners forming an irrigation district to assume joint liability for construction costs.

The Project presently includes approximately 240,000 acres of irrigable lands plus national wildlife refuge lands. The Project has generally provided water to approximately 200,000 acres of agricultural lands per year, with the actual number of irrigated acres varying annually. High irrigation efficiencies are achieved Projectwide because of water reuse within the Project's boundaries. During a normal year, the net use on the Project is approximately 2.0 acre-feet per acre including the water used by the U.S. Fish and Wildlife Service in the Tule Lake and Lower Klamath National Wildlife Refuges.

In 1999, nearly 199,000 acres of crop land were irrigated on the Klamath Project. Gross crop value for 1999 was estimated at over 104 million dollars. Principal crops raised on the

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[2] Agreement dated 10-24-07 between the United States and Southern Pacific Co./California Northeastern Railway Co. The agreement requires the railroads to maintain the railway to serve as a levee and permitted the severance of navigability.

Project include alfalfa, irrigated pasture, small grains, potatoes, onions, sugar beets, and miscellaneous crops. Wildlife benefits derived from Project operations include over 20,000 acres of seasonal and permanent marsh.

Major Project features are:

- Clear Lake Dam and Reservoir located on the Lost River in California
- Gerber Dam and Reservoir located on Miller Creek, a tributary of the Lost River in Oregon
- Malone Diversion Dam on the Lost River downstream from Clear Lake Dam in Oregon
- Lost River Diversion Dam on the Lost River in Oregon that diverts excess water to the Klamath River through the Lost River Diversion channel
- Anderson Rose Dam on the Lost River that diverts water for irrigation of California lands
- Link River Dam on the Link River at the head of the Klamath River regulates flow from Upper Klamath Lake into the Klamath River, and water diverted from Upper Klamath Lake provides the majority of irrigation supplies for the Project lands
- Tule Lake tunnel that conveys drainage water from Tule Lake to Lower Klamath Lake

The Project is operated so that flows of the Lost River and Klamath River are completely controlled except in some flood periods. Water that is diverted for use within the Project is reused several times before it returns to the Klamath River. The Project was designed based on this reuse of water.

It is important to note that the Klamath River Basin Compact (Compact) recognizes that the Lost River has been made a tributary to the Klamath River via the Project operation (see Klamath River Basin Compact, Article II—Definition of Terms[3]). The Compact was ratified by both California and Oregon and consented to by the United States (August 30, 1957; 71 Stat. 497). The stated purposes of the Compact are:

> *A. To facilitate and promote the orderly, integrated and comprehensive development, use, conservation and control thereof for various purposes, including, among others: the use of water for domestic purposes; the development of lands by irrigation and other means; the protection and enhancement of fish, wildlife and recreational resources; the use of water for industrial purposes and hydroelectric power production; and the use and control of water for navigation and flood prevention.*

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[3] Congress consented to the negotiation of the Klamath River Basin Compact (between the States of Oregon and California) by the Act of August 9, 1955, 69 Stat. 613 and to the Compact itself by the Act of August 30, 1957, Public Law 85-222, 71 Stat. 497.

> *B. To further intergovernmental cooperation and comity with respect to these resources and programs for their use and development and to remove causes of present and future controversies by providing (1) for equitable distribution and use of water among the two states and the Federal Government, (2) for preferential rights to the use of water after the effective date of this compact for the anticipated ultimate requirements for domestic and irrigation purposes in the Upper Klamath River Basin in Oregon and California, and (3) for prescribed relationship between beneficial uses of water as a practical means of accomplishing such distribution and use.*

Among other items, the Compact set relative priorities to the use of water that postdates the Compact. These priorities are:

1. Domestic use
2. Irrigation use
3. Recreational use, including use for fish and wildlife
4. Industrial use
5. Generation of hydroelectric power
6. Such other uses as are recognized under the laws of the state involved

Project Water Supply

Precipitation in the project area occurs mainly during the winter months, developing a snow pack that provides most of the water available for the Klamath Project and surrounding areas when it melts in the spring. A portion of the runoff is retained in Project reservoirs for release later during the summer. Two main sources water supply the Project. One consists of Upper Klamath Lake and the Klamath River. The other consists of Clear Lake, Gerber Reservoir, and Lost River. One additional source is Agency Lake Ranch, acquired by Reclamation in 1998, ". . . to make water available to all users in the Klamath Basin" (House Appropriation Committee 1998). Water is diverted from Sevenmile Creek onto the ranch for storage and release when needed.

Public Lease Lands

As Tule Lake receded, reclaimed lands were leased for farming before opening to homesteading. The practice of leasing served to develop and improve the land during construction of irrigation and drainage facilities to serve farm units and permit homestead entry. To protect developed homestead lands from flooding, areas at lower elevations were designated as sump areas and reserved for flood control and drainage. Some of the marginal sump acreage subject to less frequent flooding was made available for leasing, but retained in federal ownership. In addition to providing flood control, the reserved sump areas also preserved existing marsh habitat, which has been included within the basin's national wildlife refuges.

The Klamath Project currently administers federal lease contracts with about 80 farmers for crop production on over 23,000 acres of lands within Tule Lake and Lower Klamath

National Wildlife Refuge. The Kuchel Act (P.L. 88-567) specifies that these lands be leased to farmers to the extent consistent with the primary purposes of the refuges. Gross annual revenue from these leases is approximately $1.5 million. These lands are the most productive lands in the Klamath Basin and represent 10 percent of the land base receiving Project water.

Contracts are issued for 5 to 8 years but require annual renewal. The renewal and bidding for the federal leases occur from December through February to allow farmers to plan their crops, arrange financing, and order materials and equipment.

Hydroelectric Power

By contract executed in 1917, the United States authorized California-Oregon Power Company (now PacifiCorp) to construct Link River Dam. The dam, deeded to the United States, is operated and maintained by the power company in accordance with the contract. Under the contract, Reclamation directs operation of Link River Dam as necessary to meet Reclamation obligations under the Endangered Species Act (ESA), to protect tribal trust resources, and pursuant to contracts for agricultural water delivery and to wildlife refuges. Water users of the Klamath Project are provided for as preference power customers under the contract. The original contract was amended in 1956 and extended for a 50-year period. Pursuant to a 1956 contract with Reclamation, PacifiCorp operates Link River Dam. PacifiCorp independently operates several privately owned dams downstream of the project for hydroelectric power generation. These projects are operated under a Federal Energy Regulatory Commission (FERC) license, Proj. No. 2082. That license contains a schedule of minimum flows in the Klamath River below Iron Gate Dam. Relicensing of the power project by FERC is scheduled for 2006. The contract is also open for renegotiation at that time.

PROJECT FEATURES AND FACILITIES

Link River Dam and Upper Klamath Lake

General Description

Link River Dam regulates Upper Klamath Lake and is operated pursuant to contract with PacifiCorp (see p. 9, *Hydroelectric Power*). The contract gives the power company considerable latitude in operating the lake so long as all of Reclamation's obligations are met. If necessary, Reclamation reserves the right to operate the lake to meet its obligations. Releases during average years are dictated by the needs of PacifiCorp, which must balance flood control with water availability. During drought periods, such as a period in 1991, flows at critical points are monitored continuously. Reclamation provides the power company irrigation diversion requirements and minimum lake levels and flows below Keno and Iron Gate and the power company adjusts the outflow at Link River Dam to balance the system.

There are no fish screens on the outflow from Link River Dam; however, a fish ladder was constructed in 1926 and is functioning. Reclamation owns the dam, and the power company owns two power canals that carry water from the lake to two small powerplants on either side of the Link River.

The lake itself is highly eutrophic with considerable concentrations of blue-green algae during the summer months. Documented fish kills have occurred on the lake, but have not been tied directly to low water years.

Statistical Information

Location:	Section 30, Township 38 South, Range 9 East, WM
Type of Dam:	Concrete—reinforced concrete slab
Year Constructed:	1921
Spillway Crest Elevation:	4145.0 feet
Total Usable Storage Capacity:	486,830 acre-feet
Inactive Storage:	125,000 acre-feet
Dead Storage:	17,950 acre-feet
Maximum Surface Area:	77,593 acres
Shoreline Length:	98 miles
Watershed Area:	3,800 square miles
Average Annual Inflow:	1.3 million acre-feet
Operator:	PacifiCorp, pursuant to Contract No. 14-06-200-5075

Gerber Dam and Reservoir

General Description

Gerber Dam impounds the waters of upper Miller Creek to form Gerber Reservoir. Prior to the construction of the dam, no reservoir existed and Miller Creek ran dry from June to October in most years. Water is stored for irrigation of lands within Langell Valley Irrigation District (LVID) and flood protection of the Tule Lake lands.

Statistical Information

Location: Section 12, Township 39 South, Range 13 East, WM
Type of Dam: Concrete thin arch
Year Constructed: 1925
Spillway Crest Elevation: 4835.4 feet
Total Usable Storage Capacity: 94,300 acre-feet
Dead Storage: None
Maximum Surface Area: 3,830 acres at maximum storage
Shoreline Length: 17 miles
Watershed Area: 230 square miles
Average Annual Inflow: 55,000 acre-feet
Outflow: Normal irrigation release = 120 cubic feet per second (cfs)
Normal maximum irrigation release = 170 cfs
Yield: Firm annual yield = 25,000 acre-feet
Operator: LVID under purchase order pursuant to Reclamation supervision

Clear Lake Dam and Reservoir

General Description

Clear Lake Dam and Reservoir are used to store seasonal runoff to meet later irrigation needs of the Project, principally the Langell Valley Irrigation District and Horsefly Irrigation District (HID), and reduce high flows to limit runoff into the Tule Lake area. Prior to the construction of the dam, a natural lake and marsh/meadow existed above the damsite. The meadow was seasonally farmed by the Carr Livestock Company. During most years, the Lost River below the present dam ran dry from June through October.

Statistical Information

Location: Section 8, Township 47 North, Range 8 East, MDM
Type of Dam: Earth and rockfill
Year Constructed: 1910

Spillway Crest Elevation: 4543.0 feet
Total Usable Storage Capacity: 527,000 acre-feet[4]
Dead Storage: Affected by silt[4]
Maximum Surface Area: 25,760 acres at maximum storage
Watershed Area: 1,707 square miles
Average Annual Inflow: 117,000 acre-feet
Outflow: Normal irrigation release = 120 cfs
Normal maximum irrigation release = 170 cfs
Firm Annual Yield: 11,000 acre-feet
Operator: LVID under Purchase Order pursuant to Reclamation supervision.

Wilson Diversion Dam and Reservoir (Lost River Diversion Dam)

General Description

Wilson Diversion Dam is located approximately eight miles southeast of Klamath Falls on the Lost River. The purpose of the dam is to divert water from the Lost River into the Klamath River for irrigation and flood control for the Tule Lake reclaimed lands.

Statistical Information

Location: Section 29, Township 39 South, Range 10 East, WM
Type of Dam: Concrete multiple arch with earth embankment wings
Year Constructed: 1912
Spillway Crest Elevation: 4094.5 feet
Total Usable Storage Capacity: 2,300 acre-feet
Maximum Surface Area: 340 acres
Shoreline Length: N/A
Watershed Area: N/A
Average Annual Inflow: Dependent on Lost River flows
Maximum Outflow Diversion Channel: 3,000 cfs
Yield: N/A
Operator: Reclamation

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[4] Experience gained by the Project during the 1991 irrigation season indicate that considerable silting of the approach channel to the outlet works has occurred. As a result the available capacity of the reservoir has been diminished, possibly as much as 60,000 acre-feet. It has proved to be impracticable to release water when the lake elevation dropped below 4523.0.

Lost River Diversion Channel

General Description

The Diversion Channel begins at Wilson Diversion Dam and travels in a westerly direction, terminating at the Klamath River. The channel is capable of carrying 3,000 cfs to the Klamath River from the Lost River system. The channel is designed so that water can flow in either direction, depending on operational requirements. During the irrigation season, the predominant direction of flow is from the Klamath River. Miller Hill Pumping Plant is located on the channel along with the Station 48 drop to the Lost River system.

Statistical Information

Location:	Begins in Section 29, Township 39 South, Range 10 East, WM Ends in Section 17, Township 39 South, Range 9 East, WM
Type:	Earthen channel
Year Constructed:	1912 and later enlarged (the last time in 1948)
Length:	8 miles
Average Annual Inflow:	Dependent on Lost River flows
Maximum Capacity Diversion Channel:	3,000 cfs
Operator:	Reclamation

P Canal System

General Description

The P Canal system, consisting of the Tule Lake Tunnel and the P, P-1, and P-1-a Canals, conveys the water discharged from the Tunnel to multipurpose sumps located within the Lower Klamath National Wildlife Refuge. In addition, water is conveyed to federal leased lands in the lower Klamath area and to private land owners under surplus water rental agreements.

Statistical Information

Location:	Begins in Section 11, Township 47 North, Range 3 East, MDM
Type:	Unlined earth channel
Length:	15 miles
Year Constructed:	1942
Width:	Up to 25 feet
Depth:	Varies from 0 to 5 feet

Outflow:	P-1 maximum flow = 250 cfs P maximum flow = 150 cfs P-1-a maximum flow = 50 cfs
Operator:	Reclamation

Klamath Straits Drain and Pumping Plants E, EE, F, and FF

General Description

The Klamath Straits Drain begins at the Oregon-California border and proceeds north to the Klamath River. The water is relifted twice by pumps (initially at pumping plants E and EE, then at pumping plants F and FF) and is then released to the Klamath River. The Straits Drain is in the Lower Klamath National Wildlife Refuge, which in turn receives drainage water from the Tule Lake National Wildlife Refuge. An environmental impact statement was prepared on this enlargement.

Statistical Information

Location:	Begins in Section 17, Township 48 North, Range 2 East, DM Ends in Section 15 Township 40 South, Range 8 East, WM
Type:	Earth channel with relift pumping stations
Length:	8.5 miles
Year Constructed:	1941
Width:	60 feet
Depth:	4-6 feet
Maximum flow:	600 cfs
Operator:	Reclamation

Ady Canal Headworks (Southern Pacific Railroad Crossing—Ady)

General Description

The Southern Pacific Railroad constructed the headworks structure and dike, in cooperation with Reclamation, to control the flow of water from the Klamath River into the Klamath Straits. The Ady Canal was later constructed by Klamath Drainage District to serve lands within the District and later enlarged to serve water to the Lower Klamath National Wildlife Refuge. The current location of the gates in the railroad and structure constructed by the District control the flow of water in the Ady Canal system.

Statistical Information

Location:	Section 15, Township 40 South, Range 8 East, WM
Type:	Concrete box culvert with slide gates and stoplogs

Year Constructed:	1912
Maximum Flow:	Unknown
Irrigation Flow	250 cfs
Operator:	Reclamation

Malone Diversion Dam

General Description

Malone Diversion Dam is located approximately 11 miles below Clear Lake Dam on the Lost River. The purpose of the dam is to divert water released from Clear Lake into the West Canal and the East Malone Lateral for irrigation in the Langell Valley Irrigation District.

Statistical Information

Location:	Section 18, Township 41 South, Range 14 East, WM
Type of Dam:	Earth embankment wing with a concrete gate structure
Year Constructed:	1923
Spillway Crest Elevation:	4,158 feet
Total Usable Storage:	500 acre-feet (est.)
Maximum Surface Area:	N/A
Watershed Area:	N/A
Inflow:	Dependent on releases from Clear Lake
Outflow:	Normal irrigation release West Canal = 130 cfs Normal irrigation release East Canal = 30 cfs
Yield:	N/A
Operator:	Operated by LVID pursuant to Bureau supervision.

Anderson-Rose Diversion Dam (J Canal Headworks)

General Description

Reclamation constructed Anderson-Rose Dam to provide the necessary forebay for the J Canal headworks, which is located on the left abutment of the dam. The J Canal is the main distribution canal for the Tulelake Irrigation District (TID). The dam has two outlet gates into the Lost River. The dam is located on the Lost River in Oregon.

Statistical Information

Location:	Section 7, Township 41 South, Range 11 East, WM
Type of Dam:	Reinforced concrete slab and buttress, a concrete overflow spillway and gate structure
Year Constructed:	1921

Spillway Crest Elevation:	Height = 12 feet; length = 204 feet
Total Usable Storage Capacity:	N/A
Maximum Surface Area:	N/A
Watershed Area:	N/A
Average Annual Inflow:	Dependent on releases from Station 48 and irrigation return flows
Maximum Diversion:	800 cfs
Yield:	N/A
Operator:	Operated by TID pursuant to a contract with Reclamation

A Canal

General Description

The A Canal (formerly Main Canal) was the first irrigation facility completed on the Klamath Project. The canal supplies irrigation water, either directly or indirectly through return flows, to the majority of the Project. The headworks for the canal are located on Upper Klamath Lake west of the City of Klamath Falls.

Statistical Information

Location:	Begins in Section 30, Township 38 South, Range 9 East, WM Ends in Section 19 Township 39 South, Range 10 East, WM
Type:	Earth channel with lined sections
Length:	9 miles
Year Constructed:	1905
Width:	60 feet
Depth:	8 feet
Maximum flow:	1,150 cfs
Operator:	Klamath Irrigation District under contract with Reclamation

North Canal (Langell Valley Irrigation District)

General Description

A small diversion structure is located on Miller Creek approximately 6 miles below Gerber Dam. This structure diverts water released from Gerber during the irrigation season into the North Canal. No water is released to Miller Creek below the structure; however, return flows from irrigation of adjacent lands provide some inflow. The North Canal carries irrigation water to lands within LVID.

During the nonirrigation season, stoplogs in the structure are removed, allowing free passage of flow down Miller Creek.

Statistical Information

Location:	Begins in Section 5, Township 40 South, Range 14 East, WM Ends in Section 32 Township 39 South, Range 12 East, WM
Type:	Earth channel
Length:	6 miles
Year Constructed:	1918
Width:	20 feet
Depth:	4 feet
Maximum flow:	200± cfs
Operator:	Langell Valley Irrigation District under contract with Reclamation

West Canal (Langell Valley Irrigation District)

General Description

The West Canal headworks are located at Malone Dam on the Lost River approximately 10 miles below Clear Lake. Water is released at Clear Lake and then diverted by Malone into the canal. The West Canal supplies irrigation water to over 17,000 acres of land located in HID and LVID.

Statistical Information

Location:	Begins in Section 18, Township 41 South, Range 14 East, WM Ends in Section 32 Township 39 South, Range 12 East, WM
Type:	Earth channel
Length:	10 miles
Year Constructed:	1918
Width:	20 feet
Depth:	4 feet
Maximum flow:	200± cfs
Operator:	Langell Valley Irrigation District under contract with Reclamation

Miller Hill Pumping Plant (Lost River Diversion Channel)

General Description

Miller Hill Pumping Plant has three 35-cfs units that lift water from the Diversion Channel into the C-4-E Lateral (see *Lost River Diversion Channel*, p. 14) for irrigation use.

Statistical Information

Location:	Located in Section 27, Township 39 South, Range 9 East, WM
Type:	Concrete base interior design pumps

Year Constructed: 1941
Maximum flow: 105 cfs
Operator: Klamath Irrigation District pursuant to a contract with Reclamation

Station 48 Turnout (Lost River Diversion Channel)

General Description

Station 48 is a turnout located on the south bank of the Lost River Diversion Channel. The discharge from the turnout enters a short channel and then enters the Lost River. The turnout is operated by radio telemetry from the TID Headquarters.

Statistical Information

Location: Located in Section 30, Township 39 South, Range 10 East, WM
Type: Concrete box culvert w/slide gates
Year Constructed: 1948
Maximum flow: 550 cfs
Operator: Tulelake Irrigation District pursuant to a Purchase Order issued by Reclamation

Pumping Plant D (Tule Lake Sumps)

General Description

Pumping Plant D removes excess water from the Tule Lake Sumps and discharges it into the P Canal System. This is the only outlet point from the sump area. The low speed turbine type pumps are housed in a concrete building within the Tule Lake National Wildlife Refuge.

The sumps act as a natural collection area for drainage return flows from Project lands. A portion of water is then removed from the sumps and used to irrigate the reserved sump lease lands and wildlife lands within the Refuge and then returned to the sumps by pumping. A considerable area within the sumps has become a marsh due to low water depths caused by siltation.

Statistical Information

Location: Located in Section 27, Township 39 South, Range 9 East, WM
Type: Low speed interior design turbine pumps, five pumps with a combined total of 3,650 horsepower
Year Constructed: 1941, enlarged in 1949
Maximum flow: 300 cfs, total annual pumpage ranges from a low of 50,000 to a high of 143,000 acre-feet; average = 91,000 acre-feet
Operator: Tulelake Irrigation District pursuant to a contract with Reclamation

Sump Area

Location:	Located in Township 47 North, Ranges 4 & 5 East, MDM
Construction:	Earthen dikes surround the sump
Maximum Surface Area:	12,500 acres
Maximum Safe Water Surface Elev.:	4035.5 feet
Total Usable Storage Capacity:	Approximately 54,000 acre-feet
Depth:	Approximately 4 feet
Operator:	Tulelake Irrigation District pursuant to a contract with Reclamation

Minor Laterals

General Description

Reclamation constructed numerous small laterals beginning in 1905. They provide irrigation service to agricultural lands. Very little water is diverted directly from the main canal systems on the Project. Small laterals deliver approximately 95 percent of the water to farms. The laterals range in depth from 1 foot to over 5 feet, and in width from 2 feet to over 20 feet.

Statistical Information

Location:	Throughout Klamath Project Area
Type:	Earth channel (some are concrete lined)
Length:	680 miles
Year Constructed:	1905 to present
Width:	Varies
Depth:	Varies
Maximum flow:	0 to 250 cfs
Operator:	Reclamation, various irrigation districts, and U.S. Fish and Wildlife Service, pursuant to contracts and agreements with Reclamation

Minor Drains

General Description

Reclamation constructed hundreds of small drains beginning in 1905. They provide drainage to agricultural lands that receive irrigation water from Project facilities. The drains range in depth from a few feet below the land surface to over 10 feet. In most cases, water remains in the drains year round. The terminus of most drains is in either the Lost River or the Klamath River.

Statistical Information

Location: Throughout Klamath Project Area
Type: Earth channel
Length: 728 miles
Year Constructed: 1905 to present
Width: Varies
Depth: Varies
Maximum flow: 0 to 300 cfs
Operator: Reclamation, various irrigation districts, and U.S. Fish and Wildlife Service, pursuant to contracts and agreements with Reclamation

Pumping Plants (General)

General Description

Numerous small pumping plants on the Klamath Project elift irrigation water and drainage flows. These plants are generally less than 10 cfs and are located throughout the Project. They are all electrically operated and in some cases, are automatic. They range from low head slow revolution to high speed turbine pumps. Most, if not all, have trashracks associated with them that must be cleaned periodically. Districts operate some of the pumps, but individuals operate most of them for their farming operations.

Statistical Information

Location: Throughout the Klamath Project
Type: Varies
Year Constructed: Beginning in 1906
Maximum flow: Maximum Flow = 1 to 100 cfs
Operator: Reclamation, numerous irrigation and drainage districts, and individuals, pursuant to contracts and agreements with Reclamation

Direct Farm Deliveries (Water-User-Operated Facilities)

The U.S. Fish and Wildlife Service operates the Lower Klamath and Tule Lake National Wildlife Refuges. The Service makes decisions throughout the year regarding operation and management of marshlands and farmlands on the refuges. These decisions may affect Klamath Project operations and are coordinated with Reclamation.

Refuge Operations (Project Lease Lands)

General Description

Operations of the Lower Klamath and Tule Lake National Wildlife Refuges are integral with the operations of the Klamath Project. The U.S. Fish and Wildlife Service makes decisions during the year as to management of marshlands and farmlands. These decisions have an impact upon the Reclamation operations.

Klamath Project Lease Areas

The Klamath Project is responsible for leasing over 23,000 acres of farmland to individuals residing mostly in the Klamath Basin. These leases generated approximately $1.5 million in annual gross revenue in recent years. The Kuchel Act (PL 88-567) governs the leasing of these lands. The Act states in part:

> ***Sec. 4.*** *The Secretary shall, consistent with proper water fowl management, continue the present pattern of leasing the reserved lands of the Klamath Straits unit, the Southwest Sump, the League of Nations unit, the Henzel lease, and the Frog Pond unit, all within the executive order boundaries of the lower Klamath and Tule Lake National Wildlife Refuges . . . . Leases for these lands shall be at a price or prices designed to obtain the maximum lease revenues. These leases shall provide for the growing of grain forage, and soil building crops . . .(78 Stat. 851; 16 U.S.C. § 695n)*

HISTORIC OPERATION

The Klamath Project stores water in Upper Klamath Lake (Klamath River system) and in Gerber Reservoir and Clear Lake (Lost River system). The distribution system delivers water via a system of canals to lands in the Langell Valley, Poe Valley, Klamath Irrigation District, Tule Lake area, and Lower Klamath Lake area. The primary diversion points include Malone and Miller Diversion Dams in the Langell Valley; the Lost River Diversion Dam and Channel, controlling diversions into and out of the Klamath River; the A Canal diversion works on Upper Klamath Lake, controlling water to the Klamath Irrigation District as well as the Poe Valley and the Tule Lake area; the Anderson-Rose Diversion Dam, on the Lost River, which also diverts to the Tule Lake area; and the Ady Canal, which diverts water from the Klamath River into the Lower Klamath Lake area. In addition, Project irrigators divert directly from both the river systems and Upper Klamath Lake. Figure 2 on page 3 shows the Klamath Project with its features.

Typical water delivery operations of the Project begin in late fall, when the Ady and North Canals are used to deliver water from the Klamath River to lands throughout the Lower Klamath Lake area. This water is used to flood irrigate private, federal lease, and Lower Klamath National Wildlife Refuge lands. The drain water from these lands is returned to the river via the Straits Drain. Winter flooding is the primary irrigation pattern for these lands. Irrigation and refuge water deliveries, however, continue throughout the year. Diversions range from a low during the summer months of 100 cfs to a high of 500 cfs during the late fall and winter.

In March or early April, the A Canal diversions from Upper Klamath Lake begin. Flows generally begin at about 500 cfs to charge the canal system, with a gradual increase to a peak of near 1,000 cfs in May or June. This diversion serves the largest area and delivers the most water of any Project feature. Water deliveries typically continue into October. Drainage water from this service area returns to the Klamath River via the Lost River Diversion Channel and it also flows into the Lost River for reuse by other districts and the Tule Lake National Wildlife Refuge.

Diversions at Miller and Malone Diversion Dams generally begin in April with flows of about 200 cfs. Flows reach a peak of about 400 cfs and generally end in October. These diversions serve about 30,000 acres in the Langell Valley. Drainage water from this system returns to the Lost River.

Diversions at Anderson-Rose generally begin in mid-March with flows of 200 cfs. Flows reach a peak of about 450 cfs and end in October. Anderson-Rose diversions serve the Tule Lake area. All the drainage flows enter the Tule Lake sump.

The Tule Lake National Wildlife Refuge receives water from the Tule Lake area and from the Lost River. Since the Lost River is in a naturally closed basin, Reclamation has constructed a pump and tunnel system (pump "D") from Tule Lake to Lower Klamath National Wildlife Refuge. Return flows from irrigation accrue to Tule Lake and are reused for irrigation before the water is ultimately passed through the pump system and to the Lower Klamath Lake area, where it is used on agricultural and refuge lands. Finally, the water is returned to the Klamath River via the Straits Drain.

In an average year, Gerber Dam, the source of water for Miller Diversion Dam, releases about 40,000 acre-feet of irrigation water. Clear Lake releases, during an average year, will be about 36,000 acre-feet. In an average year, Upper Klamath Lake is operated to stay within a set of guidelines that provide for irrigation storage, flood protection, ESA needs, and Tribal trusts. All water that is not needed to regulate within these guidelines is released to the Klamath River. During an average year, the Klamath River release is over 900,000 acre-feet. In addition, the Klamath Project uses 350,000 to 450,000 acre-feet for irrigation and refuge operations.

Link River Dam and Upper Klamath Lake

PacifiCorp operates Link River Dam by following the flood control envelope in figure 3 during the spring run-off period. During wet years, PacifiCorp follows the lower elevation of the envelope, and during low runoff periods, the high elevation. During the drawdown phase of operations, Reclamation directs the power company to meet downstream needs, irrigation requirements, and power demands, as well as maintain a sufficient carryover storage.

Gerber Dam and Reservoir

The outlet at Gerber is opened on approximately April 15 to provide irrigation water to the LVID lands. The outlets are normally shut off on October 1. To prevent freezing of the outlet valves during the winter, approximately 1 cfs is bypassed and released into the Miller Creek channel. The bypass usually begins in November and continues to the beginning of the irrigation season.

During the irrigation season, the outlets are operated on demand of LVID. Maximum flows recently experienced are in the 170-cfs range. LVID operates the dam during the irrigation season under a Purchase Order type agreement with Reclamation. During the fall and winter, Reclamation operates the dam. During the spring, the dam is operated to provide the maximum amount of storage possible and still provide flood protection to the Tule Lake lands. There is no attendant at the dam during the year; however, experience shows that the dam is visited by the district at least twice a week to make gate changes and record readings. Studies completed by Reclamation[5] indicate that with a recurrence of the 1924-34 drought, deficiencies approaching 80 to 95 percent would occur. During the 1991 irrigation season, the reservoir release was stopped in early July due to the lack of inflow that spring.

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[5] Upper Lost River Division, Concluding report on possibilities for water resource development and a supplemental water supply for Langell Valley, Bureau of Reclamation, June 1972

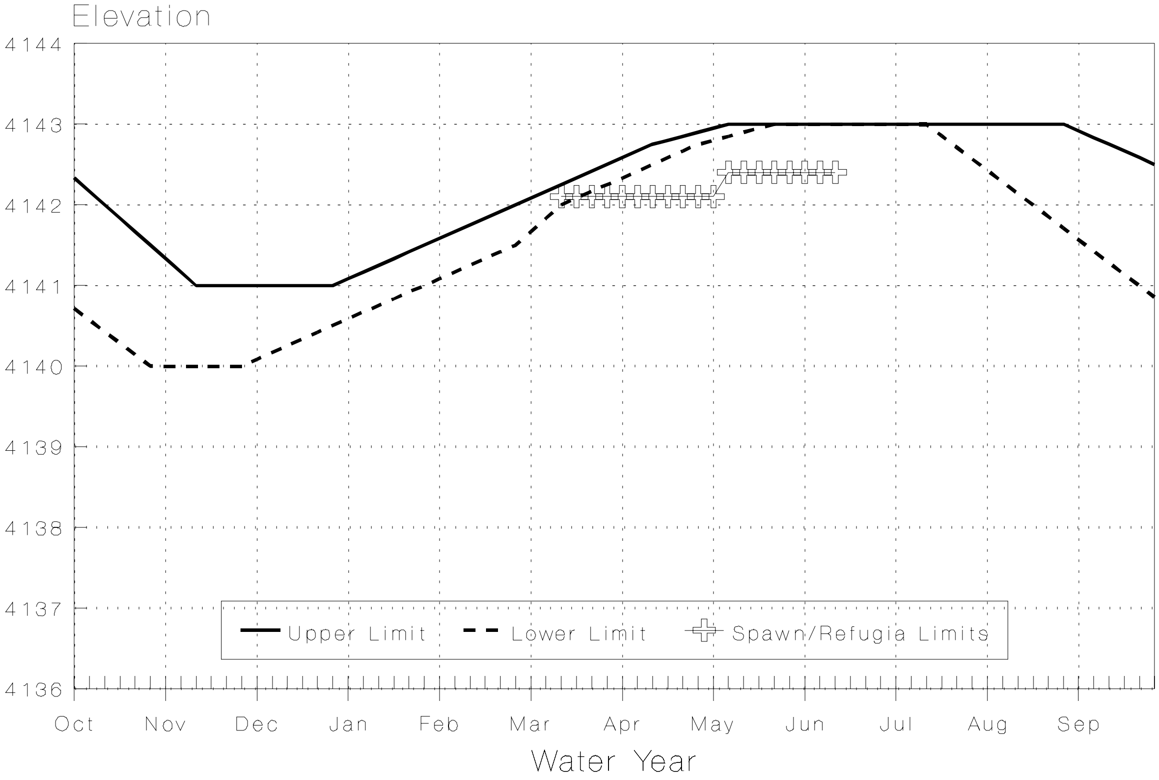

Figure 3.—Upper Klamath Lake operational envelope.

Reclamation surveyed the entire Gerber watershed in 1970 to summarize available data on the use of water above the dam[6].

Clear Lake Dam and Reservoir

The outlet at Clear Lake is opened, usually around April 15, to provide irrigation water to LVID, HID and private "Warren Act" contract lands. In most years, the outlets are closed around October 1. No other releases are made from the dam unless an emergency condition dictates otherwise. Since the reservoir has a storage limitation of 350,000 acre-feet from October 1 through March 1, occasional summer releases are necessary.

A purchase order is issued each year that permits LVID to operate the dam on a reimbursable basis. LVID operates the gates and reports the changes to Reclamation daily. Flow changes are dictated by the needs of HID and LVID and the private users along Lost River. During the nonirrigation season, Reclamation operates the dam and reservoir. The

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[6] Klamath Project, Gerber Watershed Report, Bureau of Reclamation, Water Rights Engineering Branch-Sacramento, April 1970

reservoir is managed to store as much water as possible without encroaching on the operational guidelines. Clear Lake Dam is currently under consideration for reconstruction because of safety deficiencies. Until that is complete, storage restrictions are in place that allow for the safe operation of the dam. Reconstruction of the dam is expected to be completed in 2 years. During the interim, the elevation of the reservoir determines visits to the damsite. At higher elevations, more frequent visits are necessary, as often as every day.

During 1970, a careful review and survey of all the water impoundments above the dam was made. This report[7] gave pertinent facts about private and federal storage dams and induced high water irrigation techniques.

The June 1994 Biological Opinion requires that Clear Lake reservoir be operated to ensure an elevation of 4521.0 feet on October 1 of each year, as specified in Reclamation's biological assessment dated January 20, 1994. As a result, Project water cannot be delivered in some years.

Wilson Diversion Dam and Reservoir (Lost River Diversion Dam)

The dam is operated primarily as a diversion dam, diverting Lost River flows into the Lost River Diversion Channel and thence to the Klamath River. During the irrigation season, the water surface behind the dam is raised slightly to facilitate irrigation pumping from the reservoir. During the winter and spring, the reservoir is lowered to provide a cushion for high flow conditions. The dam is able to divert a maximum of 3,000 cfs of Lost River flows into the Diversion Channel and must spill any flows above that amount into the Lost River below the dam. The dam is equipped with automatic gates that maintain a constant lake elevation.

Lost River Diversion Channel

During the fall, winter, and spring, the channel is operated so that all of the water that enters from the Lost River is bypassed to the Klamath River. During periods when the flow is in excess of 3,000 cfs, water is bypassed into the Lost River. During the spring of most years, it is necessary to import water from the Klamath River to the Lost River for early irrigation in the Tule Lake area. During the summer months, the channel is operated as a forebay for the Miller Hill Pumping Plants (see below) and the Station 48 turnout (see below). Depending on the needs of these two irrigation diversions, water that is not able to come from the Lost River must come from the Klamath River.

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[7] Klamath Project, Clear Lake Watershed Report, Water Rights Engineering Branch-Sacramento, June 1970

If necessary, Reclamation can isolate the diversion channel from both the Lost River and the Klamath River for emergency and maintenance activities. During normal operations, water levels in the channel are maintained at or near the levels in the Klamath River.

P Canal System

This system is operated to transport water to and through the Lower Klamath Refuge. Pumping Plant D removes water from the Tule Lake Sump and discharges into the Tule Lake Tunnel. The water is then used by individuals or the Refuge, or discharged to the Klamath Straits Drain and thence to the Klamath River. On occasion, Pumping Plant D is not pumping in order to maintain objective levels in the sump. During these periods, "Special Pumping" is allowed so that water users, including the refuge, in the Lower Klamath Lake area can get water.

Klamath Straits Drain and Pumping Plants E, EE, F, and FF

The Klamath Straits Drain is operated at levels that will provide adequate drainage to both private lands and refuge lands. The pumps are operated to meet the flow conditions within the drain. Water quality conditions are monitored continuously near the outlet of the channel to the Klamath River.

Ady Canal Headworks (Southern Pacific Railroad Crossing—Ady)

Gates at the railroad are left in the open position all the time. Flow through the structure is controlled by the district's automatic gates located downstream. The Ady Canal delivers water to the Lower Klamath Lake National Wildlife Refuge, in addition to private lands.

Malone Diversion Dam

When LVID begins receiving orders for irrigation deliveries from areas served by the West Canal and the East Malone Lateral, they lower the radial gates and begin to fill the reservoir. The reservoir water surface is maintained at or near 10.0 feet above the gate sill. The West and East Malone Canals are regulated at the dam. At the end of the irrigation season, the radial gates are raised to allow for passage of flood waters during the winter and spring. During some years, it is necessary to bypass flows to the Lost River through the dam.

Anderson-Rose Diversion Dam (J Canal Headworks)

During the irrigation season, the elevation of the Lost River is maintained at or very near the spillway crest. This provides for a maximum head for the J Canal intake structure. Releases are carefully controlled from Station 48, located approximately 10 miles above the dam, via telemetry. These releases are coordinated with return flows accruing to the Lost River and irrigation demands of TID (J Canal) to minimize potential spills below the dam. Occasionally, operational spills do occur because of the time lag between Station 48 and the dam, and the fact that returns to the river are not premeasured.

Anderson-Rose Dam diverts water for Tulelake Irrigation District, with an average of 135,000 acre-feet per year diverted to the J Canal. Other sources of inflow to TID include return flows from several irrigation districts. Water in the system is eventually diverted onto individual farm units, either privately owned land or leased land within the Tule Lake National Wildlife Refuge (16,925 acres of irrigated land lie within the refuge). There are currently 37 pumping plants with a total of 69 pumps within TID. Capacities of these pumps range from 2 to 300 cfs. Irrigation in the district normally starts around March 1 and continues through mid-November. Return flows from fields eventually flow to the Tulelake Sumps. Annual average operations of TID are:

• Station 48 to the Lost River	60,000 acre-feet
• Diverted at Anderson Rose Dam	135,000 acre-feet
• Diversions within the system	250,000 acre-feet
• Pumping Plant D volume	100,000 acre-feet

A Canal

The canal is operated on a demand basis. Generally, the canal is charged with water in March or April. Flows average 500 cfs for this charge-up period. Orders for water are placed by irrigators with the watermaster, who then schedules the flow in the canal. At the end of the irrigation season, generally during October, the canal is drained into the Lost River and the Lost River Diversion Channel.

North Canal (Langell Valley Irrigation District)

The canal is operated in response to crop demand, generally beginning in April. At the end of the irrigation season (October), the canal is drained and the water returned to the Lost River. The entire supply of water for this canal comes from Gerber Reservoir.

West Canal (Langell Valley Irrigation District)

The canal is operated in response to crop demand. The entire supply of water for this canal comes from Clear Lake.

Miller Hill Pumping Plant (Lost River Diversion Channel

The pumps are operated on demand of the irrigators who take water from the C-4-e system. The pumps are not used during the nonirrigation season.

Station 48 Turnout (Lost River Diversion Channel)

The Station 48 gates provide the required flow into the Lost River and then into the J Canal located at Anderson-Rose Diversion Dam. TID must estimate the amount of return flows to the Lost River between Station 48 and the headworks of the J Canal and then adjust Station 48 flows to provide for the J Canal needs. If the amount of water released is too high, the excess is spilled into the Lower Lost River below the dam. Gates are normally opened from the first of March until mid-November. From 12 to 36 hours are normally required for water from Station 48 to reach Anderson-Rose Dam. It is difficult to determine the amount of water required at the dam due to unknown quantities of return flow between Station 48 and the dam, and also the time lag between diversions at Station 48 and the dam.

Pumping Plant D (Tule Lake Sumps)

Pumping Plant D is operated to maintain certain objective water levels on the Tule Lake sumps. The sump areas provide flood control, protection of wildlife, and irrigated agriculture. The objective water levels are specified by regulations to facilitate waterfowl production and hunting, and protect the Tule Lake area and the reserved sumps that Reclamation leases for agricultural use. Occasionally, the pumping plant is operated to provide irrigation water to lands dependent upon the P Canal system, including both federal and private lands. Water delivered from the pumping plant is the sole source of irrigation water for some private lands and part of Lower Klamath National Wildlife Refuge. Water levels of the sump areas are kept low during the fall and spring to provide flood protection for private lands.

Considerable maintenance of the pumping plant is required during the operational period. Of particular concern is the need to remove great quantities of weeds that collect on the trashracks in front of the pumps.

Minor Drains

The drains are operated to provide agricultural drainage. Maintenance activities include periodic cleaning of the drains to maintain flows. Some relift pumping plants are located on the drainage system.

Minor Laterals

The laterals are operated by the various districts to provide field deliveries of irrigation water to farmers. Flows are dictated by the requirements of the farmers and the capacities of the laterals. As a rule, the laterals are drained during the nonirrigation season and refilled at the beginning of the season. During the drain-down of the laterals in the fall, water is released to drains and directly to the river systems, depending on location.

Laterals are periodically cleaned of sediment during the nonirrigation portion of the year. During the irrigation season, the laterals and canals are treated with herbicides to suppress the growth of aquatic weeds within the canal prism. This was the subject of a prior consultation with the Fish and Wildlife Service. A biological opinion, entitled *Formal Consultation on the Use of Acrolein in Canal and Drainage Ditches Within the Klamath Project Service Area,* was issued by the Fish and Wildlife Service on June 14, 1989.

Pumping Plants (General)

The pumps are operated on crop demand, to remove drainage water, or to provide irrigation. Some of the pumps are used all year and others only during the irrigation season.

Direct Farm Deliveries (Water-User-Operated Facilities)

Water deliveries are controlled, for the most part, by irrigation districts that have taken over operation and maintenance of project facilities. Scheduling of water deliveries allows the irrigation of all lands in rotation. The farmer orders a specific amount of water in advance of need.

Project Lease Lands

Leases are renewed beginning in December and any leases not renewed or coming up for rebidding are offered beginning in February to area farmers. All leasing arrangements are approved by Reclamation, in consultation with the U.S. Fish and Wildlife Service, prior to being offered.

Operations for Water Year Types

Wet Year Operations

During wetter than normal years, full supplies are available for Klamath River releases below Iron Gate Dam. Klamath Project irrigation needs are also fully met, along with the needs of the refuges. During these periods Gerber typically spills water and Clear Lake stores all inflow, or controlled releases are made to the Lost River. During a high runoff year, Upper Klamath Lake may produce as much as 2.4 million acre-feet of net inflow, most of which could not be stored and would have to be bypassed to the Klamath River.

The primary concern during wetter than normal years is for the protection of lives and property. Facilities are operated to provide for a controlled release of water from the basin. The Lost River is is prone to localized flooding during high runoff periods. A system of dikes in Langell Valley channelizes the flow during these high flow periods.

Water may be bypassed into the lower Lost River (below Wilson Dam) to the sump area in the Tule Lake Refuge when the capacity to send the water to the Klamath River is exceeded.

It was necessary to flood the federal lease lands in the Tule Lake area, thus delaying the farming operations, during the 1964-65 flood. In addition, the Lower Klamath area experienced difficulty in the removal of water in time for the planting of crops.

Average Year Operations

In most average years the Project water users, including the wildlife refuges, receive sufficient water supplies. No restrictions are in place that affect timing or quantity of deliveries. The average year inflow to Upper Klamath is 1.3 million acre-feet. The Project, including the wildlife refuges, consumptively uses approximately 350,000 acre-feet. Supplies of irrigation water in the Lost River system depend upon the carryover storage from the previous year. Average inflow to Lost River reservoirs is insufficient to meet irrigation demand without sufficient carryover storage.

Drought Year Operations

During previous drought years, in order to conserve as much water in Upper Klamath Lake as possible, the Project initiated a variance (i.e., reduced flows to below those set forth by the Federal Energy Regulatory Commission) in the Klamath River below Iron Gate. The variance was issued as soon as irrigation supplies were threatened. The variance not only conserved water for irrigation, but also allowed for later releases of water for fish enhancement in the lower Klamath River.

Water Contracts

The Klamath Project water users obtain their irrigation water supply from Project facilities pursuant to various contracts with Reclamation. Reclamation obtained water rights for the Project in accordance with California and Oregon State law, pursuant to the Reclamation Act of 1902. The priority date for Project water rights is generally 1905, and some rights may date from 1878.

Reclamation entered into numerous contracts pursuant to Article 9(d) of the Reclamation Act of 1904 with various irrigation districts to provide for the repayment of Project costs and the granting of water rights. The contracts specify an acreage to be covered by the water right granted, and in most cases, do not specify an amount of water relying on beneficial use for the amount of water used. The contracts are all written in perpetuity.

In all, over 250 contracts for water service are administered either directly or through irrigation districts on the Klamath Project. Contracts also cover the operation of the facilities that were transferred to the water users for operational responsibility. Irrigation Districts that fall into this category are Klamath Irrigation District, Tule Lake Irrigation District, and the Langell Valley Irrigation District.

In addition to the above, Reclamation entered into numerous contracts that were written pursuant to the Warren Act of 1911. These contracts provided for a water supply at a certain point, with the responsibility of the contractor to construct all the necessary conveyance facilities (i.e., pumps, laterals, and turnouts) and be responsible for their operation and maintenance.

Some of the districts (and their respective contracts, only the most recent of which is listed) that own all or a portion of their privately constructed facilities are:

District Name	Contract Date	Acreage
Van Brimmer Ditch Company	November 6, 1909	3,315
Klamath Basin Improvement District	April 25, 1932	10,403
Enterprise Irrigation District	March 18, 1935	2,981
Malin Irrigation District	May 5, 1936	3,507
Pine Grove irrigation District	June 19, 1936	927
Sunnyside Irrigation District	June 25, 1936	595
Westside Improvement District	October 20, 1936	1,190
Shasta View Irrigation District	August 20, 1938	4,141
Klamath Drainage District	April 28, 1943	19,229
Emmitt District Improvement Company	December 1, 1947	424
Midland District Improvement Company	February 2, 1952	581
Poe Valley Improvement District	July 20, 1953	2,636
Ady District Improvement Company	August 5, 1954	435
Plevna District Improvement Company	February 7, 1958	523
Horsefly Irrigation District	August 24, 1976	9,843
Upper Klamath Lake contractors	Various contract dates	7,918
Individual contracts	Various contract dates	9,960

Nearly all contracts written during the past 85 years on the Klamath Project obligate the United States to the delivery of irrigation water. Clauses in most contracts include language similar to the following example:

> *"The United States shall deliver in the Klamath River at the outlet of Upper Klamath Lake..in all a total of 522.7 irrigable acres, a sufficient quantity of water as may be beneficially used upon said lands...the quantity of water sufficient for the irrigation of said 522.7 acres shall be as determined by the Secretary of the Interior...."*

Appendix C contains more detailed information on contractual relationships.

Temporary Water Contracts

Each year Reclamation determines whether surplus water is available to irrigators (see *Water Supply Forecasting*, p. 36). In many cases, irrigators have been receiving surplus irrigation water from Reclamation for over 50 years. For numerous reasons, these irrigators were never given a permanent contract. Concurrently, the districts also make a determination whether or not to sell surplus water. The irrigable acreage covered by surplus water contracts in 2000 was approximately 5,248 acres.

The irrigable acreage represented by these temporary contracts is less than 2 percent of the total acreage irrigated on the Project. Water is delivered to these lands through the existing irrigation systems. In many cases, the water is delivered and controlled by the irrigation districts.

National Wildlife Refuges

Four national wildlife refuges lie adjacent to or within Klamath Project boundaries – Lower Klamath, Tule Lake, Clear Lake, and Upper Klamath. These refuges were established by Executive Orders dating as early as 1908. The refuges are managed by the U.S. Fish and Wildlife Service under the Migratory Bird Treaty Act, the Refuges Administration Act, the National Wildlife Refuge System Improvement Act, and other laws pertaining to the National Refuge System. These refuges support many fish and wildlife species and provide suitable habitat and resources for migratory birds of the Pacific Flyway. Portions of the refuges are also used for agricultural purposes. The refuges either receive water from or are associated with Project facilities. Reclamation has an obligation to ensure that the refuges receive adequate water to fulfill their federal reserved water rights (i.e., the amount of water necessary to fulfill the primary purposes of the refuges) when in priority and when water is available. In addition, Reclamation can continue to provide available Project water for beneficial reuse by the refuges to the extent of past and current usage and consistent with Project purposes (DOI, 1995). The refuges have federally reserved water rights for the water necessary to satisfy the refuges' primary purposes. In addition, the Lower Klamath and Tule Lake refuges have water rights based on a portion of the Klamath Project water right.

Power Contracts

In 1917, the United States entered into a contract with California Oregon Power Company, now PacifiCorp, under which the power company was given the right to construct Link River Dam at the outlet of Upper Klamath Lake, and the right to use certain amounts of water after the requirements of the Klamath Project were satisfied. The contract was to cease, and title of the dam was to vest in the United States 50 years from the date of execution. The contract was renewed early as a result of the FERC Project 2082 concerning the construction and operation of downstream Klamath dams operated by the power company. The present contract, which will expire in 2006, allows PacifiCorp to operate the dam within certain guidelines (see *Hydroelectric Power*, p. 9 and *Link River Dam and Upper Klamath Lake*, p. 11).

Water Rights Information

Acquired Water Rights

In addition to initiating the appropriative rights procedure in the State of Oregon, the United States acquired some early pre-Project rights to use water by purchase from landowners with prior rights entitlements. The fact that a considerable number of these rights were purchased by the United States indicates that early private development of the basin was well under way at the advent of Reclamation. It was necessary to purchase these rights from the entities involved so that Reclamation had full control of all of the rights to the use of water in the basin to facilitate Project operation.

Appropriation by the United States

On May 19, 1905, a "Notice of Intention to Utilize All Waters of the Klamath Basin" was filed by the Reclamation Service, Predecessor to the Bureau of Reclamation, in the office of the State Engineer of Oregon. It is recorded in "Water Filings" on page 1. This notice was also published in the *Klamath Falls Express* of Klamath Falls, Oregon on June 15, 22, 29, and July 6, 1905.

The Reclamation Service of the United States filed detailed plans and specifications covering the construction of the Klamath Irrigation Project with the State Engineer of Oregon on May 6, 1908, and on May 8, 1909, filed with the State Engineer proof of authorization of the construction of the works therein set forth.

Prior to December 19, 1914, appropriative water rights could be acquired in California by posting and recording a notice stating the nature and quantity of the proposed appropriation and by thereafter exercising due diligence in putting the water to beneficial use. The required postings were made on behalf of the United States.

Adjudication Proceedings

A formal adjudication of a river system establishes in a competent court the relative rights to the use of water within the area that is being adjudicated. Testimony is received from all persons claiming a right and the State makes determinations based on the testimony of the relative priority dates. The Klamath River Basin is in such a process.

The State of Oregon began the adjudication of the Lost River system in 1910. Certificates were issued to individuals who had rights predating the Klamath Project's filings. Since Reclamation was not a party to the adjudication, certificates were not issued to Reclamation or its contractors. The State did, however, set aside 60,000 acres for Reclamation to later claim certificates on.

A number of irrigators above Gerber Dam claimed to have not been notified of the 1918 adjudication. As a result, the State reopened the adjudication process and completed it in 1989. This portion of the adjudication set forth the relative priorities of water use above Gerber Dam.

The Klamath River Basin Adjudication covers all Project lands served by the Klamath River. Other federal entities involved include the National Park Service, U.S. Department of Agriculture, Bureau of Land Management, the U.S. Fish and Wildlife Service, and Bureau of Indian Affairs on behalf of the Klamath Tribes. In 1975, the State of Oregon, through its Water Resources Department (OWRD), initiated the Klamath River Basin adjudication to determine all claims to surface water in the Basin. By 1986, the State of Oregon had completed a considerable amount of work in mapping the places of use within the Project.

In 1990, the OWRD reissued notices of intent to adjudicate the Klamath River Basin, and during 1991, required all persons claiming a right to the use of water from the River to file. The United States did not file, claiming that the adjudication violated the McCarran Amendment which requires that any adjudication involving the United States must be complete and include ground water. In subsequent legal proceedings, the United States lost, and as a result, all claims were to be filed with the State in April 1997 for both use and storage. Open inspection of claims was extended through March 2000. In May 2000, several thousand contests were filed on individual claimants and the State's Preliminary Evaluations of Claims.

Concurrent with the Klamath adjudication, the State of Oregon has begun an Alternative Dispute Resolution (ADR) process in an attempt to resolve as many water rights issues in the adjudication as possible to avoid litigation by various claimants. The U.S. has participated in the ADR process from its beginning, along with the Klamath Tribes, various individuals, and the Klamath Project water users. Meetings are held monthly. The ADR process may help solve disputes; however, difficult issues remain to be resolved.

The State of Oregon has proposed a broad settlement framework that is being considered by the Administrative Subcommittee of the ADR Group. In addition, the Klamath Tribes and project irrigators have negotiated a framework settlement agreement which is under review by various parties to the ADR. The Klamath Tribes have also presented a settlement proposal on the tributary area above Upper Klamath Lake. Several technical teams have been formed to deal with specific ADR issues. Reclamation actively participates on the Hydrology Technical Committee.

More detailed information on existing water rights can be found in appendix C.

Water Supply Forecasting

Each year, the Klamath Project forecasts available water supplies, beginning in January. Information such as watershed conditions, carryover storage, NRCS forecasts, projected water use for both irrigation and wildlife use, and other available data for varied sources are used by Klamath Project personnel to forecast the condition of Project systems during the ensuing year. The forecast and water supply declaration have been presented in annual operations plans since 1995.

The annual operation plan is presented to the water user community as soon as practicable, usually in early May. The plan delineates how much water is available to meet the demands that may be placed upon the Project.

Chronology of Key Events (1961 to 2000) Relevant to Project Operation

1961	Klamath Project facilities completed and fully operational. Reclamation operates the Project to meet its authorized purposes, in accordance with State law, the annual forecast/availability of water and contractual obligations with Project water users and PacifiCorp.
1986	State of Oregon initiates water rights adjudication for Klamath River for the Oregon portion of the Klamath Basin.
1988	The Lost River and shortnose suckers listed as endangered under the Endangered Species Act on July 18, 1988.
1989	First discussions with the Klamath Tribes regarding effects on tribal trust resources resulting from entrainment of endangered fishes into Project canals.
1989	Initial consultation with U.S. Fish and Wildlife Service under Section 7(a)(2) of the Endangered Species Act regarding effect of Klamath Project operation on listed species ("jeopardy" biological opinion dated June 14, 1989 on the effects of use of Acrolein on Project lands).
1991-1992	Several interim Section 7(a)(2)consultations with U.S. Fish and Wildlife Service completed for Project operations (biological opinions dated August 14, 1991[jeopardy], January 6, 1992 [no jeopardy], March 27, 1992 [jeopardy] and May 1, 1992 [no jeopardy]).
1992	Critical dry water year, driest year on record since operation of Klamath Project began. Reclamation develops water conservation plan and Drought Plan.

1992	Discussions with downstream Tribe(s) regarding impacts of Project operation on Klamath River flows and tribal fishery rights and resources.
1992	Comprehensive Section 7(a)(2) formal consultation with U.S. Fish and Wildlife Service completed on the effects of long-term operation of the Klamath Project ("jeopardy" biological opinion with reasonable and prudent alternative and incidental take statement dated July, 22, 1992) that superseded previous biological opinions.
1993	The Klamath River Basin Fishery Resources Restoration Act (P.L. 99-552) enacted and Klamath River Fisheries Task Force created resulting in heightened awareness of downstream issues and effects of Project operation.
1994	Section 7(a)(2) formal consultation with U.S. Fish and Wildlife Service on the long-term operation of the Klamath Project, with special reference to operations at Clear Lake on the Lost River Sucker, Shortnose Sucker, Bald eagle and Peregrine Falcon ("jeopardy" biological opinion dated August 11, 1994—this opinion's Reasonable and Prudent Alternative superseded portions of the July 7, 1992 opinion that referred to Clear Lake and provided an updated Incidental Take Statement for Klamath Project operations.)
1994	Critical dry water year, third driest year on record. First government-to-government meetings held with Tribes, resulting in Reclamation's heightened awareness of tribal trust responsibilities. Water users, Tribes and other interested parties ask Reclamation to prepare written plan of operation to allay concerns about uncertainty about availability of Project water. First attempts to initiate a Klamath Project Operations Plan (KPOP).
1995	Section 7(a)(2) consultation with U.S. Fish and Wildlife Service on use of pesticides and fertilizers on federal lease lands, and Acrolein and herbicide use on Klamath Project right-of-ways ("no jeopardy" biological opinion on endangered fishes dated February 9, 1995)
1995	Annual Operations Plan prepared by Reclamation for Klamath Project (plans subsequently prepared for years 1996-2000)
1995	Initial conferencing with NMFS on 1995 operations plan for the Klamath Project (letter of concurrence from NMFS dated April 7, 1995 stating that 1995 plan not likely to jeopardize the coho salmon [a species proposed for listing]).
1995	Reclamation receives Memorandum from Dept. of the Interior Regional Solicitor, Pacific Southwest Region, describing certain legal rights and obligations related to the Klamath Project for use in preparation of the

	Klamath Project Operations Plan (app. A). Reclamation incorporates the advice given in this memorandum into its annual operations plans.
1996	Reinitiation of Section 7(a)(2) consultation on PacifiCorp and The New Earth Company operations permitted by Reclamation on the Lost River and Shortnose Sucker (biological opinion dated July 15, 1996 stating that the operations are not likely to jeopardize the species).
1997	Listing of the southern Oregon/northern California coho salmon as threatened under the Endangered Species Act on May 6, 1997.
1997	Reclamation publishes Notice of Intent (NOI) to prepare environmental impact statement on Klamath Project Long-Term Operations Plan (supplemental NOI issued in February 1999).
1998	First formal Section 7(a)(2) consultation with NMFS regarding Klamath Projects operations
1999	Biological Opinion issued, dated July 1999, stating that Project operation is not likely to jeopardize the coho salmon during the defined period of operation
2000	Project operation in accordance with determination pursuant to Section 7(d) of the ESA in a below-average water year

RIVER FLOWS AND LAKE ELEVATIONS RESULTING FROM HISTORIC OPERATION

Since 1995, Reclamation has operated the Klamath Project according to an annual operations plan. Each of these years was an above average water year. The most recent annual operations plan is dated April 26, 2000 and covers the period of April 1, 2000 through March 31, 2001. This water year was a below average water year. The annual operations plans have been developed to assist Reclamation in operating the Klamath Project consistent with its obligations and responsibilities, given varying hydrological conditions. Project operations plans have been influenced by events and actions such as:

- Varying hydrological conditions in the watershed from year to year
- Changes in the Klamath River watershed and lands adjacent to Upper Klamath Lake
- Changes in agricultural cropping patterns
- Changes in national wildlife refuge operations
- Previous consultations under Section 7(a)(2) of the ESA
- Recognition of trust responsibilities for Klamath Basin Indian Tribes, both upstream and downstream of the Project
- Reclamation's obligation and responsibilities described in the July 25, 1995 and January 9, 1997 Regional Solicitors' memoranda

This analysis uses historic Klamath River flows from1961 through 1997. It uses historical water elevations of Upper Klamath Lake, Clear Lake, and Gerber Reservoir from October 1960 through September 1998. This period encompasses the time when existing project features/facilities have been in operation, and it is the period of hydrological and project operation records incorporated into the water accounting spreadsheet model (KPOPSIM) for the Klamath Project.

Water Year Types

The 38 years of historic April-through-September net inflow data to Upper Klamath Lake (using 1996 bathymetric data) were used in a statistical analysis to determine hydrologic year type indicators for the KPOPSIM water model. The first step was to determine if the data fit a normal distribution. Once this determination was made, the arithmetic mean (average) was calculated (500,400 ac-ft). Next the standard deviation (based on sample) was calculated (187,600 ac-ft). Approximately 68 percent of the inflow years fall within the range of 500,400 ± 187,600 acre-feet. The average minus one standard deviation equaled approximately 312,000 acre-feet. The water years between 500,000 and 312,000 acre-feet are defined as below average inflow. Because there are significant operational spills for inflows above 500,000 acre-feet, the upper end of the area defined by mean plus one standard deviation was not used, and 500,000 acre-feet was used as the above average indicator. For the boundary between critical and dry, the mean minus two standard deviations was calculated and found to be lower than the lowest inflow on record. Since this couldn't be used, percentile rankings were developed for the full 38 years of inflow data, and the third percentile was found to be 185,000 acre-feet and was used for the dry indicator. Any year below the dry indicator was classified as a critical year.

Project Operation

From 1961 through 1994, operation decisions for flows downstream of Iron Gate Dam were made in coordination with PacifiCorp with consideration for current inflow, projected runoff, and projected irrigation and refuge needs. Deference was given to PacifiCorp's FERC flow schedule requirements when sufficient water supply was available. However, review of historic flow data contained in table 1 illustrates that the actual flows realized reflect an operation within hydrologic constraints and deliveries for agricultural and refuge uses, with a relatively minor influence of the FERC flow schedule. The data in table 1 also illustrate the lack of storage capability within the Klamath Project.

October through March

Irrigation and refuge water demands from October through March were relatively nominal, and the flows at Iron Gate were a function of balancing filling of Upper Klamath Lake against downstream flows. When flows exceeded the FERC minimum of 1,300 cfs (Note: Because the FERC minimum is an instantaneous value, when operating to the minimum, the average is generally 20 to 50 cfs above the minimum), it was a function of passing inflow to maintain flood control elevation in Upper Klamath Lake. The contrast between water year types is evident from the record during this period.

April through June

April through June is a transition period, including the recession of snow pack runoff and the onset of summer irrigation demand. The timing of runoff is highly dependent on weather and snow pack conditions. Upper Klamath Lake is operated to fill in accordance with flood control criteria and in consideration of forecasting of runoff from remaining snow pack. Inflow in excess of filling and diversion needs is released at Link River Dam. Link River releases and downstream accretions make up the flows at Iron Gate Dam. Typically there is a "lull" between late winter low elevation runoff and the onset of higher elevation snow melt. This has often resulted in a temporary reduction of flow at Iron Gate Dam. These fluctuations in flow depend on weather conditions that affect snow melt. Figure 4 illustrates these conditions. Reclamation will explore ways to minimize the depressed flows that occur during this period.

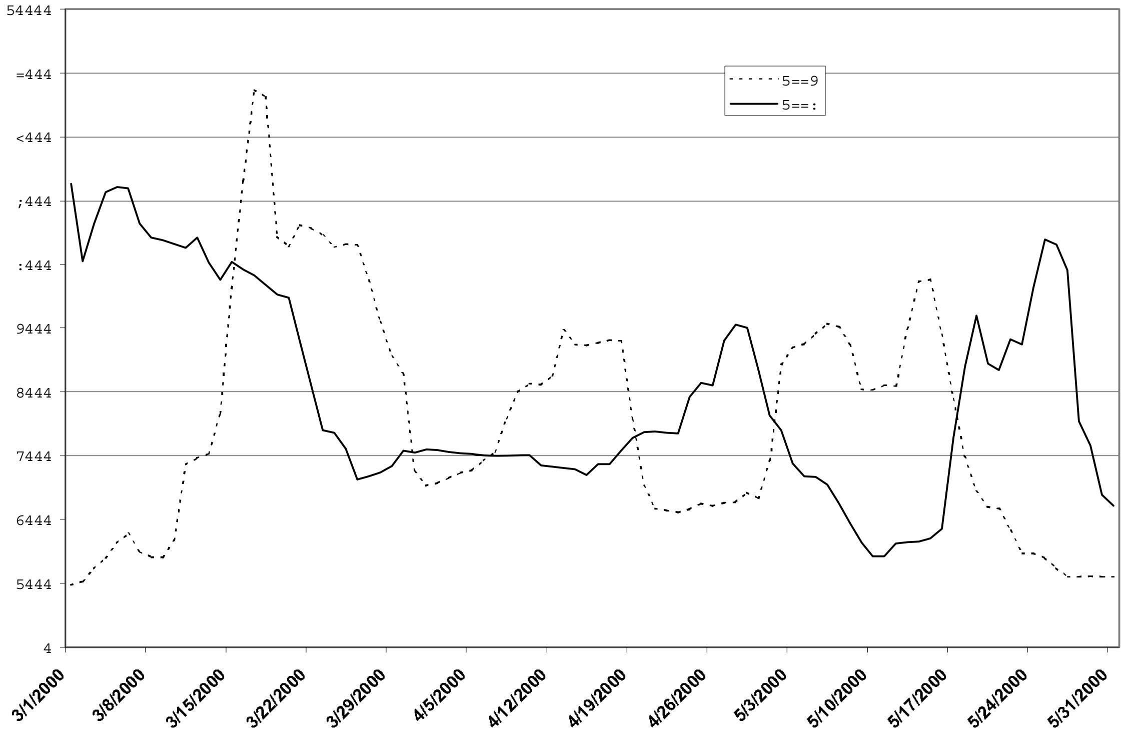

Figure 4.—Klamath River flows (in cfs) below Iron Gate Dam (1995-1996).

July - September

Snow pack has generally melted prior to this period. Inflow to reservoirs is the result of springs, stream flow, and occasional summer storms. During this period, the Project draws upon reservoir storage in addition to inflow to provide irrigation for crop production, refuge needs and flows to the Klamath River.

Klamath River Flows Below Iron Gate Dam

Table 1 contains historical data (1961 through 1997) for Iron Gate Dam flows, based on U.S. Geologic Survey (USGS) daily flow records. This table summarizes the historical daily minimum, maximum and average flows for the 17 time steps for each water year type. USGS data for historical flow at Iron Gate Dam is provided in daily cfs. Values for average monthly (or half-monthly) flow were developed for every time step in the period of record. These values were then split up by year type. Take the "dry" year type and the "October" time step for an example. Five years in the period of record are designated as dry. The five average flow values for Octobers in dry year types can be considered together to calculate an overall average for dry Octobers. Among these five values is also a lowest and highest, and these are the maximum and minimum values that appear in the table. This approach was used for every time step for every year type to create the table.

Table 1.—Historic Iron Gate Dam flows (1961 through 1997—values in cfs).

	19 Above Average				11 Below Average			
	Max.	Min.	Avg.	St. Dev.	Max.	Min.	Avg.	St. Dev.
Oct.	3353	1329	1912	586	2511	1308	1592	345
Nov.	5254	1337	2547	1071	2986	1324	1999	621
Dec.	6735	1387	2987	1213	6653	1435	2835	1507
Jan.	9553	1127	3249	1785	9489	1334	3166	2337
Feb.	9150	910	4143	2244	5656	1546	2532	1156
Mar. 1-15	12447	1953	4864	2851	5017	1439	2501	1006
Mar. 16-31	9219	2101	5268	2008	3682	1748	2391	591
Apr. 1-15	9254	1781	4805	1906	3067	1455	2009	587
Apr. 16-30	7205	1629	3860	1179	2493	1305	1701	426
May 1-15	5005	1730	3383	1088	2083	1010	1351	372
May 16-31	6247	1026	2761	1329	1714	1003	1188	228
Jun. 1-15	4495	760	1764	1150	1480	728	912	230
Jun. 16-30	2084	742	1031	365	1295	696	806	163
Jul. 1-15	2194	705	870	327	940	709	758	69
Jul. 16-31	1122	680	772	107	1023	682	784	94
Aug.	1208	1011	1049	46	1094	701	995	104
Sep.	2052	1035	1457	206	1428	725	1272	184

	5 Dry				2 Critical			
	Max.	Min.	Avg.	St. Dev.	Max.	Min.	Avg.	St. Dev.
Oct.	1382	852	1094	220	937	904	920	16
Nov.	1390	873	1218	189	915	909	912	3
Dec.	3903	889	2290	1305	944	914	929	15
Jan.	4348	888	2588	1307	1191	1011	1101	90
Feb.	2217	747	1554	505	730	525	627	103
Mar. 1-15	2790	725	1683	817	712	501	607	106
Mar. 16-31	2148	724	1464	545	572	521	547	26
Apr. 1-15	1767	728	1183	381	843	569	706	137
Apr. 16-30	1325	754	1039	241	636	574	605	31
May 1-15	1025	761	968	104	741	525	633	108
May 16-31	1039	924	996	41	714	501	608	106
Jun. 1-15	931	712	782	77	706	476	591	115
Jun. 16-30	735	612	700	45	702	536	619	83
Jul. 1-15	739	547	669	76	572	429	501	71
Jul. 16-31	742	542	678	75	575	427	501	74
Aug.	1033	647	824	152	636	398	517	119
Sep.	1048	749	953	112	906	538	722	184

Figures 5-8 graph the data in table 1. The graphs have boxes whose upper and lower bounds represent the average +1 standard deviation and the average -1 standard deviation respectively, and lines running up and down from the boxes which represent the magnitude of the maximum and minimum values that went into the average and standard deviation.

Above Average Years

Above average years (fig. 5) occurred in 19 of the 37 hydrologic years used for this analysis (51.3%). The minimum time step ranged from 680 cfs in the later part of July to 2,101 cfs in the later part of March. The average time step ranged from 772 cfs in late July to 5,268 cfs in late March.

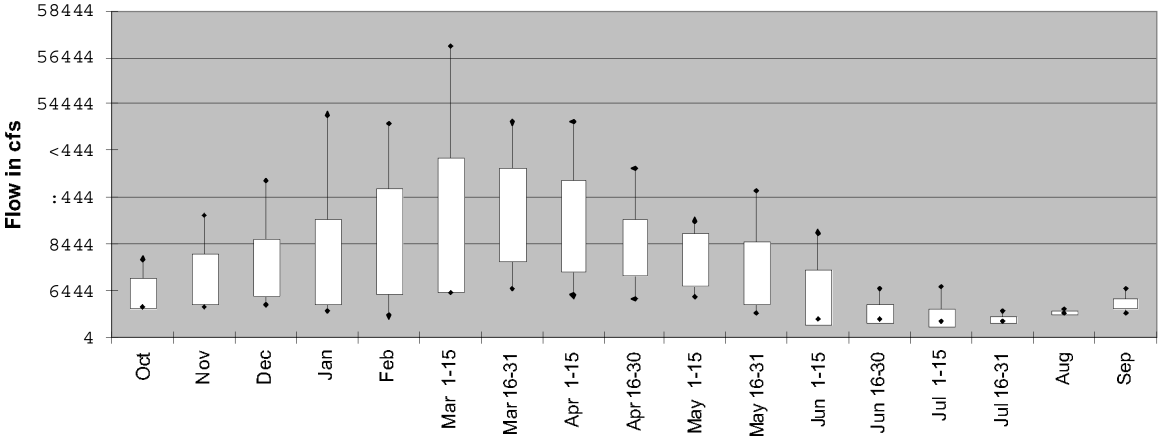

Figure 5.—Iron Gate Flow statistics—above average year types.

Below Average Years

Below average years (fig. 6) occurred in 11 of the 37 hydrologic years used for this analysis (29.7%). The minimum time step ranged from 682 cfs in late July to 1,748 cfs in late March. The average time step average ranged from 758 cfs in late July to 3166 cfs in January.

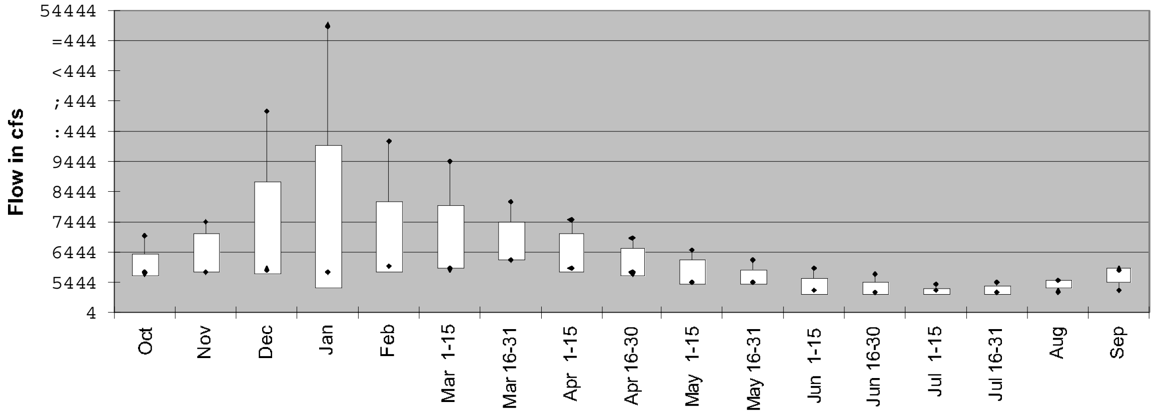

Figure 6.—Iron Gate Flow statistics—below average year types

Dry Years

Dry years (fig. 7) occurred in 5 of the 37 hydrologic years used for this analysis (13.5%). The minimum time step ranged from 542 cfs in late July to 924 cfs in late May. The average time step ranged from 669 cfs in late July to 2,588 cfs in January.

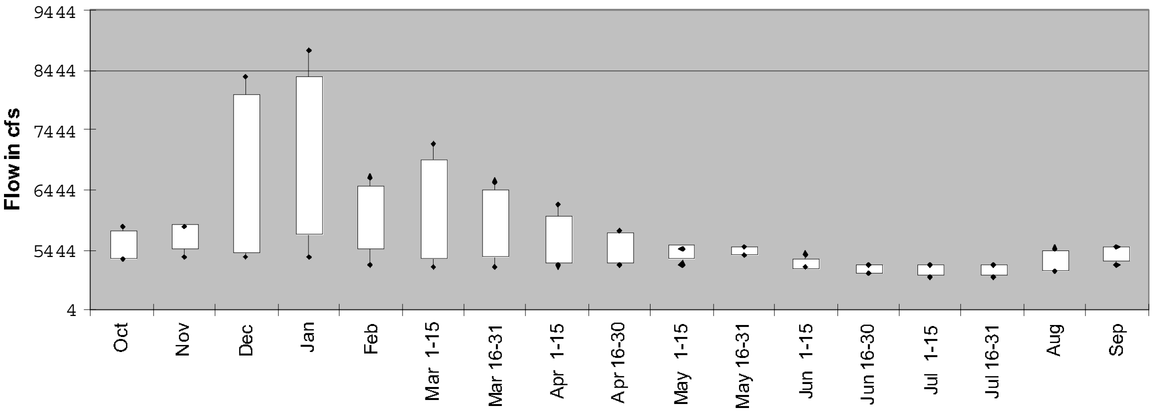

Figure 7.—Iron Gate Flow statistics—dry year types.

Critical Years

Critical years (fig. 9) occurred in 2 of the 37 hydrologic years used for this analysis (5.5%). The minimum time step ranged from 398 cfs in August to 1011 cfs in January. The average time step ranged from 501 cfs in July to 1,101 cfs in January.

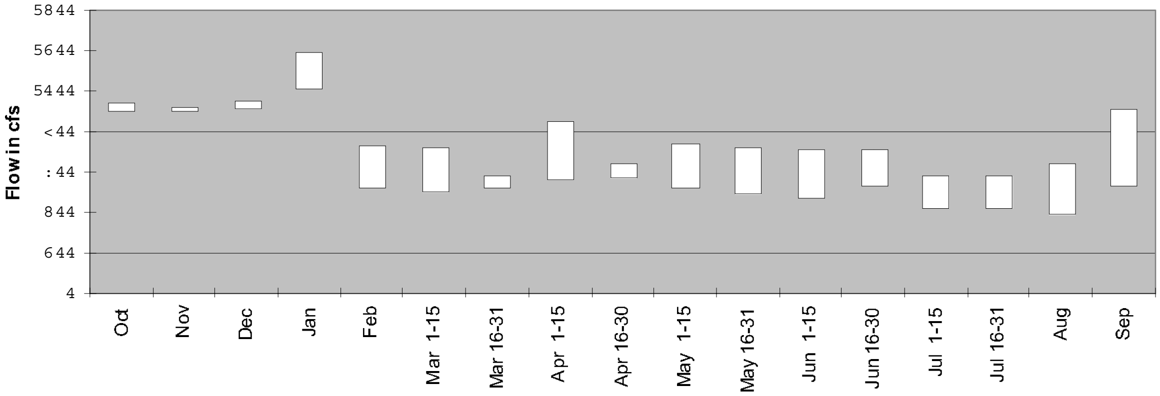

Figure 8.—Iron Gate Flow statistics—critical year types.

Upper Klamath Lake, Clear Lake, and Gerber Reservoir Elevations

Upper Klamath Lake

Table 2 contains historical water surface elevation data for water years 1961 through 1998 (October 1960 through September 1998), based on PacifiCorp's daily records. This table summarizes the historical end-of-month minimum, maximum, and average elevations for each water year type (critical, dry, below average, and above average). All values are in feet above mean sea level. Figures 9-12 present the historic data graphically. The graphs have boxes whose upper and lower bounds represent the average +1 standard deviation and the average -1 standard deviation respectively, and lines running up and down from the boxes represent the magnitude of the maximum and minimum values.

Table 2.—End-of-month Upper Klamath Lake elevations by water year type (1960-1998).

	20 Above Average				11 Below Average			
	Max.	Min.	Average	St. Dev.	Max.	Min.	Average	St. Dev.
Oct.	4141.41	4138.98	4140.57	0.73	4141.35	4138.36	4139.51	0.82
Nov.	4141.23	4139.55	4140.53	0.56	4141.21	4138.99	4140.00	0.72
Dec.	4141.63	4139.58	4140.64	0.52	4143.50	4138.80	4140.60	1.09
Jan.	4142.40	4139.54	4141.05	0.75	4143.02	4139.41	4140.96	1.00
Feb.	4142.87	4140.56	4141.86	0.55	4142.20	4140.15	4141.41	0.68
Mar.	4142.73	4141.10	4142.43	0.36	4142.73	4141.35	4142.25	0.37
Apr.	4143.21	4142.26	4142.86	0.21	4143.06	4142.15	4142.68	0.25
May.	4143.29	4142.85	4143.03	0.10	4143.16	4142.22	4142.64	0.30
Jun.	4143.25	4142.17	4142.78	0.34	4142.79	4141.30	4142.05	0.47
Jul.	4142.73	4140.83	4141.93	0.59	4141.91	4140.00	4140.97	0.61
Aug.	4142.34	4139.66	4141.07	0.78	4141.80	4138.85	4140.07	0.81
Sep.	4141.98	4138.95	4140.63	0.86	4141.46	4138.18	4139.53	0.84

	5 Dry				2 Critical			
	Max.	Min.	Average	St. Dev.	Max.	Min.	Average	St. Dev.
Oct.	4139.60	4138.18	4138.66	0.50	4137.59	4136.93	4137.26	0.33
Nov.	4140.50	4138.96	4139.78	0.51	4138.32	4137.80	4138.06	0.26
Dec.	4141.81	4139.66	4140.70	0.72	4139.27	4138.58	4138.93	0.34
Jan.	4141.54	4140.26	4141.12	0.46	4140.27	4140.01	4140.14	0.13
Feb.	4142.38	4140.41	4141.62	0.67	4141.35	4140.94	4141.15	0.20
Mar.	4142.84	4141.70	4142.42	0.43	4142.19	4141.80	4142.00	0.20
Apr.	4142.95	4141.68	4142.44	0.49	4142.12	4141.68	4141.90	0.22
May.	4142.85	4141.40	4142.43	0.54	4142.00	4140.70	4141.35	0.65
Jun.	4142.45	4140.39	4141.63	0.71	4140.81	4139.45	4140.13	0.68
Jul.	4140.86	4139.10	4140.21	0.63	4139.04	4138.77	4138.91	0.13
Aug.	4139.78	4138.38	4139.11	0.50	4137.72	4137.52	4137.62	0.10
Sep.	4139.45	4137.55	4138.49	0.62	4137.43	4136.84	4137.14	0.30

Above Average Years.—Above average years occurred in 20 of the 38 hydrologic years used for this analysis (52.6%). The minimum elevation ranged from 4139.55 at the end of November to 4142.85 at the end of May. The average ranged from 4140.53 at the end of November to 4143.03 at the end of May (table 2, fig. 9).

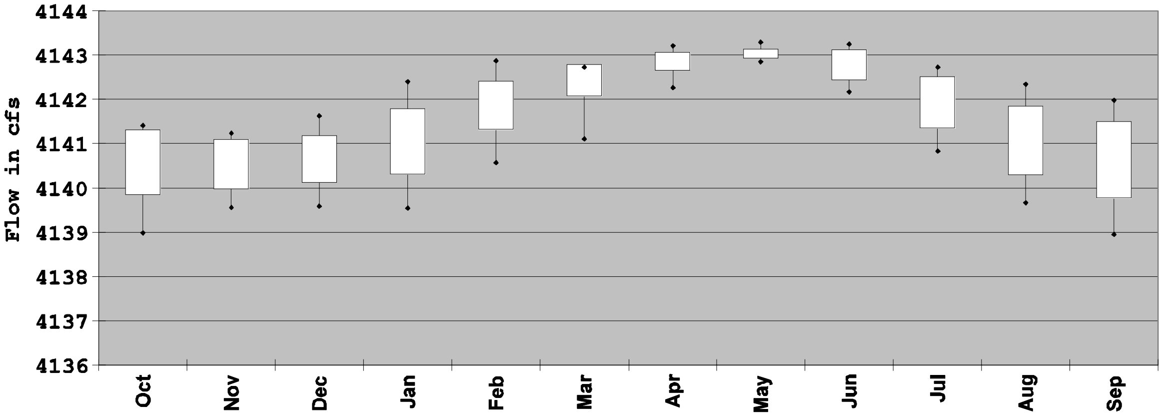

Figure 9.—Upper Klamath Lake elevations (1960-1998) by month for above average water years.

Below Average Years.—Below average years occurred 11 of the 38 hydrologic years used for this analysis (28.9%). The minimum elevation ranged from 4138.18 in September to 4142.22 in May (table 2, fig. 10). The average elevation ranged from 4139.51 in October to 4142.68 in April.

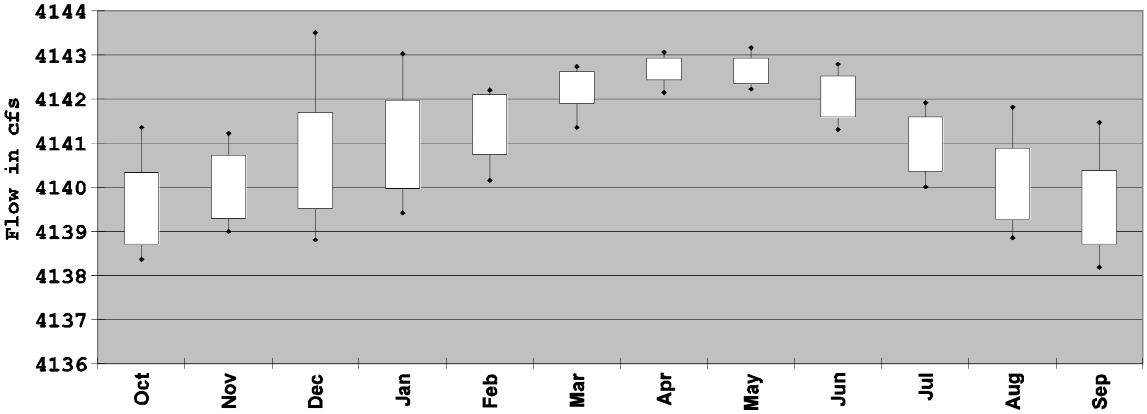

Figure 10.—Upper Klamath Lake elevations (1960-1998) by month for below average years.

Dry Years.—Dry water years occurred in 5 out of 38 years hydrologic years used for this analysis (13.2%). The minimum elevation ranged from 4137.55 in September to 4141.70 in March (table 2, fig. 11). The average elevation ranged from 4138.49 in September to 4142.44 in April.

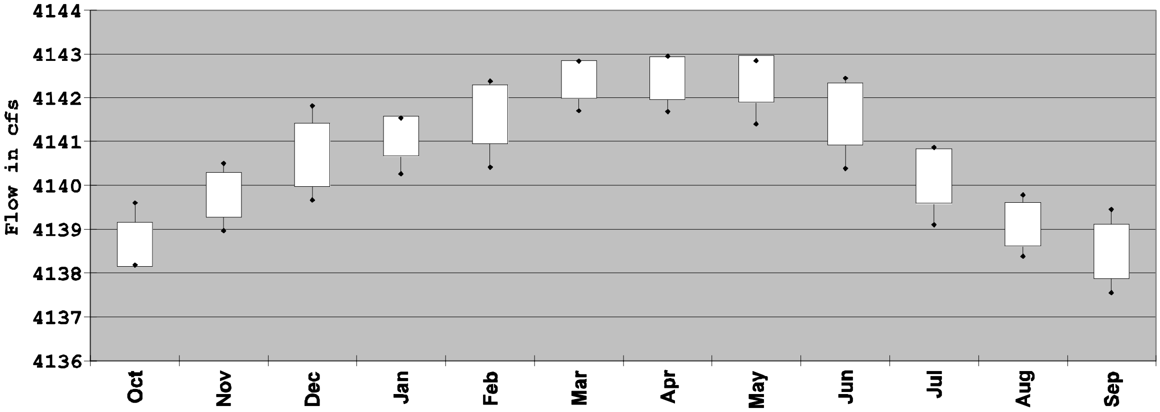

Figure 11.—Upper Klamath Lake elevations (1960-1998) by month for dry water years.

Critical Years.—Critical years occurred in 2 of the 38 hydrologic years used for this analysis (5.3%). The minimum elevation ranged from 4136.84 in September to 4141.80 March (table 2, fig. 12). The average elevation ranged from 4137.14 for September to 4142.00 for March.

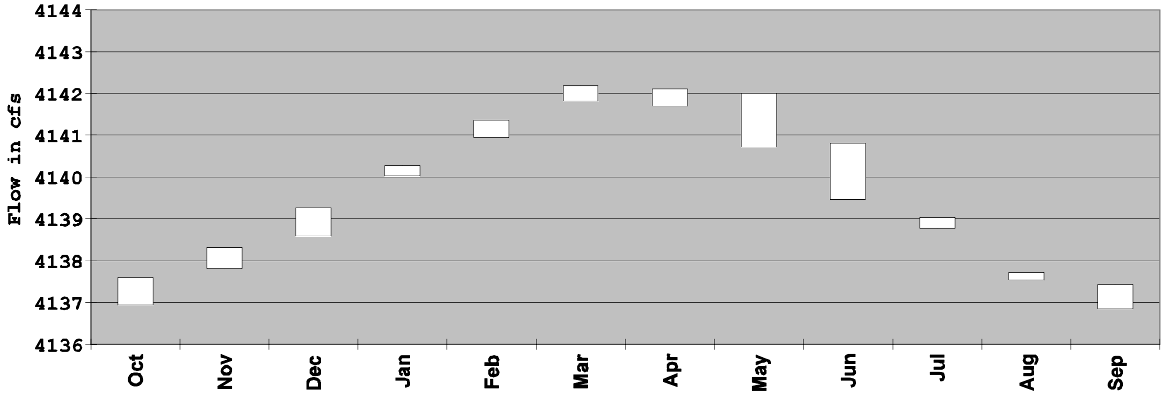

Figure 12.—Upper Klamath Lake elevations (1960-1998) by month for critical years.

Clear Lake

Table 3 summarizes historical water surface elevations for water years 1961 through 1998 (October 1960 through September 1998). Figures 13-16 present the data graphically.

Table 3.—End-of-month Clear Lake elevations by water year type (1960-1998).

	20 Above Average				11 Below Average			
	Max.	Min.	Average	St. Dev.	Max.	Min.	Average	St. Dev.
Oct.	4537.02	4524.00	4531.90	3.37	4532.60	4521.33	4527.05	3.33
Nov.	4537.05	4524.05	4531.87	3.41	4532.96	4521.47	4527.17	3.36
Dec.	4539.43	4524.15	4532.21	3.70	4533.78	4521.70	4527.86	3.37
Jan.	4539.60	4524.30	4532.93	3.98	4535.44	4521.87	4528.70	3.75
Feb.	4540.11	4521.46	4532.97	4.68	4536.50	4523.37	4530.18	4.37
Mar.	4541.63	4526.57	4535.07	4.21	4537.45	4524.25	4530.91	4.35
Apr.	4542.28	4527.52	4536.08	3.80	4537.15	4525.50	4531.25	3.81
May.	4541.89	4527.70	4535.91	3.67	4536.50	4525.10	4530.66	3.69
Jun.	4541.27	4526.70	4535.16	3.68	4535.84	4524.08	4529.96	3.69
Jul.	4540.33	4525.70	4534.14	3.66	4534.70	4522.88	4528.81	3.77
Aug.	4538.97	4524.70	4533.08	3.57	4533.65	4521.90	4527.86	3.80
Sep.	4537.86	4524.12	4532.29	3.49	4532.86	4521.28	4527.17	3.78

	5 Dry				2 Critical			
	Max.	Min.	Average	St. Dev.	Max.	Min.	Average	St. Dev.
Oct.	4528.30	4522.50	4525.38	1.91	4521.54	4519.30	4520.42	1.12
Nov.	4528.30	4522.51	4525.71	1.85	4521.65	4519.29	4520.47	1.18
Dec.	4528.48	4522.80	4526.60	2.05	4521.96	4519.35	4520.66	1.30
Jan.	4529.02	4522.85	4527.45	2.32	4525.89	4519.40	4522.65	3.24
Feb.	4532.00	4527.00	4529.45	1.83	4526.20	4523.00	4524.60	1.60
Mar.	4532.68	4527.10	4529.85	1.87	4526.30	4522.84	4524.57	1.73
Apr.	4532.54	4526.90	4529.59	1.83	4525.84	4522.75	4524.30	1.54
May.	4532.18	4526.42	4529.14	1.87	4525.39	4521.77	4523.58	1.81
Jun.	4531.20	4525.65	4528.28	1.81	4524.49	4521.18	4522.84	1.66
Jul.	4530.20	4524.45	4527.11	1.87	4523.16	4520.44	4521.80	1.36
Aug.	4529.13	4523.52	4526.18	1.86	4521.43	4519.82	4520.63	0.80
Sep.	4528.30	4522.75	4525.52	1.88	4521.70	4519.42	4520.56	1.14

Above Average Years.—The minimum elevation ranged from 4524.00 in October to 4527.70 in May (table 3, fig. 13). The average ranged from 4531.87 in November to 4536.08 in April.

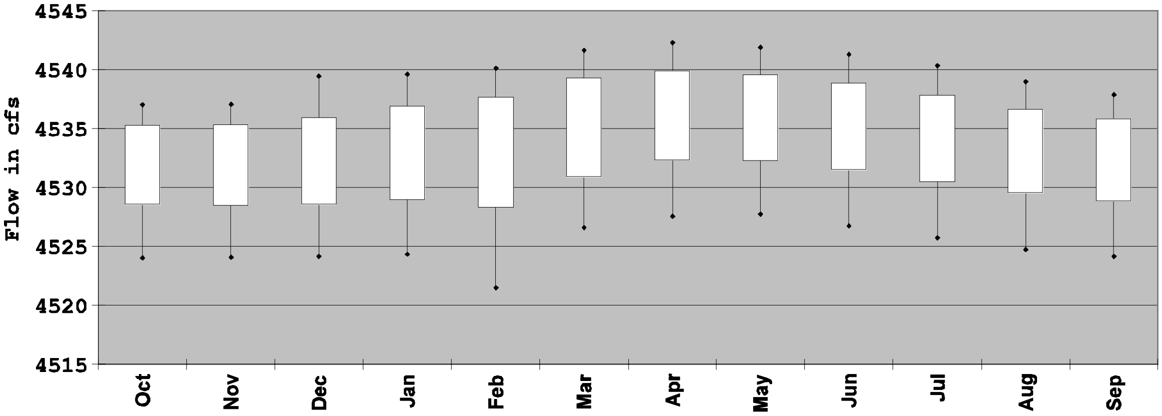

Figure 13.—Clear Lake elevations (1960-1998) by month for above average years.

Below Average Years.—The minimum elevation ranged from 4521.28 in September to 4525.50 in April (table 3, fig. 14). The average ranged from 4527.05 in October to 4531.25 in April.

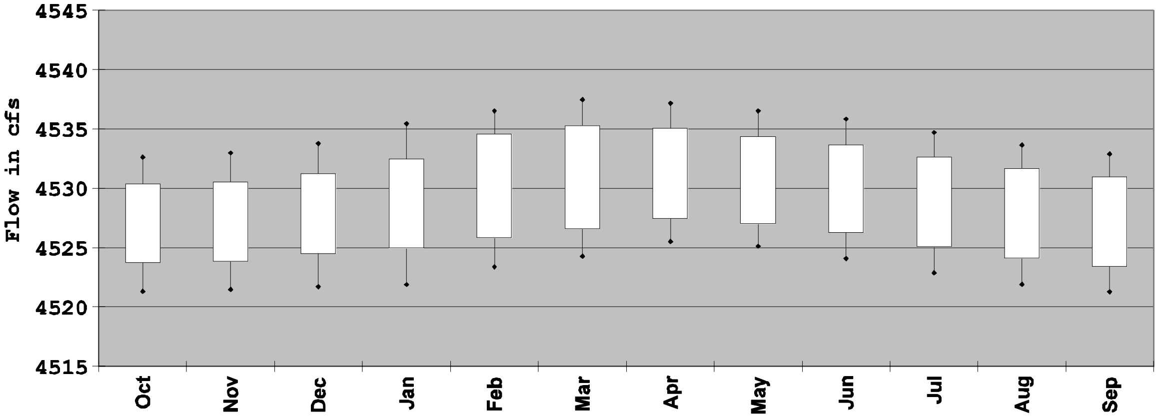

Figure 14.—Clear Lake elevations (1960-1998) by month for below average years.

Dry Years.—The minimum elevation ranged from 4522.50 in October to 4527.10 in March (table 3, fig. 15). The average ranged from 4525.38 in October to 4529.85 in March.

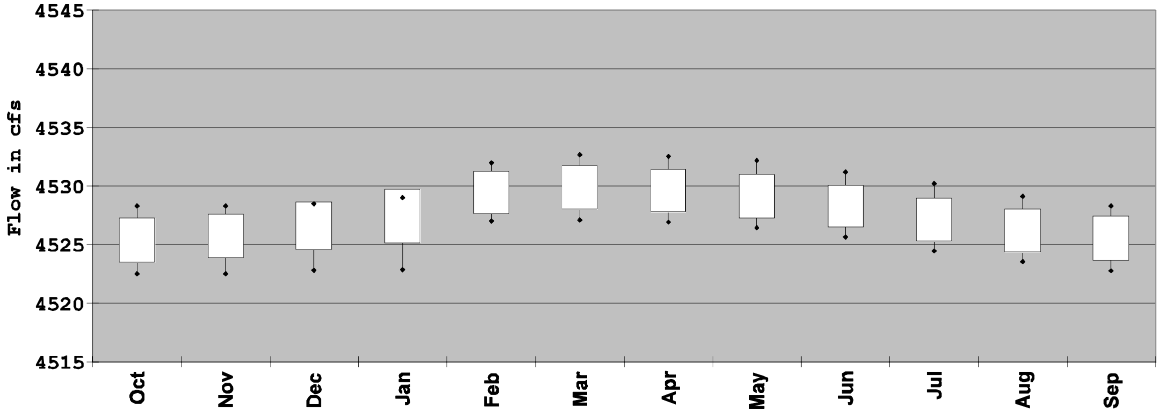

Figure 15.—Clear Lake elevations (1960-1998) by month for dry years.

Critical Years.—The minimum elevation ranged from 4519.30 in October to 4523.00 in February (table 3, fig. 16). The average ranged from 4520.42 in October to 4524.60 in February.

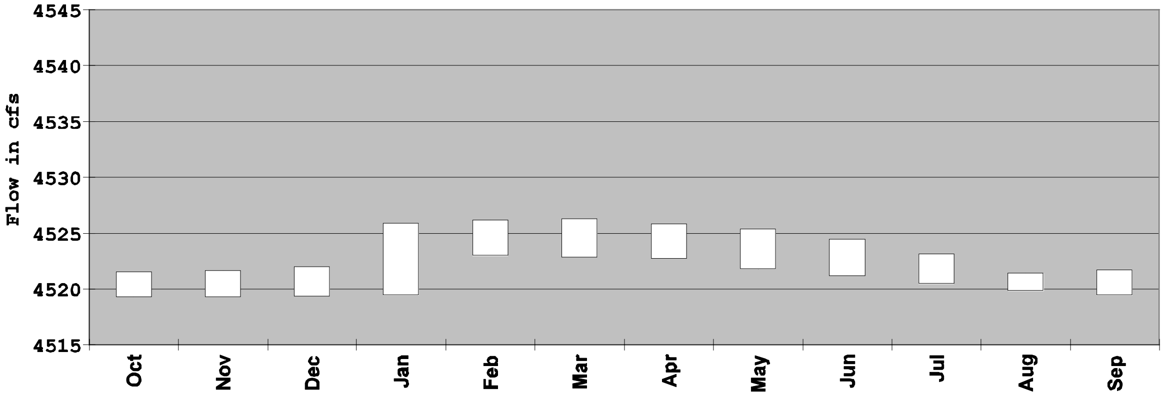

Figure 16.—Clear Lake elevations (1960-1998) by month for critical years.

Gerber Reservoir

Table 4 summarizes Gerber Reservoir historical water surface elevations for water years 1961 through 1998 (October 1960 through September 30, 1998). Figures 17-20 present the data graphically.

Table 4.—End-of-month Gerber Reservoir elevations by water year type (1960-1998).

	20 Above Average				11 Below Average			
	Max.	Min.	Average	St. Dev.	Max.	Min.	Average	St. Dev.
Oct.	4826.26	4815.18	4822.30	3.32	4821.49	4794.27	4810.09	8.00
Nov.	4828.12	4815.16	4822.54	3.55	4823.04	4795.93	4810.89	7.91
Dec.	4834.60	4815.20	4823.50	4.49	4831.40	4798.80	4814.01	9.16
Jan.	4834.18	4816.58	4824.79	4.94	4829.70	4799.14	4815.54	9.37
Feb.	4835.04	4802.24	4825.11	9.14	4832.03	4803.80	4819.94	7.85
Mar.	4836.19	4821.30	4831.21	5.00	4835.00	4809.00	4823.32	7.49
Apr.	4836.48	4827.30	4833.75	2.85	4834.59	4812.37	4825.40	5.94
May.	4836.29	4827.00	4832.83	2.71	4832.57	4810.35	4823.20	5.75
Jun.	4835.16	4824.10	4830.66	2.99	4830.03	4807.88	4820.67	6.04
Jul.	4832.68	4820.81	4827.80	3.19	4826.78	4804.13	4817.16	6.33
Aug.	4830.39	4817.98	4825.00	3.34	4823.64	4801.24	4814.01	6.61
Sep.	4828.00	4815.26	4822.76	3.39	4821.63	4794.47	4810.77	7.86

	5 Dry				2 Critical			
	Max.	Min.	Average	St. Dev.	Max.	Min.	Average	St. Dev.
Oct.	4809.20	4797.98	4803.25	3.64	4806.59	4796.62	4801.61	4.99
Nov.	4811.50	4797.96	4805.52	4.78	4806.74	4796.62	4801.68	5.06
Dec.	4821.60	4798.04	4808.91	7.84	4807.08	4797.06	4802.07	5.01
Jan.	4822.20	4798.18	4811.02	8.61	4816.63	4798.79	4807.71	8.92
Feb.	4825.65	4804.82	4816.35	6.69	4822.94	4800.74	4811.84	11.10
Mar.	4825.91	4804.18	4817.55	7.24	4823.30	4801.28	4812.29	11.01
Apr.	4824.71	4808.26	4818.08	5.58	4822.48	4801.14	4811.81	10.67
May.	4822.84	4808.10	4816.55	4.91	4820.80	4798.86	4809.83	10.97
Jun.	4819.52	4803.60	4813.29	5.39	4817.81	4798.36	4808.09	9.73
Jul.	4815.48	4799.22	4809.19	5.55	4814.08	4797.73	4805.91	8.18
Aug.	4812.90	4798.60	4806.10	4.70	4810.16	4797.01	4803.59	6.57
Sep.	4809.64	4798.08	4803.37	3.74	4806.78	4796.52	4801.65	5.13

Above Average Years.—The minimum elevation ranged from 4815.16 in November to 4827.30 in April (table 4, fig. 17). The average ranged from 4826.26 in October to 4836.48 in April.

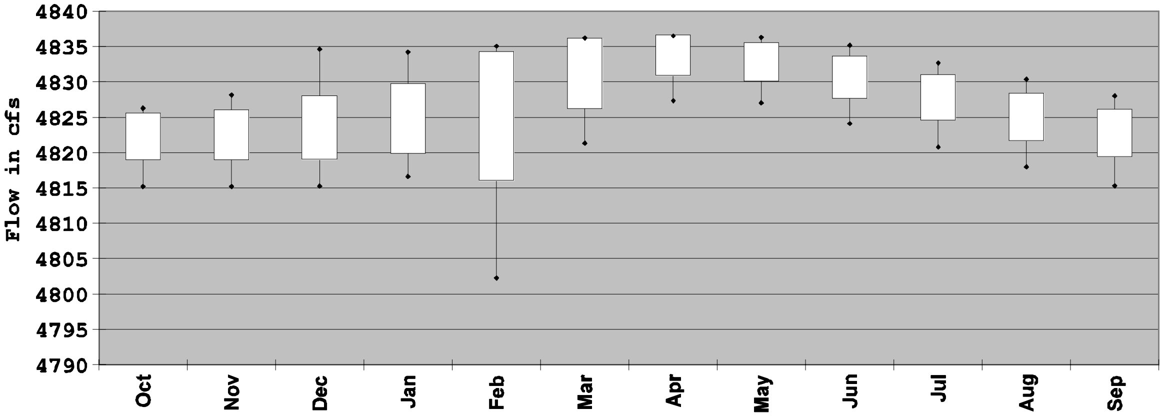

Figure 17.—Gerber Reservoir elevations (1960-1998) by month for above average years.

Below Average Years.—The minimum elevation ranged from 4794.27 in October to 4812.37 in April (table 4, fig. 18). The average ranged from 4810.09 in October to 4825.40 in April.

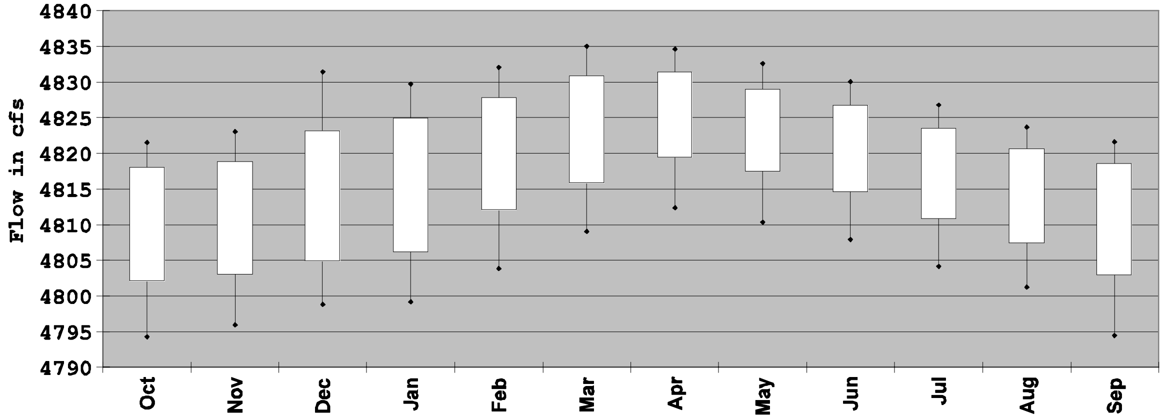

Figure 18.—Gerber Reservoir elevations (1960-1998) by month for below average years.

Dry Years.—The minimum elevation ranged from 4797.98 in October to 4808.26 April (table 4, fig. 19). The average ranged from 4803.25 in October to 4818.08 in April.

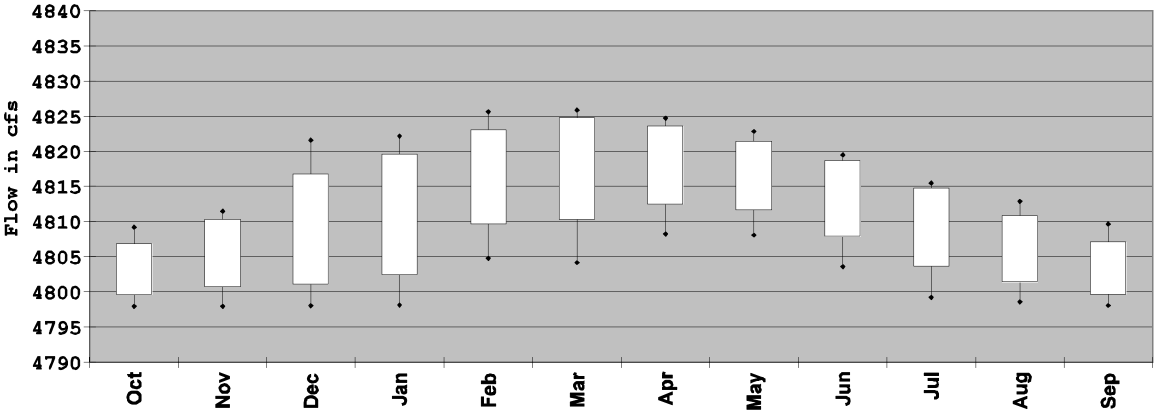

Figure 19.—Gerber Reservoir elevations (1960-1998) by month for dry years.

Critical Years.—The minimum elevation ranged from 4796.52 in September to 4801.28 in March (table 4, fig. 20). The average ranged from 4801.61 in October to 4812.29 in March.

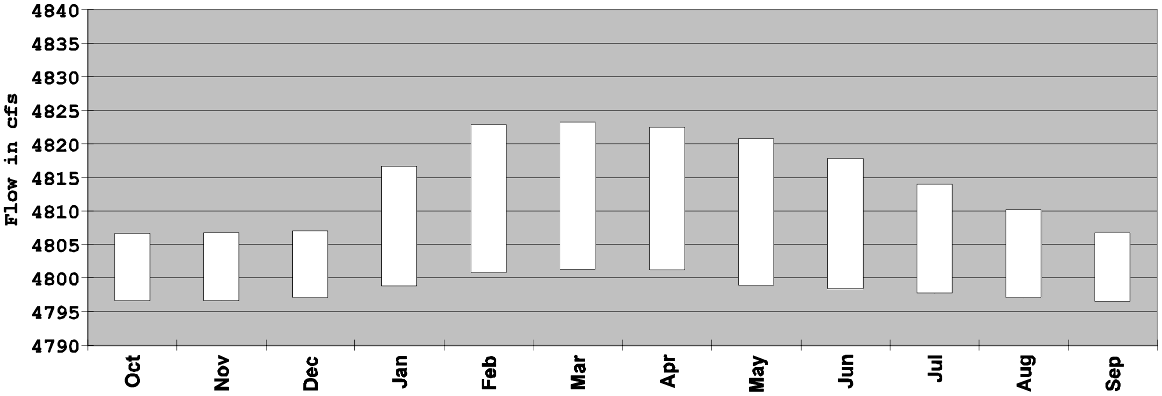

Figure 20.—Gerber Reservoir elevations (1960-1998) by month for critical years.

Appendix A

REGIONAL SOLICITORS' MEMORANDA

UNITED STATES DEPARTMENT OF THE INTERIOR
OFFICE OF THE SOLICITOR
PACIFIC SOUTHWEST REGION

Memorandum dated July 25, 1995 describing certain legal rights and obligations related to the U.S. Bureau of Reclamation, Klamath Project for use in preparation of the Klamath Project Operations Plan

Memorandum dated January 9, 1997 from Pacific Southwest and Pacific Northwest Regional Solicitors describing legal rights and obligations related to the Klamath Project

United States Department of the Interior

OFFICE OF THE SOLICITOR
Pacific Southwest Region
2800 Cottage Way
Room E-2753
Sacramento, California 95825-1890

IN REPLY REFER TO:

JUL 25 1995

TO: Regional Director, Bureau of Reclamation, Mid-Pacific Region

FROM: Regional Solicitor, Pacific Southwest Region

SUBJECT: Certain Legal Rights and Obligations Related to the U.S. Bureau of Reclamation, Klamath Project for Use in Preparation of the Klamath Project Operations Plan (KPOP)

This memorandum describes the general rights to the waters in the Klamath and Lost River drainages affected by the operation of the U.S. Bureau of Reclamation's (Reclamation) Klamath Irrigation Project located within the Upper Klamath and Lost River Basins in Oregon and California. In addition, the obligations of Reclamation to the holders of these rights are discussed. The rights that are treated in this memorandum include those of the Klamath Project water users (those who hold contracts with the United States to receive water from the project), the Upper Klamath, Lower Klamath, Tule Lake, and Clear Lake National Wildlife Refuges (NWR) managed by the U.S. Fish and Wildlife Service (these refuges are located within the exterior boundaries of the Klamath Project), and the Klamath, Yurok, and Hoopa Tribes (they have treaty-based or federally reserved fishing and water rights that are or may be affected by project operations). None of the above water rights has been quantified.[1]

Rights

Klamath Project Water Users

The Klamath Project water users obtain their supply of water for irrigation purposes from the project facilities pursuant to various contracts with Reclamation entered into pursuant to the Reclamation Act of 1902, 32 Stat. 390, 43 U.S.C. §§ 371 et seq., as amended and supplemented. The contracts are between Reclamation and a water district or Reclamation and an individual water user. These contracts provide, in general, that the water user is to receive enough water to satisfy the beneficial use for

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[1] The existence and nature of the Klamath Tribes' reserved water rights for hunting, fishing, and gathering were declared in United States v. Adair, 723 F.2d 1394, 1412 (9th Cir.), cert. denied, 467 U.S. 1252 (1984).

the irrigation of a specified acreage. Certain of the contracts specify the beneficial use amount on a per acre basis.

The underlying water rights for the project, upon which the water supply stated in each of the contracts discussed above depends, were obtained by Reclamation, in accordance with state law, in 1905, when Reclamation filed a notice of intent to appropriate all of the available water in the Klamath River and Lost River and their tributaries in Oregon. Similar filings were made for the waters originating in California, within the Lost River and Clear Lake drainages.[2] Subsequent to these filings, Reclamation constructed project facilities through which water is delivered to the project water users. The project's 1905 water rights are junior to the reserved water rights of the tribes but senior to the reserved water rights of the refuges, as discussed below.

Federal law provides that Reclamation obtain water rights for its projects and administer its projects pursuant to state law relating to the control, appropriation, use or distribution of water used in irrigation, unless the state laws are inconsistent with express or clearly implied congressional directives. 43 U.S.C. § 383; California v. United States, 438 U.S. 645, 678 (1978); appeal on remand, 694 F.2d 117 (1982). The beneficial ownership of a project water right is in the water users who put the water to beneficial use. Nevada v. United States, 463 U.S. 110 (1983). Under law of most western states a water right is obtained through appropriation followed by application within a reasonable time to beneficial use. Nebraska v. Wyoming, 325 U.S. 589 (1945); Ickes v. Fox, 300 U.S. 82 (1937). Oregon law (as well as California law) is similar to the laws of most other western states in that actual application of the water to the land is required to perfect a water right for agricultural use.[3]

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[2] Oregon statutes concerning the appropriation of water before February 24, 1909, the effective date of the Oregon Water Rights Act of 1909, provided that the extent of the appropriation was determined by the actual capacity of the completed diversion structure, assuming that the requirement to post a notice of intent to appropriate together with application of water to beneficial use within a reasonable time had occurred. See In re Waters of the Tualatin River and its Tributaries, 366 P.2d 174 (Or. 1961). The laws for appropriation of water in California that were in effect in 1905 were similar to those in Oregon. Cal. Civil Code of 1872, §§ 1410-22 (Deering 1977). The effective date of the California Water Commission Act, which established California's current appropriation scheme, is December 19, 1914.

[3] See ORS §§ 539.010 et seq.; State ex rel. v. Hibbard, 570 P.2d 1190, 1194 (Or. Ct. App. 1977); Alexander v. Central Oregon Irrigation District, 528 P.2d 582 (Or. Ct. App. 1974), and Cal.

Oregon also recognizes that water for irrigation purposes is appurtenant to the land for which it is appropriated and applied, but is not inseparable from the land. In re Deschutes River and Tributaries, 286 P. 563 (Or. 1930); see also United States v. Alpine Land & Reservoir Co., 697 F.2d 851, 858 (9th Cir.), cert. denied, 464 U.S. 863 (1983). Federal law concerning Reclamation projects also provides that the use of water acquired under the Act "shall be appurtenant to the land irrigated, and beneficial use shall be the basis, measure, and the limit of the right." 43 U.S.C. § 372. Beneficial use is determined in accordance with state law to the extent not inconsistent with congressional directives. See Alpine Land & Reservoir Co., 697 F.2d at 853-854; see also California v. United States, 438 U.S. at 678.

Wildlife Refuges

There are two National Wildlife Refuges that are particularly dependent on project operations: Lower Klamath and Tule Lake NWRs.[4] The Lower Klamath NWR consists of 51,713 acres which straddle the Oregon-California border. This NWR was created by Executive Order No. 924 (Aug. 8, 1908) "as a preserve and breeding ground for native birds." The boundaries of the Lower Klamath NWR were altered by Executive Order No. 2200 (May 14, 1915). The Tule Lake NWR is a 39,990 acre marsh area located in northern California just south of the Oregon border. Tule Lake was created by Executive Order No. 4975 (Oct. 4, 1928) also "as a refuge and breeding ground for birds."[5]

Each refuge has a federal reserved water right to the amount of water, unappropriated at the time of creation of the refuge, necessary to fulfill the primary purposes of the refuge. See United States v. New Mexico, 438 U.S. 696 (1978). The priority date for the reserved water right of each refuge is the date of the executive order creating that refuge. See Cappaert v. United

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Water Code § 1240; Joerger v. Pacific Gas & Elec. Co., 276 P. 1017 (Cal. 1929); Madera Irr. Dist. v. All Persons, 306 P.2d 886 (Cal. 1957).

[4] There are two other National Wildlife Refuges within the exterior boundaries of the project that are also dependent on project operations. The Upper Klamath NWR was created in 1928 and is located at the northern portion of Upper Klamath Lake. It encompasses 14,965 acres of marsh and open water. The Clear Lake NWR was created in 1911 and encompasses 20,000 acres of water surface and upland area within the Clear Lake drainage in the Lost River Basin.

[5] The interrelation of the Klamath Project irrigation uses and the NWR purposes are further delineated in the Kuchel Act, 16 U.S.C. §§ 695k-695r.

States, 426 U.S. 128, 138 (1976). In addition, certain lands within the Lower Klamath and Tule Lake refuges that are irrigated have a priority date of 1905 based on the Klamath Project water rights. Finally, the refuges receive significant quantities of return flows and other project waters which, although initially used for irrigation purposes, are beneficially reused for refuge purposes.

Klamath Indian Tribes

The Klamath Indian Tribes have treaty-based rights. The exercise of certain of these rights are affected by project operations. The Tribes' primary interest is in the operation of Upper Klamath Lake because it serves as habitat for fish protected by their treaty rights, including two endangered species of fish, the Lost River and shortnose suckers. These fish are a traditional food source for the Tribes. Changing water elevation in the lake and recurring water quality problems impact the suckers.

A treaty entered into in 1864 reserves to the Klamath Tribes fishing, hunting, and gathering rights on lands that were formerly part of the original Klamath Indian Reservation in Oregon.[6] The reservation abutted Upper Klamath Lake and included several of its tributaries, notably the Williamson River. Treaty Between the United States of America and the Klamath and Modoc Tribes and Yahooskin Band of Snake Indians, Oct. 14, 1864, 16 Stat. 107. The treaty reserves to the Tribes a federal Indian reserved water right to support their hunting, fishing, and gathering rights.[7] United States v. Adair, 723 F.2d 1394 (9th Cir.), cert. denied, 444 U.S. 1252 (1984). The Tribes' water

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[6] In 1954, the Klamath Indian Reservation in Oregon was terminated pursuant to the Klamath Termination Act. Act of Aug. 13, 1954, c. 732, § 1, 68 Stat. 718 (codified at 25 U.S.C. §§ 564-564x). Under this Act, reservation lands were disposed to private parties, individual Indians, the Forest Service and the Fish and Wildlife Service, but the Tribes' hunting, fishing, and gathering rights, and supporting water rights, were left intact. United States v. Adair, 723 F.2d 1394, 1412 (9th Cir.), cert. denied, 467 U.S. 1252 (1984); Kimball v. Callahan, 590 F.2d 768, 775 (9th Cir.), cert. denied, 444 U.S. 826 (1979); Kimball v. Callahan, 493 F.2d 564, 568-69 (9th Cir.), cert. denied, 419 U.S. 1019 (1974). The Klamath Tribes were later restored as a federally recognized tribe under the Klamath Restoration Act of 1986. Pub. L. No. 99-398, 100 Stat. 849.

[7] The Tribes' water right is not dependent on state law, but rather is controlled by federal law. However, in an adjudication of water rights pursuant to the McCarran Amendment, 43 U.S.C. § 666, this federal right would be subject to quantification by a state court. Adair, 723 F.2d at 1411 n.19.

Tribes' water right includes "the right to prevent other appropriators from depleting the streams['] waters below a protected level in any area where the non-consumptive right applies." Adair, 723 F.2d at 1411; accord Joint Board of Control v. United States, 832 F.2d 1127, 1131-32 (9th Cir. 1987), cert. denied, 486 U.S. 1007 (1988); Kittitas Reclamation District v. Sunnyside Valley Irrigation District, 763 F.2d 1032, 1033 (9th Cir. 1985), cert. denied, 474 U.S. 1032 (1985).

The Tribes' water right includes the right to certain conditions of water quality and flow to support all life stages of fish. See United States v. Anderson, 591 F.Supp. 1, 5-6 (E.D. Wash. 1982), aff'd in part & rev'd in part on other grounds, 736 F.2d 1358 (9th Cir. 1984); see also United States v. Gila Valley Irrigation Dist., 804 F.Supp. 1, 7 (D. Ariz. 1992), aff'd in part & vacated in part, 31 F.3d 1428 (9th Cir. 1994), on remand Globe Equity No. 59, Phase IV, slip op. (April 14, 1995). The Tribes' water right attaches to bodies of water located within the original boundaries of the Klamath Indian Reservation. The Tribes' fishing right also supports a water right in off-reservation areas to the extent necessary to support a tribal fishery within the original reservation.[8] Cf. Arizona v. California, 373 U.S. 546, 595 n.97, 600, decree entered, 376 U.S. 340, 344 (1964) (awarding reserved water right in off-reservation river). The standard to be applied in determining the quantity of water secured by this right has not been determined as of the date of this memorandum. The Tribes' water right is aboriginal in origin and thus has a priority date of time immemorial. Adair, 723 F.2d at 1415.

Yurok and Hoopa Valley Indian Tribes

The Yurok and Hoopa Valley Tribes have federal Indian reserved fishing rights to take anadromous fish within their reservations in California. Memorandum from the Solicitor to the Secretary, Fishing Rights of the Yurok and Hoopa Valley Tribes, M-36979 (Oct. 4, 1993) (Sol. Op.). These rights were secured to the Yurok and Hoopa Indians by a series of nineteenth century executive orders and confirmed to the Yurok and Hoopa Tribes by

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[8] In the pending Snake River Basin Adjudication in Idaho, the United States has made claims for off-reservation instream flow water rights derived from Indian fishing rights to anadromous fish. The quantity of flow claimed is that amount required to provide adequate flows to maintain fisheries habitat in the stream reach on a monthly basis.

the 1988 Hoopa-Yurok Settlement Act (HYSA), 25 U.S.C. § 1300i et seq.[9]

In 1855, the President, by Executive Proclamation, established the Klamath Reservation in California.[10] I C. Kappler, Indian Affairs: Laws and Treaties 816-817 (1904). The Hoopa Valley Reservation was formally set aside for Indian purposes by executive order in 1876, and the reservation was extended by another executive order in 1891 to encompass the Klamath Reservation and the connecting strip of land in between.[11] Id. at 815; see People v. McCovey, 685 P.2d 687, 689 (Cal. 1984); see also Donnelly v. United States, 228 U.S. 243, 253-259 (1912); Blake v. Arnett, 663 F.2d 906, 911 (9th Cir. 1981); Esler v. Gill Net Number One, 54 Cal. Rptr. 568, 571-72 (1966). The HYSA partitioned the extended reservation into the present Hoopa Valley and Yurok Reservations and declared the assets of each reservation held in trust by the United States for the benefit of the respective Tribes. 25 U.S.C. § 1300i-1(b).

The Yurok and Hoopa Valley Tribes' fishing rights entitle them to take fish for ceremonial, subsistence, and commercial purposes. United States v. Eberhardt, 789 F.2d 1353, 1359 (9th Cir. 1986). Their fishing rights "include the right to harvest quantities of fish on their reservations sufficient to support a moderate standard of living." Sol. Op. at 3.

The executive orders setting aside what are now the Yurok and Hoopa Valley Reservations also reserved rights to an instream flow of water sufficient to protect the Tribes' rights to take fish within their reservations. See Colville Confederated Tribes v. Walton, 647 F.2d 42, 48 (9th Cir.), cert. denied, 454 U.S. 1092 (1981); Anderson, 591 F.Supp. at 5-6. As with the Klamath Tribes, the Yurok and Hoopa Tribes' water rights include the right to prevent other appropriators from depleting the streams' waters below a protected level. See Joint Board of Control, 832 F.2d at 1131-32; Adair, 723 F.2d at 1411; see also Kittitas Reclamation District, 763 F.2d at 1033. The Tribes' rights include the right to certain conditions of water quality and flow

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[9] For the purpose of determining the existence of reserved water rights, there is no consequence to the fact that the Tribes' rights are derived from executive orders rather than treaties. Arizona v. California, 373 U.S. at 598.

[10] The executive order establishing the Klamath Indian Reservation was issued pursuant to the Act of March 3, 1853, 10 Stat. 238, authorizing the President "to make . . . reservations in the State of California for Indian purposes."

[11] These executive orders were issued pursuant to the Act of April 8, 1864, 13 Stat. 39.

to support all life stages of fish. See Anderson, 591 F.Supp. at 5-6; see also Gila Valley Irrigation District, 804 F.Supp. at 7. The Tribes' fishing right also supports a water right in off-reservation areas to the extent necessary to support the Tribes' on-reservation fisheries. Cf. Arizona v. California, 373 U.S. at 595 n.97, 600 (awarding reserved water right in off-reservation river). The exact standard to determine the amount of water secured by these rights has not been determined as of the date of this memorandum. The priority date of the Yurok and Hoopa water rights are at least as early as 1891, and may be earlier.

Obligations

Klamath Project Water Users

Reclamation has an obligation to deliver water to the project water users in accordance with the project water rights and the contracts between Reclamation and the water user (which may be through a water district) subject to the availability of water. Reclamation must protect the rights of the users of project water, see Filing of Claims for Water Rights in General Stream Adjudications, M-36966, 97 I.D. 21 (July 6, 1989), and cannot "ignore . . . the obligations that necessarily devolve upon it from having mere title to water rights for the [project], when the beneficial ownership of these water rights resides elsewhere." Nevada v. United States, 463 U.S. at 127. Water would not be available, for example, due to drought, a need to forego diversions to satisfy prior existing rights, or compliance with other federal laws such as the Endangered Species Act. Water lawfully stored in the project's reservoirs can be used for domestic and irrigation purposes to the extent the water is applied to beneficial use within the project. Reclamation cannot store or divert water for project purposes that is needed to satisfy prior existing rights.

Refuges

Reclamation has an obligation to ensure that the refuges receive adequate water to fulfill their federal reserved water rights (i.e., the amount of water necessary to fulfill the primary purposes of the refuges) when in priority and when water is available. In addition, Reclamation can continue to provide available project water for beneficial reuse by the refuges to the extent of past and current usage and consistent with project purposes.

The Kuchel Act (see footnote 5) requires that the refuge lands be used primarily for waterfowl purposes but with full consideration given to optimum agricultural use so far as agricultural use is consistent with the refuge purposes. 16 U.S.C. § 6951. In addition, the pattern of agricultural leasing existing in 1964 is to be continued on specified lands within the refuges as consistent with proper waterfowl management. Id. § 695n. Thus, it is possible that certain irrigated lands within the refuge boundaries would not be cultivated in the usual manner if that would be inconsistent with the purposes of the refuges. If such change in cultivation resulted in less water being used for irrigation within the project, then more water may be available for the refuges, pursuant to a change in the water right or otherwise, subject to prior existing rights and water availability.

The Tribes

The United States has a trust responsibility to protect tribal trust resources. This trust responsibility is one held by all federal agencies. Pyramid Lake Paiute Tribe v. Department of the Navy, 898 F.2d 1410, 1420 (9th Cir. 1990). In general, the trust responsibility requires the United States to protect tribal fishing and water rights, which are held in trust for the benefit of the tribes. See Mitchell v. United States, 463 U.S. 206, 224-226 (1982); Fort Mojave Indian Tribe v. United States, 23 Cl. Ct. 417, 425-426 (1991); Joint Board of Control of the Flathead, Mission and Jocko Irr. Dist. v. United States, 862 F.2d 195 (1988).

Reclamation is obligated to ensure that project operations not interfere with the Tribes' senior water rights. This is dictated by the doctrine of prior appropriation as well as Reclamation's trust responsibility to protect tribal trust resources.

With respect to the Tribes' fishing rights, Reclamation must, pursuant to its trust responsibility and consistent with its other legal obligations, prevent activities under its control that would adversely affect those rights, even though those activities take place off-reservation. See Parravano v. Babbitt, 861 F.Supp. 914, 924 (N.D. Cal. 1994), appeal pending. Thus, Reclamation must use any operational discretion it may have to ensure that those rights are not diminished. In doing so, Reclamation, in formulating any operating plan, must minimize unnecessary waste and take such other steps within its legal and contractual authority as are necessary to protect tribal rights. Pyramid Lake Paiute Tribe of Indians v. Morton, 354 F.Supp. 252, 255-256 (1973). In relation to a different Reclamation project, a court directed Reclamation, in formulating an operating plan, to provide, among other things, an effective means to measure water use, to end delivery of water to unentitled lands, and to assure compliance with such measures by project water users. Id. at 258.

Endangered Species Act

The Endangered Species Act (ESA), 16 U.S.C. §§ 1531 et seq., requires Reclamation to review its programs and utilize them in furtherance of the purposes of the ESA. 16 U.S.C. § 1536(a)(1). Reclamation has an obligation not to engage in any action that is likely to jeopardize the continued existence of a listed species. In addition, Reclamation must consult with the U.S. Fish and Wildlife Service (FWS) or the National Marine Fisheries Service (NMFS) (with respect to anadromous species) to insure that any action is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of critical habitat of such species.[12] Id. § 1536(a)(2). If as a result of such consultation, FWS or NMFS, as appropriate, finds that the action will result in the incidental taking of a listed species but is not likely to jeopardize the continued existence of the species, or that there is a reasonable and prudent alternative to the proposed action that will avoid such jeopardy, then FWS or NMFS will set forth the impact of such incidental taking, the reasonable and prudent measures necessary to minimize such impact, and the terms and conditions that Reclamation must comply with to implement such measures. Id. § 1536(b)(4).

Two species of sucker fish that occupy Upper Klamath Lake and its tributaries (as well as other water bodies within and adjacent to the project) have been listed as endangered under the ESA and Reclamation has consulted with the FWS with respect to the effects of project operations on these species. The FWS issued a Biological Opinion in 1992 (Long Term Biological Opinion) that set certain mandatory lake level elevations for Upper Klamath Lake necessary to avoid jeopardizing the species.

The coastal steelhead has been proposed for listing by NMFS. 60 Fed. Reg. 14253 (March 16, 1995). Reclamation has, through the conferencing provisions of the ESA, Id. § 1536(a)(4), determined that the 1995 operations of the Klamath Project will not jeopardize the continued existence of the steelhead. NMFS has concurred in this determination.[13]

Conclusion

None of the rights discussed above are quantified (except see footnote 1). Even so, Reclamation is not free to disregard these

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[12] Critical habitat has not been designated for the Lost River and shortnose suckers.

[13] A petition to list the chinook salmon has been received by NMFS. 60 Fed. Reg. 30263 (June 8, 1995). NMFS has proposed to list the coho salmon. ____ Fed. Reg. (____ July ___, 1995).

rights, and its discretion to determine the necessary means to protect and fulfill each of these rights is limited. Reclamation must exercise its statutory and contractual authority to the fullest extent to protect the tribal fisheries and tribal water rights. Reclamation must also, consistent with its statutory, contractual and trust obligations, fulfill the rights of the project water users and the refuges.

David Nawi
David Nawi

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United States Department of the Interior

OFFICE OF THE SOLICITOR
Pacific Southwest Region
2800 Cottage Way
Room W-2215
Sacramento, California 95825-1890

IN REPLY REFER TO:

BUREAU
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JAN 0 9 1997
KLAMATH FALLS OREGON

JAN 9 1997

Memorandum

To: Regional Director, Region 1, U.S. Fish and Wildlife Service, Portland, OR
Regional Director, U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA
Area Director, Portland Area Office, Bureau of Indian Affairs, Portland, OR
Area Director, Sacramento Area Office, Bureau of Indian Affairs, Sacramento, CA

From: Regional Solicitor
Pacific Southwest Region David Nawi

Regional Solicitor
Pacific Northwest Region Lynn Peterson

Subject: Oregon Assistant Attorney General's March 18, 1996, Letter Regarding Klamath Basin Water Rights Adjudication and Management of the Klamath Project

As requested, we have reviewed the March 18, 1996, letter from Stephen Sanders, Assistant Attorney General, Natural Resources Section, to Martha Pagel, Director, Oregon Water Resources Department (OWRD) (March 18 letter). The March 18 letter responds to a request of the Director of the OWRD for "a description of the types of claims likely to be asserted by the federal government in the Klamath Basin adjudication, and an analysis of water management authority in the basin pending the completion of the adjudication." We are responding jointly because the March 18 letter addresses issues of concern to agencies within the responsibility of both the Pacific Southwest and the Pacific Northwest Regions of the Solicitor's Office.

The issues raised in the March 18 letter arise in the context of actions by the Secretary of the Interior (Secretary), acting through the Bureau of Reclamation (Reclamation), to manage and operate the Klamath Project (Project) and particularly to develop a Project operations plan. In so doing, Reclamation and other Federal agencies with responsibility related to water and wildlife resources, including Indian trust resources, in the Klamath Basin (Fish and Wildlife Service, Bureau of Indian Affairs, and National Marine Fisheries Service) are engaged in a process of consultation with and consideration of the interests of diverse groups, including agricultural water users, Indian tribes, and wildlife interests, regarding Project operations and the development of a plan intended to govern operations pending completion of the Klamath Basin adjudication presently being conducted by the State of Oregon.[1]

The March 18 letter raises issues regarding the authority of the Secretary to manage the Klamath Project pending completion of the adjudication, as well as issues regarding the United States' water rights, including tribal water rights the United States holds in trust, in the Klamath Basin. The March 18 letter is in wide circulation and may be read as calling into question the legal basis of various federal actions to manage the Project, including the development of an operations plan. Our conclusions regarding a number of the issues differ from those contained in the March 18 letter. For these reasons, we think it important to set out in general terms our views on the major issues for our client agencies and interested parties.

This memorandum reaffirms long-standing positions of the United States regarding management of water projects for irrigation, wildlife protection, and Indian rights, and builds on the July 25, 1995, memorandum from the Regional Solicitor, Pacific Southwest Region, to the Regional Director, Bureau of Reclamation, Mid-Pacific Region (July 25 memorandum).[2] This memorandum does not attempt to provide a complete legal analysis of all the issues raised by the March 18 letter. Further legal analysis will be presented, as needed, in connection with the adjudication or otherwise.

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[1] Upon completion of the adjudication and pursuant to section 8 of the Reclamation Act of 1902, the Project will be operated in accordance with the outcome of the adjudication, as well as with other applicable requirements, and the operations plan will be revised as appropriate. As discussed throughout this memorandum, many of the issues raised in the March 18 letter arise as a result of Reclamation's need to meet its obligations and responsibilities in operating the Project, the absence of a completed adjudication of the Klamath Basin, and the lack of any other action by the State of Oregon to administer junior water rights in relation to senior unadjudicated water rights in the Basin.

[2] The March 18 letter contains several references to the July 25 memorandum, which describes the general rights to the waters of the Klamath and Lost River drainages affected by the operation of the Klamath Project and the obligations of the Bureau of Reclamation to the holders of these rights. We adhere to the conclusions set forth in the July 25 memorandum. This memorandum addresses additional issues not raised in the July 25 memorandum.

I. Management of the Klamath Project

The March 18 letter states that the United States, through development of an operations plan by Reclamation, is asserting that it has the authority to regulate water uses in the Klamath Basin where no such authority exists. March 18 letter, pages 5-7. The United States is not, however, seeking in the operations plan to preempt or supplant the State's role in adjudicating and administering water uses; rather, it is carrying out the responsibilities federal law places on it in managing the Klamath Project.[3]

An operations plan is being developed through an open process, including consultation with affected government and other interests and an opportunity for public comment, to arrive at an informed decision regarding Reclamation's operation of the Project pending completion of the adjudication. Reclamation is using this process to review Project operations to assure that they are consistent with all of Reclamation's responsibilities and obligations concerning senior water rights, tribal trust resources, Project water users' contractual rights, the Endangered Species Act (ESA) and other requirements mandated by law and within the authority of the Secretary.[4]

The March 18 letter states that it is unclear how water must be managed pending completion of the adjudication and declares that the state will not regulate or administer unadjudicated water rights or water uses. March 18 letter, page 5. The March 18 letter also asserts that the federal government lacks authority to manage any water uses in the basin, even those involving water

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[3] The March 18 letter refers to the project operations plan as the Klamath Project Operations Plan or "KPOP." KPOP is no longer the label applied to the operations plan now being developed which will address project management pending completion of the Klamath Basin adjudication being conducted by the State of Oregon. Our analysis of the underlying authorities is applicable to whatever operations plan is ultimately adopted.

[4] The March 18 letter bases its analysis and conclusions on the proposition that the 1905 water rights filing by the United States for development of the Klamath Project is limited to irrigation uses. ("The rights developed under the Reclamation Act and the 1905 Notice must, therefore, be used for the purpose specified in the Act and the Notice, that is, only for irrigation." March 18 letter, page 3.) This memorandum focuses on the issue of authority raised in the March 18 letter. The nature of the Project water rights will be addressed at the appropriate time in the pending adjudication.

rights and uses subject to federal law. For the reasons set out below, we have a different view.

The Secretary, through Reclamation, must manage and operate reclamation projects developed pursuant to the Reclamation Act of 1902 (43 U.S.C. § 372 et seq., Act of June 17, 1902, 32 Stat. 388) and its amendments and supplements. Specifically, section 10 of the Reclamation Act, 43 U.S.C. § 373, expressly directs the Secretary "to perform any and all acts and to make such rules and regulations as may be necessary and proper" to carry out the reclamation laws. See United States v. Alpine Land and Reservoir Co., 887 F.2d 207, 212 (9th Cir. 1989). Districts and water users within the project must comply with such actions taken pursuant to section 10 and pursuant to contracts between Reclamation and the districts and water users. Id.; Pyramid Lake Paiute Tribe v. Hodel, 878 F.2d 1215 (9th Cir. 1989); Truckee-Carson Irrigation District v. Secretary of Department of Interior, 742 F.2d 527 (9th Cir. 1984), cert. denied, 472 U.S. 1007 (1985). The operations plan process and resulting plan are clearly authorized by section 10 of the Reclamation Act of 1902. See July 25 memorandum for further discussion.[5]

The federal courts have not hesitated to order the Secretary to fulfill his tribal trust obligations and to comply with the ESA in operating reclamation projects. See Pyramid Lake Paiute Tribe v. Morton, 353 F.Supp. 252, 255-56 (D.D.C. 1973). The Secretary, through Reclamation, must operate reclamation projects consistent with vested, fairly implied senior Indian water rights. Kittitas Reclamation District v. Sunnyside Valley Irrigation District, 763 F.2d 1032, 1033 (9th Cir.), cert. denied, 474 U.S. 1032 (1985) (district court did not abuse its discretion in ordering Reclamation to make water available to protect unquantified, unadjudicated treaty-reserved fisheries related water rights); Pyramid Lake Paiute Tribe v. Morton, supra (Secretary of the Interior "was obliged to formulate a closely developed regulation that would preserve water for the Tribe . . . [and] to assert his statutory and contractual authority to the fullest extent possible to accomplish the result." Id. at 256). Cf. Joint Board of Control of the Flathead, Mission, and Jocko Irrigation Districts v. United States, 832 F.2d 1127 (9th Cir. 1987), cert. denied, 486

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[5] See also Israel v. Morton, 549 F.2d 128, 132-33 (9th Cir. 1977) (water obtained from a federal reclamation project is not there for the taking by the landowner, but for the giving by the United States, and terms upon which water can be put to use, and manner in which rights to use can be acquired, are only for the United States to fix, and if such rights are subject to becoming vested beyond the power of the United States to take without compensation, such vesting can only occur on terms fixed by the United States).

U.S. 1007 (1988) (prior to allocating water from a federal irrigation project among project water users, the Department had to adequately protect the tribe's senior instream flow water rights). See also Parravano v. Babbitt, 861 F.Supp. 914 (N.D. Cal. 1994), aff'd, 70 F.3d 539 (9th Cir. 1995), cert. denied, 116 S. Ct. 2546 (1996) (Secretary of Commerce properly considered the tribe's federally reserved fishing rights in issuing emergency regulations reducing harvest limits of Klamath River salmon).

Moreover, a specific statutory directive is not needed for Reclamation to manage irrigation deliveries to protect senior tribal water rights. Although the Klamath Tribes' water rights have not yet been quantified in an adjudication, the existence of the Klamath Tribes' rights to the water needed to protect their treaty-reserved hunting and fishing rights (with a priority date of time immemorial) and for agricultural uses has been confirmed by the Ninth Circuit Court of Appeals. United States v. Adair, 723 F.2d 1394 (9th Cir. 1983), cert. denied, 467 U.S. 1252 (1984). The Yurok and Hoopa Valley Tribes in California hold unadjudicated water rights which vested at the latest in 1891 and perhaps as early as 1855. See, e.g., United States v. Adair, supra; Arizona v. California, 373 U.S. 546, 600 (1963); United States v. Winans, 198 U.S. 371 (1905). Cf. Solicitor's Opinion, M-36979, Fishing Rights of the Yurok and Hoopa Valley Tribes (Oct. 4, 1993).[6]

While the March 18 letter asserts that "[o]nly the state has the authority and the regulatory system to establish relative priority dates and enforce the priority system," March 18 letter, page 7, both federal and state courts have jurisdiction in appropriate cases to establish and enforce the priority system. See, e.g., Cappaert v. United States, 426 U.S. 126 (1976) and Winters v. United States, 207 U.S. 564 (1908). In addition, nothing in the McCarran Amendment, 43 U.S.C. § 666, prohibits the United States from managing and operating its reclamation projects. The priority water rights system is one of the bases upon which reclamation projects are operated. While Reclamation does not adjudicate water rights, the absence of a completed adjudication and Reclamation's legal obligation to manage the project in accordance with law require that Reclamation use its best efforts to operate the project consistent with existing water rights.

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[6] Although tacitly recognizing the fisheries reserved water rights of the Klamath Tribes and the Yurok and Hoopa Valley Tribes, the March 18 letter questions without answering the extent of the Klamath tribal right, and implies that the Yurok and Hoopa Valley Tribes' rights are "paper" rights with no enforceability. March 18 letter, pages 6-7, fn. 4. As discussed above, and in the July 25 memorandum, pages 4-5, in our view the tribes' rights are senior and enforceable against junior uses, and adjustments may be required in how the Klamath Project is operated to be consistent with the tribes' rights.

The March 18 letter further asserts that regulation in favor of senior tribal, federal, and project water rights may not occur until those rights have been adjudicated and cites South Delta Water Agency v. U.S. Department of the Interior, 767 F.2d 531 (9th Cir. 1985), as supporting the proposition. March 18 letter, pages 5-6. However, that case does not address the issue. The Ninth Circuit merely held that, contrary to the State of California's argument, suit cannot be brought pursuant to the McCarran Amendment against the United States for the administration of water rights without a prior general stream adjudication having determined those rights.

The State of Oregon has declined to administer junior rights to protect senior tribal, project, and other federal rights on the grounds that such rights are unknown until the adjudication is complete. However, in the absence of a completed adjudication or other determination of the senior water rights, the project must be operated based on the best available information. For example, the Project irrigation water rights can be reasonably estimated. Similarly, although the tribal instream flow and lake rights are complex, they also may be reasonably estimated; and even though unadjudicated, they are vested, senior rights, and Reclamation must operate the project consistent with those rights. Joint Board of Control of the Flathead, Mission, and Jocko Irrigation Districts v. United States, supra, at 1131-32. ("The priority date of time immemorial obviously predates all competing rights" and to ignore this would violate "the fundamental principles of the appropriative system of water rights.")

The March 18 letter also states that users junior to the Klamath Project should provide water to senior rights holders before the Project does so. March 18 letter, page 7. We agree that to do so best comports with the priority system of water rights administration. But the March 18 letter does not address the situation, as in this case, where the State is not protecting senior water rights. Moreover, the March 18 letter offers no avenue or mechanism for effecting calls on junior users. It adopts a hands-off position even though the State is in a better position to deal with junior nonfederal water users.[7] In such a situation, the Secretary must exercise what authority he has in managing the Project to protect senior water rights and meet requirements of federal law.

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[7] The March 18 letter sets forth at page 5 Oregon's position that it "neither regulates in favor of nor against unadjudicated water rights." The letter fails, however, to discuss whether the State has authority to regulate junior water rights in relation to senior unadjudicated rights prior to completion of the adjudication, and if so, whether the State should exercise that authority in the Klamath Basin. This has contributed to the demand for Reclamation to prepare an operations plan.

We disagree with the assertions in the March 18 letter regarding the water rights for the national wildlife refuges.[8] March 18 letter, pages 5-6. Among others, bases for the refuge water rights include state-based rights perfected by applying project water or return flows to beneficial use, and federal reserved rights to the water unappropriated at the time of the refuges' creation and needed to carry out the refuges' purposes. See Arizona v. California, supra, at 598.

In sum, the operations plan is not an attempt to regulate water uses in the Klamath Basin. Rather, it reflects Reclamation's effort to exercise its authority to manage the project consistent with all of its obligations, including senior Indian water rights, contractual obligations and ESA requirements. See Pyramid Lake Paiute Tribes v. Morton, supra; United States v. Alpine Land and Reservoir Co., supra.[9]

II. The Project Operations Plan is not a "Reallocation" of Klamath Project Water

The March 18 letter states that obligations to Indian tribes and listed species do not provide authority to "reallocate" water

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[8] Although the distinction may not be at issue here, we also disagree with the view expressed at page 6 of the March 18 letter that "[as] a technical matter, only 'land set aside from the public domain' may acquire a reserved right" and not land acquired by the United States. See Memorandum, Department of Justice, Office of Legal Counsel, June 16, 1982, at pages 77-78. In that opinion, the issue of reserved rights for acquired lands was directly addressed:

> Much of the language used by the Court to describe the scope of the reservation doctrine, in fact, is broad enough to cover all lands set aside for a particular federal purpose, regardless of the prior ownership of the land. . . . [I]n [United States v. New Mexico], the Court did not suggest that the reserved rights doctrine applies only to lands that may be formally reserved from the public domain; it recognized rather that the doctrine applies to any land that has been set aside as a national forest (which could be reserved or acquired lands). See 438 U.S. at 698-99.

Id. at 78.

[9] For the Newlands Project, discussed in United States v. Alpine Land and Reservoir Co., supra, the initial project operation criteria and procedures (OCAP) were issued prior to a final adjudication of water rights in the Newlands Project, while the final OCAP were adopted after the final decree was affirmed. The Alpine decision upheld the final OCAP.

II-8

absent specific federal authority for the new use and compliance with state law. March 18 letter, page 9; see also pages 3, 5, 8, 10, 11. Once again, we believe the March 18 letter mischaracterizes the nature of the issue. The lack of a completed water rights adjudication does not legitimize uses of water that would not otherwise be authorized. Reclamation's actions are intended to result in management and operation of the Klamath Project in a manner which is consistent with and carries out all its legal obligations and responsibilities. Operation of the project to reflect Reclamation's obligations is not a reallocation of water.

The March 18 letter cites several cases to support the proposition that Project water stored under a water right "acquired for irrigation" cannot be used to meet the United States' obligations to Indian tribes and under the ESA. March 18 letter, pages 9-10. In our view, the cases cited either do not apply to the situation at hand or do not support the proposition that the United States may ignore Indian water rights or its obligations under the ESA.

In Nevada v. United States, 463 U.S. 110 (1983), the Supreme Court simply held that the United States could not ignore the limits of decreed federal reserved or other water rights where all the water rights, including the Indian rights, had already been fully adjudicated. Nevada does not address the issue of whether project operations must be consistent with existing senior water rights or the ESA where none of the water rights have been fully adjudicated.

In Carson-Truckee Water Conservancy District v. Clark, 741 F.2d 257 (9th Cir. 1984), cert. denied, 470 U.S. 1083 (1985), the court found that the Secretary's decision to operate Stampede Dam solely for the purpose of conserving an endangered species of fish was not arbitrary. Although the court explicitly found that it need not address tribal water rights to reach its decision, the court stated that any asserted obligation of the Secretary to enter into contracts for the sale of project water for municipal and industrial purposes pursuant to the project's authorizing legislation should be considered only when his superseding obligations to the Tribe and under the ESA have been fulfilled. (This case concerned the same Reclamation project that was the subject of Nevada v. United States. However, the water rights connected with Stampede Dam are not adjudicated.)

Likewise, in O'Neill v. United States, 50 F.3d 677 (9th Cir.), cert. denied, U.S. 116 S. Ct. 672 (1995), the court held that the United States was not liable for not furnishing the full contractual amount of water to water users when that amount could not be delivered consistent with the requirements of the ESA and the Central Valley Project Improvement Act, Pub. L. No. 102-575. The court found that the provisions in the contract which precluded federal liability for water shortage were broad enough to include the "mandates of valid legislation."[10]

Reclamation is mandated by the ESA to avoid jeopardizing the continued existence of listed species and to conserve listed species.[11] In addition, individual water users and water districts, as well as Reclamation, are subject to the prohibition in section 9 of the ESA on taking listed species. See, e.g., United States v. Glenn-Colusa Irrigation District, 788 F.Supp. 1126 (E.D. Cal. 1992).

As a final matter, the March 18 letter seems to assume that once the Klamath Basin adjudication is completed and the State begins administering the water rights, the Secretary will no longer need to manage the Project. See, e.g., March 18 letter, pages 2, 4-5. The cases make clear, however, that the Secretary's authority and responsibilities under federal law to manage the Project will continue, concurrent with the requirement to operate the Project consistent with adjudicated water rights. See Pyramid Lake Paiute Tribes v. Morton, supra and United States v. Alpine Land and Reservoir Co., supra, cases which involved previously adjudicated project water rights.

III. The Klamath Basin Adjudication

The March 18 letter addresses the three general categories of claims the author believes will be resolved in the Klamath Basin adjudication. We do not propose to address these issues now. The United States will make appropriate arguments and set forth in full the federal position regarding these issues in the course of the adjudication. We do, however, make the observations set out below with respect to certain points raised in the March 18 letter concerning the adjudication.[12]

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[10] Similar shortage provisions are found in Klamath Project contracts.

[11] Reclamation is also obligated to confer with the Fish and Wildlife Service or the National Marine Fisheries Service on any action which is likely to jeopardize the continued existence of any species proposed to be listed, and is authorized to take conservation measures to minimize impacts on the proposed species. ESA, section 7(a)(4), 16 U.S.C. § 1536(a)(4), and section 5(a), 16 U.S.C. § 1534(a).

[12] The March 18 letter was written by an Assistant Attorney General of the State of Oregon who we understand will advise the decision maker in the administrative phase of the adjudication. Several aspects of his letter raise a concern that he appears to have taken positions on issues to be determined in the adjudication before the parties have had opportunity to brief and litigate them.

The March 18 letter states that Klamath Project water rights "likely . . . are held by the irrigation districts or perhaps by individual district members" rather than by the United States. March 18 letter, page 4. It is well established, however, that the United States through the Bureau of Reclamation holds the legal title to the water rights for the project. Nevada v. United States, supra; Ide v. United States, 263 U.S. 497 (1924); United States v. Humboldt Lovelock Irr. Light & Power Co., 97 F.2d 38 (9th Cir. 1938), cert. denied, 305 U.S. 636 (1938); United States v. Tilley, 124 F.2d 850 (8th Cir. 1942); see also Solicitor's Opinion, M-36966, 97 I.D. 21, Filings of Claims for Water Rights in General Stream Adjudications (July 6, 1989); Solicitor's Opinion, M-36967, 97 I.D. 32, Authority to Provide Water to Stillwater Wildlife Management Area (July 10, 1989). In 1905, the United States, through the Secretary of the Interior, pursuant to the Reclamation Act of 1902 and Oregon law, initiated the appropriation of the amount of water necessary to develop the Klamath Project.

The United States Supreme Court has long held that individual water users who have entered into contracts with the United States to receive project water, hold a beneficial interest in that portion of the project water right actually put to beneficial use. Nevada v. United States, supra; Nebraska v. Wyoming, 325 U.S. 589 (1945); Ickes v. Fox, 300 U.S. 82 (1937). Unlike the United States and individual water users, in the typical case irrigation districts hold neither a legal nor beneficial interest in the water right. They have no property interest in the water, nor have they in their own right diverted the water to storage. Truckee-Carson Irrigation District v. Secretary of the Interior, supra. Moreover, the districts have not put the water to beneficial use and thus do not hold an interest in the water right.

In light of the foregoing, Reclamation is the proper entity to file claims on and hold the water rights for the Klamath Project, 97 I.D. 21, recognizing the beneficial interest of individual water users entitled to use project water for beneficial uses, provided that the use comports with the terms of applicable Reclamation contracts and state and federal law.

Although the March 18 letter does not discuss the subject, there are federally owned lands within the project boundaries that receive project water. The United States is the proper party to file for those water rights in this situation, where the United States holds both the legal and beneficial interests in the lands and the water.

Finally, the United States has control of the project return flows within the boundaries of the project, has the right to use the return flows, and has the right to continue such use. Ide v. United States, supra. Contrary to assertions in the March 18 letter, the United States Supreme Court did not hold in Ide that use of recaptured water had to be the original use; the Court merely held that the recaptured water had to be beneficially used. Thus, we do not believe that Ide or subsequent cases preclude the United States from using return flows for uses other than irrigation and domestic purposes.

Similarly, Jones v. Warmsprings Irrigation District, 91 P.2d 542 (Or. 1939), is not applicable to circumstances where water remains within the project boundaries and control of the appropriator; that case concerned return flow deemed to be abandoned because there had been no indication of an attempt to recapture. Finally, the Oregon Supreme Court in Cleaver v. Judd, 393 P.2d 193 (Or. 1964), recognized that under Oregon law an appropriator is justified in recapturing waste, seepage, and occasional surface water runoff.

IV. CONCLUSION

Pending completion of the adjudication, Reclamation is authorized and obligated to manage and operate the Klamath Project consistent with all of Reclamation's responsibilities and obligations concerning senior water rights, tribal trust resources, Project water users' contractual rights, the Endangered Species Act and other requirements mandated by law and within the authority of the Secretary. These obligations may be clarified or otherwise affected by the pending adjudication; however, Reclamation will continue to have authority to manage and operate the Project consistent with its obligations after completion of the adjudication.

Appendix B

DROUGHT PLAN

February 12, 1992

DROUGHT PLAN

Upper Klamath Lake Watershed

Priority and Execution Plan for Administration of Water Rights and Water Delivery on the Klamath Project in the Event of a Drought

General

It should be emphasized that before any actions are taken to limit the amount of water available to Klamath Project water users, efforts will be made to minimize, or possibly avert, the shortages that are forecasted. Water users will be represented in these efforts to attempt to work out a plan that will be fair and equitable to those involved.

It should also be noted that return flows generated by Project water users are an important factor in determining the total amount of water use figures. These return flows are reused many times in the agricultural use cycle and may ultimately affect several downstream users.

An emphasis would be placed on conserving water, growing crops that use less water, farming practices that will save water, possible fallowing of land that is less productive, and most important, cooperation among the water users. Only after avenues of conservation and cooperation are explored would the water be allocated on a priority basis within the Klamath Project.

One of the key themes in any prioritization of water rights on the Project is that we claim a 1905 right for all Project lands regardless of the type of contract that the water users may have. However, within the Project we can prioritize use by date of contract and type of contract. All other diverters of water not in the Project would be considered junior to our Project needs if their priority date was after 1905.

There are two basic types of contracts on the Project, a 9(d) Repayment contract and a Warren Act type contract. The 9(d) type contract was used for Main and Tulelake Divisions of the Project. These Divisions were, for the most part, homesteaded by Reclamation. The Warren Act was used to grant a secondary right of use to users above the gravity system and/or not in the above mentioned Divisions of the Klamath Project.

First Priority of Use Within the Project (Class A)

Van Brimmer Irrigation District's contract with the United States recognizes that district's right to the use of 50 cfs. The United States eliminated the district's supply of water by reclaiming Lower Klamath Lake, and was then obligated to provide another source of supply. The result of that obligation is that the Van Brimmer Irrigation District has a priority that predates 1905.

Klamath Irrigation District, also known as the Main Division, was the first land developed for irrigation and, as such, would have the first right to the use of irrigation water after Van Brimmer. The district was the successor to the Klamath Water Users Association who contracted with the United States on November 6, 1905. The first contract between the United States and the district was dated July 6, 1918 and was written pursuant to the 1902 Federal Reclamation Act.

Tulelake Irrigation District's contract is dated September 9, 1956, and is also a 9(d) type contract. The contract specifically states that the district has the same contractual right and priority date as other contracts written pursuant to the 1902 Act on the Project.

Federally owned areas leased by the United States are considered to have the same priority date as other Class A users. During extreme drought circumstances Reclamation may voluntarily limit deliveries to federal lease lands, thus preserving a supply to the other Class A water users.

There are several individual contracts within Klamath Irrigation District that were written pursuant to the 1902 Act in the 1970's. These are for minor acreages, somewhere in the neighborhood of 400 acres.

Second Priority of Use Within the Project (Class B)

All of the following contracts were written pursuant to the Warren Act of February 21, 1911. These contracts include a clause which states that the water right is subject to the main division land's first right. The Warren Act was cited in the contracts so that a secondary right could be issued to the contractor. The Warren Act contains a clause in Article 1 which states in part "..., preserving a first right to lands and entrymen under the Project.". In addition, most of the contracts contain the very same wording. Given that understanding, the following order of precedence by contract date will be followed:

Enterprise Irrigation District Receives water out of the A-Canal through the Klamath Irrigation District system. The date of the contract is October 5, 1920.

Klamath Drainage District Receives water out of the Klamath River below the Link River Dam. The date of the contract is August 24, 1921.

Malin Irrigation District Receives water out of the D-Canal through the Klamath Irrigation District system. The date of the contract is September 9, 1922

Shasta View Irrigation District Receives water out of the D-Canal through the Klamath Irrigation District system. The date of the contract is October 6, 1922.

<u>Sunnyside Irrigation District</u> Receives water out of the Van Brimmer Canal system. The Van Brimmer Canal gets its supply of water from Upper Klamath Lake through the Klamath Irrigation District system. The date of the contract is October 24, 1922.

<u>Pine Grove Irrigation District</u> Receives water out of the A-Canal (Klamath Irrigation District system). The date of the contract is June 19, 1936.

<u>Colonial Realty Company-Westside Improvement District</u> Receives water out of the Tulelake Sump and at the end of the J-1 lateral. The District was incorporated into Tulelake Irrigation District as an improvement district. The date of the contract is October 20, 1936.

<u>Plevna District Improvement Company</u> Receives water out of the Klamath River below the Link River Dam. The date of the contract is April 1, 1940.

<u>Emmitt District Improvement Company</u> Receives water out of the Klamath River below the Link River Dam. The date of the contract is December 1, 1947.

<u>Midland District Improvement Company</u> Receives water out of the Klamath River below the Link River Dam. The date of the contract is February 2, 1952.

<u>Poe Valley Improvement District</u> Receives water out of the Lost River below Harpold Dam. The District is highly dependent on return flows from the Klamath Irrigation District system in Poe Valley. The contract does not mention where the water is to come from, only that it will be made available in the Lost River. The date of the contract is July 20, 1953.

<u>Ady District Improvement Company</u> Receives water out of the Klamath River below the Link River Dam. The date of the contract is August 5, 1954.

<u>Klamath Basin Improvement District</u> Receives water through the Klamath Irrigation District system. The date of the contract is April 25, 1962.

<u>Miscellaneous Warren Act Contracts</u> This group of contracts are scattered throughout the Project and get their water supply from the Lost River and Upper Klamath Lake/Klamath River. Some of the contracts have been turned over to Klamath Irrigation District to administer. Contract dates range from 1915± to 1960±.

Third Priority of Use Within the Project (Class C)

The first group of water users that would need to be shut off in the event of water shortages would be the temporary water rental contracts. Rental water is sold to individual farmers on an "if and when available" status. Klamath Irrigation District and Tulelake Irrigation District both have clauses that allow them to sell rental water. In addition, Reclamation has rental contracts with users in the P-Canal and the Lost River areas.

EXECUTION PLAN

In the event that there was insufficient projected supplies of water available within the system from the Klamath River the following actions would be taken:

March 10 If necessary, on this date or before, letters will be sent to all water users advising them that we can expect a deficiency in supplies of irrigation water and that sales of rental water may not be allowed pending the outcome of the April 10 meeting and April forecasts. Also, at this time, separate letters will be sent to the Class B users advising them of our intent to limit their use of water should supplies fall below our projections. The letter would also request that the appropriate portion of Exhibit 1 be completed by the respective districts and returned to the Bureau of Reclamation no later than March 26.

April 10 On or before this date an allocation projection meeting would be hosted by Reclamation in which the district manager and the board chairman from each district would attend. Reclamation would have the information from Exhibit 1 compiled and a proposed allocation available. This would become the basis for discussions, potential revisions and efforts to arrive at an equitable reallocation of available supplies. Factors such as reduced acreages, crops that use less water, farming practices that reduce water use, and other water saving measures would be taken into consideration. The final projected allocation would be determined from this meeting.

May 10 Reclamation would revise the allocation using percentages based on changes in storage and run-off that occur between April 1 and May 1 and send the data to the districts via certified mail.

In the event that the cooperative effort discussed in the April 10 meeting reaches an impasse, the following plan would be followed:

The sufficiency of the water supply would re-evaluated by the Klamath Project and, if found insufficient to meet secondary demands, Klamath Irrigation District, Tulelake Irrigation District and Klamath Drainage District, would be notified to stop or limit deliveries to the specified Class B users under their delivery control points. In addition, The Klamath Project would notify other specified Class B users to stop or limit delivery of irrigation water.

Letters would be sent to the Class A Users assigning them an acre-foot allocation and flow schedule for the balance of the irrigation season.

The above described measures would remain in effect until the Bureau of Reclamation declared a water supply status capable of meeting all contractual commitments.

Appendix C

CONTRACTS AND WATER RIGHTS

Contractual Relationships

Power Contract

In 1917, the United States entered into a contract with California Oregon Power Company, now PacifiCorp, under which the power company was given the right to construct Link River Dam at the outlet of Upper Klamath Lake, and the right to use certain amounts of water after the requirements of the Klamath Project were satisfied. The contract was to cease, and title of the dam was to vest in the United States 50 years from the date of execution. The contract was renewed early as a result of the FERC Project 2082 concerning the construction and operation of downstream Klamath dams operated by the power company. The present contract, which will expire in 2006, allows PacifiCorp to operate the dam within certain guidelines (see *Hydroelectric Power*, p. 9 and *Link River Dam and Upper Klamath Lake*, p. 11).

Repayment Contracts

The Bureau of Reclamation entered into numerous contracts pursuant to Article 9(d) of the Reclamation Act of 1939 with various irrigation districts to provide for repayment of Project costs and a supply of Project water. The contracts specify an acreage to be covered and in most cases, do not specify an amount of water, relying on beneficial use for the amount of water used. The contracts are all written in perpetuity.

In all, over 250 contracts for delivery of Project water are administered either directly or through irrigation districts on the Klamath Project. Contracts also cover the operation of the system that was transferred to the water users for operational responsibility. Irrigation districts that fall into this category and the contracts follow:

Klamath Irrigation District

November 29, 1954	Operational responsibility and water supply
June 2, 1950	Water supply
November 24, 1928	Drainage and repayment
June 25, 1927	Exclusion of land payment adjustment
April 10, 1922	Amendment to earlier contract
June 28, 1920	Repayment adjustment
July 6, 1918	Original contract

Tulelake Irrigation District

September 10, 1956	Operational responsibility and water supply

Langell Valley Irrigation District

July 29, 1965	Acreage and payment adjustment
May 17, 1951	Water rights adjustment/inclusion

November 18, 1935	Water rights adjustment
January 11, 1934	Water rights adjustment
April 13, 1931	Dredging Clear Lake/priority of use
October 17, 1925	Rechannel Lost River/Miller Creek
October 15, 1923	Increase water entitlement to HID
June 18, 1923	Construction of Gerber Dam on Miller Creek
March 27, 1922	Original water supply/repayment contract

In addition to the above, Reclamation entered into numerous contracts that were written pursuant to the Warren Act of 1911. These contracts provided for a water supply at a certain point, with the responsibility of the contractor to construct all the necessary conveyance facilities (i.e., pumps, laterals, and turnouts) and be responsible for their operation and maintenance.

Some of the districts (and their respective contracts, only the most recent of which is listed) that own all or a portion of their privately constructed facilities are:

District Name	Contract Date	Acreage
Van Brimmer Ditch Company	November 6, 1909	3,315
Klamath Basin Improvement District	April 25, 1932	10,403
Enterprise Irrigation District	March 18, 1935	2,981
Malin Irrigation District	May 5, 1936	3,507
Pine Grove irrigation District	June 19, 1936	927
Sunnyside Irrigation District	June 25, 1936	595
Westside Improvement District	October 20, 1936	1,190
Shasta View Irrigation District	August 20, 1938	4,141
Klamath Drainage District	April 28, 1943	19,229
Emmitt District Improvement Company	December 1, 1947	424
Midland District Improvement Company	February 2, 1952	581
Poe Valley Improvement District	July 20, 1953	2,636
Ady District Improvement Company	August 5, 1954	435
Plevna District Improvement Company	February 7, 1958	523
Horsefly Irrigation District	August 24, 1976	9,843
Upper Klamath Lake contractors	Various contract dates	7,918
Individual contracts	Various contract dates	9,960

Temporary Water Contracts

Each year Reclamation determines whether surplus water is available to irrigators (see *Water Supply Forecasting*, p. 36). In many cases, irrigators have been receiving surplus irrigation water from Reclamation for over 50 years. For numerous reasons, these irrigators were never given a permanent contract. Concurrently, the districts also make a determination whether or not to sell surplus water. The following irrigable acreages were covered by surplus water contracts in 1990:

Klamath Irrigation District	59.0
Langell Valley Irrigation District	134.0
Tulelake Irrigation District	1,955.0
Bureau of Reclamation	1,649.0
	3,797.0

The irrigable acreage represented by these temporary contracts is less than 2 percent of the total acreage irrigated on the Project. Water is delivered to these lands through the existing irrigation systems. In many cases, the water is delivered and controlled by the irrigation districts.

Water Rights Information

Acquired Water Rights

In addition to initiating the appropriative rights procedure in the State of Oregon, the United States acquired some early pre-Project rights to use water by purchase from landowners with prior rights entitlements. Water Rights were acquired from: Moore Brothers, Link River; Klamath Canal Company, Link River; Klamath Falls Irrigating Company (Ankeny Canal System), Upper Klamath Lake; Little Klamath Water Ditch Company (Adams Canal), Lower Klamath Lake; Van Brimmer Ditch Company, Lower Klamath Lake; Tule Lake Land and Livestock Company (Jesse D. Carr Land and Livestock Company Ranch in Clear Lake); Jesse D. Carr Land and Livestock Company, Tule Lake; and Griffith & Phillips, Lost River.

The fact that a considerable number of these rights were purchased by the United States indicates that early private development of the basin was well under way at the advent of Reclamation. It was necessary to purchase these rights from the entities involved so that Reclamation had full control of all of the rights to the use of water in the basin to facilitate Project operation.

Appropriation by the United States

The basic water rights required for the operation of the Klamath Project are derived from certain legislation of the State of Oregon enacted in 1905 (Chap. 228, Ore. Gen. Laws, 1905) and later (Sec. 116.438, Ore. Comp. Laws Annotated). This act was repealed by House Bill 224, approved April 13, 1953. Section 2 of this act provides:

> *Whenever the proper officers of the United States, authorized by law to construct works for the utilization of water within this State, shall file in the office of the State Engineer a written notice that the United States intends to utilize certain specified waters, the waters described in such notice and unappropriated at the time of the filing thereof shall not be subject to further appropriation under the laws of this State, but shall be deemed to have been appropriated by the United States; provided that within a period of three years from the date of filing such notice the proper officer of the United States shall file final plans of the proposed works in the office of the State Engineer for his information; and provided further, that within four years from the date of such notice the United States shall authorize the construction of such proposed work. No adverse claims to the use of the water required in connection with such plans shall be acquired under the laws of this State except as for such amount of said waters described in such notice as may be formally released in writing by an officer of the United States thereunto duly authorized, which release shall also be filed in the office of the State Engineer. In case of failure of the United States to file such plans or authorized construction of such works within the respective periods herein provided, the waters specified in such notices, filed by the United States, shall become subject to appropriation by other parties. Notice of the withdrawal herein mentioned shall be published by the State Engineer in a newspaper published and of general circulation in the stream system affected thereby, and a like notice upon the release of any lands so withdrawn, such notices to be published for a period not exceeding thirty days.*

At the same session, Chapter 5, General Laws of Oregon, 1905, was enacted. It provides:

> *Section 1. That for the purpose of aiding in the operations of irrigation and reclamation, conducted by the Reclamation Service of the United States, established by the act of Congress, approved June 17, 1902 (32 Stat. 388), known as the Reclamation Act, the United States is hereby authorized to lower the water level of Upper Klamath Lake, situate in Klamath County, Oregon, and to lower the water level of, or to drain any or all of the following lakes: Lower or Little Klamath Lake, and the Tule or Rhett Lake, situate in Klamath County, Oregon, and Goose Lake, situate in Lake County, Oregon; and to use any part or all of the beds of said lakes for the storage of water in connection with such operations.*
>
> *Section 2. That there be and hereby is ceded to the United States all the right, title, interest, or claim of this State to any land uncovered by the lowering of the water levels, or by the drainage of any or all of said lakes not already disposed of by the State; and the lands hereby ceded may be disposed of by the United States, free of any claim on the part of this State in any manner that may be deemed advisable by its authorized agencies, in pursuance of the provisions of said Reclamation Act.*

Similar legislation was enacted by the Legislature of California on February 3, 1905, relative to the Klamath Project areas in California. The following is quoted therefrom:

> *The people of the State of California, Represented in Senate and Assembly, do Enact as Follows:*
>
> *Section 1. That for the purpose of aiding in the operations of irrigation and reclamation conducted by the Reclamation Service of the United States, established by the act of Congress approved June seventeenth, nineteen hundred and two (Thirty-second Statutes, page three hundred and eighty-eight),*

> *known as the reclamation act, the United States is hereby authorized to lower following lakes: Lower or Little Klamath Lake, Tule or Rhett Lake, Goose Lake, and Clear Lake, situated in Siskiyou and Modoc Counties, as shown by the map of the United States Geological Survey, and to use any part or all of the beds of said lakes for the storage of water in connection with such operations.*
>
> *Section 2. And there is hereby ceded to the United States all the right, title, interest, or claim of this State to any lands uncovered by the lowering of the water levels of any or all of said lakes not already disposed of by this State; and the lands hereby ceded may be disposed of by the United States free of any claim on the part of this State in any manner that may be deemed advisable by the authorized agencies of the United States in pursuance of the provisions of said reclamation act: Provided, That this act shall not be in effect as to lakes herein named, which lie partly in the State of Oregon, until a similar cession has been made by that State.*
>
> *Approved February 3, 1905. (Cal. Stats. 1905, P.)*

On May 19, 1905, a "Notice of Intention to Utilize All Waters of the Klamath Basin" was filed by the Reclamation Service, Predecessor to the Bureau of Reclamation, in the office of the State Engineer of Oregon. It is recorded in "Water Filings" at Page 1. The notice is as follows:

NOTICE

> *Notice is hereby given that the United States intends to utilize certain specified waters, as follows, to-wit:*
>
> *All of the waters of the Klamath Basin in Oregon, constituting the entire drainage basins of the Klamath River and Lost River and Lost River, and all of the lakes, streams, and rivers supplying water thereto or receiving water therefrom, including the following and all their tributaries:*
>
> *Upper Klamath Lake, Lower Klamath Lake, Tule or Rhett Lake, Little Klamath Lake, Lake Ewauna, White Lake, Miller Lake, Swan Lake, Alkali Lake, Dry Lake, Sprague River, Sycan River, Williamson River, Crooked River, Wood River, Link River, Seven Mile Creek, Klamath River, Three Mile Creek, Cherry Creek, Rock Creek, Four Mile Creek, and the slough or stream connecting Lower or Little Klamath Lake with Klamath River, Clear Lake, Spencer Creek, Lost River, Miller Creek, Prairie Creek, Barnes Valley Creek, and Buck Creek.*
>
> *It is the intention of the United States to completely utilize all the waters of the Klamath Basin in Oregon, and to this end this notice includes all lakes, springs, streams, marshes, and all other available waters lying or flowing therein.*
>
> *That the United States intends to use the above-described waters in the operation of works for the utilization of water in the State of Oregon under the provisions of the act of Congress approved June 17, 1902 (32 Stat. 388) known as the Reclamation Act.*

This notice is given under the provisions of Section Two (2) of an act passed by the Legislature of the State of Oregon, filed in the office of the Secretary of State, February 22, 1905, and constituting Chapter 288 of the General Laws of Oregon 1905, as compiled by the Secretary of State.

This notice is given by T.H. Humphreys, Engineer of the United States Reclamation Service thereto duly authorized by the Secretary of the Interior of the United States.

Dated at Klamath Falls, Oregon, this 17th day of May, 1905.

T.H. Humphreys
Engineer of the U.S. Reclamation Service

The Reclamation Service of the United States filed detailed plans and specifications covering the construction of the Klamath Irrigation Project with the State Engineer of Oregon on May 6, 1908, and on May 8, 1909, filed with the State Engineer proof of authorization of the construction of the works therein set forth.

Prior to December 19, 1914, appropriative water rights could be acquired in California by posting and recording a notice stating the nature and quantity of the proposed appropriation and by thereafter exercising due diligence in putting the water to beneficial use. The following postings were made.

1. Notice of Appropriation of all the unappropriated waters, approximately 10,000 miners' inches (equivalent to a flow of 250 cubic feet per second) (in California and Oregon a flow of 40 miners' inches is equivalent to a cubic foot per second), and maximum flow of 150,000 miners' inches, of Willow Creek, Miller Creek, Clear Lake and its tributaries, and Lost River in Modoc County, California, was posted on behalf of the United States at the intended point of diversion on July 8, 1909, and was filed and recorded July 14, 1909, in Volume 2, Page 84 of "Water Claims", Modoc County, California.

2. A previous notice of appropriation covering 5,000 second-feet of the waters of Lost River was posted December 19, 1904, and recorded on December 28, 1904, on Page 15 of Volume 2 of "Water Claims" of Modoc County. This notice was also recorded in Klamath County, Oregon, Volume 1, at Page 185, "Water Rights."

3. A Notice of Appropriation of all of the unappropriated waters of Willow Creek, Mill Creek, Clear Lake, Lost River and Tributaries, etc., being an average yearly flow of 10,000 miners' inches (250 cfs) and maximum flow of 150,000 miners' inches, was posted relative to diversion in Sections 22, 23, 26, and 27 of T. 48 N., R. 7 E., MDB&M, and was recorded April 9, 1910, on Page 132 of Volume 2 of "Water Claims", Modoc County.

4. A nearly identical notice concerning diversion in Sections 25, 26, 35, 36 of T. 48 N., R. 7 E., MDB&M, was posted and recorded on April 9, 1910, on Page 134 of Volume 2 of "Water Claims", Modoc County, California.

Adjudication Proceedings

A formal adjudication of a river system establishes in a competent court the relative rights to the use of water within the area that is being adjudicated. Testimony is received from all persons claiming a right and the State makes determinations based on the testimony of the relative priority dates. The Klamath River Basin is in such a process.

The State of Oregon began the adjudication of the Lost River system in 1910. Certificates were issued to individuals who had rights predating the Klamath Project's filings. Since Reclamation was not a party to the adjudication, certificates were not issued to Reclamation or its contractors. The State did, however, set aside 60,000 acres for Reclamation to later claim certificates on.

A number of irrigators above Gerber Dam claimed to have not been notified of the 1918 adjudication. As a result, the State reopened the adjudication process and completed it in 1989. This portion of the adjudication set forth the relative priorities of water use above Gerber Dam.

The Klamath River Basin Adjudication covers all Project lands served by the Klamath River. Other federal entities involved include the National Park Service, U.S. Department of Agriculture, Bureau of Land Management, the U.S. Fish and Wildlife Service, and Bureau of Indian Affairs on behalf of the Klamath Tribes. In 1975, the State of Oregon, through its Water Resources Department (OWRD), initiated the Klamath River Basin adjudication to determine all claims to surface water in the Basin. By 1986, the State of Oregon had completed a considerable amount of work in mapping the places of use within the Project.

In 1990, the OWRD reissued notices of intent to adjudicate the Klamath River Basin, and during 1991, required all persons claiming a right to the use of water from the River to file. The United States did not file, claiming that the adjudication violated the McCarran Amendment which requires that any adjudication involving the United States must be complete and include ground water. In subsequent legal proceedings, the United States lost, and as a result, all claims were to be filed with the State in April 1997 for both use and storage. Open inspection of claims was extended through March 2000. In May 2000, several thousand contests were filed on individual claimants and the State's Preliminary Evaluations of Claims.

Concurrent with the Klamath adjudication, the State of Oregon has begun an Alternative Dispute Resolution (ADR) process in an attempt to resolve as many water rights issues in the adjudication as possible to avoid litigation by various claimants. The U.S. has participated in the ADR process from its beginning, along with the Klamath Tribes, various individuals, and the Klamath Project water users. Meetings are held monthly. The ADR process may help solve disputes; however, difficult issues remain to be resolved.

The State of Oregon has proposed a broad settlement framework that is being considered by the Administrative Subcommittee of the ADR Group. In addition, the Klamath Tribes and project irrigators have negotiated a framework settlement agreement which is under review by various parties to the ADR. The Klamath Tribes have also presented a settlement proposal on the tributary area above Upper Klamath Lake. Several technical teams have been formed to deal with specific ADR issues. Reclamation actively participates on the Hydrology Technical Committee.

Coho Salmon (*Oncorhynchus kisutch*) Life History Patterns in the Pacific Northwest and California

Final Report

March 2007

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U.S. Bureau of Reclamation
Klamath Area Office

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Special thanks are due to the five scientists who kindly responded to an invitation from USBR to give technical peer review of the report. Each of these individuals are experts on coho life history and have first-hand experience in researching this species in different geographic areas. These are Walt Duffy, Humboldt State University, James Hall, Oregon State University (retired), Gordon Hartman, Department of Fisheries and Oceans Canada (retired), Peter Moyle, University of California at Davis, and Tom Quinn, University of Washington. Tom Nickelson, previously mentioned for his review, deserves to be ranked with this distinguished group for his expertise on coho life history.

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Executive Summary

In 1997 coho salmon (*Oncorhynchus kisutch*) in the Klamath River basin, as part of the Southern Oregon Northern California Coasts evolutionary significant unit (SONCC Coho ESU), were listed as threatened under the Endangered Species Act (ESA). The National Marine Fisheries Service (NMFS) cited water management, water quality, loss of habitat, overfishing, and other factors as causing a serious decline of the species within this ESU.

In the Klamath basin, the roles of different habitats to the performance of coho salmon have been a subject of much debate and controversy. Of particular concern is the use and importance of the mainstem Klamath River relative to the tributaries. This issue has a significant bearing on how flows are to be regulated in the mainstem river for the protection and restoration of the species. It also bears on how managers perceive the relative importance of different habitats in formulating an overall recovery plan for coho salmon in this basin.

The purpose of this report is to review coho life history patterns and associated life stage specific survivals. The report is a stand-alone document that synthesizes a large body of scientific information on life histories of the species over most of their range in North America. Emphasis is given to the Pacific Northwest (Southeast Alaska, British Columbia, Washington, and Oregon) and California. The report describes patterns of life history evident across this range and variations from common patterns. It describes how coho salmon utilize different types of habitat, including various sizes of streams and rivers, as part of their repertoire of life history tactics.

This report also serves as a background reference for an analysis of coho performance in the Klamath River basin being prepared by Cramer Fish Sciences (CFS). Their analysis summarizes and synthesizes extensive data collected in the Klamath basin and includes the formulation of a life cycle model designed to help assess coho performance in the basin.

This report aims to describe the central themes of coho salmon life histories as well as the types and extent of variation documented in the Pacific Northwest and California. Two underlying questions are considered throughout the report. How similar are coho life history patterns across the species' range? And what kinds and extent of variation occur with respect to these patterns, particularly as variation might relate to the SONCC Coho ESU and Klamath River coho?

Life History Overview

Distribution Patterns

Coho salmon inhabit very small coastal streams as well as the largest rivers in western North America. Within larger river systems, coho salmon spawning is typically distributed in tributaries to mainstem rivers. This pattern for spawning principally in smaller streams has given coho salmon a reputation of being primarily associated with small rivers and streams.

In the ocean, coho salmon generally do not migrate as far as the other species of Pacific salmon and steelhead trout . Coho originating in rivers of California, Oregon, and Washington tend to feed along the Continental Shelf associated with the region of origin.

Life Cycle Overview and Unique Characteristics

Most coho salmon across the species' geographic range have a three year life cycle, divided about equally between time spent in fresh and salt water. The basic life history begins in natal streams when spawners mate and deposit eggs into nests dug in the stream substrate. Spawning typically occurs between mid autumn and early winter in small tributaries to larger rivers, though timing can occur much later for some populations.

Returning adults in populations at the southern end of the range (both California and southern Oregon) are sometimes stalled in their river entry due to a lack of rainfall and sufficient stream flow for upstream migration, delaying spawning, sometimes even pushing it into March. This suggests that southern coho populations may have greater flexibility in adjusting their maturation timing than more northern populations; maturation would appear to be controlled partially by entry into fresh water. Factors controlling variability in maturation timing of coho salmon are not well known.

After spawning, the adults die. Following egg incubation, surviving fry emerge from the substrate in late winter and spring and begin their free swimming life.

The emergent fry move quickly to slow velocity, quiescent waters, usually along the stream's margins or into backwaters where velocities are minimal, a consistent behavior across the species range This affinity for slow velocity areas remains characteristic of juvenile coho throughout their freshwater life, unlike most other salmonid species.

Juvenile coho typically spend one year rearing in fresh water, during which time they may remain close to their natal sites or they may move considerable distances to find suitable summer and/or overwintering habitat. Dispersal by some fry to areas downstream shortly following fry emergence is a pattern seen throughout the geographic range of the species. In fall another movement pattern often occurs with juveniles in some areas of the river system redistributing to habitats more favorable for overwinter survival, particularly to off-channel habitats.

At approximately 18 months of age, coho juveniles undergo smoltification during spring and enter the marine environment, where they experience very rapid growth. Their smolt to adult survival rate can be strongly affected by exposure to large estuarine complexes like Puget Sound or the Strait of Georgia. In contrast, wild smolts entering the Pacific Ocean from the rivers along the outer coasts of Washington, Oregon, and California typically survive at 1/4 to 1/3 of rates for fish moving through large estuarine complexes.. This difference gives populations originating inside the Strait of Juan de Fuca a tremendous boost in productivity compared to those along the outer coasts and makes them naturally more resilient to habitat perturbations.

Adult coho begin arriving at the entrances to their home rivers in late summer, but more typically in early autumn. Fish arrive earliest back to their home river in northern most rivers and latest in populations further south. This pattern is related to the timing of fall and winter rains and increases in stream flow—flows typically rise later moving from north to south.

Within the basic life history, variations exist in age structure, generally following patterns associated with latitude. One variation occurs because some juveniles spend an additional year rearing in fresh water and emigrate seaward at approximately 30 months of age; these return and spawn at four years of age. This life history pattern primarily occurs in more northern populations, particularly in Alaska One notable occurrence of age 2 smolts has been found in Prairie Creek, tributary to Redwood Creek, in Northern California.

A central theme in the freshwater life history of juvenile coho is their close association with slow velocity habitats. Body morphology and fin sizes of juvenile coho salmon are particularly adapted to slow velocity habitats. Most coho juveniles have a laterally compressed body with long dorsal and anal fins, thought to be adaptations for life in slow water. In contrast, steelhead fry have cylindrical bodies in cross section with short dorsal and anal fins, adapted to higher velocity habitats than used by juvenile coho. Juvenile Chinook have a body form and fin sizes intermediate between coho and steelhead.

These differences in body shape and fin sizes are consistent with water velocity and depth preferences reported for these three species. Coho prefer much slower velocities than either steelhead or Chinook; Chinook preferences are intermediate between coho and steelhead. It is logical to expect that selection of habitat types by these species would reflect their adaptation to water velocity and depth.

Variation has been found to exist between regions both with respect to body morphology and swimming performance. Two morphological forms have been identified based on differences in body shape and fin size: a “coastal” form, characterized by large dorsal and anal fins and a deep robust body, and an “interior” form with smaller fins and a more streamlined body shape. These two forms have been found to have different swimming performance characteristics. The interior form has a body form and swimming performance that would generally favor long distance in-river migrations, such as occurs in the Fraser River. It is not known whether both morphological forms exist in the Klamath River, where both interior and coastal ecoregions exist. Differences have also been found in the body morphology between juveniles that inhabit lakes and those in streams.

Another aspect of life history that may differ between regions is foraging behavior. Foraging behaviors can vary between individuals of the same population or even of the same family. Four foraging behaviors have been identified in Northern California as distinct phenotypes, referred to as *thalweg* (the stereotypical coho foraging type), *margin-backwater*, *estuarine*, and *early emerging*. Juveniles typically do not switch to other foraging phenotypes once they begin to display a certain type. Three of the phenotypes are known to exist in other regions. One type (early emerging) may be unique to the southern portion of the species’ range (i.e., California). These phenotypes utilize habitats differently. The early emerging type has been characterized as being more trout-like than is common among juvenile coho. During summer this type forages only at dawn and dusk on drifting invertebrates. During the day, they seek refuge in undercut banks, often associated with cold-seeps along terrace cutbanks. It has been suggested that this phenotype represents a pattern of adaptation significant to coho salmon in the southern portion of their range.

Freshwater Habitat Utilization

Spawning Migration

Adult coho salmon use the main channel of mainstem rivers and tributaries for migrating to spawning sites. They utilize all habitat types within the main stream and can generally be found holding to rest during the migration in deep water areas, particularly pools.

Survival during the freshwater migration is assumed to be high in streams of the Pacific Northwest. In short rivers where natural predators are not abundant, survival exclusive of any harvest impact is likely very high – it may approach 100% in many cases.

Spawning

Coho salmon tend to spawn in small streams or in side channels to larger rivers. They also sometimes spawn along the river margins of larger streams, but normally not in large numbers.

Coho salmon spawn heavily in groundwater channels where these habitats exist along the floodplains of rivers, often in relatively high densities.

Egg and Alevin Incubation

Survival from egg deposition to fry emergence can vary significantly between streams depending on stream characteristics and local conditions. Changes in stream conditions due to land use can severely reduce survival to emergence.

Average survival to emergence for coho in streams that might be considered typical in the Pacific Northwest is much less than occurs under optimal conditions in nature. In streams with no or relatively moderate and recent land use, survival to emergence averages approximately 30%, as seen in studies in Oregon, Washington, and British Columbia.

Two factors are most often cited as affecting the survival to emergence of coho salmon: fine sediment loading and bed scour. Following extensive and prolonged land use practices in a watershed, survival to emergence can be reduced by half or more. Survival in spring fed streams with upwelling groundwater is often much higher than in runoff streams.

Fry Colonization

Upon emergence coho fry move quickly to slow velocity habitats, typically along the channel margin, or they continue to move downstream. They have a strong affinity for very slow velocity water and generally move there as rapidly as possible. Fish that emerge during high flows can be swept downstream, moving them to less suitable habitats, increasing bioenergetic costs, and increasing predation exposure. Large rivers typically provide little suitable habitat for young coho fry.

Young coho fry that move to larger rivers can subsequently move into off-channel habitats as a result of their need for calm, slow velocity water.

Survival during the fry colonization stage is mostly density-independent because of the short time period involved. Estimated survival rates for Deer Creek in the Alsea watershed study (Oregon Coast) show a modest density-dependent effect. An estimate of the density-independent component of survival for Deer Creek is 81% during a period prior to logging and recently completed logging.

Subyearling Summer Rearing

Juvenile coho are found residing in a wide variety of stream types and sizes during summer. They are typically found in highest densities within their natal streams since the majority of fry usually do not migrate large distances from spawning sites.

The need for slow velocity water by juvenile coho remains strong during this life stage. Juvenile Chinook and steelhead will often be found feeding near velocity shears within main channels, while coho remain more closely associated with the shoreline or dense cover of woody debris. This pattern indicates a much stronger affinity for slow velocity by coho salmon than the other species during this life stage.

Juvenile coho are most often found in pools. The highest densities of juvenile coho during this life stage are usually found in the smallest streams. The large differences seen between densities of small and large streams likely occurs because a smaller proportion of the total cross-section in large streams provides depths and velocities preferred by juvenile coho salmon.

The influence of wood on rearing densities during summer is not the same across all stream types and sizes. Evidence exists that the affinity of juvenile coho salmon for wood accumulations increases through the summer with growth. In mainstem rivers during summer the presence of large wood is much more important than in small streams for juvenile coho salmon

In large rivers, secondary channels (i.e., side channels and off-channel habitats) provides important rearing areas for juvenile coho. Groundwater channels are usually utilized almost exclusively by coho salmon and can be very productive for the species.

High water temperatures during summer can be an important factor affecting the distribution, growth, and survival of juvenile coho salmon. High water temperatures can trigger movement of juvenile coho salmon during summer, when little movement typically occurs. Movement occurs as fish seek refuge from high temperatures. One foraging behavior that has only been described in Northern California streams may be particularly adapted to use of thermal refugia.

Survival of juvenile coho salmon during summer can be strongly density-dependent in smaller streams. Competition for shrinking space—due to declining flows in late summer—and limited food results in reduced survival at higher juvenile abundance.

An estimate of the density-independent component of survival for Deer Creek (Alsea watershed, Oregon) is 86% during a period prior to logging and recently completed logging.

Fall Redistribution and Overwintering

In many streams, some juvenile coho salmon move from their summer rearing locations in fall, triggered by increased flows associated with autumn rainfall. This movement is another demonstration of the affinity that these fish have for slow velocity water. Water velocities increase in main stream habitats with rising flow, either dislodging juveniles from summer rearing sites or stimulating them to move to find more favorable habitats prior to the coming of larger, more frequent winter storms.

During this period of redistribution, some juvenile coho salmon immigrate into off-channel habitats. These habitats provide refuge from high flow velocities. This movement of juvenile coho salmon from mainstem streams during fall and winter appears to be due to fish leaving unfavorable areas in search of improved survival conditions. Within mainstem streams, they evacuate sites with high exposure to high velocities. Large wood accumulations are especially important as velocity refuge sites during winter, particularly in large streams. Juvenile coho have been found to rarely use cobble substrate as overwinter cover.

Overwinter survival of juvenile coho is approximately 2-6 times greater in off-channel habitats than within main channel habitats. This difference in survival rates between in-channel and off-channel habitats is especially important in watersheds that have undergone significant changes due to land use. Coho populations subject to high overwinter mortality—as experienced within main channel habitats—have much reduced life cycle productivity compared to populations with good overwinter habitat.

Smolt Migration

Smoltification and the corresponding smolt migration begins earlier in the southerly part of the species' geographic range, being somewhat later in northern streams. The timing pattern is very similar in California, Oregon, Washington, and southern British Columbia.

A wide range of smolt outmigration patterns can exist within the overall critical time window in a single watershed. Both migration timing and rate of migration can be affected by smolt size, location in the watershed at the start of the migration, migration distance, and stream flow. This overview is focused primarily on free-flowing rivers.

Larger salmonid smolts, for several species including coho salmon, generally begin their migration earlier than smaller ones, presumably because smaller ones require additional time to gain size necessary for smoltification and for improved marine survival.

In streams on the Washington Coast, the coho smolt migration typically begins first for fish emigrating from off channel sites, followed by fish from runoff tributaries. Smolts emigrating from off channel sites are consistently larger than those coming from runoff tributaries.

Early migrants tend to migrate downstream more slowly than late timed fish, a pattern that occurs for salmonid species in general.

Smolts that begin their migration far from the estuary generally travel downstream much faster than those that begin closer.

Flow can affect migration timing and migration rate, which has been well described in the Columbia River system. The effects of flow on migration rate is most evident through the extensive reservoir system of the Columbia and Snake rivers.

Factors that can affect the survival rates of migrant smolts in fresh water have been extensively studied in the Columbia and Snake rivers—and intensely debated. Much of the debate has focused on the relationship between mainstem flow and outmigrant survival. It is well known that predation can be high on juvenile salmonids as they outmigrate through impounded systems such as the Columbia River. The Columbia system has large populations of northern pikeminnow and exotic predatory fishes. It has often been assumed in these cases that the travel rate of smolts, affected by flow, determines predation rates by regulating the amount of time that juvenile migrants are exposed to the predators. More recent research, however, indicates that while migration rate is affected by flow, survival of yearling and older smolts appears to be largely a function of migration distance and not travel rate.

Within the mainstem Columbia River hydrosystem, another factor shown to be important to the survival of outmigrant yearling smolts is water temperature. It is thought the effect of temperature on yearling smolt survival operates mainly by affecting the activity of predatory fishes (pikeminnow and exotics)—as water temperatures increase, their feeding rate increases.

The effect of migration distance on yearling smolt survival has also been demonstrated for free-flowing streams upstream of Lower Granite Dam on the Snake River. A strong inverse relationship exists between survival and migration distance for hatchery spring Chinook smolts released at various hatchery sites in the Snake River system. In this case, it appears that water temperature during the period of migration does not help explain mortality within the free-flowing tributaries to the Snake River, suggesting that temperature has a stronger role in the prey-predator dynamics within the extensive reservoir system downstream.

Studies conducted in free-flowing rivers without pikeminnow and abundant exotics present suggest that smolt survival during their outmigration is typically very high.

Studies of wild coho smolts show that their migration is not continuous but interspersed by periods of holding. In many cases, it is not rapid once it has been initiated, apparently progressing as if in stages. Smolts generally use slow velocity habitats during periods of holding and resting.

Discussion and Conclusions

Two underlying questions are considered throughout this report as they relate to how coho salmon utilize physical habitats within a watershed. How similar are coho life history patterns across the species' range? And what kinds and extent of variation occur with respect to these patterns, particularly as variation might relate to the SONCC Coho ESU and Klamath River coho?

These questions relate to Moyle's statements about coho salmon in his book "Inland Fishes of California":

> "…evolutionary forces keep coho salmon (and other salmon) surprisingly uniform in morphology and life history throughout their range, while producing runs that show strong, genetically based adaptations to local or regional environments. In California coho populations are the southernmost for the species, and they have adapted to the extreme conditions (for the species) of many coastal streams."

On its surface, Moyle's statement may seem contradictory. He concludes that coho salmon show a high degree of uniformity (or similarity) in life history patterns across their range, yet he asserts there is also significant variation and local adaptation. In context, Moyle is saying that coho salmon—like other salmonid species—exhibit significant variation in life histories, but the range of variation remains within what he sees as unifying life history themes for the species. The central themes of life history similarity are morphology, age structure, spatial distribution within a watershed, general timing patterns of migrations and other movements, development and growth patterns, foraging patterns, effects of environmental stressors, and habitat use patterns—among others. But significant variations exists within these unifying themes, enabling considerable adaptation to local conditions.

One unifying theme in the freshwater life history of juvenile coho is their affinity for slow velocity habitats in all life stages. Body morphology and fin sizes appear to be generally adapted to life in these habitats—notwithstanding variations that exist between coastal and interior forms (discussed further below). Their affinity for slow water is evident across the species' range—in both northern and southern regions and coastal and interior regions. Juveniles in all life stages—though to a lesser extent during the smolt stage—primarily rear and seek refuge in slow velocities associated with pools, channel margins, backwaters, and off-channel sites (alcoves, ponds, and groundwater channels). Their affinity for low velocity water is strongest during the fry (very young fry) and overwintering life stages.

This association with low velocity habitats tends to result in several patterns of distribution within a watershed. Juvenile rearing—particularly in summer—occurs to a large extent within the natal streams. Emergent fry generally remain relatively close to their natal areas, though some dispersal downstream typically occurs. The maximum extent that dispersal occurs downstream is not known. Spawning which occurs in higher gradient streams appears to result in a greater downstream dispersal of fry. In that case, the young move—or are displaced by high velocity flows—to low velocity habitats in reaches of lower gradient.

Another related distribution pattern is the association that juvenile coho have for physical cover. Cover types within the water column or overhead are preferred (wood, rooted macrophytes, roots, overhead structure), as opposed to substrate cover provided by cobbles or turbulence cover associated with velocity shears. In smaller streams, cover is not a strong determinant of habitat selection in summer, though association with it grows by summer's end. Physical cover appears to be a much greater determinant of habitat selection in large rivers, probably due to the likelihood for higher water velocities and more predators.

The affinity for low velocity habitats is particularly strong during winter. This season often brings rapidly changing, adverse conditions within a stream—both in coastal and interior regions—whether due to flow fluctuations or extreme cold and icing. Survival appears to be strongly related to how successful juvenile coho are in locating suitable refuge from harsh conditions. Movement seems to be volitional, or when flows are high, due to displacement. In dynamic rivers, redistribution to overwintering sites can be quite dramatic in terms of distances traveled and numbers of fish that move.

Off channel sites (alcoves, ponds, groundwater channels) are particularly desirable overwintering habitats throughout the Pacific Northwest and California. These provide the highest survival rates compared to other habitats. Low velocity locations within main stream channels having undercut banks with exposed root masses or sites of large wood accumulations also provide refuge habitat. Side channels with low velocities and some form of cover are also used. Juvenile coho rarely use cobble substrate for overwintering cover, as commonly occurs for juvenile steelhead.

Variations on the central themes of coho life history exist and several types could affect habitat utilization patterns. Juvenile coho in the southern part of the range can exhibit a summer movement pattern different from what is seen further north. This movement pattern appears to be a redistribution to find thermal refugia. There is no evidence that fish in the southern region have a higher thermal tolerance than fish further north, though some greater tolerance may exist. While the fate of fish that move in search of thermal refugia has not been determined, some do successfully arrive at cooler water sites. It is unknown what level of mortality or loss in other performance measures might occur while moving to refugia or the distance that fish can travel. The early emerging foraging phenotype, having some adaptation to warm conditions, may be suited for movement during early to mid summer to seek out refugia. Their larger size than other foraging phenotypes would be advantageous for such movement. Habitat utilization in warm water streams will reflect overlapping areas of tolerable temperatures and water velocities.

Another life history variation is seen in differences in body morphology and fin sizes between coastal and interior populations and associated swimming performances. It is not known how far south such a coastal-interior distinction might extend. Do both forms exist within the Klamath River basin? There is no evidence that these morphological forms have different habitat requirements, i.e., does the interior form, which has greater swimming stamina, have less of an affinity for slow water habitats than the coastal form? Or do cover type preferences differ between the forms? Evidence shows that both forms exhibit the same selection for slow water habitat types and cover types. Researchers have suggested that the adaptive benefit of these variations to interior coho (more streamlined body, smaller fins, greater swimming stamina) is in their ability to negotiate long in-river migrations, both as smolts and adults. An interior-type body form would presumably aid upper Klamath River coho in their movements (including summer and fall redistribution movements) within the mainstem Klamath River, if this body form occurs there.

Perhaps the most obvious variation in life history patterns seen in southern coho populations is their ability to delay river entry timing during periods of drought or late arriving rainfall. In the extreme, river entry can apparently be stalled several months. This would thereby delay spawning and would presumably have cascading effects on emergence timing and subsequent growth and habitat use patterns.

Coho salmon exhibit a wide variety of life history patterns in large, diverse watersheds. These patterns are phenotypic expressions of the interaction of genotype and environmental factors. Among others, these factors include flow characteristics, gradient, water temperature, and habitat structure. Diverse phenotypic expressions enable the species to utilize a wide variety of physical habitats across a range of gradients, habitat sizes, and qualities—but within limits set by the species' genetic blueprint. To understand the performance of a species in any watershed requires a life history perspective, seen across the full cycle.

Coho Salmon (*Oncorhynchus kisutch*) Life History Patterns in the Pacific Northwest and California

1.0 Introduction

In 1997 coho salmon (*Oncorhynchus kisutch*) in the Klamath River basin, as part of the Southern Oregon Northern California Coasts evolutionary significant unit (SONCC Coho ESU), were listed as threatened under the Endangered Species Act (ESA). The National Marine Fisheries Service (NMFS) cited water management, water quality, loss of habitat, overfishing, and other factors as causing a serious decline of the species within this ESU. The SONCC Coho ESU is composed of populations produced between Cape Blanco in Southern Oregon (just north of the Rogue River) to Punta Gorda in Northern California (includes the Mattole River). The geographic setting of the SONCC Coho ESU includes three large basins, which include Klamath basin, and numerous smaller basins across diverse landscapes (Williams et al. 2006). The large basins encompass both interior and coastal type landscapes.

In the Klamath basin, the roles of different habitats to the performance of coho salmon have been a subject of much debate and controversy (Hardy and Addley 2001; Vogel 2003; NRC 2004). Of particular concern is the use and importance of the mainstem Klamath River relative to the tributaries. This issue has a significant bearing on how flows are to be regulated in the mainstem river for the protection and restoration of the species. It also bears on how managers perceive the relative importance of different habitats in formulating an overall recovery plan for coho salmon in this basin. Complicating this issue is the fact that habitats, including associated flow patterns, have been altered in both the mainstem and tributaries due to land use, flow regulation, and irrigation withdrawals.

The purpose of this report is to review coho life history patterns and associated life stage specific survivals. The report is a stand-alone document that synthesizes a large body of scientific information on life histories of the species over most of their range in North America. Emphasis is given to the Pacific Northwest (Southeast Alaska, British Columbia, Washington, and Oregon) and California. The report describes patterns of life history evident across this range and variations from common patterns. It describes how coho salmon utilize different types of habitat, including various sizes of streams and rivers, as part of their repertoire of life history tactics. Uncertainties are identified where evident.

This report is intended to serve as a background reference for an analysis of coho performance in the Klamath River basin being prepared by Cramer Fish Sciences (CFS). Their analysis summarizes and synthesizes extensive data collected in the Klamath basin and includes the formulation of a life cycle model designed to help assess coho performance in the basin. The CFS analysis is intended to assess the effects of flow regulation within the Klamath river relative to other survival factors in the basin. That analysis focuses on characteristics of habitat and populations within the Klamath basin. Therefore, the report presented here makes no attempt to synthesize various data sets from the Klamath watershed, nor to draw conclusions about specific factors affecting coho population performance in that basin. The focus here is broader, though information from the Klamath basin is incorporated as part of the coastwide perspective. Some commentary is given to address specific situations in the Klamath basin to aid the reader in considering how Klamath population characteristics might differ or align with those in other basins.

This report is not redundant of the many other documents that summarize life history patterns of coho salmon (e.g., Shapovalov and Taft 1954; Laufle et al. 1986; Hassler 1987; Sandercock 1991; Pearcy 1992; Behnke 2002; CDFG 2002; Moyle 2002; Quinn 2005). Those documents are used as the basis for some of the material presented here. A more in-depth presentation is provided here of habitat utilization patterns exhibited by the species and some of the factors believed to shape those patterns. To the extent that information is available, variations from common patterns are described. Survival rates associated with particular life history strategies are described where possible.

Life histories lie at the heart of the biology of a species (Stearns 1992). Life history traits are directly related to survival and reproduction—they are phenotypic expressions of the interaction of genotype and environment. Individuals of a population that express different life history traits vary in fitness within a set of environmental conditions. This drives natural selection. Habitats are the templates that organize life history traits (Southwood 1977). The range of life history diversity within a species is the result of evolutionary trade-offs of costs versus benefits in the process of adaptation to habitats.

Each salmon species has a characteristic general life history pattern with unique attributes that separate it from the other species (Lichatowich 1999). Among these attributes are age structure, length of freshwater residence, and their spawning and rearing distributions within a watershed. These generalized life histories are central themes around which populations express life history variation in response to local habitat conditions (Lichatowich 1999). Moyle’s (2002) description of this dynamic is useful here:

> “Coho salmon have thousands of semi-isolated populations in coastal streams over a wide range. At the same time, fish from different regions mix at sea, and individuals may ‘stray’ into nonnatal streams for spawning. These two opposing and dynamic evolutionary forces keep coho salmon (and other salmon) surprisingly uniform in morphology and life history throughout their range, while producing runs that show strong, genetically based adaptations to local or regional environments. In California coho populations are the southernmost for the species, and they have adapted to the extreme conditions (for the species) of many coastal streams.”

This report aims to describe the central themes of coho salmon life histories as related to habitat use as well as the types and extent of variation documented in the Pacific Northwest and California. Two underlying questions are considered throughout the report. How similar are coho life history patterns across the species’ range? And what kinds and extent of variation occur with respect to these patterns, particularly as variation might relate to the SONCC Coho ESU and Klamath River coho?

The report is organized into four sections:

1. Introduction
2. Life history overview
3. Freshwater habitat utilization
4. Discussion and conclusions

Section 2 provides an overview of the distribution and major life history characteristics of coho salmon. These topics are well covered elsewhere (e.g., Sandercock 1991) and the intention here is not to duplicate this material. Coverage here highlights recurring patterns and issues seen to be particularly applicable to the life history and performance of Klamath coho salmon as related to habitat utilization and survival.

Section 3 describes patterns and rates of utilization of different freshwater habitats by coho salmon as seen in various areas of western North America. Variations from and within these patterns are identified together with causal factors. Life stage specific survival rates are summarized.

Section 4 provides discussion and conclusions regarding the two central questions being examined: 1) How similar are life history patterns across the species' range that relate to habitat utilization; and 2) what kinds of variations are expressed by the species as they might relate to Klamath River coho?

2.0 Life History Overview

This section provides an overview of the major patterns and characteristics of coho life history in Western North America. Variations to life history themes are described, particularly as they might provide insight about variations in California coho life histories. Life history characteristics that can affect habitat utilization patterns are emphasized here.

2.1 Distribution Patterns

Populations of spawning coho salmon are distributed along the coasts of both the Asian and North American coasts of the North Pacific Ocean. In North America, they currently populate streams from Monterey Bay (Waddell and Scott creeks) in Central California (south of San Francisco Bay) to Point Hope on the northwest corner of Alaska (Sandercock 1991; Brown et al. 1994). They are much less common in both the northern and southern fringes of their distribution and most abundant across the mid section of their ranges (Sandercock 1991). Naturally produced coho in California, both in the SONCC ESU and Central California Coast Coho ESU (CCC Coho ESU), are believed to be in a general state of decline; the number of streams supporting the species is substantially reduced from historic distribution (Brown and Moyle 1991; CDFG 2002). This is particularly true on the extreme southern fringe of their distribution—within the CCC ESU.

Coho salmon inhabit very small coastal streams as well as the largest rivers in Western North America—including connected lakes within these stream systems. Within the largest rivers, their upstream migrations are longest in more northerly rivers, being approximately 1,400 miles on the

Yukon River, 425 miles in the Fraser system, and currently about 300 miles in the Columbia system (Sandercock 1991). Historically, they inhabited streams in the Columbia River Basin 500 miles from the ocean (Mullan 1984). In the Klamath River, they are believed to have historically ascended to the vicinity of Spencer Creek, approximately 230 miles from the river mouth (Hamilton et al. 2005). In the Sacramento River, Behnke (2002) states that coho salmon were always extremely rare and says it is unclear why conditions are so ill-fitted for this species. Brown et al. (1994), however, suggests that coho may not have been entirely rare in the system historically. Moyle (2002), citing Leidy (1984), states that coho were never common in the Sacramento basin but small numbers probably once spawned in the McCloud and upper Sacramento rivers, in excess of 300 miles from the marine environment.

Within larger river systems, coho salmon spawning is typically distributed in tributaries to mainstem rivers. In smaller streams that empty directly to the marine environment, they will spawn over the stream's length, from just above tide water to headwater reaches. This pattern of spawning principally in smaller streams has given coho salmon a reputation of being primarily associated with small rivers and streams (Behnke 2002). In contrast, Chinook (*O. tshawytscha*), chum (*O. keta*), and pink (*O. gorbuscha*) salmon often spawn in large mainstem rivers, although each of these also spawn in small streams. Coho also spawn on beaches of some Alaskan lakes (Ruggerone and Rogers 1992). Sandercock (1991) described the typical spawning distribution of coho salmon as follows:

> "Their success as a species may be partly attributed to their utilization of a myriad of small coastal streams and to their aggressiveness and apparent determination to reach the small headwater creeks and tributaries of larger rivers to spawn. In many cases, they overcome difficult obstructions to reach areas inaccessible to other salmon and then share these locations with only migrant steelhead or perhaps resident cutthroat trout. These small headwater streams generally provide cool, clear, well-oxygenated water, with stable flows that are ideal for incubation and subsequent rearing."

Lichatowich (1999) illustrated differences in typical patterns of spawning distribution for salmon species in a hypothetical watershed (Figure 1), showing that coho salmon normally spawn higher in river systems relative to other species. In large rivers (e.g., Columbia, Snake, and Fraser rivers), Chinook salmon ascend the mainstem river further than coho.

A representative example of this pattern is seen in the Clearwater River on the Olympic Peninsula (Washington Coast). Edie (1975) delineated three zones within the river system as utilized by anadromous salmonids (Figure 2): Chinook zone, coho zone, and cutthroat (*O. clarki*) zone. These distributions are related to the physical and hydrological characteristics of the stream system, not to differences in water quality variables such as temperature. Water temperature remains within safe limits for these species in this river. Flow in the mainstem river during spawning months is typically in the range of 800-3,000 cfs. Edie (1975) described the Chinook zone as being the main river and the lower reaches of larger tributaries (see Figure 43 top for a picture of the Clearwater River). This zone is mostly used by Chinook salmon and steelhead (*O. mykiss*) trout and to a much lesser degree by coho salmon. Stream gradient is mostly less than about 1%. The coho zone, immediately upstream of the Chinook zone, encompasses the middle reaches of larger tributaries, the downstream portion of smaller tributaries, and the very upper portion of the mainstem river. Gradients in this zone are moderate, mostly 1-2% but can be as high as 4%. This zone is primarily used by coho salmon and steelhead trout but significant cutthroat utilization can also occur. The upper zone, the cutthroat zone, is the domain of cutthroat trout. Streams are steep (2-6% but can be higher) and small (1-10 ft in width). This zone can be used by sea run cutthroat trout as well as small resident fish. While spawning by different salmonid species overlaps across zones, the pattern is instructive regarding general species usage.[1]

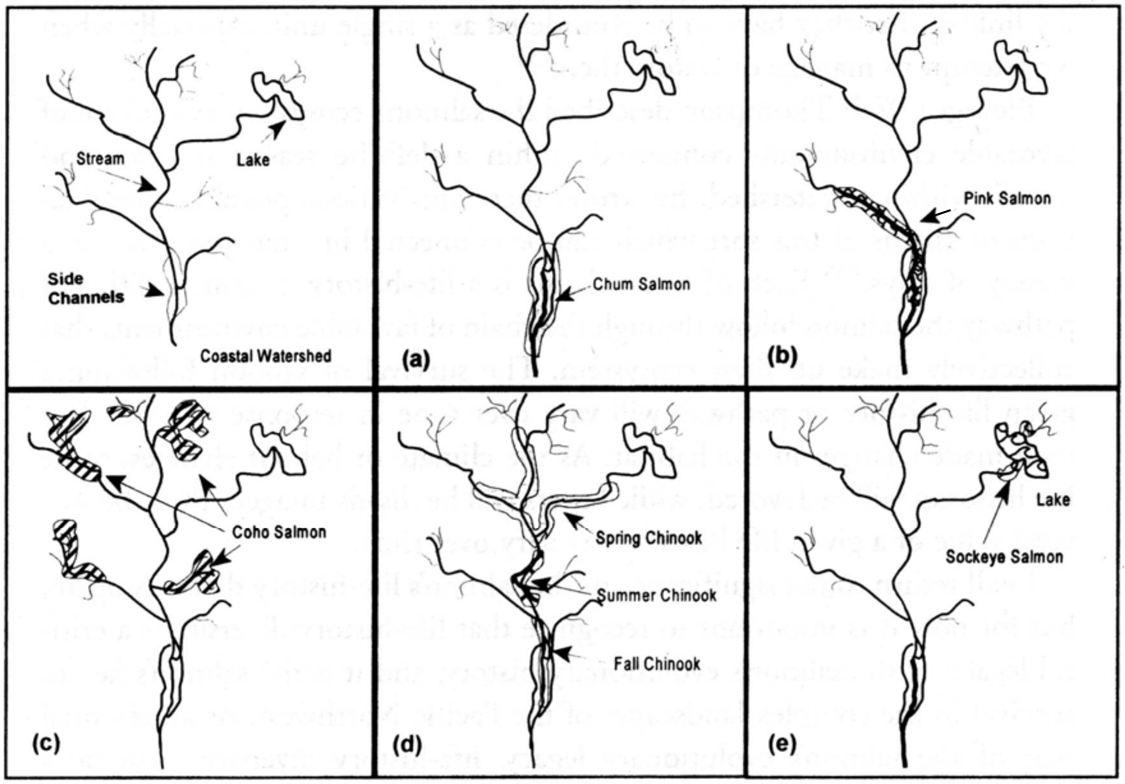

Figure 1. The spawning distribution of Pacific salmon in a hypothetical watershed. Typical distribution of chum (a), pink (b), coho (c), Chinook (d), and sockeye (e). From Lichatowich (1999).

In the ocean, coho salmon generally do not migrate as far as the other species of Pacific salmon and steelhead trout (Behnke 2002). Coho originating in rivers of California, Oregon, and Washington tend to feed along the Continental Shelf associated with the region of origin (Sandercock 1991; Pearcy 1992; Moyle 2002)(Figure 3). However, coho stocks originating farther north are found farther offshore (Quinn and Myers 2005).

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[1] / One reviewer of this report raused a question regarding how habitat alterations due to land use might have influenced the pattern observed by Edie (1975). In the view of this author, whose research on the Clearwater began in 1971, when major areas of the watershed were still unroaded and unlogged, the pattern depicted by Edie is representive of the pristine state.

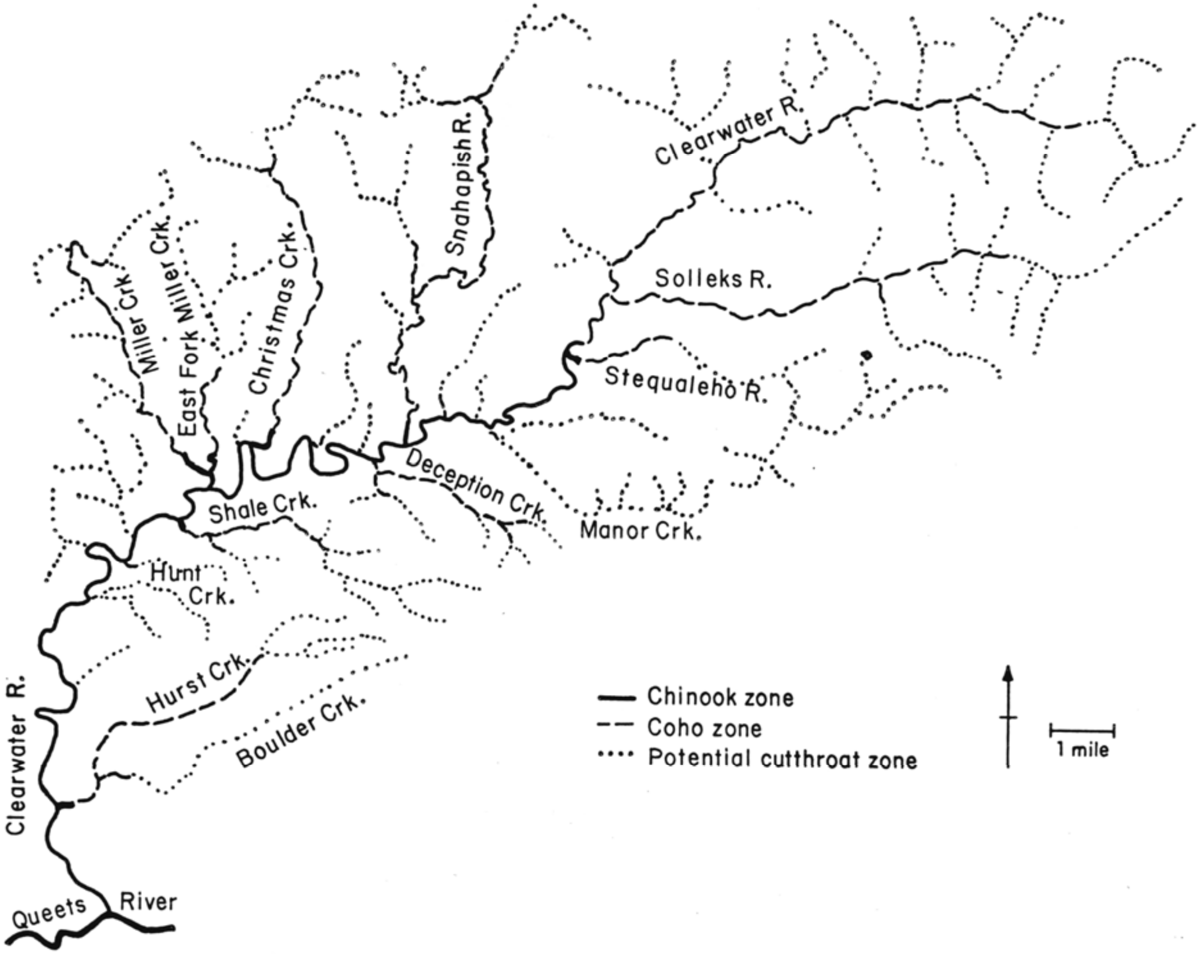

Figure 2. Salmonid usage zones in the Clearwater River (Olympic Peninsula, Washington) delineated by predominate species. From Edie (1975). Distribution patterns in this river reflect those that commonly occur for these species in the Pacific Northwest and California.

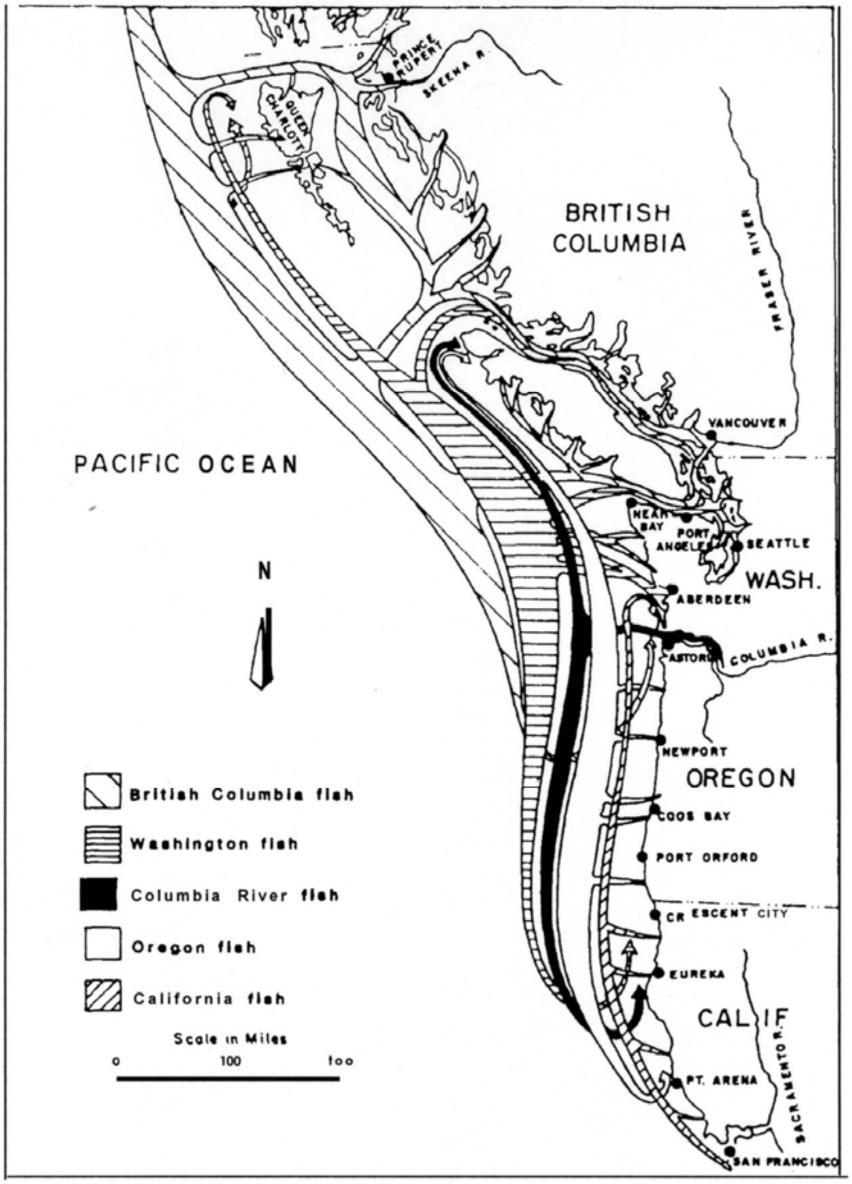

Figure 3. Oceanic distribution patterns of coho salmon originating in California, Oregon, Washington, and British Columbia. From Wright (1968).

2.2 Life Cycle Overview and Unique Characteristics

Most coho salmon across the species’ geographic range have a three year life cycle, divided about equally between time spent in fresh and salt water (Sandercock 1991). The basic life history begins in natal streams when spawners mate and deposit eggs into nests dug in the stream substrate. Spawning typically occurs between mid autumn and early winter in small tributaries to larger rivers, though timing can occur much later for some populations.

Returning adults in populations at the southern end of the range (both California and southern Oregon) are sometimes stalled in their river entry due to a lack of rainfall and sufficient stream flow for upstream migration, delaying spawning, sometimes even pushing it into March (Shapovalov and Taft 1954; Moyle 2002). This suggests that southern coho populations may have greater flexibility in adjusting their maturation timing than more northern populations; maturation would appear to be controlled partially by entry into fresh water.[2] Factors controlling variability in maturation timing of coho salmon are not well known.

After spawning, the adults die. Following egg incubation, surviving fry emerge from the substrate in late winter and spring and begin their free swimming life.

The emergent fry move quickly to slow velocity, quiescent waters, usually along the stream's margins or into backwaters where velocities are minimal, a consistent behavior across the species range (Sandercock 1991; Nickelson et al. 1992; Hampton 1988; Nielsen 1994; CDFG 2002). An affinity for slow velocity areas remains characteristic of juvenile coho throughout their freshwater life, unlike most other salmonid species.

Juvenile coho typically spend one year rearing in fresh water, during which time they may remain close to their natal sites or they may move considerable distances to find suitable summer and/or overwintering habitat. Their movements can disperse them to streams of all sizes—from tiny rivulets to large rivers and all sorts of connected water bodies, including lakes, ponds, springbrooks, flooded wetlands, and estuarine areas.

Figure 4, based on extensive studies in the Clearwater River (Olympic Peninsula, Washington), illustrates a variety of life history patterns within the same river system (Lestelle et al. 1993a). Most spawning in this river occurs in tributaries, in both low (<1.5%) and high (>1.5%) gradient streams, and in the upper portion of the mainstem where it narrows and steepens. The low gradient tributaries typify streams considered by many biologists to be highly productive for coho salmon—small low velocity streams with abundant pool habitat interspersed with woody debris. While the steeper streams support good numbers of spawners, emergent fry appear to largely disperse downstream from them into more suitable summer habitat.

Dispersal by some fry from natal reaches to areas downstream shortly following fry emergence is a pattern seen throughout the geographic range of the species (Figure 5)(Lister and Genoe 1970; Au 1972; Hartman et al. 1982; Murphy et al. 1984; Nielsen 1994). Downstream movement by young fry can result from intraspecific competition with other fry (Chapman 1962), displacement during high flows (Hartman et al. 1982), or not finding suitable colonization habitat (Au 1972). Some fry emigrants arrive at the stream mouth estuary (not shown in Figure 4) where they rear successfully in brackish water conditions. They apparently utilize the freshwater surface water

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[2] / Pink and chum salmon can reach sexual maturation while still in saltwater (Groot and Margolis 1991), while some species like sockeye salmon seem to need to mature in freshwater (Hodgson and Quinn 2002). This author has found that fall Chinook salmon returning to rivers on the Olympic Peninsula (Washington Coast) appear to have very little flexibility in adjusting maturation based on their river entry timing. These populations enter the rivers from the ocean mostly during freshet conditions. In years of severe drought, they delay entry until just before or the time of full maturation, when they swim in large numbers over shallow riffles in the lower river. They tend to spawn in the lower reaches of the river during such years. Their maturation timing appears to be little different, even unchanged, from years during normal river entry patterns.

lens to some extent, a rearing strategy observed in California (Nielsen 1994), Oregon (Miller and Sadro 2003), Washington (Beamer et al. 2004), British Columbia (Tschaplinski 1988), and Alaska (Murphy et al. 1984).

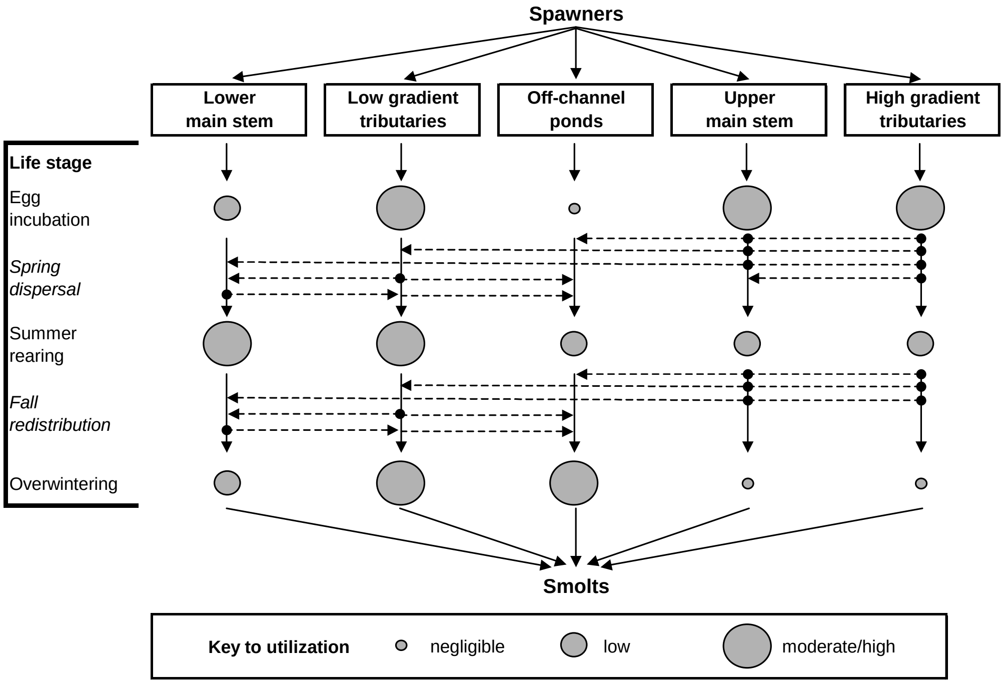

Figure 4. Utilization pattern by coho salmon of different areas of the Clearwater River (Olympic Peninsula, Washington) by life stage. Circle size reflects the relative amounts of production attributed to each area. Dashed lines show movements of fish from one area (dot) to another area (arrow). From Lestelle et al. (1993a). The chart illustrates the extent that coho juveniles can move during freshwater life to locate suitable habitats.

Freshwater rearing during summer typically occurs without extensive movement where flow and temperature conditions do not reach extreme conditions for survival (Figure 5)(Au 1972; Lindsay 1974; Kahler et al. 2001). However, more limited movement appears to be the norm in at least some streams. Kahler et al. (2001) observed that small-scale movement (i.e., several habitat units) and especially upstream movement was common for juvenile coho in three study streams in Western Washington. The researchers concluded that habitat quality rather than social dominance was the primary factor affecting movement.

More extensive summer movement, perhaps over relatively long distances, can be triggered by excessively high water temperatures or severely diminished flows, as documented in some Northern California and coastal Oregon streams (Figure 6)(Kruzic 1998; Chesney and Yokel 2003). Direction of movement in these cases has been observed to be downstream as seen in screw trap catches, though it should be noted that the sampling gear could only detect downstream movement. Juvenile coho have been found to move out of mainstem rivers during periods of high water temperature and into cool water tributaries. This behavior has been described in the Klamath River, where juvenile coho have been found moving upstream in excess of 3,000 ft from the mainstem in cool water tributaries (Toz Soto, Karuk Department of Natural Resources *personal communications*).[3]

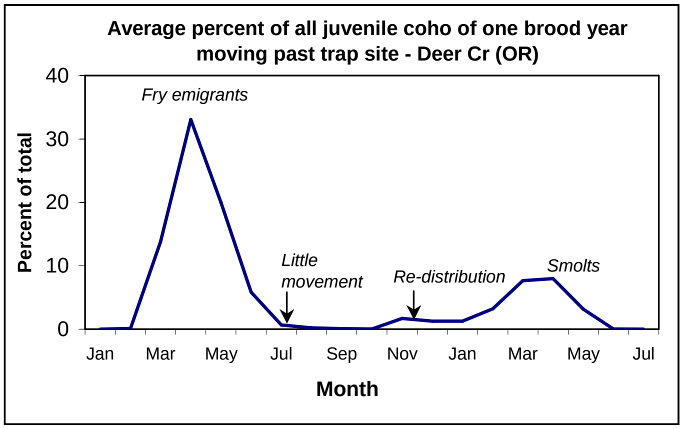

Figure 5. Representative pattern of movement and migration of juvenile coho salmon seen in many streams across the species' geographic range. Created from data in Au (1972) for Deer Creek, Alsea River system (Oregon Coast).

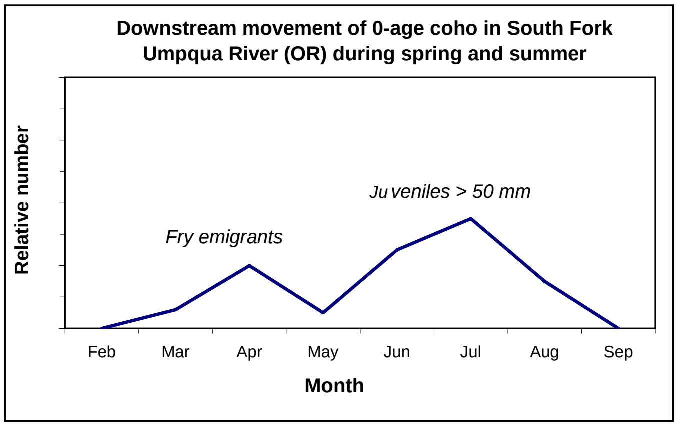

Figure 6. Movement of juvenile coho salmon past trap site in the South Fork Umpqua River (Oregon Coast) during spring and summer. Pattern is stylized from data in Kruzic (1998). Movement of juveniles during summer is believed due to high water temperatures.

In fall another movement pattern often occurs with some juveniles redistributing from oversummering sites to habitats more favorable for overwinter survival (Figure 4)(Skeesick 1970; Bustard and Narver 1975; Peterson 1982a; Cederholm and Scarlett 1982; Swales et al. 1986; Brown 2002). Harsh winter conditions for survival exist in many streams of the Pacific

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[3] / Stream-type juvenile Chinook exhibit the same behavior to escape high water temperatures in mainstem rivers. Lindsay et al. (1986) reported juvenile Chinook to move up to 7.5 miles upstream in some cool water tributaries from the mainstem John Day River (Central Oregon) during periods of high water temperature.

Northwest and Northern California, due either to frequent high flows in western regions or prolonged cold temperatures in eastern regions (Brown 2002). Limited winter habitat is believed to be a major constraint on coho populations in many Pacific Northwest watersheds (Mason 1976a; Hartman et al. 1998; Solazzi et al. 2000; Brown 2002). Moyle (2002), in referring to the importance of overwintering habitat for juvenile coho in California, concluded:

> "Availability of overwintering habitat is one of the most important and least appreciated factors influencing the survival of juvenile coho in streams."

A redistribution in fall at the onset of high flows or cold temperatures is an adaptation that many salmonids exhibit, particularly coho salmon. The question arises as to how far juvenile coho will move during this fall redistribution. In the Clearwater River, juvenile coho have been found to move up to 20 miles downstream from summer rearing sites to overwintering habitat (Peterson 1982a; Cederholm and Scarlett 1982). This distance was nearly the maximum that could possibly have been observed in that river due to its size and how the study was designed. In the Vedder-Chilliwack River (tributary to the lower Fraser River), Fedorenko and Cook (1982) found some juvenile coho to redistribute downstream from summer rearing sites nearly 40 miles to overwintering sites. In this case, juveniles had been captured and tagged in Chilliwack Lake in fall, then were recaptured the following spring emigrating from tributaries to the lower river—downstream of the lake up to 40 miles. These lower tributaries are only a short distance from the mainstem Fraser River, thus it is possible that some fall migrants had gone even further downstream to overwinter. But how far will juvenile coho travel to find suitable overwintering sites in large river systems, such as the Klamath River?

Inquiry was made of Richard Bailey[4] of Fisheries and Oceans Canada on what is known about redistributions of juvenile coho in the Fraser River system. Bailey reported that his agency is currently pursuing the answer to this very question. It has been hypothesized that juvenile coho move downstream from the upper Thompson River (upstream of the city of Kamloops) in fall to the Fraser River, and continue to move until they arrive in the lower Fraser River valley where abundant overwintering habitat exists, a distance of over 250 miles. In summer of 2006, Bailey's agency initiated a study to investigate this matter. The Thompson River is in the interior region of the Fraser Basin.

The Fraser River study highlights the level of importance that biologists in that region associate with the potential role of overwintering habitats to coho salmon. Such a view is consistent with Moyle's perspective of an equally important role to California coho, quoted above.

Figure 4 illustrates the effect of how movements during the freshwater life history can result in a significant rearrangement of where smolts are produced compared to where spawning takes place. Movements, though mostly directed downstream, can also occur in upstream directions. The pattern seen in Figure 4 is considered representative of many coho populations in the Pacific Northwest (Fedorenko and Cook 1982; Hartman et al. 1998; Brown 2002). It is reasonable to conclude that multiple life history patterns that incorporate some form of redistribution within a

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[4] / Richard Bailey, based in Kamloops, British Columbia, is assigned to assess the performance of Thompson River coho, a population that has experienced significant decline in recent years. It is a stock of concern in planning fisheries off the coasts of the Pacific Northewest by the Pacific Fishery Management Council.

watershed are common to the species. It is believed that coho home to their natal sites, regardless of redistributions that occur during freshwater residence (Lestelle et al. 1993a).

Moyle (2002) described the importance of redistributions of juvenile coho to California populations as follows:

> "Juveniles show pronounced shifts in habitat with season, especially in California streams. In spring, when stream flows are moderate and fish are small, they are widely distributed in riffles, runs, and pools. As stream flows diminish in summer, they increasingly concentrate in pools or deeper runs. During winter, before emigration, they seek refuges from high velocity flows generated by winter storms. Especially important are large off-channel pools with complex cover or small spring-fed tributary streams."

The utilization pattern illustrated in Figure 4 can be viewed as being representative of a river system with one or more connected lakes having access to coho. Lakes provide a significant component of coho production in some watersheds in coastal Oregon (Zhou 2000), Western Washington (Baranski 1989; Lestelle et al. 1993b), British Columbia (Holtby et al. 1993), and Alaska (Ruggerone and Rogers 1992; Ruggerone and Harvey 1994). Lakes can be important rearing areas during summer (Swain and Holtby 1989) and/or winter (Quinn and Peterson 1996). Lakes would tend to function in the same way as off-channel ponds.

At approximately 18-19 months of age (from egg fertilization), coho juveniles undergo smoltification during spring and enter the marine environment, where they experience very rapid growth. Their smolt to adult survival rate can be strongly affected by exposure to large estuarine complexes like Puget Sound or the Strait of Georgia (Spence 1995; Coronado and Hilborn 1998; Pinnix 1999; Beamish et al. 2000). For example, wild coho smolts that enter Puget Sound survive at rates that average nearly 20% (survival to recruitment to fisheries) during favorable regimes of the Pacific Decadal Oscillation (PDO)(Lestelle et al. 1993b). In contrast, wild smolts entering the Pacific Ocean from the rivers along the Washington north coast, which have no or limited extended estuarine habitat, typically survive at 1/6 to 1/3 that rate (Figure 7)(Sharma et al. 2006; Volkhardt et al. 2007; Quinault Department of Natural Resources *unpublished*). This difference gives populations originating inside the Strait of Juan de Fuca a tremendous boost in productivity compared to those along the outer coasts and makes them naturally more resilient to habitat perturbations. Spence (1995) suggested that coho smolts originating in rivers on the outer coast of Washington, Oregon, and California are affected by ocean upwelling conditions, which influences prey abundance, more immediately and directly than smolts passing through extensive estuarine areas. Hence, marine survival of smolts produced on the outer coasts are more strongly affected by interannual variability in intensity and timing of ocean upwelling events.

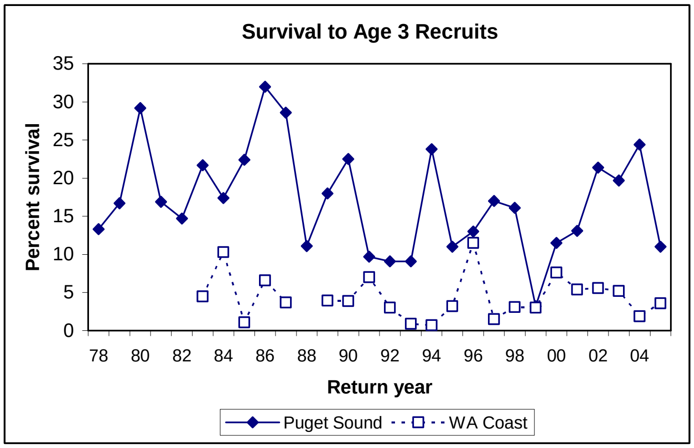

Figure 7. Marine survival from smolt to 3-year old ocean recruitment for wild coho originating in rivers of the Puget Sound and Washington outer coastal regions. Populations representing the two regions are Big Beef Creek and Bingham Creek for Puget Sound and WA coast, respectively. Data from Volkhardt et al. (2007).

Marine survival for populations along the south to central coast of California typically are the lowest of North American coho (Coronado and Hilborn 1998). Those in Northern California (e.g., Klamath) are higher but still below average when compared to other states and provinces (Coronado and Hilborn 1998). Survival rates for Oregon coho are higher yet but tend to also be less than in regions farther north. This latitudinal pattern in survival is correlated with certain factors as reported by Pearcy (1992). He indicated that protected bays, inlets, and shallow littoral areas that favor survival of juveniles are rarer to the south, especially off California and Oregon. In addition, oceanographic variability, resulting from interannual fluctuations in the intensity of upwelling or El Niño events, appears to be greater in the southern part of the species' range.

Recently reported marine survivals for wild fish (brood years 1996-2001) in the West Fork Smith River (Umpqua Basin, Oregon Coast)(Miller 2005) range between 1.3 to 21.7% (mean of 10.2% over 6 yrs) and illustrate the tremendous variation that has occurred over the past decade.[5] A regime shift in ocean conditions is believed to have occurred in 1998-1999, positively affecting many salmon populations in the southern half of their range (Beamish et al. 2004). However, marine survival for some populations within this part of their range was extremely poor in return year 2006 and is forecasted to again be low for 2007 (Volkhardt et al. 2007).

The ocean migration of coho salmon occurs mainly along the coastal waters of the continental shelf in the southern part of the species' range (Quinn and Myers 2004). Northern populations migrate farther off-shore (averaging four times as far from tag recovery work). In the southern region, waters are warmer farther off-shore, less productive, and dominated by other fishes (Pearcy 1992).

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[5] / The mean for these years reported for West Fork Smith River is much higher than would be expected over a much longer period because it is skewed high by exceptionally high survivals in several years since the regime shift of 1998. Such high survivals also occurred in areas farther north, as seen for some populations on the Washington Coast. This apparently was not the case for Bingham Creek coho shown in Figure xx.

After roughly 16-17 months in the sea, adult coho return to their home rivers. They begin arriving at the entrances to their home rivers in late summer, but more typically in early autumn. Sandercock (1991) noted that fish arrive earliest back to their home river in northern most rivers and latest to rivers farther south. This pattern is generally correlated with the timing of fall and winter rains and increases in stream flow—flows typically rise later moving from north to south. Many smaller streams in Oregon and California are blocked to upstream migration until elevated flows open sand bars formed across their mouths during summer. In larger rivers whose mouths remain open to the ocean, low flows that extend into early or mid fall keep riffles shallow and can slow upstream migration of adult salmon.[6] Major runs within British Columbia and Washington enter their home rivers primarily during September through November (Sandercock 1991). Moyle (2002) described river entry timing for Klamath River coho as between September and late December, peaking in October and November. He noted that river entry in the Eel River, located farther south, is approximately 4-6 weeks later. Shapovalov and Taft (1954) reported entry timing for several Central California streams as being primarily between mid October and end of January. A similar latitudinal pattern of river entry timing also exists for fall-run Chinook in many short coastal rivers (Nicholas and Hankin 1988; Healey 1991), presumably due to effects of flow timing and in-river thermal patterns regulating spawning timing.

To this author's knowledge, an effect of stream temperature on the upstream migration timing of adult coho has not been described in the scientific literature. Water temperatures are typically cooling when adult coho begin their freshwater migration.[7] Quinn (2005) concluded that variation in river entry and migration timing seems to be fundamentally controlled by accessibility to spawning grounds and spawning date. As shown earlier in this section, however, coho in the southern extent of their range appear to be able to postpone spawning if access is significantly delayed. Much remains unknown about factors affecting both migration and spawning timing, including the connection between flow and thermal regimes (Quinn 2005).

River entry across an entire run of fish often occurs in pulses—coinciding with storm events—over a period of three months or more (Shapovalov and Taft 1954; Sandercock 1991), though it can be shorter in small coastal systems. River entry can be continuous when flows are sustained by frequent storms (Holtby et al. 1984). Shapovalov and Taft (1954) reported that run entry in Waddell Creek at the southern end of the geographic range extended over about three months.

Typically moving during high flows, coho salmon return to their natal streams—usually with a high degree of fidelity—to complete their life cycle at spawning. Time of spawning is typically later than that of other species and more protracted such that instantaneous spawner density is often low.

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[6] / Prolonged low flows in fall can slow the upstream migration rate of adult coho even when the river mouth remains open to the ocean, as seen by the author in major rivers on the Olympic Peninsula in Washington when rains are significantly delayed. This same effect has been noted in the early part of the run on the Klamath River when flows are exceptionally low (CDFG 2004).

[7] / Water temperatures in the lower reaches of rivers in the southern part of the range are often still elevated in September when the earliest run component of coho can begin entering freshwater. Elevated temperatures at this time can contribute to mortality rate on migrating coho, as documented in at least one case on the Klamath River (CDFG 2004).

Within the basic life history, variations exist in age structure, generally following patterns associated with latitude. While the majority of coho are age 3 at spawning, some males mature precociously at age 2 as "jacks", after spending approximately six months at sea (Sandercock 1991). Drucker (1972) suggested that the percentage of jacks in the population decreases from south to north. This life history is virtually absent in the northern end of the range. Precocity, while having some genetic basis, is related to freshwater growth rate and smolt size, both of which decrease with latitude. In the southern half of the range, percentage of jacks in a population is related to quality and productivity of habitat (Young 1999). High quality habitats produce faster growth and larger smolts, resulting in greater precocity—though the percentage of jacks in a population can vary significantly between years (Shapovalov and Taft 1954; Young 1999). Young (1999) suggested that jacks could be critically important in maintaining genetic structure of coho populations because they provide the only gene flow between otherwise isolated brood years for the species.

Another deviation from a three year life cycle occurs because some juveniles spend an additional year rearing in fresh water and emigrate seaward at approximately 30 months of age; these return and spawn at four years of age. This pattern occurs primarily in more northern populations, particularly in Alaska (Sandercock 1991), and is due to growth rates being slower in colder streams, requiring an additional year for fish to attain a size necessary for smoltification. South of British Columbia, very few juveniles typically smolt at 30 months of age (Sandercock 1991), though exceptions exist.

One notable occurrence of age 2 smolts has been found in Prairie Creek, tributary to Redwood Creek, in Northern California by Bell (2001). Twenty eight percent of the smolt yield was reported to be age 2 (approximately 30 months old) in a single year of study. Bell noted that age 2 coho smolts had not been previously documented in California and that they are a small component of smolt yield on the Oregon Coast (citing Moring and Lantz 1975). Walt Duffy (Humboldt State University, *personal communications*) indicates that such a high percentage of age 2 smolts does not occur every year in Prairie Creek, but small numbers likely do, as well as in other Northern California streams. Bell attributed the occurrence of age 2 smolts in Prairie Creek to poor winter and spring growth rates. Duffy (*personal communications*) believes that high rearing densities associated with cool summer temperatures in this stream may be responsible. Nielsen (1992a) observed that one foraging phenotype in some Northern California streams produced exceptionally small yearling migrants (< 70 mm) without smolt like characteristics. Nielsen's observations may provide insights into the occurrence of age 2 smolts in Prairie Creek and other California streams; this is discussed further later in this section.

A central theme in the freshwater life history of juvenile coho is their close association with slow velocity habitats. Body morphology and fin sizes of juvenile coho salmon are particularly adapted to slow velocity habitats. Most coho juveniles have a laterally compressed body with long dorsal and anal fins, thought to be adaptations for life in slow water (Bisson et al. 1988b)(Figures 8-10). Figures 9-10 are from Stein et al. (1972) from observations made on coho and Chinook salmon in the Sixes River (Oregon Coast).[8] Note the significant differences in fin sizes between Chinook and coho juveniles at around 60 mm body length in Figure 9. In contrast

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[8] / The Sixes River in Southern Oregon is the first river immediately north of the northern boundary of the Southern Oregon Northern California Coasts Coho ESU.

to coho fry, steelhead fry have cylindrical bodies in cross section with short dorsal and anal fins, adapted to higher velocity habitats than used by juvenile coho (Bisson et al. 1988b). Juvenile Chinook have a body form and fin sizes intermediate between coho and steelhead (Figures 8 and 9). These morphological differences between juvenile coho and other salmonid species appear to favor coho in interspecific interactions in habitats most favored by coho (Stein et al. 1972; Hartman 1965; Glova 1986; Young 2001). Coho generally dominate in competitive interactions within slow water habitats with Chinook, steelhead, and cutthroat. Fin morphology is believed to be important in social interactions of salmonids (Keenleyside and Yamamoto 1962; Stein et al. 1972).

These differences in body shape and fin sizes between species are also consistent with water velocity and depth preferences reported for these species (Figure 11). Data in Figure 11 come from a study in the Trinity River in the Klamath River basin (Northern California)(Hampton 1988). Almost identical depth and velocity preferences are reported for juvenile coho salmon in rivers of Western Washington (Figure 12)(Beecher et al. 2002). Coho prefer much slower velocities than either steelhead or Chinook; Chinook preferences are intermediate between coho and steelhead. It is noteworthy that preferred water velocities of juvenile coho salmon change little between fry (<50 mm) and parr (>50 mm), whereas a significant change occurs for juvenile Chinook salmon. Juvenile coho are typically 60-70 mm in size by the end of their first summer of life. It is logical to expect that selection of habitat types by these species would reflect their adaptation to water velocity and depth.

Figure 8. Juvenile coho salmon (top), Chinook salmon (middle), and steelhead trout (bottom) illustrating differences in fin size and body morphology. Photos courtesy of Roger Tabor, U.S. Fish and Wildlife Service, Lacey, Washington. Note that the dorsal and anal fins of the coho are easily recognized by their white leading edges.

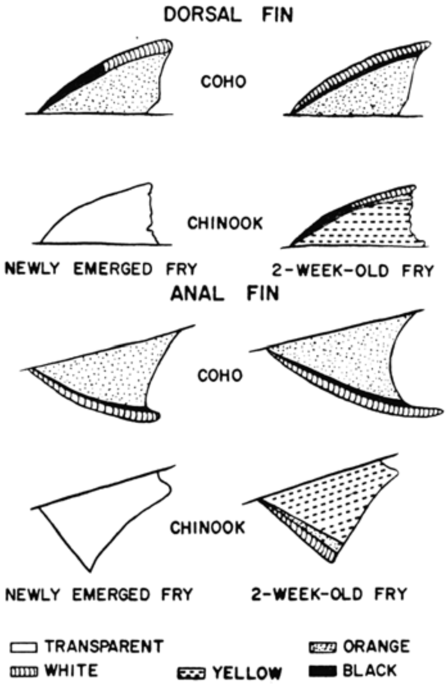

Figure 9. Diagrammatic sketches of the dorsal and anal fins of recently emerged and 2-week old coho and fall Chinook salmon in Sixes River (Oregon Coast). From Stein et al. (1972). Note that differences in size of fins between species increase as fish grow (see Figure 10) and appear to be greatest at lengths of about 60 mm, which for coho would typically occur between mid to late summer.

Juvenile coho can adjust their velocity preferences to a limited extent depending on food availability. Based on controlled experiments, Rosenfeld et al. (2005) reported that increased food abundance resulted in greater growth of both dominant and subdominant juvenile coho and a shift to higher average focal velocities. Increased food permits juvenile coho to exploit higher velocity microhabitats that might otherwise be bioenergetically unsuitable with less available food. The authors observed that average focal velocities shifted from 6.5 cm/s to 8.4 cm/s, with maximum growth occurring in the range of 10-12 cm/s. Still, the shift reported by these authors was small, with velocities remaining within the strongly preferred range shown in Figure 12.

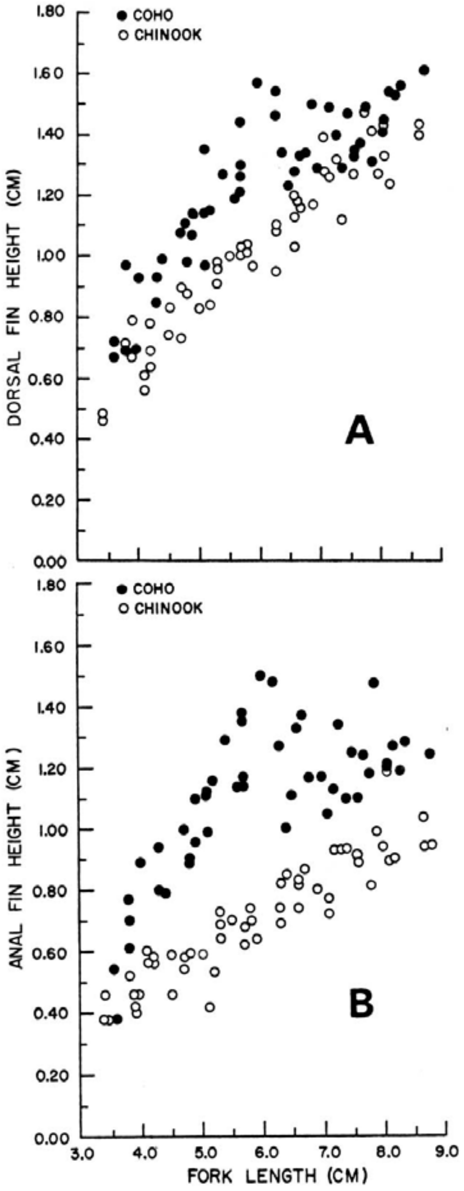

Figure 10. Differences in dorsal and anal fin sizes between juvenile coho and Chinook salmon. From Stein et al. (1972).

Variation has been found to exist between regions both with respect to body morphology and swimming performance. Taylor and McPhail (1985a) identified two morphological forms based on differences in body shape and fin size: a "coastal" form, characterized by large dorsal and anal fins and a deep robust body, and an "interior" form with smaller fins and a more streamlined body shape. Figures 8-10 illustrate characteristics of what those authors called the coastal form. The study was based on a comparison of samples collected in the Thompson River subbasin (interior Fraser basin), lower Fraser River tributaries, and Vancouver Island streams. In addition, the authors performed breeding experiments to determine if these morphological differences are inherited. Further, to see if morphological differences between interior and coastal populations found in these areas exist in other regions, they sampled preserved juvenile coho (from fish museums) from the upper Columbia system and from creeks in north coastal British Columbia and Alaska. They concluded that the coastal-interior stock differences in morphology is part of a coastwide pattern and that the differences are at least partially inherited. The authors also reported that adult coho sampled in the same areas showed some of the same morphological differences displayed by the juveniles.

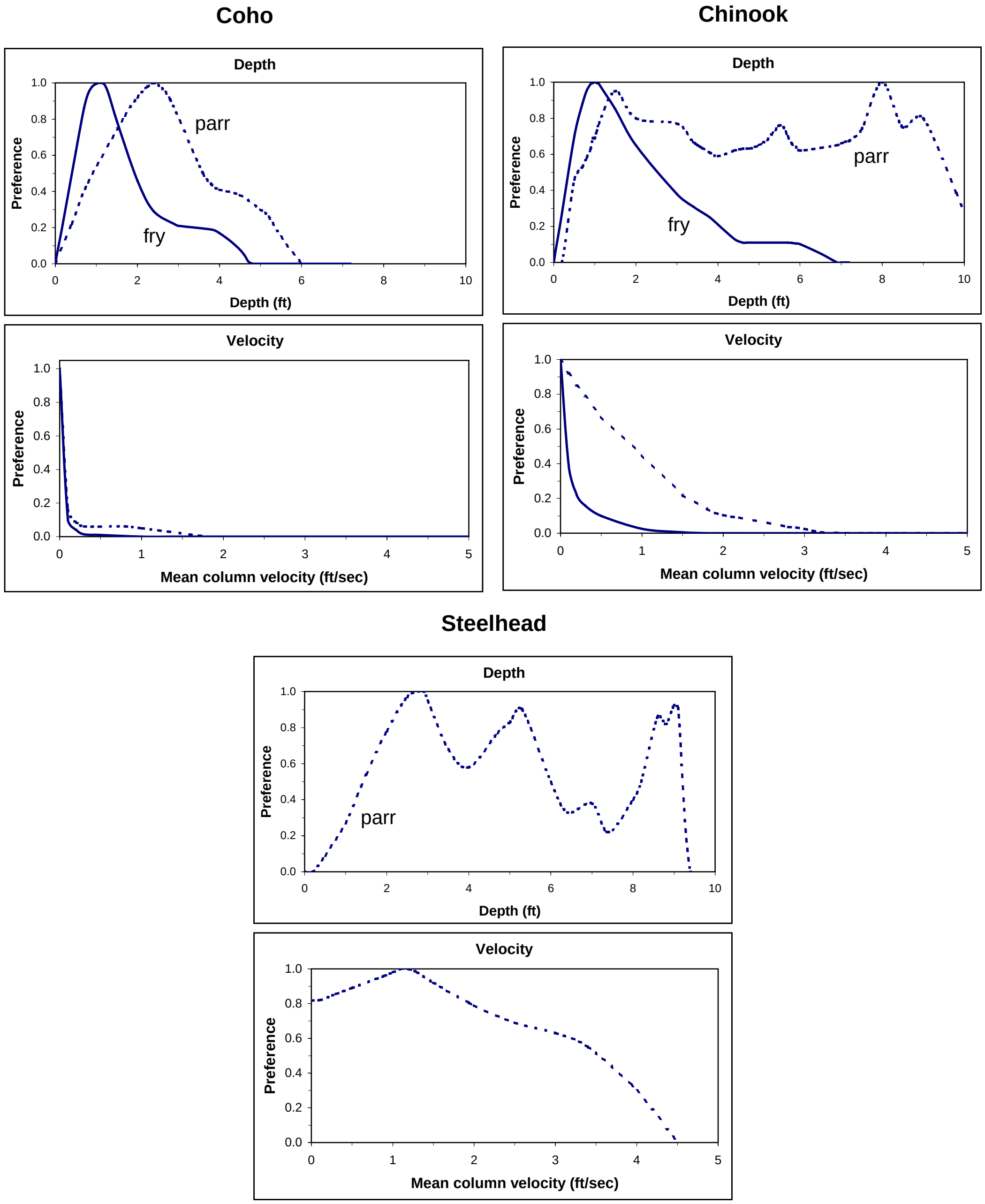

Figure 11. Water depth and velocity preferences of coho salmon, Chinook salmon, and steelhead trout fry (<50 mm) and parr (>50 mm), as observed in the Trinity River in the Klamath River basin (Northern California). Water velocities are mean column values. Adapted from Hampton (1988).

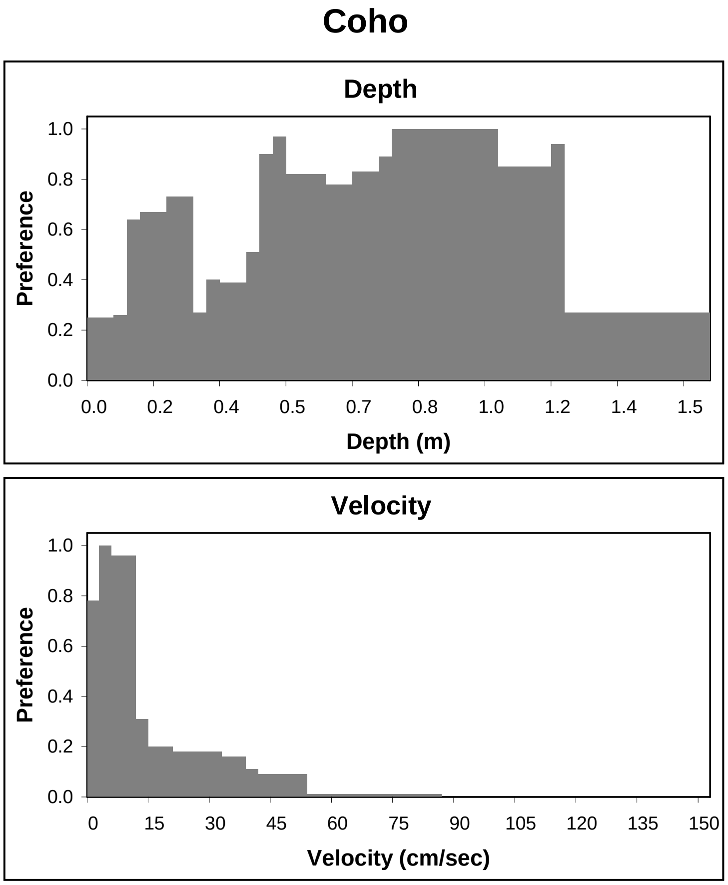

Figure 12. Water depth and velocity preferences of subyearling coho salmon found in rivers of Western Washington. From Beecher et al. (2002). Water velocities are measured at 0.6 depth (approximately equal to mean water column values). Note: 30.5 cm = 1 ft.

These two morphological phenotypes differ in swimming performance (Taylor and McPhail 1985b). Coastal juveniles were found to have greater burst velocities (fast start) than the more streamlined interior form. In contrast, the interior form was found to have significantly greater swimming stamina, on average four to five times the prolonged swimming performance of coastal juveniles. Taylor and McPhail (1985b) concluded that differences in swimming performance were related to body and fin morphology. They noted that variations in swimming performance are probably adaptive and related to differences in the energetic demands of their freshwater migrations (smolt and adult) and perhaps to levels of predation experienced by coastal and interior forms. Burst speed would favor fish exposed to abundant predators under conditions where swimming stamina is not as important. In contrast, swimming stamina would favor smolts and returning adults that migrate long distances in swift, turbulent rivers, such as the Fraser and Thompson rivers.[9]

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[9] / Swimming stamina would also favor long distance movements of pre-smolts, as has been hypothesized for a fall redistribution of Thompson River coho described earlier.

The findings of Taylor and McPhail (1985a and b) raise a question about whether both morphological forms exist in the Klamath River where interior and coastal ecoregions occur. Within the interior portion of this basin, some coho are currently produced in excess of 200 miles from the ocean. Their migrations in the mainstem Klamath River traverse many turbulent, swift reaches, not unlike the Fraser River but on a smaller scale. Implications of this question are discussed later in this document.

Variation in morphological forms—similar to that described above—has also been found at a much smaller scale than that of ecoregions. Swain and Holtby (1989) reported distinct differences in body morphology between life history forms associated with different habitat use patterns in a single river system. Certain morphological characteristics of juvenile coho rearing in a small lake within the Cowichan River system (Vancouver Island) were significantly different than those of stream-rearing coho in the lake's inlet stream. Lake rearing fish had more posteriorly placed pectoral fins, shallower bodies and smaller, less brightly colored dorsal and anal fins than did stream rearing fish. The dorsal and anal fins of stream fish were larger and more falcate than lake fish. Lake rearing fish were schooling and non-territorial, unlike the highly territorial stream fish, which displayed frequent aggressive behavior. These characteristics, both morphological and behavioral, were maintained when both forms were placed within a common laboratory environment for two months.

The researchers concluded that differences between forms may be genetically based, or environmentally induced and fixed early in life. They inferred that the differences between forms are adaptive, with fin size, body shape, coloration, and behavior of each form more suited to survival within their respective rearing environments. While they proposed a plausible mechanism for genetic differentiation, phenotypic plasticity seemed just as likely. Their findings showed that either through genetic divergence or phenotypic plasticity, coho within a relatively small—yet diverse—river system can adapt to exploit contrasting habitats, thereby reducing intraspecific competition and increasing overall utilization of the system. More recent research suggests that the findings of Swain and Holtby (1989) were due to phenotypic plasticity—not genetic differentiation—as fin size and body morphology of juvenile salmonids has been found to be shaped by water velocity (Pakkasmaa and Piironen 2001). It should be noted that species-specific responses to water velocity differs between species, likely due to different energetics and cost reduction strategies.

Another aspect of life history that may differs between regions is foraging behavior. Foraging behaviors can vary between individuals of the same population or even of the same family. Nielsen (1992a; 1992b; 1994) identified four foraging behaviors of juvenile coho—she considered them distinct phenotypes. She suggested that one of the four types may be unique to the southern portion of the species' range (i.e., California); see also Moyle (2002). Nielsen's findings were based on studies conducted in one Puget Sound stream over two years of study (Nielsen 1992b) and in ten Northern California streams over four years (Nielsen 1992a and 1994). In the California work, Nielsen (1992a and 1994) monitored foraging behaviors of individual fish from fry emergence until outmigration as yearlings. Fry were trapped and marked as they emerged from distinct redd sites, their subsequent movements and feeding patterns were observed, they were remarked at larger sizes (still knowing their origin) so they could continue to be followed and observed through summer and winter. Drought conditions in California during the years of study allowed observations to continue throughout winter. Each foraging phenotype was found to utilize habitat features differently (Table 1). All four phenotypes were consistently found in the Northern California streams. Fish rarely changed their foraging behavior once they had been associated with a phenotype. Nielsen concluded (Nielsen 1994; Jennifer Nielsen, U.S. Geological Survey, *personal communications*) that the phenotypes are not genetically distinct but are the result of population responses to different environmental conditions.[10]

In her earlier work, Nielsen identified two of the four foraging phenotypes in a Puget Sound stream (Nielsen 1992b), the *thalweg hierarchy* and *margin-backwater* types. The *thalweg hierarchy* type is the most common foraging behavior of juvenile coho found in the Pacific Northwest and California during summer. It is the stereotypical coho foraging pattern, used by the largest proportion of a population (Table 1). The primary habitat used by this type is main channel pool, i.e., pools associated with the channel thalweg. Fish that employ this foraging pattern are grouped in partial dominance hierarchies, with dominant and subdominant individuals. They feed predominantly on invertebrate drift and grow throughout the summer, attaining sizes of 60-85 mm by winter (Figure 13), when growth typically slows. A surge in growth occurs in spring, when they reach sizes of 90-105 mm in California streams. They smolt and emigrate to sea between March to June. This foraging pattern occurs in other regions.

The second phenotype found both in Washington and California is the *margin-backwater* type, called “floaters” in Nielsen (1992a)(see also Puckett and Dill 1985). This type is composed of fish that move to slack water habitats at or near the channel margin immediately following emergence and do not subsequently move to deeper water as they grow. They do not form dominance hierarchies but instead roam relatively large forage arenas feeding opportunistically on food of terrestrial and aquatic origin. Forage arenas are characterized by extremely low velocity flow along the channel margin or in backwater pools. Growth rates of these fish are low compared to other foraging phenotypes (Figure 13). Margin-backwater fish remain small throughout summer, fall, and winter (Nielsen 1992a and b).

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[10] Nielsen (1994) gives details on the numbers of families and individuals that were monitored by marking wild fish for brood years 1990 and 1991. Newly emerged fry were captured by trapping 16 distinct redds in five of the study streams. Fry were marked using a broadcast spray of fluorescent pigment, with different colors used on fish from adjacent redds. Fish were released at the redd sites following marking and allowed to disperse naturally. After several weeks, marked fish were recaptured (at approximately 45 mm in size), then re-marked as individuals using a Pan Jet innoculator with acrylic paint. Surviving marked individuals were observed over the course of the study. A total of 105 individuals were observed at the time of smolt migration and an additional 40 fish were sacrificed for analysis at 6-16 months following marking with the Pan Jet. Nielsen did not identify how many other marked fish were observed at various times during the study.

Table 1. Characteristics used to depict wild coho phenotypes in 10 streams in Mendocino County, Northern California 1989-1992. Recreated from Nielsen (1994). Sample sizes were not reported for each phenotype in the original papers—see footnote in text regarding overall numbers of marked fish observed in some years of the study.

Coho characteristic	**Coho foraging phenotype**			
	Thalweg	**Margin**	**Estuarine**	**Early emerging**
Primary habitat	thalweg flows	margin/backwater	estuary tidal prism	cutbank/rootwad
Social system	large groups (17-38) operating in partial dominance hierarchy	isolated roving individuals	individuals found in widely dispersed large groups (14-23)	small integrated groups of 2-4 fish, no obvious hierarchy
Emergence timing	February – April	February – April	February – March	January – February
Foraging behavior	forage stations	forage stations	opportunistic	forage stations
Forage timing	diurnal	diurnal	diurnal	crepuscular
Primary diet source	aquatic invertebrates	terrestrial invertebrates	aquatic invertebrates	terrestrial invertebrates
Mean diet caloric content (season)	low (all year)	empty to high (seasonally mixed)	highly variable (all year)	high (all year)
Intraspecific agonistic behavior	highly competitive	little interaction	highly competitive	little interaction
General growth pattern – spring	dominant = fast subdominant = average	slow	slow	fast
General growth pattern – summer	dominant = average subdominant = slow	slow	average	slow
General growth pattern – fall/winter	dominant = fast subdominant = fast	slow	slow	fast
Size-at-age	dominant = large subdominant = average	small	average	large
% emerging population	67%	17%	13%	3%

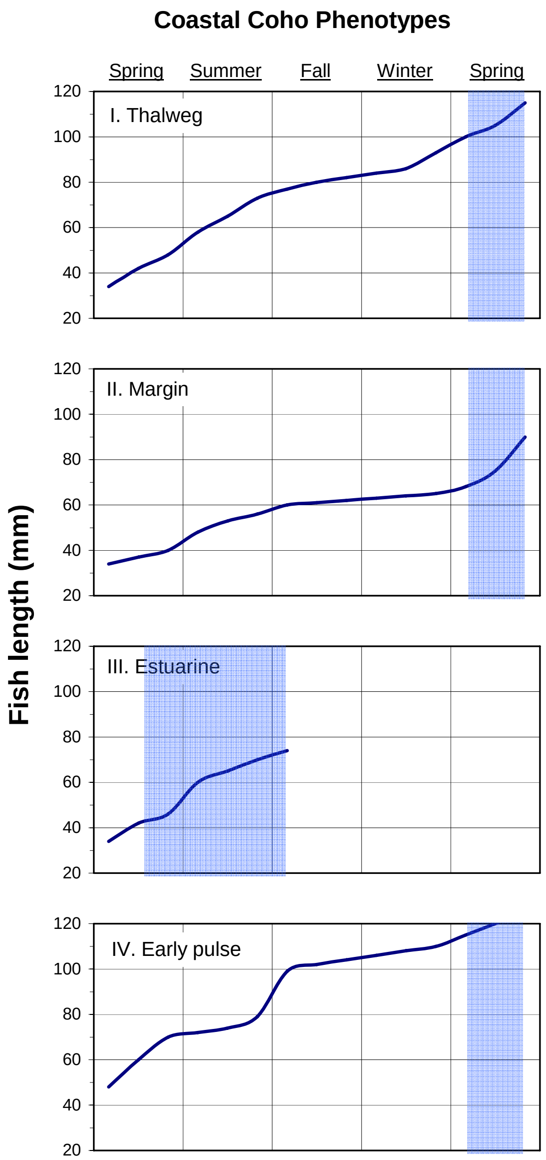

Figure 13. Coastal coho foraging phenotypes, showing unique growth rate cycles and movement from fresh water to the stream mouth estuary, as documented in Northern California streams. Presence within the stream mouth estuary is shown as shaded. Adapted from Nielsen (1992a).

In Northern California streams, Nielsen (1992a) reported that margin-backwater juveniles moved to the estuary in spring as small yearlings (<70 mm) without smolt characteristics, their fate being uncertain. Fish of this size should tend to remain in fresh water for another year and smolt as two year olds. This would explain Bell's finding of a large number of age 2 smolts in Prairie Creek in one year. Nielsen (1994), however, noted that no evidence was ever found for age 2 smolts in the ten populations studied in Northern California (from scale analysis). Perhaps all of the conditions that would cause fish of this phenotype to remain in fresh water for an added year occurs infrequently in this region. The question arises as to the adaptive benefit of a foraging strategy that produces such small yearling migrants, whose survival appears questionable. They may experience rapid growth in the stream mouth estuary and move into the open ocean at a much larger size (Figure 13). Alternatively, if fry exhibiting this phenotype move from natal tributaries following emergence into larger mainstem rivers, when present (see Figure 4), and find greater food supplies there, growth could be much faster during summer. Growth rates during summer in mainstem rivers, where water temperatures are suitable[11], normally exceed those in small natal streams (Cederholm and Scarlett 1982). Fish displaying this foraging behavior may also be those found to move into riverine ponds or alcoves soon after emergence, residing there through summer and winter (discussed later in this document). Fish that do so would be expected to attain a size necessary for smoltification, assuming suitable water temperatures exist in summer. Thus, the contribution of this foraging type to population sustainability may depend on availability of certain habitat types and adequate food resources.

The third phenotype is the *estuarine* type (Table 1; Figure 13). Although not observed by Nielsen in Washington (due to the location of the study), this foraging behavior occurs across the species' range, as described earlier in this document. In California, Nielsen (1994) described fish exhibiting this phenotype as moving up and down the stream mouth estuary[12] during spring and summer within the freshwater surface layer. The juvenile coho foraged opportunistically on whatever was found in the water column, as well as picking up food items along the substrate. They fed on items of both freshwater and marine origin. In an Alaskan stream, Murphy et al. (1984) found young of the year coho to grow more quickly in the stream mouth estuary than in freshwater reaches upstream. Similarly, Tschaplinski (1988) found juvenile coho within a stream mouth estuary in British Columbia to significantly outgrow those rearing upstream; by fall the estuarine fish were longer by 16-18 mm.

Nielsen was unable to follow the estuarine fish through winter—she noted that their distributions during winter and the following spring remained unknown (Nielsen 1992a). Murphy et al. (1984) found in an Alaskan stream that most juvenile coho evacuated the stream mouth estuary prior to winter; the authors presumed—but could not confirm—that fish moved upstream to more favorable freshwater sites. In British Columbia, Tschaplinski (1988) reported that juvenile coho left the stream mouth estuary between late September and November—no overwintering occurred in the estuary. Moreover, Tschaplinski found only a small number of juveniles to move back upstream into fresh water to overwinter. He inferred that the majority of estuarine juveniles moved into Barkley Sound. Based on lab studies, he concluded that juveniles that reared in the stream mouth estuary during summer, gradually being acclimated to brackish water, were able to physiologically tolerate brackish to moderately high salinity of the nearshore, surface waters of Barkley Sound. However, the lab studies showed that the estuarine reared juveniles could not fully osmoregulate in 30 ‰ sea water at the time of their departure despite their size being comparable to yearling smolts. Miller and Sadro (2003) conducted extensive marking and ultrasonic tag tracking studies to investigate seasonal movements of juvenile coho within portions of the relatively large Coos Bay estuary in Southern Oregon. They found no evidence that juveniles moved beyond the upper estuary into the strongly marine environment during fall. They concluded that similarities in life history patterns between southern and northern regions of

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[11] / Suitability of various temperatures to growth and survival is discussed later in this report.

[12] / The estuarine zone immediately associated with its principal freshwater source is referred to in this document as a stream mouth estuary. Estuaries can be very large and can include a continuum of conditions from areas having no salinity (at the upper end of tidal influence) to those with near fully marine characteristics. Puget Sound is technically considered an estuary.

the species' range include downstream movement to the stream mouth estuary at age 0 during both spring and fall, use of the upper estuarine zone for months, and upstream movements during fall to overwinter in fresh water. They stated that regional differences likely exist in how estuaries are used by juvenile coho given the profound differences in nearshore oceanographic conditions between regions.

Nielsen (1992a; 1994) called the fourth foraging phenotype the *early emerging* or *early pulse* type (Table 1). This phenotype has only been described in Northern California. It is comprised mainly of early emerging fry from individual redds. Nielsen found that a small proportion of the fry in a redd emerged much earlier than the majority of fry; approximately 3% emerged during January and February. These fish demonstrated an unusually fast growth pulse immediately after emergence.[13] They attained lengths of 65 to 78 mm by late May or early June (Figure 13). Growth then shut down during summer, followed by another growth pulse in early fall. By late September they could be 105 mm in size and by spring they tended to resemble two year olds.

The foraging behavior of early emerging fish was found to be distinctly different than the behaviors of the other phenotypes. Upon emerging, the fry fed initially in groups of 3 to 5 fish on drifting aquatic invertebrates at the margins of pools. Few agonistic interactions occurred within the small groups. As they grew, these fish occasionally left their positions at the margins and fed briefly on drift aquatic invertebrates in deeper water (March to April). By summer their foraging behavior was characterized as being more trout-like than is common among juvenile coho. They foraged only at dawn and dusk on drifting invertebrates in the water column. During the day, they sought refuge in undercut banks, often associated with cold-seeps along terrace cutbanks.

Nielsen (1992a) stated that only this fourth phenotype was found to be in close proximity to cold-seeps along terrace cutbanks. She reported that this phenotypic expression was dominant in streams subject to drying during the drought that was then underway at the time of the study. She concluded that this behavior is "the one most likely to survive to smoltification in freshwater stream habitats" subject to extreme drought conditions. Thus, she suggested that the phenotype represents a pattern of adaptation significant to coho salmon in the southern portion of their range.[14]

Limitations of Nielsen's descriptions of foraging phenotypes should be recognized. The descriptions did not identify how fish moved longitudinally within a stream system upstream of the estuary, as depicted in Figure 4. It is not known whether one or more type is more likely to move longitudinally along the stream system during spring, summer, or fall. A further limitation is that the observations were made during drought conditions. It is uncertain how the types might

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[13] / It is noteworthy that Koski (1966) found that the earliest emerging coho fry from individual redds in Oregon coastal streams were consistently the largest of all fry produced from the redd. Fry length typically would steadily diminish for later emerging fish. The size differential between the early and late emerging fry was nearly 3 mm on average (38 mm vs 35 mm). The average number of days over which fry emerged from a individual redd was about 35 days.

[14] / It is uncertain to this author whether or to what extent juvenile coho might switch from the thalweg phenotype to an early pulse type phenotype under severe drought or high water temperature conditions. Nielsen's work suggests that switching would generally not occur, that is, fry that emerge during the peak of emergence would not display the foraging behavior of the early emerging fry.

differ during wet cycle years with regard to phenotype composition, foraging and growth patterns, and migrant sizes. It is also unknown how the patterns might differ with stream size.

3.0 Freshwater Habitat Utilization

This section describes the relative utilization—or importance—of various physical habitats to coho salmon and associated survivals within the freshwater environment. It is necessary for clarity to begin with a short description of the various riverine habitats utilized by salmonids. In fresh water, coho primarily utilize stream habitats, though they also rear in lakes where present within the accessible stream network of a watershed (Sandercock 1991). Emphasis is given in this report to describing use of stream habitats with some limited coverage on lake utilization.

3.1 Description of Channel and Habitat Types

Riverine habitat types refer to physical features of the aquatic system defined by channel and valley morphology and flow characteristics—they can be defined at multiple scales (Frissell et al. 1986; Burnett 2002). In this document they are defined either by geomorphic (channel) unit type, edge unit type, or channel type (Figure 14).[15]

Geomorphic units (or channel units) are distinct physical features of the channel that have relatively homogenous characteristics of depth, velocity, and substrate (Bisson et al. 1982; Montgomery and Buffington 1998). There are many classification schemes in use to distinguish geomorphic units (e.g., Hawkins et al. 1993)—the units shown here capture the main ones referred to often in salmonid ecology studies. In studies of coho salmon, pools are often further delineated as being either scour pools or dammed pools (such as beaver ponds)(Level II from Hawkins et al. 1993) or even further into other pool types as often done on the Oregon Coast (e.g., Nickelson et al. 1992).[16] It suffices here to keep the delineation fairly broad but reference to Nickelson's classification is also used in this document.

Delineation of channel edge habitats is based on Murphy et al. (1989), Beechie et al. (2005), and Schwartz and Herricks (2005). Three types of edge units are recognized, consistent with Beechie et al. (2005): backwater pools, bank edges, and bar edges (Figure 15). These habitats can be particularly important as velocity refugia to small fish as flows increase. Backwater units (or backwaters) are partially enclosed, low velocity areas separated from the main river channel (Figures 16). They often form at the mouths of remnant channels or small tributaries. Expansion eddy units, as defined by Schwartz and Herricks (2005), are considered backwater units here. Bank and bar edges are localized hydraulic dead zones formed at the channel margins associated either with vegetated banks or gravel bars. As flows increase above baseflow, vegetation along bank edges can be wetted and inundated (Figure 17).Another aspect of the channel form sometimes used to distinguish habitat types is channel type, such as main channel, side channel,

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[15] / Habitat type delineation in this document is drawn from Lestelle et al. (2005).

[16] / The classification scheme applied to pool types in Oregon coastal streams refers to one type as an alcove, which is actually an off-channel habitat type. Along mainstem rivers, this habitat type is often called an off-channel pond, as commonly done in Washington State and British Columbia. Hence, in this report alcoves and off-channel ponds are synonymous. Elsewhere in Oregon State, such as along the Willamette River, the term "alcove" is sometimes used to refer to backwater pool units (Landers et al. 2002—discussed in Lestelle et al. 2005).

or wall-base channel (Peterson and Reid 1984; Stanford et al. 2002). Identification of channel type is particularly important in addressing habitat issues in large mainstem rivers where geomorphic channel units do not adequately describe all of the features utilized by salmonids. In this document, channel types are grouped according to Lestelle et al. (2005).

All channels other than the primary (or largest) channel of the main river—including off-channels—are called secondary channels. Numerous terms have been applied to the continuum of secondary channels that exist in various river types—often without clear definitions of distinguishing characteristics. Types are grouped here to facilitate recognition of various habitats referred to in the scientific literature and as a way to simplify a wide variety of terms that have been used. (It is recognized that classifying channel types presents difficulties, however, because there is actually a continuum of channel conditions that change with flow level. Some channels are mixtures of different types and some are transitional between types.)

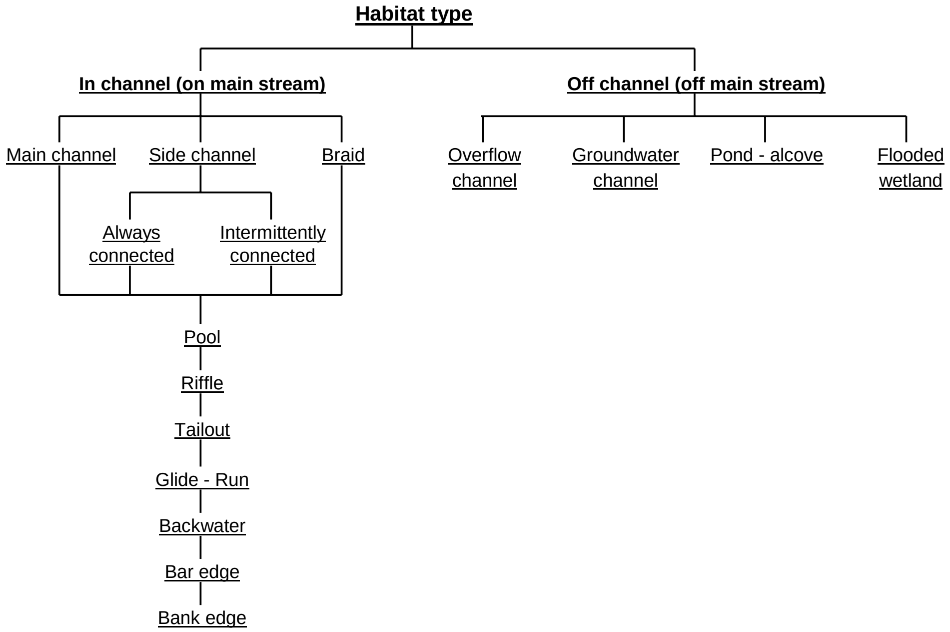

Figure 14. Riverine habitat types utilized by salmonid species. From Lestelle et al. (2005) with revision to use of the term "alcove" – see text. In channel mesohabitats occur in the main channel, side channels, and braids.

Riverine habitat types can be grouped according to their location with respect to the main stream channel as being either in-channel or off-channel. The distinction here is made consistent with Peterson and Reid's (1984) classification (Figure 18), which closely resembled the more recent classification of riverine channels by Tockner et al. (1998), Ward et al. (1999), and Zah et al. (2000).[17] The relative importance of main river versus off-channel habitats can vary widely

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[17] / Tockner et al. (1998) and Ward et al. (1999) identified six channels based on surface hydrological connectivity with the main channel and source of water: (1) main channel, (2) side channels, (3) intermittenly-connected side channels, (4) mixed channels, (5) groundwater channels, and (6) tributaries. They also provided a subdivision of groundwater channels. They did not address braids. Mixed channels were those that had a mixture of flow sources. Zah et al. (2000) subdivided ground water channels into (a) alluvial groundwater channel and (b) lateral groundwater channel, comparable to Peterson and Reid's percolation and wall-base channels.

between salmonid species and life stages. The need to recognize off-channel habitats is particularly relevant to coho salmon.

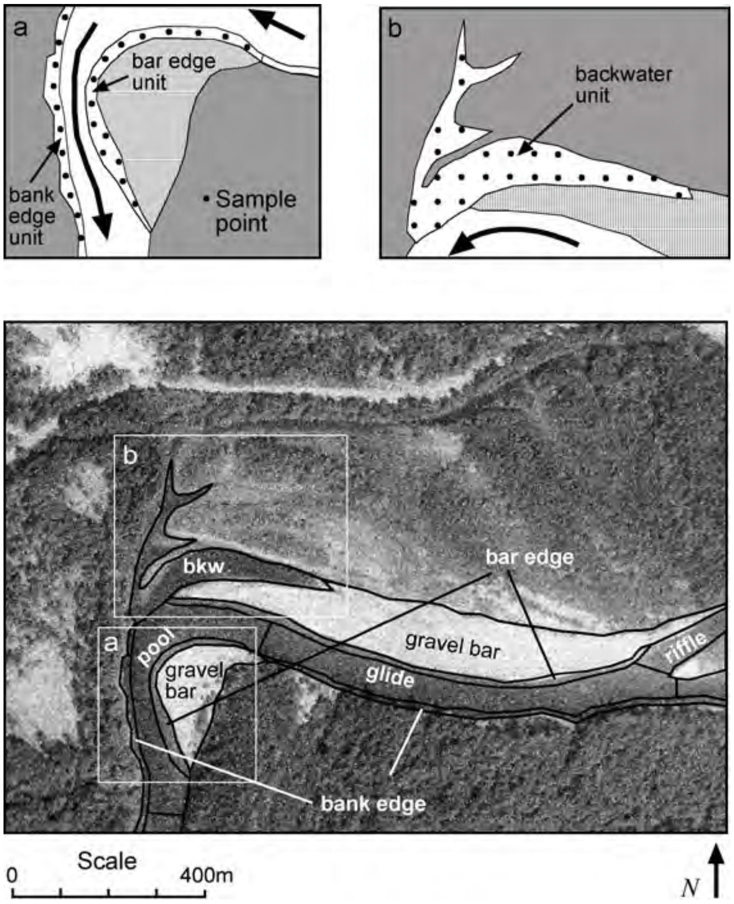

Figure 15. Illustration from Beechie et al. (2005) showing example of locations of habitat units delineated on the Skagit River (Washington). Note the very large backwater unit. Backwater units were most commonly located where off-channels or side channels joined the main river. See Figure 16 for photograph of the backwater shown in this figure.

Figure 16. Backwater habitat unit on the Skagit River illustrated in Figure 15. Photograph provided by Eric Beamer of the Skagit River System Cooperative.

Figure 17. Bank edge habitat unit along the Klamath River during spring runoff.

Although Peterson and Reid's (1984) classification of channels is often cited in the scientific literature, some of these references are inconsistent with Peterson and Reid in that they classify side channels as being off-channel habitats (e.g., Sedell et al. 1984; Landers et al. 2002; Saldi-Caromile et al. 2004). The term "off-channel" as applied here is reserved to those habitats without direct openings at their upstream end to the main river, except when flows overtop the floodplain, consistent with Peterson and Reid (1984). Flow source and fish behavior, such as how fish move into a habitat, differ markedly between off-channel habitats as defined here and those located in main river channels.

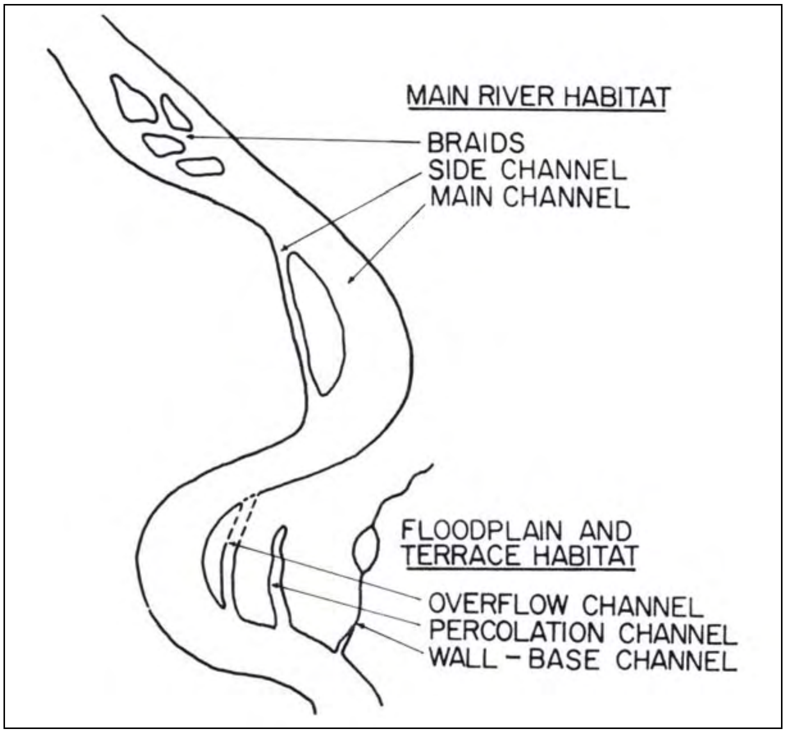

Figure 18. Main river and off-channel channel types from Peterson and Reid (1984).

Within the category of main river habitat, the distinction between braids and side channels is important. A <u>braided channel</u> reach is one that typically has numerous branches, separated by exposed alluvial bars. The bars tend to be transient, unvegetated and submerged at bankfull flow (Knighton 1988). Braided channels generally have high bed load, erodible banks, and relatively high stream power—hence they are unstable and prone to shift. Braided reaches occur naturally, particularly in glacial valleys, but they can also result from riparian destabilization caused by vegetation removal (Buffington et al. 2003). From an ecological perspective, they are hostile environments because of their dynamic nature (Tockner et al. *in press*). A <u>side channel</u> is an active channel separated from the main river by a vegetated or otherwise stable island (Knighton 1988) and carries surface flow at flows less than bankfull. Islands tend to be large relative to the size of the channels. While side channels can occur in almost any type of river, they frequently occur in anastomosing rivers—those characterized by having extensive multiple channels with relatively stable islands. This river type is normally associated with unconfined channels with relatively wide floodplains. Historically such rivers in the Pacific Northwest often carried high wood loads, which acted to create and stabilize islands and frequency of channel avulsions (i.e., shifts). These features served to “meter” flow into many small side channels, providing very stable conditions for small fish year-round (Sedell and Frogatt 1984; Collins et al. 2003).

Off-channel habitat types are those not fed by surface water from the main river when flows are less than bankfull.[18] They are fed by floodwaters, groundwater (or hyporheic flow)[19], and in some cases, by water sources from higher terraces. They occur on a stream's floodplain, sometimes on the higher elevations of the extremities of the floodplain (Figure 19). Peterson and Reid (1984) identified three types of off-channel habitats: overflow channels, percolation channels, and wall-base channels. Tockner et al. (1999) combined percolation channels and some forms of wall-base channels and called them groundwater channels, which is done here. Saldi-Caromile et al. (2004) separated floodplain ponds from wall-base channels, also done here. None of these authors included seasonally flooded wetlands as a distinct channel type but they are increasingly recognized as being an important habitat feature in some rivers (Sommer et al. 2001; Lestelle et al. 2005).

For some salmonid species, groundwater channels, ponds/alcoves, and seasonally flooded wetlands can be especially important in their life history. Groundwater channels are usually relict river or overflow channels fed largely by subsurface flow, though surface flow from higher terraces can also contribute. They can be small features with little base flow (Sedell et al. 1984) or much more extensive where former river channels receive substantial subsurface flow (Figure 20). They usually have little flow velocity, clear water, and temperatures colder in summer and warmer in winter than in the main river. Stanford and Ward (1993) referred to them as "hotspots" of production for some aquatic species.[20] Groundwater channels often can be recognized by the presence of abundant aquatic vegetation, indicating stable flow and substrate (Figure 21).

Floodplain ponds and alcoves are water filled depressions, partially or entirely filled with water year-round (Dykaar 2000). Floodplain ponds are often cut-off oxbows with small egress channels to the main river (Figure 19). Ponds in meandering valley segments are vulnerable to high water temperatures and low dissolved oxygen during summer, depending on their water source, but these often provide high quality habitat during winter. Where present along tributaries to larger rivers, floodplain ponds are often small features and called alcoves within some classification schemes (as commonly done on Oregon coastal and Northern California streams). Alcoves along small streams can be very small features (Figure 20). In Prairie Creek in Northern California, some alcoves are as small as 3 ft across or smaller (Walt Duffy, Humboldt State University, *personal communications*).

Seasonally flooded wetlands occur on the floodplains of large rivers and are the remnants of ancient ponds and relict channels (Dykaar 2000). These areas are typically flooded during fall-winter or spring, depending on a river's runoff pattern (Figure 21). They can be relatively small

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[18] / It is recognized that the lower ends of some off-channel types can be supplied from surface water backed up from the main channel.

[19] / Technically hyporheic water and true groundwater are not the same. Hyporheic water is a type of shallow subsurface water beneath and beside streams—it is the interface between true groundwater and surface water (Edwards 1998). True groundwater is typically deeper and older in its origin than hyporheic flow. In this document, they are treated as the same as is often done in the fish ecology literature.

[20] / Groundwater channels as defined here are referred to by different terms in the scientific literature: springbrooks, spring channels, percolation channels, hyporheic channels, groundwater side channels, wall-base channels, and terrace tributaries—all tend to have similar features.

in size or very expansive, as occurred historically along many large rivers in the Pacific Northwest and California (Sommer et al. 2001; Lestelle et al. 2005).

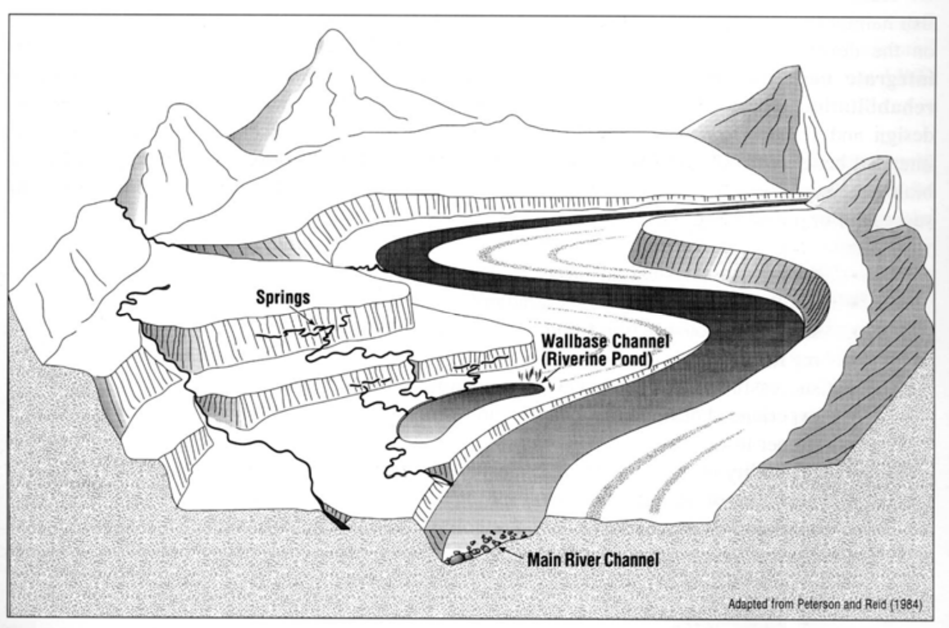

Figure 19. Up-valley oblique view of meandering river and associated floodplain, showing examples of wall-base channels—a subtype of groundwater channel—and a riverine (floodplain) pond. From Peterson and Reid (1984) and Cederholm et al. (1997a).

Figure 20. Groundwater channel contained within a relict channel of the Yakima River (Eastern Washington) supplied by hyporheic water. The mouth of the groundwater channel is shown (where individual is standing). The flowing river channel is shown in the immediate foreground.

Figure 21. Groundwater channels often contain abundant aquatic vegetation, indicating stable, low velocity flows and stable substrate conditions, seen here in a groundwater channel along the Queets River within Olympic National Park (Olympic Peninsula, Washington). Abundant newly emerged coho fry were actively feeding amongst the vegetation when this picture was taken.

Figure 22. Four acre floodplain pond formed within an ancient channel of the Chehalis River (Western Washington). Pond drains to the main river through a small egress channel seen on left side of pond.

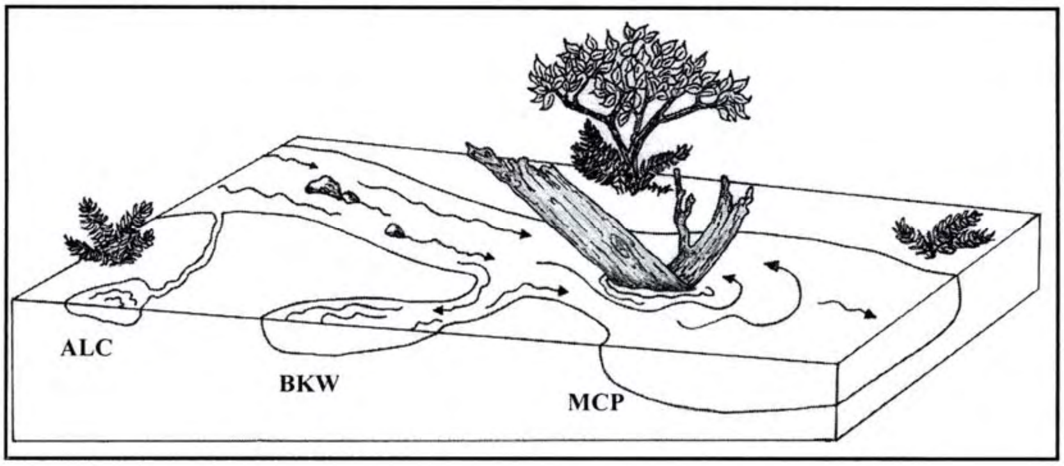

Figure 23. Diagrammatic view of three habitat types within small to medium sized streams. ALC = alcove, BKW = backwater pool, MCP = main channel pool. Diagram is based on features found in Prairie Creek (Redwood Creek basin), Northern California. From Bell (2001).

All of these off-channel types can provide critical habitats in some life stages to salmonids – particularly for coho salmon. These habitats provide refuge from high velocity flow, as well as thermal refugia during some times of the year.

3.2 Life Stage-Specific Habitat Utilization and Survival

Utilization patterns by coho salmon of different habitat types in each life stage are described below, together with reported survival rates. Variations from common patterns are described where they have been found. Only freshwater life stages are covered.

3.2.1 Spawning Migration

Adult coho salmon use the main channel of mainstem rivers and tributaries for migrating to spawning sites. They utilize all habitat types within the main stream and can generally be found holding to rest during the migration in deep water areas, particularly pools.

As described earlier, river entry of adult coho is primarily keyed to storm events in autumn. Their migration into tributary natal streams often occurs during high flows (Koski 1966).

Because arrival time to rivers generally coincides with the onset of fall rains, water temperature usually poses no problems for migration success. Fish that enter the river at the beginning of a run may encounter elevated water temperatures, as reported in some years in the Klamath River—in which case, mortality can result (CDFG 2004).

Survival during the freshwater migration is assumed to be generally high in streams of the Pacific Northwest. In short rivers where natural predators are not abundant, survival exclusive of any harvest impact is likely very high, perhaps approaching 100% in many cases. Predation by sea lions and seals can occur in the lower reaches of rivers and estuaries, potentially preventing recovery of listed coho populations under some circumstances (Moyle 2002). Hillemeier (1999) determined that pinnipeds preyed primarily on Chinook salmon in the lower Klamath River, consuming over 8% of the returning run in 1997. The predation rate on returning coho salmon was much less, roughly estimated at 2% of the run. Williamson and Hillemeier (2001) found a similar pattern of relative impacts on Chinook and coho salmon in that river in 1999 with estimated losses of 2.3% and 1.3% of the returning run sizes.

Figure 24. (Top) Oxbow-wetland within the floodplain of the Chehalis River (Western Washington) during a flood event in March 2003. The site is flooded from its lower end where it drains to the main river, located at the far end of the photo. No river water enters at the top end of the ponded area. (Bottom) Water levels receding at the same site in April 2003. Water is draining toward the main river, located in the far end of photo. Water drains through a swale in a natural levee. Structure in picture is the fyke net and a migrant trap located in the distance. Both Chinook and coho juveniles were captured by fyke net and migrant trap. The site was dry by late spring. From Henning (2004).

In drought years in Southern Oregon and California when sand bars blocking stream mouths persist, it is reasonable to assume that some adults may be prevented from spawning. Walt Duffy (Humboldt State University, *personal communications*) has observed late timed adult coho struggling to swim over barely inundated sand bars blocking Stone Lagoon, a lagoon about 2 miles south of Redwood Creek (Northern California).

Coho production from some streams is correlated with streamflow during the migration and spawning life stages (Lestelle et al. 1993b; Volkhardt et al. 2007). In years of high flow during these life stages, penetration by migrating adults into a river system is believed to be increased, thereby increasing the total miles of habitat able to be used by the population, resulting in increased production (Bradford et al. 1997). Scarnecchia (1981) found that the annual catch of coho off the Oregon Coast from 1942 to 1962 was correlated with total streamflow during the corresponding years of freshwater life. He suggested that one likely explanation was that years of high flow would have allowed greater access by spawners to streams in the upper areas of river systems.

3.2.2 Spawning

Coho salmon spawn mainly in small streams or in side channels to larger rivers, a pattern seen across the species range (Burner 1951; Sandercock 1991; Moyle 2002). They sometimes spawn along the river margins of larger streams, but normally not in large numbers (author's personal observations). Under unusually dry weather conditions when access into smaller spawning tributaries may be blocked, they will spawn in larger numbers in mainstem rivers. Such behavior has been observed in the Thompson River in the Fraser River interior region; survival of eggs and fry is thought to be reduced in such case due to relatively poor quality of habitat for incubation (Richard Bailey, Fisheries and Oceans Canada, *personal communications*). Coho have also been observed to spawn in significant numbers in mainstem rivers where hatcheries are located in close proximity to the river downstream of a dam. This has been observed in the mainstem Rogue River (Southern Oregon)(McPherson and Cramer 1981) and the Klamath River (Brown and Moyle 1994; NRC 2004) and in rivers farther north.

Coho salmon spawn on pool tailouts and along the margins of riffles in main channel habitats, often close to or under cover. They generally spawn in small gravels (Burner 1951).

They spawn heavily in groundwater channels where these habitats exist along the floodplains of rivers, often in relatively high densities (author's personal observations). These channels often have fine substrates with high amounts of fine or sand sized particles. These areas, despite their high sediment load, produce high egg survival because of upwelling that occurs there (Bjornn and Reiser 1991; Waters 1995).

They also spawn within the littoral areas of some lakes in Alaska, such as Chignik Lake (Ruggerone and Rogers 1992).

High water temperature is generally not an issue to spawning success of coho salmon in the Pacific Northwest and California. Spawning begins in late fall after streams have had significant cooling.

Survival from the onset of nest digging to the completion of spawning in rivers of the Pacific Northwest is assumed to very high under normal conditions.

3.2.3 Egg and Alevin Incubation

Egg and alevin incubation habitat is the same as that described above for spawning. Nest sites are selected by spawners, eggs are deposited, and except for some relatively small amount of lateral movement by pre-emergent fry, eggs and fry remain within or very near the original nest sites.

Survival from egg deposition to fry emergence can vary significantly between streams depending on stream characteristics and local conditions. Changes in stream conditions due to land use can severely reduce survival to emergence.

Under the most optimal conditions occurring in nature survival to emergence can reach approximately 80%. Quinn (2005), referring to salmon species in general, states that “if scour does not occur and the size of gravel is ideal, up to 80% of the eggs may survive to produce free-swimming fry. This typically only takes place in artificial spawning channels where presorted gravel and regulated flows provide nearly ideal conditions.” Moring and Lantz (1975) reported that the maximum observed survival to emergence in a study of three streams in the Alsea watershed (Oregon Coast) for coho salmon was 82% (of 94 redds trapped). The eight year study included years prior to and following logging. Tagart (1984) reported a maximum observed survival to emergence of 77% for coho salmon in tributaries to the Clearwater River (Olympic Peninsula, Washington)(of 19 redds trapped over two years). The EDT model[21] applies a 60% survival from egg deposition to emergence to represent the average survival expected over some period of years (e.g., 10 years) in stream reaches that contain the best conditions that occur in nature (Lestelle et al. 2004). The single highest observed survivals in studies like those conducted by Koski and Tagart would not be expected to occur for groups of redds in an optimal stream reach averaged over a period of years. The average survival in this case is lower than maximum observed values.

Average survival to emergence for coho in streams that might be considered typical in the Pacific Northwest and California is much less than occurs under optimal conditions in nature. Moring and Lantz (1975) summarized survival to emergence in three small Oregon coastal streams over eight years (Table 2). In redds where some fry emergence occurred, the average survival across all years and streams was 32.7%. Including redds with no successful emergence, average survival was 28%. Zero emergence occurred in 14.5% of the redds. Koski (1966), who reported on the first year of study, included redds with zero emergence to compute an average survival to emergence. He discounted the possibility of false redds because of the intensive observations he made on spawners and redds. Koski concluded that redds with zero emergence resulted from gravel scour. Logging occurred in the Deer Creek and Needle Branch watersheds approximately half way through the eight year study. Flynn Creek remained unlogged. There was no significant shift in survival rates in the two logged watersheds following logging.

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[21] / The Ecosystem Diagnosis and Treatment (EDT) model is used throughout the Pacific Northwest to help assess the performance of salmon populations in relation to habitat condition. http://www.mobrand.com/MBI/edt.html

Table 2. Summary of survival from egg deposition to fry emergence for coho salmon in the Alsea River (Oregon Coast) study streams averaged over eight years (Moring and Lantz 1975).

Measure	Deer Cr.	Flynn Cr.	Needle Br.	Mean
No. of redds trapped	32	30	32	
% survival for successful emergence only	37.9%	25.7%	34.6%	32.7%
% survival including zero emergence	33.5%	20.8%	29.8%	28.0%

Tagart (1984) assessed survival from redds in tributaries to the Clearwater River (Olympic Peninsula, Washington) during a period of active logging in the watershed. Most of the logging in his study streams had occurred within a period of 1-10 years prior to his study. Over two years, he monitored survival in 19 redds. The average survival for all redds monitored was 29.8% (arithmetic mean). Tagart reported a geometric mean of 22.1%. Tagart cautioned, however, that redds were selected in the study on the basis of how he felt they would aid in developing a relationship between intergravel sediment load and survival. Redds were not selected randomly to assess mean survival to emergence in the river system. Moreover, he specifically excluded redds for trapping that were determined to be subject to scour. Jeff Cederholm[22] (*personal communications*, cited in WDF and Quinault Treaty Tribes [1982]) reviewed Tagart's study and concluded that Tagart's arithmetic mean of 29.8% was a reasonable estimate of average survival in the river system at that time, including redds with no successful emergence.

Prior to logging, the average estimated survival to emergence for coho salmon in Carnation Creek (Vancouver Island) was 29.1% (Scrivener and Brownlee 1989), a value nearly identical to the estimates for Clearwater and Alsea tributaries. It should be noted that Carnation Creek and all of the study streams in the Clearwater and Alsea watersheds are small streams, characteristic of many coho spawning streams.

Sandercock (1991) stated that Briggs (1953) reported in a California study that "average egg-to-fry survival was 74.3%" based on 22 coho redds sampled. However, Sandercock failed to identify that Briggs had not estimated survival to emergence. Briggs employed egg and alevin pumping to obtain estimates of the ratio of live to live plus dead at the time of pumping. The estimates did not take into account dead eggs that had disintegrated nor the loss that would have occurred from that time until emergence. Koski (1966) suggested that much of the mortality that occurs in redds is due to pre-emergent fry being prevented from emerging successfully from the redd. Thus, it appears that Briggs' estimates do not reflect survival to emergence comparable to the other studies cited above.

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[22] / Jeff Cedarholm was Project Leader for the Clearwater River effects of logging studies conducted by the Fisheries Research Institute of the University of Washington. Tagart's study was part of this project.

Data collected in the Alsea watershed study streams (Oregon Coast) suggest that survival to emergence of coho salmon generally lacks a density-dependent effect. Relationships between the numbers of emigrant fry trapped in the lower end of the three study streams and numbers of female spawners are linear across the range of spawners seen during the eight year study period (Figure 25). Linearity in these relationships indicates that survival to emergence is density-independent in these streams. This means that over the range of spawners seen that the availability of spawning area was sufficient to minimize any effect of competition for redd sites and redd superimposition.

Two factors are most often cited as affecting the survival to emergence of coho salmon: fine sediment loading and bed scour. A third factor, presence of an egg-eating oligochaete worm, has also been found to have significant effects on survival to emergence in some areas of Northern California. A brief summary of the magnitude of these effects is useful here.

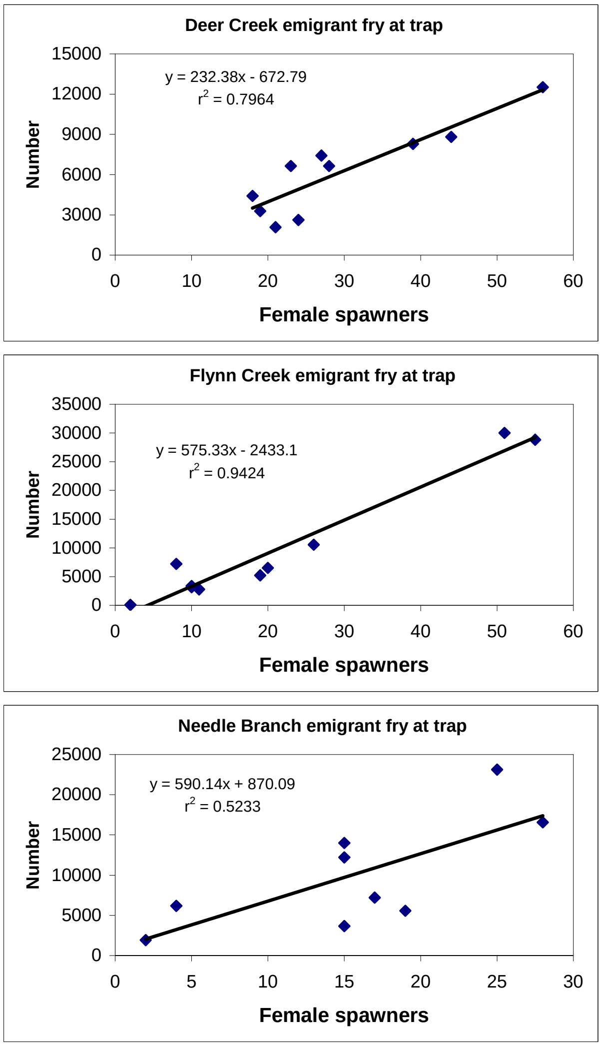

Figure 25. Relationships between female coho salmon spawners and emigrant fry captured in traps at the downstream ends of study streams in the Alsea watershed (Oregon Coast). Emigrant fry data from Au (1972). Spawner abundance data from Knight (1980).

Following logging, the estimated average survival to emergence of coho salmon in Carnation Creek was approximately half that prior to logging. Average survival was estimated to have declined from 29.1% to 16.4% (Scrivener and Brownlee 1989). This was attributed primarily to sediment loading. Mortality likely occurred both as a result of reduced oxygenation associated with increased fine sediment and to increased bed scour associated with the greater sediment load. Scrivener and Tripp (1998) provided updated estimates of survival for Carnation Creek. They listed 25% as the unlogged average and 19% as the logged average in the absence of mass wasting. With mass wasting, they estimated survival to emergence to be 15%. Cause of mortality was listing as being both reduced oxygenation and increased bed scour.

Tagart (1984) characterized the relationship between fine sediment and survival to emergence for coho salmon as curvilinear across the range of fines examined (Figure 26). Relatively small increases in fine sediment within the intermediate range of values produced a steep decline in survival. At higher levels of fines, the rate of decline in survival slowed substantially, suggesting that egg pocket structure affords some protection against further degradation as fines within the surrounding redd environment increase to higher levels. Chapman (1988) predicted that egg pocket structure within natural redds would afford such protection.

Koski (1966) characterized the relationship between sand sized particles and survival to emergence for coho salmon within the Alsea watershed study streams (Oregon Coast) as being linear (Figure 27). Variability in survival increased at higher levels of sand concentrations.

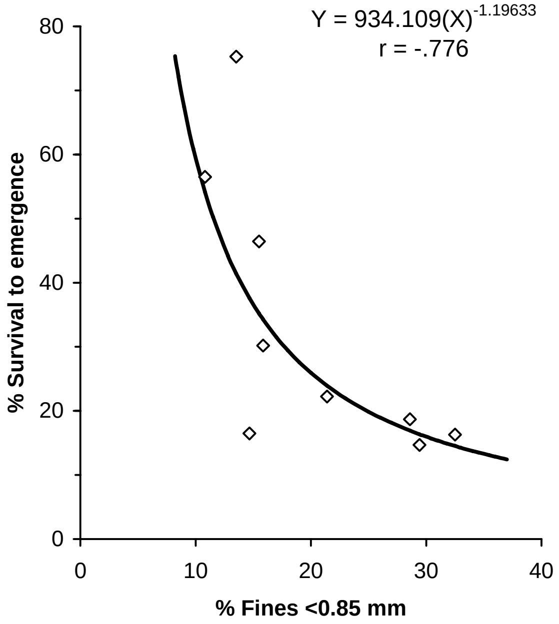

Figure 26. Relationship between percent of substrate <0.85 mm in size and percent survival to emergence of coho salmon in the Clearwater River (Olympic Peninsula, Washington). From Tagart (1984).

The relationships between fines/sand and survival shown in Figures 26-27 apply where flow through the redd is downwelling. Tributaries in the Clearwater River watershed are little affected by spring sources and flow through salmon redds is downwelling (i.e., water flow moves from the surface flow down through the redd).

In streams fed largely by springs, salmonid spawning can occur at sites with upwelling due to the groundwater influx occurring through a reach (Figure 28). When spawning occurs in upwelling groundwater, the adverse effects of sediment on eggs and emerging fry are largely negated, resulting in high survival, provided the groundwater is not low in dissolved oxygen (Bjornn and Reiser 1991; Waters 1995; Garrett et al. 1998). Spawning areas at these locations can be very high in fines. This explains why salmonids can have very high rates of reproduction in some streams despite excessive deposits of fine sediment. Coho salmon will spawn heavily in groundwater channels if available (personal observations of author).

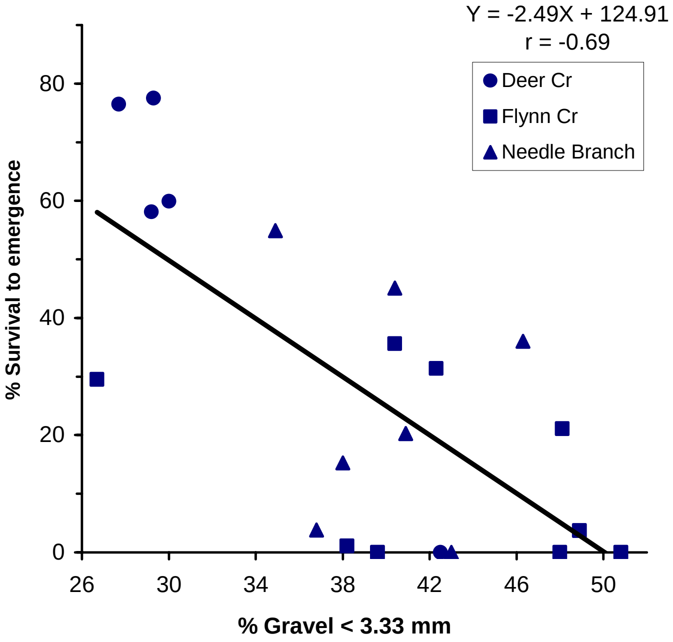

Figure 27. Relationship between percent of substrate <3.33 mm in size and percent survival to emergence of coho salmon in the Alsea River study streams (Oregon Coast). From Koski (1966).

Bed scour can have very high adverse effects on incubating salmon eggs. On the Queen Charlotte Islands, Tripp and Poulin (1986) cite bed scour as being a significant factor affecting survival to emergence of coho salmon. It is most damaging to egg survival in relatively high gradient streams having little large woody debris. It is made worse following logging that leads to mass wastage. If the loss of eggs to scouring is assumed to be directly related to depth of the incubating eggs, mortality due to scouring alone could be greater than 70% for coho salmon in many streams on the Queen Charlottes (Scrivener and Tripp 1998).

Montgomery et al. (1996) found that even minor increases in depth of bed scour due to land use practices can significantly reduce salmon embryo survival. Scour and fill of gravel beds is a normal physical process that occurs during high flow events, but watershed development can change their rates and associated equilibria. Schuett-Hames and Adams (2003) reported that the depth of bed scour in salmonid spawning tributaries of the upper White River (Western Washington) is a function of peak flow (Figure 29). They projected significant egg losses for spring Chinook due to bed scour. Channel simplification and loss of stable large woody debris (LWD) appears to have increased the extent of bed scour at flow in those streams. Peak flows also appear to have increased as a result of timber harvest and road building.

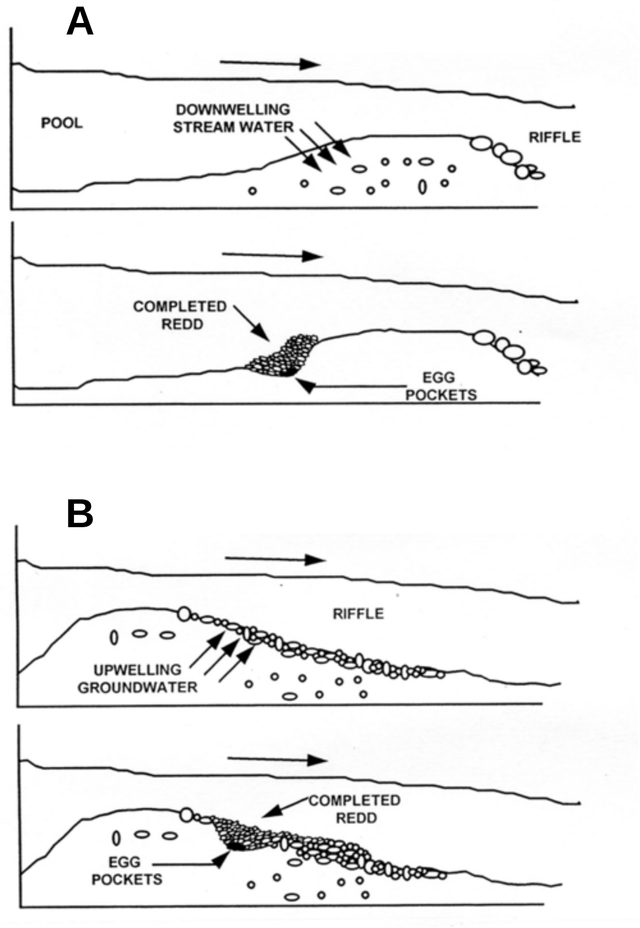

Figure 28. Salmonid redd construction in relation to sites of downwelling (A) and upwelling (B). From Waters (1995).

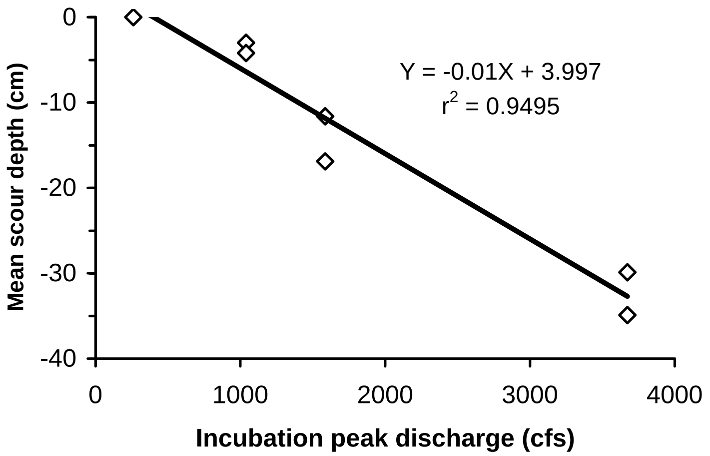

Figure 29. Relationship between mean scour depth at spring Chinook redd sites (averaged by reach) and peak flow during incubation period in a spawning tributary of the upper White River (Western Washington). The White River drains the north slopes of Mt. Rainier. Adapted from Schuett-Hames and Adams (2003).

Rates of scour and fill within a stream segment can be highly variable due to widely differing site specific conditions (Montgomery et al. 1999; Rennie and Millar 2000). For example, side channels provide much greater bed stability than found in the main channel. Stable LWD can also provide favorable spawning sites, protected from high velocities in exposed areas during freshet conditions. Shellberg (2002) reported that in streams having high flows during fall and winter that bull trout redds were scoured in stream reaches lacking features that protect from instability (e.g., side channels and stable LWD). He concluded that loss of LWD and channel simplification had increased the probability for redd scour in some streams.

Montgomery et al. (1996) studied bed scour and chum salmon egg pocket depths in two streams, one located in Puget Sound (Kennedy Creek). They concluded that close correspondence found between egg burial depths and scour depths implies a finely tuned adaptation to long-term rates of sediment transport. Further, they said that changes in gravel transport rates, as can occur with land use, can dramatically affect egg survival because egg pockets tend to be just below the usual depth of scour in pristine streams. They reported that egg pocket depths averaged about 22 cm for chum salmon (median = 20 cm), although the range between the shallowest and the deepest was quite large (10 to 49 cm). Egg pocket depths reported are the distances from the level of stream bed to the ceiling of the egg pocket. Their results demonstrated that relatively small increases in scour depth would jeopardize the majority of egg pockets (Figure 30). Depths of egg pockets for coho salmon are very similar to those of chum salmon (DeVries 1997).

Montgomery et al. (1999) examined the spawning distributions of Chinook and coho salmon and trout species in several rivers of Washington and Oregon to assess the role of geomorphic factors on distribution. They concluded that the spawning distributions of all fall spawning salmon species in rain-dominated stream systems are strongly affected by channel gradient and valley floor width. Bed scour generally increases with channel gradient and the degree of channel confinement. In rain dominated systems, these authors concluded that coho salmon would infrequently spawn in streams with gradients greater than 3% or in highly confined channels because bed scour would usually be prohibitively high to sustain the population.

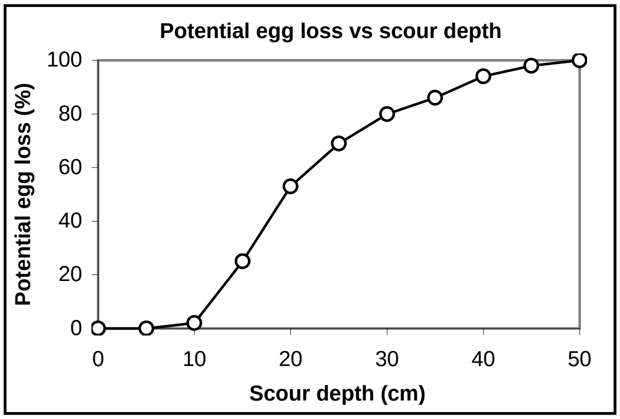

Figure 30. Potential egg loss (as a percent of egg deposition) for chum salmon in Kennedy Creek (Puget Sound region, Washington). From Montgomery et al. (1996). Egg pocket depths of coho salmon are similar to those of chum salmon (DeVries 1997).

Another mortality factor found to significantly affect coho survival to emergence in some streams in Northern California, is an oligochaete worm (Briggs 1953; Sparkman 2003). The worm, *Haplotaxis ichthyophagous*, can kill eggs with copious mucous secretions, although Sparkman (2003) found evidence that the worms also consume portions of live eggs. When worms are present survival to emergence can be reduced to 0%. Sparkman reported that two factors best explained survival to emergence in natural redds within the Prairie Creek watershed in Northern California—amount of fine sediment and presence/absence of the oligochaete worm. In artificially constructed redds, egg survival averaged 9% and 78% when worms were present and not present, respectively. The distribution of this worm species outside Prairie Creek is unknown. Egg mortality associated with the worm has not been reported outside of Northern California (Sparkman 2003).

3.2.4 Fry Colonization

Upon emergence coho fry move quickly to slow velocity habitats, typically along the channel margin, or they continue to move downstream. They have a strong affinity for very slow velocity water (Figure 11) and generally move there as rapidly as possible. Fry emergence can be very protracted, which can help facilitate dispersal (Mason 1976b).

Fish that emerge during high flows can be swept downstream (Chapman and Bjornn 1969; Hartman and Holtby 1982; Holtby 1988; Shirvell 1990; Fausch 1993), in some situations moving them to less suitable habitats, increasing bioenergetic costs, and increasing predation exposure. In rivers with abundant floodplain habitat, emergence during high flows (i.e., spring runoff) can be beneficial if fry gain access to those habitats, then subsequently return to the main river without being stranded (Sommer et al. 2001; Henning 2004; Lestelle et al. 2005). Backwaters and bank edges along vegetated shorelines during spring runoff are also important refuge sites for emergent fry. However, in streams lacking suitable velocity refugia, fry survival is likely diminished if emergence occurs during periods of prolonged high flow (Shirvell 1990; Smith 2000; Fausch et al. 2001; Lestelle et al. 2006).

Young fry are most often found in shallow, slackwater along stream margins and often associated with some form of bank cover—particularly back eddies, or behind fallen trees, undercut tree roots, and other well-protected areas (Mundie 1969; Lister and Genoe 1970).

Nickelson et al. (1992) reported that coho fry densities in small streams on the Oregon Coast were by far highest in backwater pool units (Figure 31) compared to other habitat types, although they could be found along the margins of virtually all types. They were not present in off-channel habitats (alcoves) as fry, presumably because these habitats were not well connected to the stream during time of emergence. Of the habitat types inhabited, backwater units had the slowest water velocities.

Mundie (1969) reported that newly emerged coho fry were relatively scarce in large mainstem rivers like the Stamp River on Vancouver Island (Figure 32). He stated: "Contrary to appearances large coastal rivers like this one are not important feeding areas for coho. The food produced in them is sparse, and the recently emerged fry are confined to marginal slack water out of reach of the main stream drift." Mundie's observations suggest that low velocity refugia are limited in this river.

Following emergence, some fry move longer distances than others (Au 1972), partly as a result of emigration due to intraspecific competition (Chapman 1962). This effect can result in moving some fish into larger streams and lakes downstream of natal tributaries. In some cases, emergent fry may move upstream into a lake if spawning occurs in the lake's outlet stream (Swain and Holtby 1989).

In cases where spawning is not distant from the sea, some fry can move into stream mouth estuary (Tschaplinski 1988; Nielsen 1994), as described earlier in this report. These movements are typical of coho fry and serve as a dispersal mechanism. However, large numbers of fry sometimes captured at stream trapping facilities, usually assumed to be fry emigrants (Au 1972), are apparently often merely moving a short distance downstream of the trapping site (Lindsay 1974). In such cases, emergence sites are likely not far upstream of trapping sites. This suggests that the distance traveled from natal sites as fry is typically not extensive for coho salmon.

Young coho fry that move to larger rivers can subsequently move into off-channel habitats as a result of their need for calm, slow velocity water. Peterson and Reid (1984) reported trapping small fry moving into off-channel ponds via low velocity egress channels connected to the outlets of the ponds. This movement is the likely source of juvenile coho found in many off-channel habitats during summer—both in coastal regions (e.g., Sedell et al. 1984; Coe 2001) and interior regions (Brown 2002).

Water temperature is generally not an issue to young coho fry in the Pacific Northwest and California because of their emergence timing during spring.

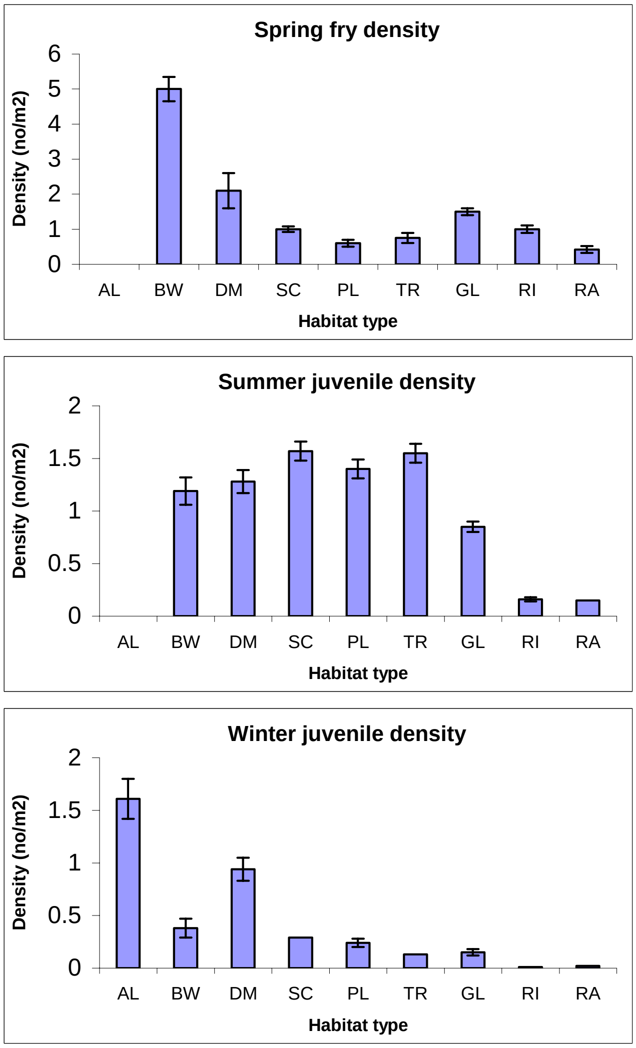

Figure 31. Mean density (+/- SE) of juvenile coho salmon by habitat type during spring, summer, and winter reported for Oregon coastal streams. AL = alcove; BW = backwater pool; DM = dammed pool; SC = scour pool; PL = plunge pool; TR = trench pool; GL = glide; RI = riffle; RA = rapid. Adapted from Nickelson et al. (1992).

Survival during the fry colonization stage is likely mostly density-independent because of the short time period involved. Estimated survival rates for Deer Creek in the Alsea watershed study (Oregon Coast) show a modest density-dependent effect (Figure 33 – derived from data in Au 1972). An estimate of the density-independent component of survival can be obtained from Figure 33 by simply extending the regression line to the Y-axis (zero density), giving a value of 81%. This represents the average survival rate for the fry colonization phase for Deer Creek—a small coho stream—absent any effect of fry density.

Figure 32. Stamp River, Vancouver Island. Mundie (1969) reported that this river is of a size that keeps it from being an important nursery area for coho salmon fry. Fry in rivers like this one must remain confined to marginal, slow velocity water, which is generally limited in amount and distribution.

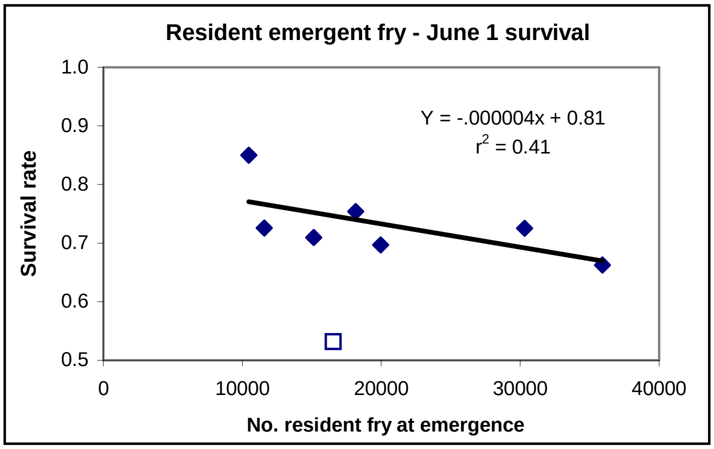

Figure 33. Relationship between the number of newly emerged, resident coho fry (total emergent fry minus fry emigrants) and survival to June 1 in Deer Creek, Alsea watershed (Oregon Coast). Survival shown is for the fry colonization phase for resident fry. Derived from data in Au (1972). Estimated density-independent survival is the point where the regression line would cross the Y-axis (0.81). The open square symbol was assumed to be an outlier and was not used in the regression.

3.2.5 Subyearling Summer Rearing

Juvenile coho reside in a wide variety of stream types and sizes during summer, in addition to connected lakes where present. They are typically found in highest densities within their natal streams since the majority of fry usually do not migrate long distances from spawning sites

(Lindsay 1974), unless the natal stream has a high gradient promoting longer distance movement (Lestelle et al. 1993a).

The need for slow velocity water by juvenile coho remains strong during this life stage (Figure 11). In larger streams, juvenile Chinook and steelhead are more frequently associated with some surface water turbulence than coho salmon, as seen in a study of velocity-depth preferences in the Trinity River in the Klamath basin (Hampton 1988)(Figure 34). Juvenile Chinook and steelhead are often found feeding near velocity shears within main channels, while coho remain more closely associated with the shoreline or dense cover of woody debris. This pattern—seen across the species' range—indicates a much stronger affinity for slow velocity by coho salmon than the other species during this life stage. All of the foraging phenotypes described by Nielsen (1992a, 1992b, 1994) are closely associated with habitat types having slow water velocities.

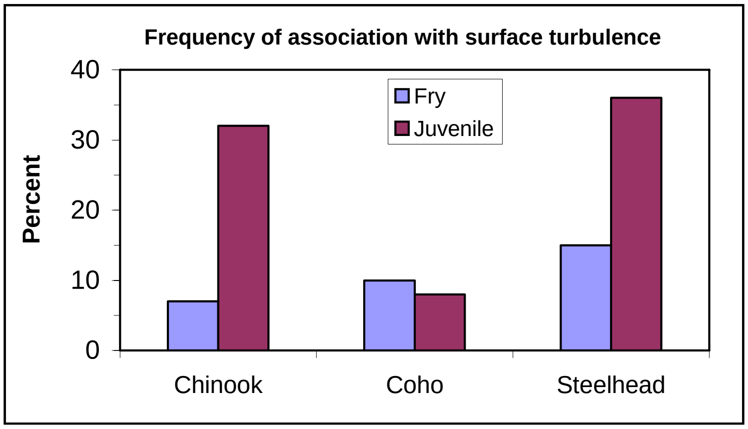

Figure 34. Percent of observations of fry (<50 mm) and juvenile (>50 mm) Chinook, coho, and steelhead found occurring with surface turbulence in the Trinity River in the Klamath River basin (Northern California). Recreated from Hampton (1988).

Juvenile coho are most often found in pools as shown in data for the Oregon Coast (Figure 23)(Nickelson et al. 1992). In smaller streams, they are found in highest densities in all pool types, intermediate densities in glides, and lowest densities in riffles and cascades. It is important to note that these densities occur where fry recruitment is high (i.e., high spawning escapements) and habitat quality is not degraded. This pattern of habitat selection occurs throughout their range (Hartman 1965; Bisson et al. 1988b; Schwartz 1991; Lau 1994; Sharma and Hilborn 2001; Brakensiek 2002).The densities reported by Nickelson et al. (1992) are very consistent with those predicted for key habitats (pools) using relationships developed for coho salmon in British Columbia (Ptolemy 1993). Those relationships show, however, that density can be strongly affected by stream productivity, i.e., by the amount of food it produces to support salmonids. Highly productive streams can support higher juvenile coho densities than less productive ones (Mason 1976a; Ptolemy 1993; Ward et al. 2003)

The highest densities of juvenile coho during this life stage are usually found in the smallest streams (Rosenfeld et al. 2000). Although utilization patterns have not been well defined for all habitat types in large streams, qualitative descriptions indicate that densities drop sharply in large streams (Allen 1969; Mundie 1969; Marshall and Britton 1980; Murphy et al. 1989; Jepsen and Rodgers 2004; Jepsen 2006).

The most extensive data set comparing densities between low and high order streams (i.e., small versus large streams) occurs in Jepsen and Rodgers (2004) and Jepsen (2006). This study, the Western Oregon Rearing Project, provides a quantitative comparison based on an exceptionally large number of pools sampled by snorkeling in late summer in watersheds spread across the Oregon coast (Table 3; Figure 35). Spawning escapements for brood years that produced these data were high compared to earlier years (PFMC 2006). The large differences seen between densities of small and large streams occurs because a smaller proportion of the total cross-section in large streams affords depths and velocities preferred by juvenile coho salmon, though other factors are also operative. This largely explains why average coho smolt production for different sizes of watersheds between Southeast Alaska and California has been found to be linearly correlated with the total utilized stream length in a watershed (Bradford 1997; Bocking and Peacock 2004).[23]

Within the SONCC Coho ESU, extensive sampling for juvenile salmonids occurred annually in the mainstem Rogue River between 1974-1983 to evaluate the effects of Lost Creek Dam on salmonids. Sites were sampled between the dam site (RM 157) and the river mouth throughout spring, summer, and fall. Prior to the return of hatchery coho to Cole Rivers Hatchery, few subyearling coho were captured each year in the mainstem river, suggesting that this species was rearing almost entirely within the tributaries (Cramer and Martin 1978; Cramer and Martin 1979; McPherson and Cramer 1981; Cramer et al. 1985). Following the return of adult hatchery to Cole Rivers Hatchery near the dam, more juvenile coho than in previous years—though still small numbers—were captured in the upper part of the mainstem (within approximately 25 miles of the dam)(McPherson and Cramer 1983). The researchers believed that this was due to stray hatchery adults spawning in the mainstem river below the dam (Cramer et al. 1985).

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[23] / The linear relationship suggests that, on average, the same number of smolts is produced in a mile of a large river as in a mile of a small tributary to that river. Substantial variability is evident about the relationship, indicating effects of stream type, geomorphology, climate, habitat quality, nutrients, etc. For example, in stream systems with substantial ponds or lakes, smolts produced per mile of stream is linearly correlated with the percentage of total wetted surface area in the system comprised of ponds or lakes (Baranski 1989; Lestelle et al. 1993b). It should be noted that within large watersheds, the large majority of stream miles utilized are found in tributaries to the mainstem river.

Table 3. Densities (fish/m^2 pool) and SE of means of juvenile coho salmon in two size groups of streams on the Oregon Coast: 1st-3rd order (small streams) and 4th-5th order (large streams). Data were collected by snorkeling in late summer. Ratios of density for small streams to large streams, maximum and minimum observed densities, number of reaches sampled, and number of pools sampled are also shown. Only sites where coho were found are included in statistics. Data from Jepsen and Rodgers (2004) and Jepsen (2006).

Year	Measure	Stream order		Ratio
		1st-3rd	4th-5th	
2002	Ave density (fish/m^2)	0.68	0.03	0.038
	Standard error	0.077	0.009	
	Range	0.00-6.37	0.00-0.29	
	No. reaches sampled	179	44	
	No. pools sampled	2800	448	
2003	Ave density (fish/m^2)	0.48	0.08	0.164
	Standard error	0.060	0.041	
	Range	0.00-7.75	0.00-1.78	
	No. reaches sampled	251	52	
	No. pools sampled	4008	409	
2004	Ave density (fish/m^2)	0.31	0.03	0.104
	Standard error	0.032	0.012	
	Range	0.00-3.32	0.00-0.59	
	No. reaches sampled	231	55	
	No. pools sampled	3877	404	
Mean	Overall ave density	0.49	0.05	0.100

Juvenile coho that rear in mainstem rivers usually remain in close association with the shoreline (Mundie 1969; Marshall and Britton 1980; Beechie et al. 2005). Beechie et al. (2005) assessed the relative utilization by juvenile salmonids, including coho, of mainstem habitat units in the Skagit River (Western Washington). The researchers concluded that juvenile coho were largely using edge habitats with very little use of mid channel habitats. This pattern was evident during both summer and winter. Among the three edge unit types, juvenile coho were found primarily in bank and backwater units during both summer and winter, with little use of bar edges in either season (Figure 36A). During summer, they were almost always closely associated with cover comprised of wood or aquatic plants—little use was made of cobble cover (Figure 36C).[24] In winter, only wood appeared to provide suitable cover. Banks had the most abundant wood cover, whereas backwaters contained aquatic plants and wood cover. Bars contained mainly cobble-boulder cover. Among edge units, bars and banks tended to have similar velocity distributions, with backwaters comprised exclusively of low velocity points. While juvenile coho were found

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[24] / For purposes of this study, wood was defined as anchored brush, bank roots, debris piles or jams, root wads, logs, and branches. Aquatic plants were defined as live, non-woody aquatic vegetation.

associated with both low and medium velocity classes in summer (Figure 36B), they were almost always found within the low velocity class in winter.

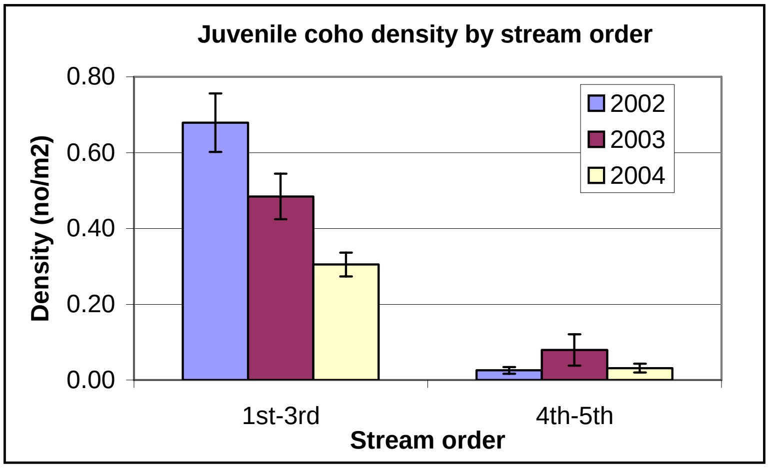

Figure 35. Densities (fish/m2 pool +/- SE) of juvenile coho salmon in two size groups of streams on the Oregon Coast: 1st-3rd order (small streams) and 4th-5th order (large streams). Data from Jepsen and Rodgers (2004) and Jepsen (2006).

In large rivers, secondary channels (i.e., side channels and off-channel habitats) provide important rearing areas for juvenile coho. Murphy et al. (1989) determined utilization rates of various channel and habitat types in the lower Taku River, Alaska during mid to late summer. Within the main river, they sampled channel edges, backwater pools, braids, and side channels (called sloughs by the authors). On the valley floor off the main river (i.e., off-channel habitat), they sampled terrace tributaries (type of groundwater channel), tributary mouths, upland sloughs (type of groundwater channel), and off-channel beaver complexes. Within the main river (including side channels), habitats beyond the channel edge were too swift to sample and were assumed to not hold rearing juveniles because of fast current.25 Coho and Chinook generally occupied different habitats. Juvenile Chinook were more abundant in main river channel and habitat types than coho salmon, whereas the latter were more abundant in off-channel habitats (Figures 37 and 38). Coho salmon occupied significantly slower current than Chinook. Coho densities were highest in still or slow water (<10 cm/s), whereas Chinook density was highest in slow-to-moderate current (1-20 cm/s). Both species were virtually absent from areas with currents > 30 cm/s. Coho almost exclusively occupied off-channel habitats and were consistently scarce in river habitats, even those with slow water.

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[25] / Although this assumption could not be verified through actual observation in the river, it is extremely unlikely that coho juveniles were rearing in this large, swift mainstem river.

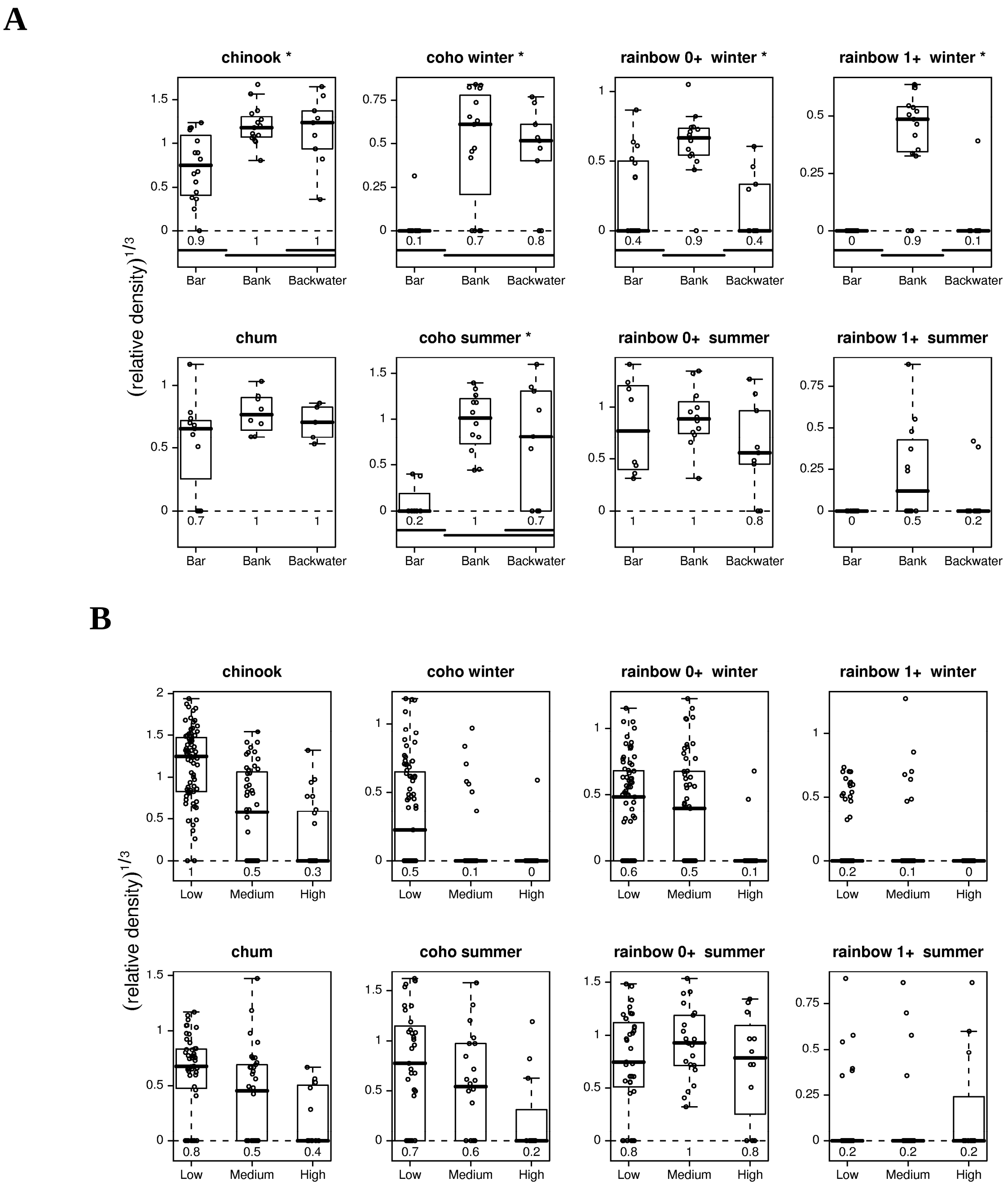


Figure 36. Relative fish density (fish per point standardized by year) by species-age class and (A) edge unit type, (B) water velocity class, and (C – continued to next page) cover type in the Skagit River (Western Washington). Asterisk indicates statistically significant difference among unit types (a = 0.05). Numbers below x-axis indicate the proportion of points at which fish of that species were captured. Bars below x-axis indicate results of multiple comparisons (bars at similar elevation indicate that differences are not significant). See Figure 15 for edge unit types. Velocity classes defined as high (>45 cm/s), medium (15 - 45 cm/s), and low (<15 cm/s). Relative densities are not comparable between species. From Beechie et al. (2005).

C

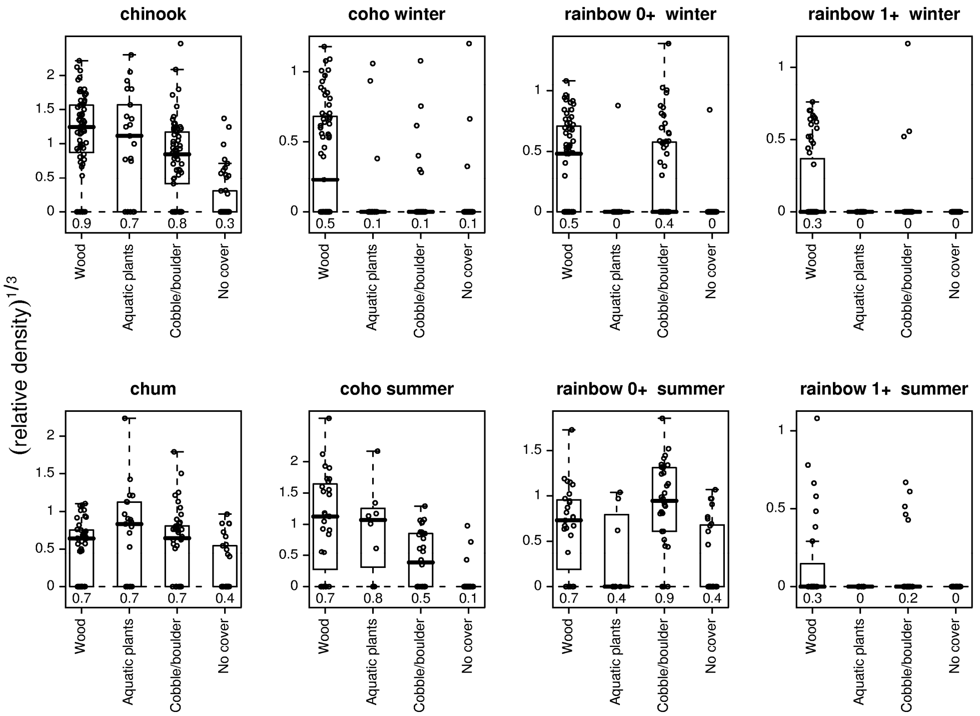
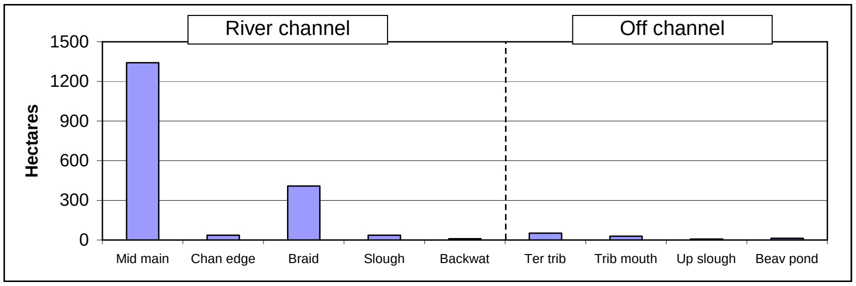
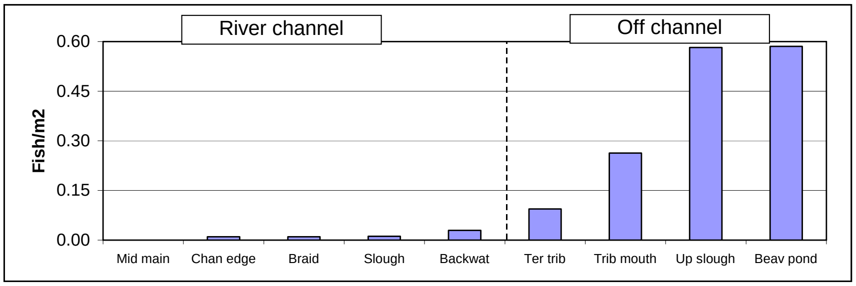


Figure 36 C – *continued from previous page*. Relative fish density by species-age class and cover type in the Skagit River (Western Washington).

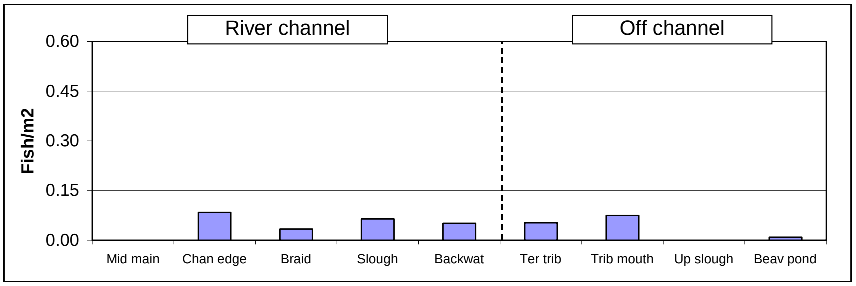
The importance of side channels and groundwater channels of large rivers to juvenile coho during summer has been described in several studies in Washington State. Juvenile coho are often found in small side channels to mainstem rivers (Sedell et al. 1984; Rot 2003; Pess et al. 2005), together with juvenile Chinook and steelhead trout. Juvenile coho can occur in especially high densities (0.8 fish/m2 total area) in stable side channels, i.e., those protected at their head end by large blocking log jams (Sedell et al. 1984). In groundwater channels, juvenile coho are frequently found in larger numbers than in surface water fed side channels. Groundwater channels are usually utilized almost exclusively by coho salmon, rarely by juvenile Chinook or steelhead trout (Sedell et al. 1984; Rot 2003; Pess et al. 2005). Both of these channel types can be major rearing areas for juvenile coho during summer in some parts of large river systems (Sedell et al. 1984). Both types, particularly groundwater channels, provide low velocity rearing habitat. In addition, groundwater channels normally have cooler water temperatures in summer than occur in mainstem rivers and their side channels. Stanford and Ward (1993) described groundwater channels as being exceptionally productive for some salmonid species—as seen by this author for juvenile coho in this channel type along the mainstem Queets River (Olympic Peninsula, Washington). In rivers of Western Washington, coho salmon utilize groundwater channels more than any other species.



Area of habitat type



Coho



Chinook

Figure 37. Wetted area (hectares) of different channel and habitat types in the lower Taku River (Alaska)(top) and corresponding mean densities (mid to later summer) of juvenile coho and Chinook (adapted from Murphy et al. (1989). Channel and habitat types are: mid channel of main river channel and side channels (Mid main), channel edge of main river and side channels (Chan edge), braid (Braid), slough (Slough), backwater (Backwat), terrace tributary (Ter trib), tributary mouth (Trib mouth), upland slough (Up slough), and beaver pond (Beav pond).

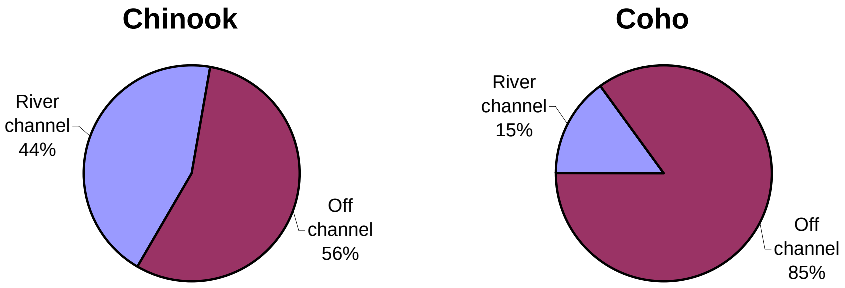


Figure 38. Distribution of juvenile Chinook and coho salmon between river channel and off-channel habitats in the lower Taku River (Alaska) in mid to late summer. Derived from Murphy et al. (1987).

The influence of wood on coho rearing densities during summer is not the same across all stream types and sizes and its role in this life stage is not altogether clear (Giannico and Healey 1999). Some studies have reported that juvenile coho densities in smaller streams during summer are positively correlated with quantity of large woody debris (Hartman and Scrivener 1990; Koski 1992; Roni and Quinn 2001)(Figure 39) while others have not found strong association (Grette 1985; Bugert et al. 1991; Fransen et al. 1993; Spalding et al. 1995; Cederholm et al. 1997b). Part of the discrepancy appears to be due to whether authors distinguish the role that wood has in pool formation from its role as cover. Greater amounts of large wood often equate to more frequent and larger pools (as seen in the study of Roni and Quinn 2001), which in turn, results in a greater number of juvenile coho per channel length (reported by Roni and Quinn 2001). Cover in small streams can be provided by other stream components besides large wood, such as undercut banks, overhanging riparian vegetation, macrophytes—these items may dilute the role of large wood as cover in some streams during summer (Grette 1985; Bugert et al. 1991). There is also evidence that the affinity of juvenile coho salmon for wood accumulations increases through the summer with growth (Hartman 1965; Dolloff and Reeves 1990; Fransen et al. 1993; Peters 1996)(Figure 40). Therefore, differences between studies may be partly due to within season variation.

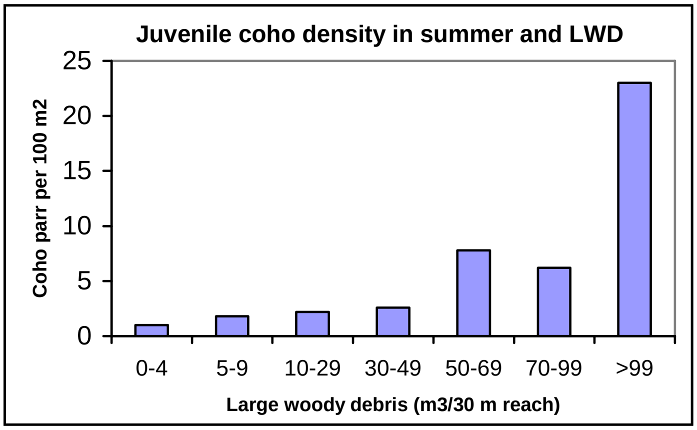


Figure 39. Density of juvenile coho salmon during summer in streams in Southeast Alaska, expressed as number of fish per square meter of total wetted channel area in relation to volume of large woody debris (LWD). Recreated from Koski (1992).

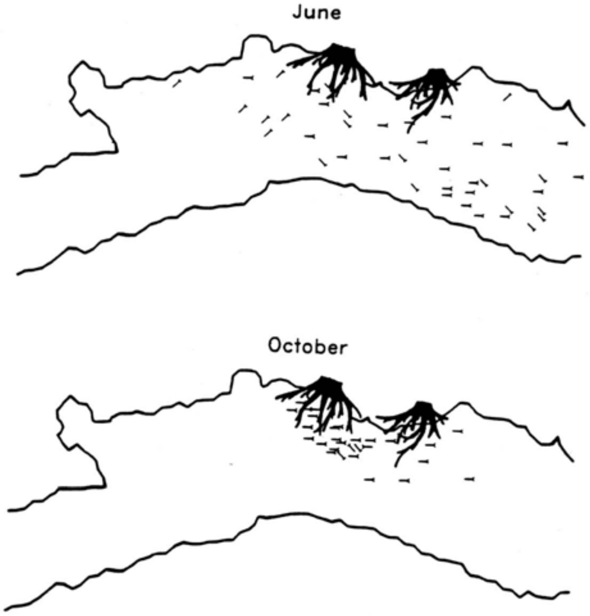


Figure 40. Location of juvenile coho in June and early October in a lateral scour pool relative to rootwads in Huckleberry Creek (Western Washington). The pool was at low flow when observations were made. From Fransen et al. (1993).

In mainstem rivers during summer the presence of large wood appears to be much more important than in small streams for juvenile coho salmon. Peters (1996)—in the most extensive study of mainstem coho utilization known to this author—found that juvenile coho rearing in the mainstem Clearwater River (Washington) was strongly associated with large wood (Figure 41). Highest juvenile coho densities were associated with the most complex wood matrices sampled. Areas containing sparse wood had few juvenile coho present. John McMillan with the Center for Wild Salmon in Washington State has conducted extensive snorkeling surveys of several rivers on the Olympic Peninsula (Washington). His findings (*personal communications*) are comparable to those of Peters (1996). Areas of no or little wood have few juvenile coho relative to sites with dense large wood. Hartman (1965) reported very similar findings for the mainstem Chilliwack River (British Columbia); association with wood increased as juveniles grew and by late summer and fall juveniles were almost always associated with log jams.

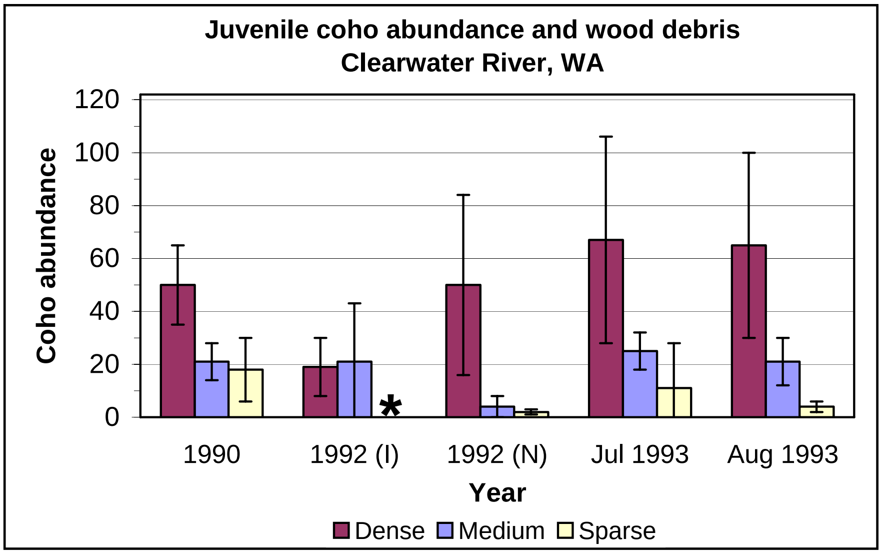


Figure 41. Mean (+/- 2 SE) coho salmon abundance (#/debris accumulation) at natural and introduced woody debris (combined) accumulations of different density during 1990 and 1993 and natural (N) and introduced (I)(separate) debris accumulations during 1992 in the mainstem Clearwater River (Washington). Recreated from Peters (1996). (* = no stations classified as sparse) Wood is classified by its relative accumulation as dense, medium, or sparse.

Peters (1996) concluded that the reason why juvenile coho were so tightly associated with wood in the mainstem river during summer was not simply to avoid higher water velocities. Many debris accumulations were located in sites with current velocities well below those preferred by juvenile coho (10 cm/s in Murphy et al. 1989; 20 cm/s in Dollof and Reeves 1990). In most cases wood was located such that water velocities were not appreciably different within wood matrices than outside them. Peters hypothesized that the attraction of wood during summer in mainstem rivers is due to its providing refuge cover from predators and not primarily as water velocity refuge. In his study, the attraction of wood increased as coho grew larger, i.e., wood association was greater later in the summer—identical to the findings of Hartman (1965) cited above. (As noted earlier, this same pattern is also evident in streams smaller than the Clearwater River – see Figure 40). Peters concluded that as juvenile coho grow they become more wary of predators, seeking greater association with dense wood. He stated:

> “This is supported by the observation that juvenile coho salmon are less willing than other Pacific salmon to take risks during feeding (Abrahams and Healey 1993), which results in reduced attack distance to food following the presentation of model predators (Dill and Fraser 1984).”

This suggests that not only are juvenile coho poor swimmers in swift water, they are much less daring than other salmonid species in their willingness to move away from cover to feed. In larger and swifter rivers than the one studied by Peters (1996), large wood is also likely important as velocity refuge, suggested in other aspects of Hartman’s (1965) study (described below for the overwintering life stage).

High water temperatures during summer can be an important factor affecting the distribution, growth, and survival of juvenile coho salmon.[26] Preferred temperatures in this life stage are 12-14°C (Brett 1952) with optimum temperatures for growth at about 14-18°C (Sullivan et al. 2000). Food availability is an important determinant in how well juvenile salmon can cope with elevated temperatures (Brett et al. 1982; McCullough et al. 2001). As food abundance increases, they are better able function (e.g., grow) with higher temperatures, but within limits. The maximum temperature that juvenile coho can tolerate without mortality is less clear because of the many ways that temperature can affect performance (McCullough 1999; Sullivan et al. 2000).

Eaton et al. (1995) used an extensive database of stream temperatures and species presence to estimate the weekly mean temperatures (daily maximums) that species can tolerate. For coho salmon, the value was estimated to be 23.4°C but it was not made clear what level of mortality could be expected above that point. This value is below laboratory-determined lethal temperature limits. Although it is clear that juvenile coho can tolerate higher temperatures under some natural conditions, it is evident that performance is usually adversely affected. Adverse effects have also been described at lower temperatures in various field investigations. Welsh et al. (2001) concluded that the findings of Eaton et al. (1995) for coho salmon were skewed by data representing large (and presumably diverse) river reaches and by use of less sensitive life stages. In a field investigation relating water temperature to juvenile coho distribution in the Mattole River (Northern California), the authors found that temperatures in the warmest tributaries containing juvenile coho salmon were 18°C or less (maximum weekly maximum temperature or MWMT). The study suggests that MWMT greater than 18.1°C would preclude coho presence. Madej et al. (2006) reported that the coho distribution in Redwood Creek (Northern California) is currently limited to the lowermost 12 miles of the stream, a point downstream of where the MWMT ranges between 23 to 27°C; historically coho migrated upstream another 45 miles. Frissell (1992) found juvenile coho salmon to be absent or rare in stream segments where temperatures exceeded 21°C in Sixes River (Southern Oregon).

In stark contrast to the findings of Welsh et al. (2001) and Frissell (1992), Bisson et al. (1988a) reported that juvenile coho showed no evidence of mortality or lethargy when temperatures exceeded 24.5°C during extended periods in streams near Mount St. Helens (Washington). In that case, water temperatures peaked at 29.5°C. Bisson et al. (1988a) hypothesized that an unusually high abundance of food may have enabled the juvenile coho to survive. However, these streams had extreme diurnal fluctuations in temperature (Martin et al. 1986) that likely afforded some measure of relief. The authors did not attempt to identify potential thermal refuge sites as described by Nielsen (1992a) or Ebersole et al. (2003a).

High water temperatures apparently can trigger movement of juvenile coho salmon during summer, when little movement typically occurs, as reported on the South Fork Umpqua River (Oregon Coast)(Figure 6; Kruzic 1998). It is not clear from the study results what the sole effect of elevated temperatures was on juvenile movement (compared to flow and initial fry dispersal) but it is strongly evident that a temperature effect was occurring. Temperatures when movement

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[26] / A separate report addressing coho salmon performance in the Klamath River authored by Cramer Fish Sciences (in preparation) provides a thorough review of the effects of water temperature on coho salmon. This issue is dealt with only briefly in this report.

occurred ranged between 15-23°C. High temperature also appears to trigger downstream movement of juvenile coho in the Klamath River basin (Chesney and Yokel 2003).

One way that juvenile salmonids cope with high temperatures is to find thermal refuge sites. Groundwater channels described earlier can provide such refuge. Ebersole et al. (2003a) described four cold water patch types in streams of the Grande Ronde basin (Northeast Oregon): cold alcoves, floodplain springbrooks (type of groundwater channel), cold side channels, and lateral seeps. All of these tended to be small. Ebersole et al. (2003b) reported that the abundances of juvenile Chinook and rainbow trout abundance were affected by the frequency of occurrence of coldwater patches. Higher frequency of occurrence of patches increased abundance, suggesting that survival is related to the probability that juveniles can successfully find patches. Ebersole et al. (2001) reported that patches appeared to be able to accommodate limited number of juvenile rainbow trout, suggesting that patch size may limit how many juveniles will survive even if patches can be readily located. Ebersole et al. (2003b) found no evidence that patch size affected abundance of juvenile Chinook salmon.

Juvenile coho have been found to use thermal refuge sites in Northern California streams. Nielsen (1992a) reported that juvenile coho used cool water pools at confluences with cool tributaries and coldwater seeps along hillslopes where some groundwater influence exists. One coho foraging phenotype, called “early emerging” (see Table 1), exhibited a unique feeding behavior that relied on cold water seeps for refuge during hours of high temperature.

Juvenile coho are found to be restricted to thermal refugia in the mainstem Klamath River during extended periods of the summer (Belchik 1997; Sutton et al. 2002; Deas and Tanaka 2006). Deas and Tanaka (2006) provided detailed observations on how subyearling coho, in addition to juvenile Chinook and steelhead, were distributed in several thermal refuge sites in the mainstem river in relation to water temperature. Figure 42 shows juvenile salmonid counts made by snorkeling within a thermal refuge site (Beaver Creek confluence) on the mainstem Klamath River at RM 162, showing fish numbers of each species within a sampling grid. The figure also shows temperature patterns at the time of the fish counts, made on July 28, 2005 at 7 pm. More examples are provided in the Deas and Tanaka report. Figure 43 is a photograph of the site taken on December 19, 2005, showing the backwater pool seen mapped in Figure 42 in relation to other channel and related flow features (flows are much higher in the December photo). Figure 42 shows that the distributions of the three species appear to be related to the thermal pattern. It also appears, in consideration of flow features seen in Figure 43, that the distributions were affected by flow velocities. Note that the juvenile coho show little association with where the velocity shear line would be expected to be (along the outer edge of the thermal refuge), in contrast to the other species. The authors noted that the juvenile coho were closely associated with an “algae mat” on the backwater pool (remnant of the mat is visible in Figure 43); the pool also contained abundant small woody debris on the substrate as well as rooted aquatic vegetation. No large wood pieces are present at the site. The composition of cover types in this backwater unit is comparable to that described earlier for backwaters in the Skagit River.

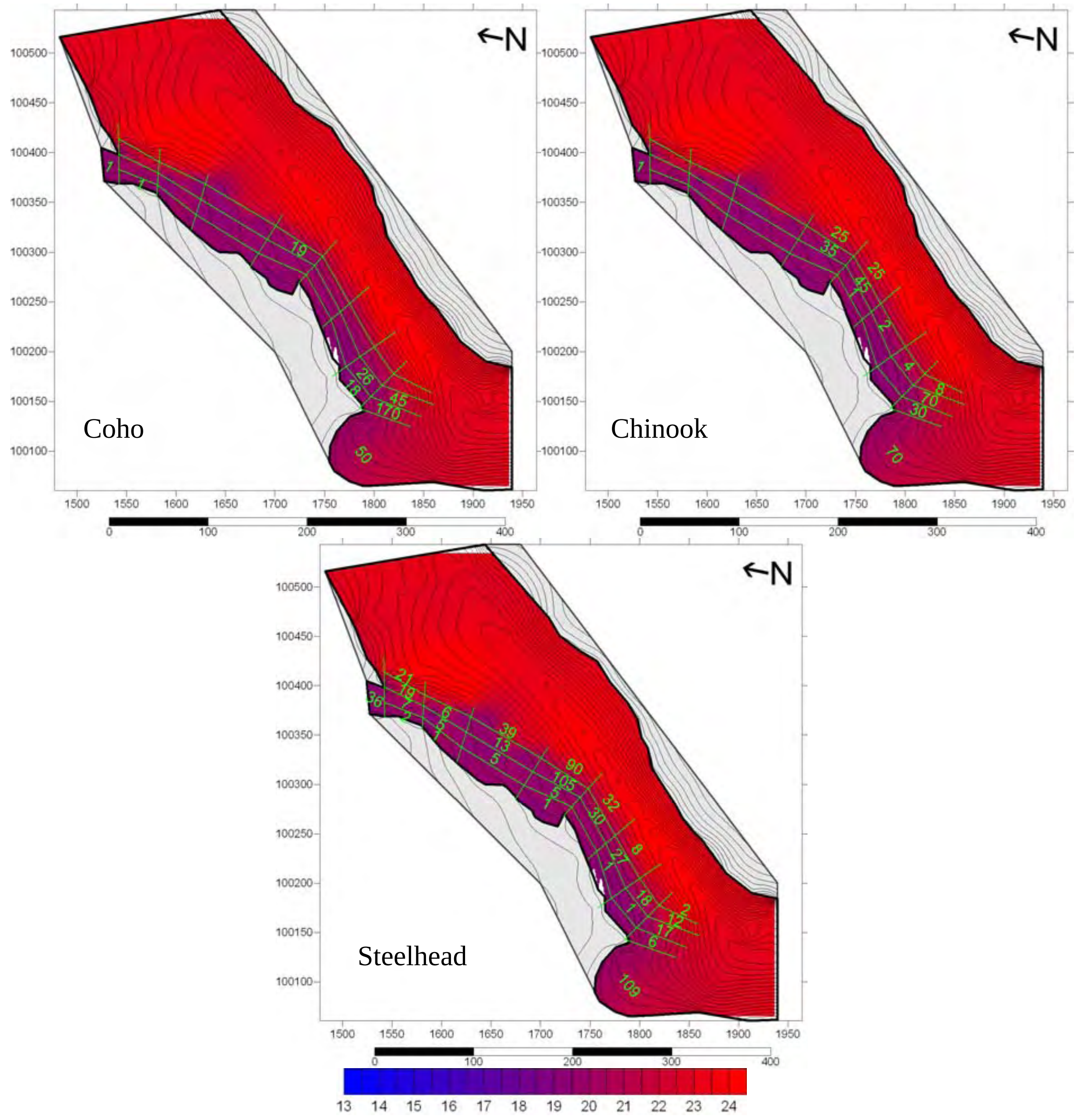

Figure 42. Fish counts by species at a thermal refuge site in the mainstem Klamath River (Northern California) on July 28, 2005 at 7:00 pm. Beaver Creek enters the mainstem river at upper left, shown as a cool water plume. Cool water also emerges along the gravel bar downstream of the mouth of Beaver Creek. A backwater pool is located in the bottom of the figure. Water temperatures are shown by the color scale. From Deas and Tanaka (2006). See Figure 43 for photograph of site.

Figure 43. Beaver Creek thermal refuge site in the Klamath River illustrated in Figure 42. Photograph taken on December 19, 2005. Backwater pool unit is plainly evident in lower left quadrant; remnant algae mat covers the inner part of the pool.

Survival of juvenile coho salmon during summer can be strongly density-dependent (Au 1972; Marshall and Britton 1980; Fransen et al. 1993; Quinn 2005). Competition for shrinking space—due to declining flows in late summer—and limited food results in reduced survival at higher juvenile abundance (Figure 44). Thus, the amount of suitable living space during summer can limit the size of a coho population in a watershed. Such limitations can be plainly evident in smaller watersheds where the population does not exhibit extensive redistributions between life stages. This is readily seen in the relationship between summer low flow and smolt yield in the following spring in some streams in the Puget Sound region (Figure 45). Relationships like this one are found in streams that have an abundance of overwintering habitat (Lestelle et al. 1993b).[27] In streams with little overwintering habitat, smolt yield is often controlled by winter conditions, thereby obscuring the effects of summer low flow on abundance.

Figure 44, derived from data for Deer Creek in the Alsea watershed study (Au 1972), provides an estimate of the density-independent component of survival for the stream by extending the regression line to the Y-axis (zero density), giving a value of 86%. This represents the average survival rate for the summer rearing phase for Deer Creek between June 1 and October 15 absent any effect of juvenile density. The Deer Creek watershed was partly logged approximately halfway during the study. Combined with the density-independent rate reported earlier in this document for the fry colonization phase the overall rate absent density effects for this stream would be 70% (multiplying 0.81 times 0.86).

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[27] / In streams that lack abundant overwintering habitat, such as occurs for many streams on the Oregon Coast (Solazzi et al. 1990), coho production from strreams is not correlated with summer low flow (Scarnecchia 1981). A lack of correlation is also evident in Washington streams where overwintering habitat is not abundant (Lestelle et al. 1993b).

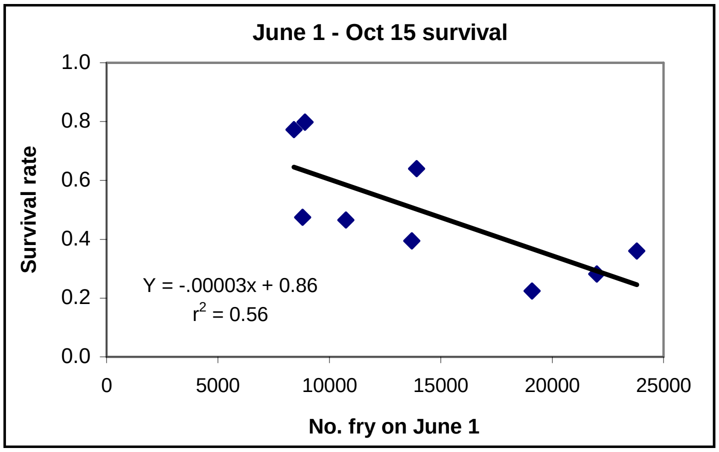

Figure 44. Relationship between the number of resident coho fry present on June 1 and survival to October 15 in Deer Creek, Alsea watershed (Oregon Coast). Survival shown is for the summer life stage for resident juveniles. Derived from data in Au (1972). Estimated density-independent survival is the point where the regression line would cross the Y-axis (0.86).

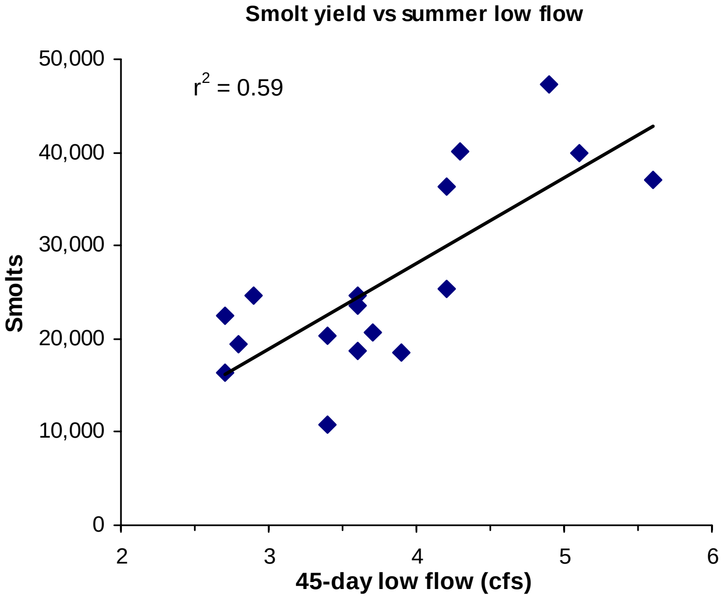

Figure 45. Relationship between the 45-day average lowest summer flow and coho smolt yield the following spring in Big Beef Creek (Western Washington). From Lestelle et al. (1993b).

3.2.6 Fall Redistribution and Overwintering

In many streams, some juvenile coho salmon move from their summer rearing locations in fall, triggered by increased flows associated with autumn rainfall. This movement is another demonstration of the affinity that these fish have for slow velocity water. Water velocities increase in main stream habitats with rising flow, either dislodging juveniles from summer rearing sites or stimulating them to move to find more favorable habitats prior to the coming of larger, more frequent winter storms (Tschaplinski and Hartman 1983). Moyle (2002) suggests that the availability of overwintering habitat is one of the most important and least appreciated factors influencing the survival of juvenile coho in streams.

This pattern of downstream movement in fall associated with rising flow has been reported in the Klamath River (USFWS 1998; Toz Soto, Karuk Department of Natural Resources *personal communications*), Oregon coastal streams (Rodgers et al. 1987)(Figure 46); Western Washington streams (Allee 1974; Peterson 1982), and British Columbia streams (Tschaplinski and Hartman 1983; Brown 2002). In some cases, juveniles captured at the head of tidal influence (Rodgers et al. 1987; Allee 1974; IMWSOC 2006) have been found to continue moving into estuarine habitat (Miller and Sadro 2003). It is evident, however, that these fish have not undergone smoltification and are not prepared for survival in full strength seawater (Rodgers et al. 1987). Miller and Sadro (2003) found them to reside into winter in the extensive upper parts of the Coos Bay estuary (i.e., within the estuary-freshwater ecotone) (Oregon Coast). In rivers that have minimal estuarine habitat, such as rivers on the Washington North Coast (e.g., Queets River), juvenile coho swept into the ocean during fall freshets likely perish.[28]

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[28] / Some uncertainty remains regarding the fate of fall emigrants that move into the marine environment. This author believes that probability of survival is related to whether the juveniles can find low salinity habitats along the nearshore environment or whether they can locate and reenter nearby streams to overwinter. This topic is being researched in streams along the western portion of the Strait of Juan de Fuca (see IMWSOC 2006)—a significant downstream emigration of juvenile coho past a trap site immediately above tide water has been found in East Twin River between mid October and mid December. East Twin River and other streams in the immediate vicinity have very small stream mouth estuaries—the streams discharge directly into the outer coast of Strait of Jaun de Fuca. Data on East Twin River is being analyzed as part of a Master's Thesis by Todd Bennett (University of Washington).

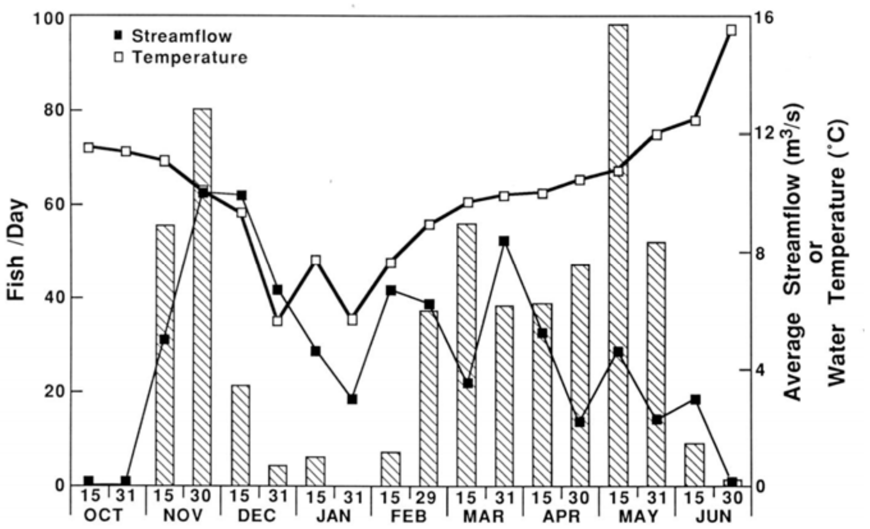

Figure 46. Pattern of juvenile coho downstream movement in Knowles Creek, Oregon. From Rodgers et al. (1987). Average catch per day of fish trapped near the head of tidewater is shown. Fish captured in fall reflect the pattern of redistribution seen in many streams. Fish captured after February are smolts moving seaward.

During this period of redistribution, some juvenile coho salmon immigrate into off-channel habitats. These habitats provide refuge from high flow velocities. Peterson (1982a) and Peterson and Reid (1984) described extensive movements of juvenile coho out of the mainstem Clearwater River (Washington Coast) into off-channel ponds (Figure 47). Thousands of juvenile coho salmon can move upstream through a tiny egress channel into a single pond within a short period of time—showing this to be a very striking pattern of migration for this species. Juvenile Chinook and steelhead trout do not generally exhibit such a movement into these habitats (Brown 2002; Lestelle et al. 2005). Once coho juveniles have moved into these sites, few move back out into the main stream during the winter—the large majority stay for the duration and emigrate in the spring as smolts. Their overwinter survival in these sites is typically high (approximately 70%) although it can apparently be less in very shallow ponds (Peterson 1982b; Peterson and Reid 1984). Similar movements occur by juvenile coho into off-channel alcoves along small streams (Nickelson et al. 1992; Bell et al. 2001). Bell et al. (2001) reported very high fidelity of overwintering coho to alcoves in Prairie Creek (Northern California), a finding comparable to the lack of movement out of riverine ponds until smolt emigration. Winker et al. (1995) suggested that stable residency within a habitat type is indicative of high quality habitat.

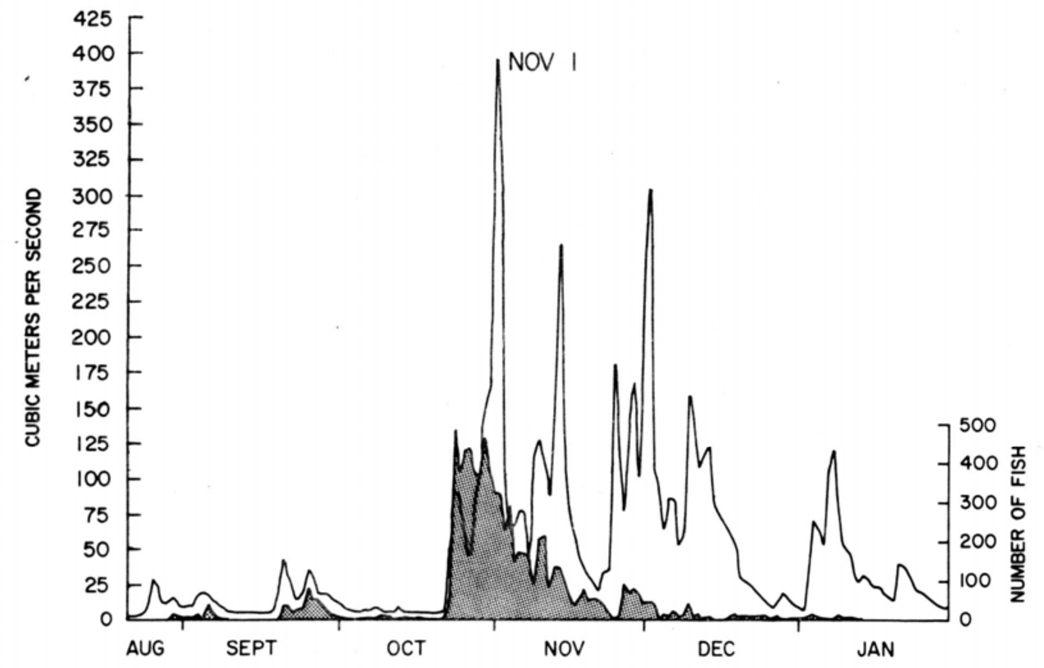

Figure 47. Pattern of trap catches of juvenile coho salmon moving into an off-channel pond along the Clearwater River (Washington) in relation to stream discharge in the mainstem river. From Peterson (1982a).

To aid the reader in visualizing the differences in the quality of different habitats for overwintering coho, three reference photos are provided here. Figure 48-top shows the Clearwater River (the river where Peterson conducted his studies) during moderately low winter flow—the reach shown is typical of the river. Figure 48-middle shows the Smith River in Oregon, comparable to the Clearwater River in size, during a flow event exceeding bankfull. Figure 48bottom shows a riverine pond habitat on the Clearwater River—conditions shown exist throughout the winter. These pictures illustrate the extreme differences in conditions between in-channel and off-channel habitats during winter.

Figure 48. Winter habitat conditions in rivers used by juvenile coho salmon. (Top) Clearwater River (Washington) during moderately low winter flow. (Middle) Lower Smith River (Oregon Coast) during flood event—this river is comparable in size to the Clearwater River. (Bottom) Riverine pond adjacent to the Clearwater River. Smith River photo is courtesy of Ron Rasmussen, U.S. Forest Service.

The same type of movement observed by Peterson is also found into groundwater channels (or small spring-fed floodplain tributaries)(Skeesick 1970; Giannico and Hinch 2003). Skeesick (1970) summarized the results of monitoring the movements of juvenile coho out of the mainstem Wilson River (Oregon Coast) into a small spring-fed floodplain tributary over a period of ten years. Immigrants were marked at the time of their capture in fall so that overwinter survival could be assessed; surviving smolts were enumerated in late winter and spring at the time of their emigration as smolts. Overwinter survival for the ten year period ranged between 46% to 91% and averaged 72%.

Bustard and Narver (1975) and Tschaplinski and Hartman (1983) monitored coho juveniles moving out of the mainstem Carnation Creek (Vancouver Island) into a series of small beaver ponds on the stream’s floodplain. As found by Peterson (1982a), once fish moved into the site they generally did not leave again until late winter and spring. Tschaplinski and Hartman (1983) estimated the average overwinter survival over a six year period to be either 67% or 72% (using two methods of estimation).

Overwinter survival in off-channel habitats has been found to be improved if cover in the form of wood is added (Giannico and Hinch 2003), although the effect is not as evident in relatively warm groundwater channels. Apparently fish remain more active in warmer groundwater channels and may be more effective at evading predation. Juvenile coho have a greater cover-seeking response in very low temperatures (Bustard and Narver 1975; Taylor 1988).

Besides moving into off-channel habitats, juvenile coho salmon will also move from large streams (mainstem rivers) into small tributaries during this period of redistribution (Cederholm and Scarlett 1982; Scarlett and Cederholm 1984; Bramblett et al. 2002). In the Clearwater River (Washington), Cederholm and Scarlett monitored the movements of juvenile coho from the mainstem river into small tributaries. These streams are not spring fed—they are perennial runoff tributaries (1-1.5% channel gradients) that respond rapidly to rainfall events. Fish were found to move up to 1,100 meters upstream of the mainstem Clearwater River into these streams. The pattern of residency appeared to be different than reported for ponds by Peterson (1982a) and Tschaplinski and Hartman (1983). In the runoff tributaries, fish exhibited a greater amount of movement through the winter—fish appeared to be arriving and departing more often than seen in the ponds. This suggests that fish were leaving the mainstem in an effort to find improved conditions, then continued that search to other areas during the course of winter. This may reflect an urgency to leave the large mainstem river when conditions are particularly harsh, followed later by more movement to escape conditions found unfavorable for continued residency. It suggests a transient residency pattern of fish that have not found high quality overwintering sites.

This movement of juvenile coho salmon from mainstem streams during fall and winter appears to be due to fish leaving unfavorable areas in search of improved survival conditions. Within mainstem streams, they evacuate sites with high exposure to high velocities. In Carnation Creek (Vancouver Island), sites within the main channel jammed with logs, undercut banks, and deep pools filled with upturned tree roots and other forest debris contained almost all of the juvenile coho remaining in the main stream during the winter (Tschaplinski and Hartman 1983). The large reductions in the main stream population in fall coincided with the largest movement of juvenile coho into the off-channel sites. No coho were found in midstream locations within the stream and they did not inhabit areas under banks unless the sites contained tree roots or other lodged debris (Figure 49), consistent with the findings of Beechie et al. (2005) in the Skagit River described above (Figure 36C). Bustard and Narver (1975) reported the same pattern for cover use in Carnation Creek in earlier work than that of Tschaplinski and Hartman as seen in Figure 50, which nicely contrasts species differences in cover type preferences. Juvenile steelhead, in addition to also overwintering in wood accumulations (yearling and older fish), utilize cobble substrates. Young of the year steelhead predominantly utilize cobble or boulder substrates for overwintering, which coho rarely use (Ruggles 1966; USFWS 1988; McMahon and Hartman 1989).

Grette (1985) reported similar results for small streams on the Olympic Peninsula (Washington), stating:

> "During winter, coho were observed to be closely associated with instream cover, especially debris-related instream cover. Often, the majority of the coho population in a particular pool would be found near debris cover along a slow velocity stream margin. Although cover appeared to be important, the single most important factor determining distribution of coho during winter appeared to be velocity. A slow velocity pool with instream cover (often even a very small area of cover) was likely to have coho present, while a high velocity habitat with abundant instream cover often had no coho."

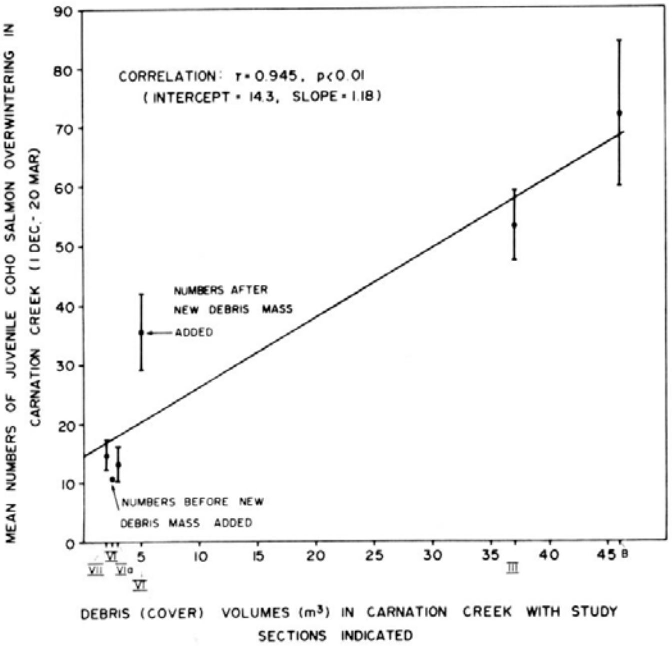

Figure 49. Relationship between instream wood volume and numbers of juvenile coho salmon overwintering at sites in Carnation Creek (Vancouver Island). From Tschaplinski and Hartman (1983).

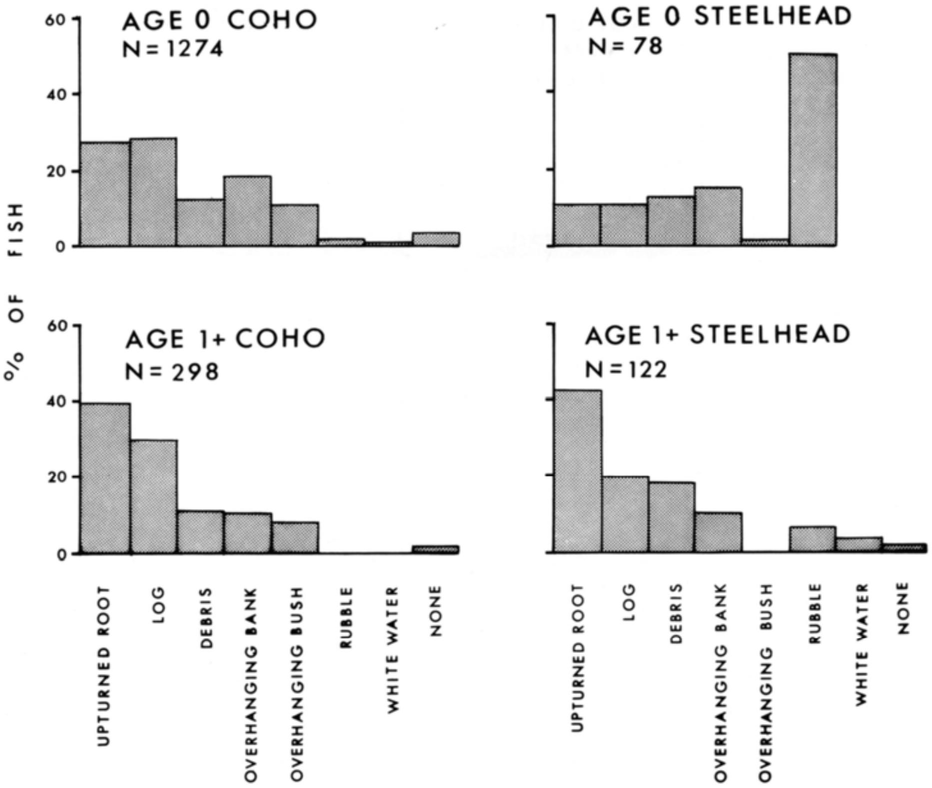

Figure 50. Cover types selected by juvenile coho and steelhead at water temperatures of 7 °C or less during winter in Carnation Creek (Vancouver Island). From Bustard and Narver (1975).

The USFWS (1988) investigated habitat types used by overwintering juvenile coho and steelhead in the Trinity River within the Klamath River basin. Juvenile coho were found overwintering in side channels in “still water with aquatic vegetation or woody debris as the main cover type.” Juvenile coho were rarely observed holding underneath cobbles as was the common behavior for juvenile steelhead. The researchers noted that “use of large woody debris by juvenile coho salmon would have probably been greater had this type of cover been available in greater quantities within the study sites or the Trinity River in general.”

The association between juvenile coho and cover increases as water temperature drops. Distance between individual juvenile coho and nearest cover diminishes with falling temperature, as seen in Carnation Creek. (Figure 51). At temperatures <3 °C, virtually all individuals were found tight within cover. Toz Soto (Karuk Department of Natural Resources *personal communications*) has observed a similar pattern in snorkeling surveys in tributaries to the Klamath River. Juvenile coho, like several salmonid species, are nocturnal at low temperatures during winter months (McMahon and Hartman 1989; Roni and Fayram 2000).

Hartman (1965) described the importance of large, stable instream wood to juvenile coho overwintering in main stream habitats in British Columbia)(Hartman 1965). The Chilliwack River, the focus study stream, at the time contained numerous large wood accumulations. Hartman’s study is particularly notable in how he performed his sampling within this mainstem river—he used “Prima Cord” explosives to sample for small fish at various sites within the river. This proved to be an effective way to sample under log jams. Sampling was conducted in all seasons, including winter. To this author’s knowledge, it is the only study to conduct such a rigorous sampling of log jam sites. Hartman reported that the large majority of juvenile coho found at sampling sites in the mainstem river during fall were located in close association with log jam cover. During winter, nearly all coho juveniles were associated with log jams.

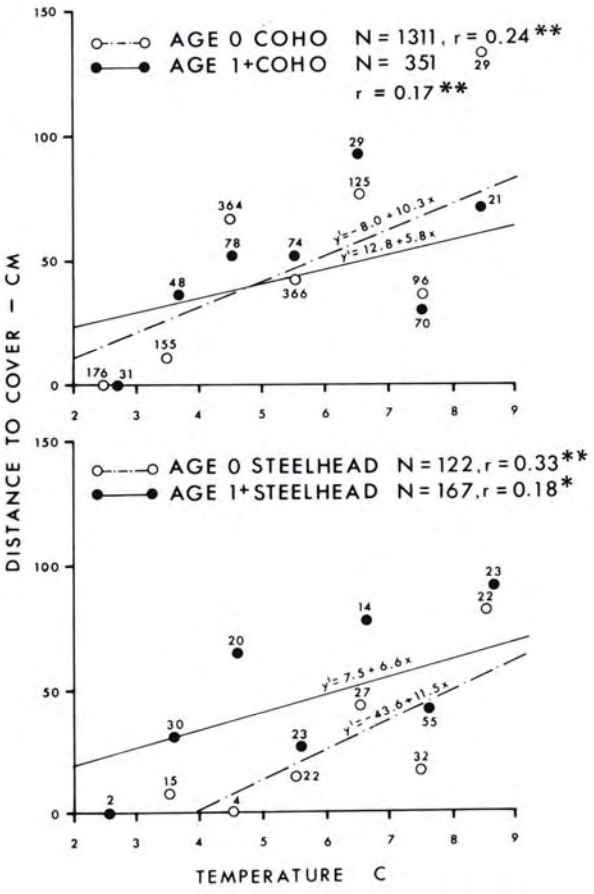

Figure 51. Mean distance to cover of juvenile coho and steelhead in relation to water temperature during winter in Carnation Creek (Vancouver Island). From Bustard and Narver (1975). Sample size is indicated by the associated numbers. Regression lines were derived from N observations.

The importance of large wood to overwintering coho salmon has also been documented in Porter Creek, tributary to the Chehalis River (Washington)(Cederholm et al. 1997b). This study looked at the effect of wood enhancement on numbers of coho and juvenile steelhead produced in this medium sized creek. Although wood enhancement also increased pool quantity in the stream, smolt numbers were much more responsive to wood than merely to changes in pool quantity (Figure 52).

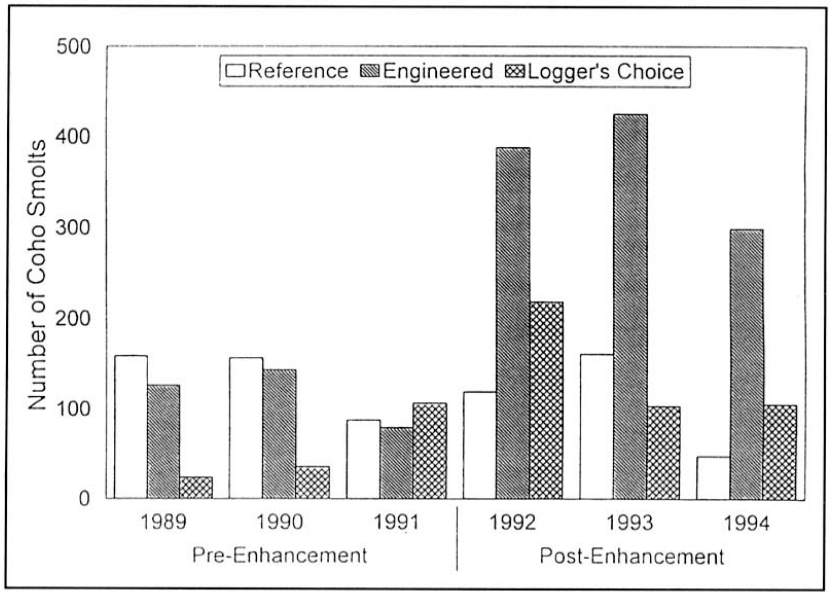

Figure 52. Results of large wood enhancement in Porter Creek, Washington. Juvenile coho smolt numbers are compared between reference (control) reaches, reaches with wood placed strategically (engineered), and reaches where loggers chose to add wood. From Cederholm et al. (1997b).

It bears noting that the size and density of large, stable wood in stream channels varies greatly by channel size, channel type, and available wood sources (Abbe and Montgomery 1996; Bilby and Bisson 1998; Montgomery et al. 2003). Small channels retain wood much more readily than large channels (Figures 53-54). Wood is much more easily transported in large channels. Channel type (i.e., extent of confinement) also influences how much wood is retained in a channel—confined channels with boulder or bedrock substrate contain about half or less number of pieces of wood found in similarly sized, unconfined reaches with small substrate (Bilby and Wasserman 1989; Bilby and Bisson 1998). The amount and sizes of wood that are recruited into a stream channel also greatly affects the extent of wood retained within a channel (Hyatt and Naiman 2001). Where riparian forests have been reduced by development or where they are composed of small trees, stream channels contain much less wood compared to heavily forested areas with large trees (Montgomery et al. 2003). Large wood jams are still abundant on a few large rivers of the Pacific Northwest, as seen on the Queets River within the Olympic National Park (Washington)(Figure 55)—a river subject to extreme flood conditions associated with high precipitation but still able to retain large wood volumes within its channel.

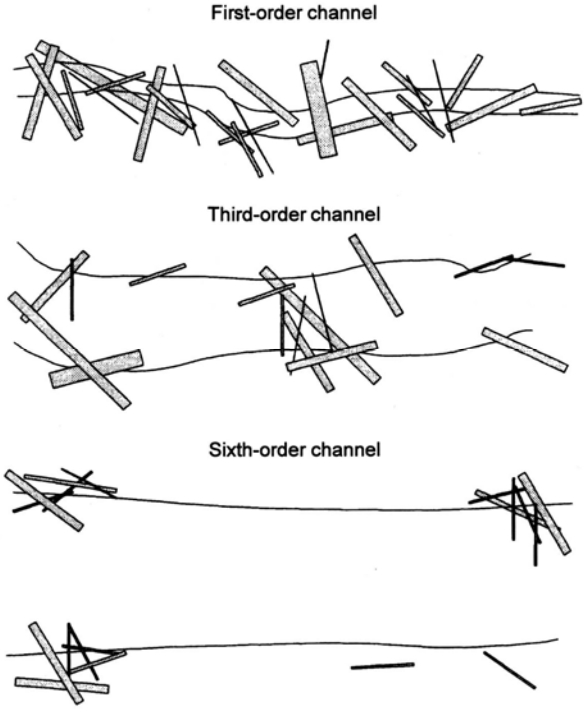

Figure 53. Typical distribution of large woody debris in channels of various sizes. From Bilby and Bisson (1998).

In smaller mainstem streams on the Oregon Coast, Nickelson et al. (1992) reported that juvenile coho predominantly overwinter in pools—particularly dammed pools and backwater pools—and in alcoves (Figure 31), all having low velocities. Densities are highest in alcoves. Nickelson et al. (1992) reported that riffle habitats hold virtually no coho juveniles during winter.

Researchers on the Oregon Coast concluded on the basis of various analyses (e.g., Reeves et al. 1989) that coho salmon in Oregon coastal streams were largely limited by the amount of suitable overwintering habitat compared to available summer habitat. This entire region has been subject to extensive logging in the past; habitats have been altered and wood loads are far below historic levels. A project was initiated in several streams to add winter habitat, primarily by increasing the amount of alcoves and dammed pools (Solazzi et al. 2000). The well designed study monitored two reference streams and two treatment streams over a period of eight years. A key response variable considered was overwinter survival of juvenile coho salmon. Overwinter survival was increased significantly in both treatment streams as a result of habitat modifications. This study provides some of the best evidence that overwinter survival is related to the availability of low velocity habitat. Prior to treatment and including the reference streams, average survival in these streams was in the range of 10-20%. Average overwinter survival in the two treatment streams following habitat modification was 39%. These post-treatment survivals are similar to overwinter survivals estimated in Prairie Creek (Northern California, a nearly pristine stream within old growth redwood forest) of 45% (Brakensiek 2003) and in Carnation Creek prior to logging of 35% (Bustard and Narver 1975).

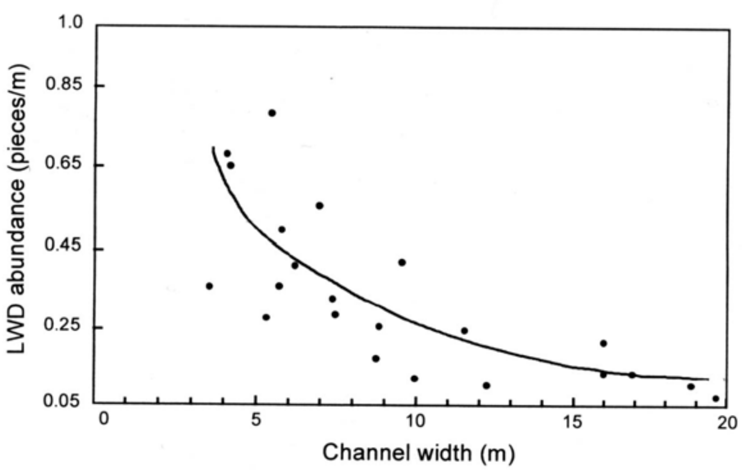

Figure 54. Abundance of large woody debris in relation to channel size in old-growth forests in southeastern Washington. From Bilby and Bisson (1998) as modified from Bilby and Ward (1989).

The role of winter conditions to the performance of Oregon coastal coho has also been demonstrated in an analysis of winter flows and smolt yields. Knight (1980) found smolt yields in the three Alsea River study streams to be significantly correlated to the level of high flow during the overwintering period (Figure 56). These results provide further evidence that the quantity and quality of winter habitats limit coho production on the Oregon Coast. At high flows, the distinction between pools and riffles can be obscured. Gordon et al. (2004), in their excellent book on stream hydrology, describe it as follows:

> “As kayakers are well aware, the water surface slope, depth of flow and speed of the current become more uniform over the stream reach at high flows. At these times, it becomes questionable whether the terms ‘pool’ and ‘riffle’ are even applicable. As discharge increases, velocity and depth rise more rapidly in pools than in riffles, and energy loss becomes more uniform. The shear stress in pools can eventually exceed that in riffles.”

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Figure 55. Abundant log jams still exist on some rivers in the Pacific Northwest as seen in the Queets River within Olympic National Park (Washington). Dense accumulations of wood, built on large key pieces, provide cover and velocity refugia for small salmonids. Note the young alder trees growing from a large key piece (middle picture), indicating a degree of interannual stability of jams, despite extreme flow fluctuations within this river due to high precipitation.

This suggests that the effective size of pools shrinks—from the perspective of the coho—as winter flows increase; hence Figure 56 suggests that smolt yields in effect decline as pools become less effective as velocity refuge sites. Grette (1985), in describing the role of pools for overwintering coho, reported that some habitats classified as pools during summer were recognized as riffles during winter flows for the reasons described by Gordon et al. (2004). This dynamic of how velocities change in main channel pools also highlights the importance of off-channel habitats to coho that need low velocity habitats. Moreover, it emphasizes the importance of large, stable wood for fish residing in the main channel during winter.

Figures 57 and 58 and Table 4 summarize estimates made of overwinter survival for juvenile coho salmon in streams of the Pacific Northwest and California. The estimates are presented corresponding to the major channel type (main stream or off-channel) utilized by coho in each study. There is a clear pattern showing much higher survivals for off-channel sites. Figure 58 separates the estimates further into altered main stream channels (by land use practices), pristine main channel habitat, and several types of off-channel habitats.

Another factor that can affect overwinter survival of juvenile coho is fish size in fall, just prior to the redistribution movement. Overwinter survival can be higher for larger fish at the end of the summer rearing period (Holtby 1988; Quinn and Peterson 1996). In a small Puget Sound stream, Quinn and Peterson (1996) reported that juvenile coho in larger size-classes had significantly higher overwinter survival rates than smaller fish in the winter of 1990-1991 but not in 1991-1992—though a pattern for increasing survival with size was still evident in the second year (Figure 59). Maximum daily flows during the winter of 1990-1991 were almost twice as high as those in 1991-1992, suggesting that the benefit of fish size is greatest during winters with high peak flows. This further suggests that the effect of fish size is demonstrated most in runoff-type streams as opposed to within off-channel habitats where velocity effects are minimal. Moreover, juvenile coho that rear during summer in mainstem rivers are usually larger than those rearing in small tributaries (Marshall and Britton 1980; Scarlett and Cederholm 1984; Peterson and Reid 1984), except when mainstem temperatures are extremely high, which limits growth. Hence, where juvenile coho find favorable conditions in mainstem rivers for summer growth and remain there overwinter, their larger size may compensate to some degree for harsher winter conditions that often exist there compared to smaller tributaries. Quinn and Peterson (1996) suggested that the superior survival of larger fish during winter may be explained by some combination of size-biased predation and resistance to displacement by floods.

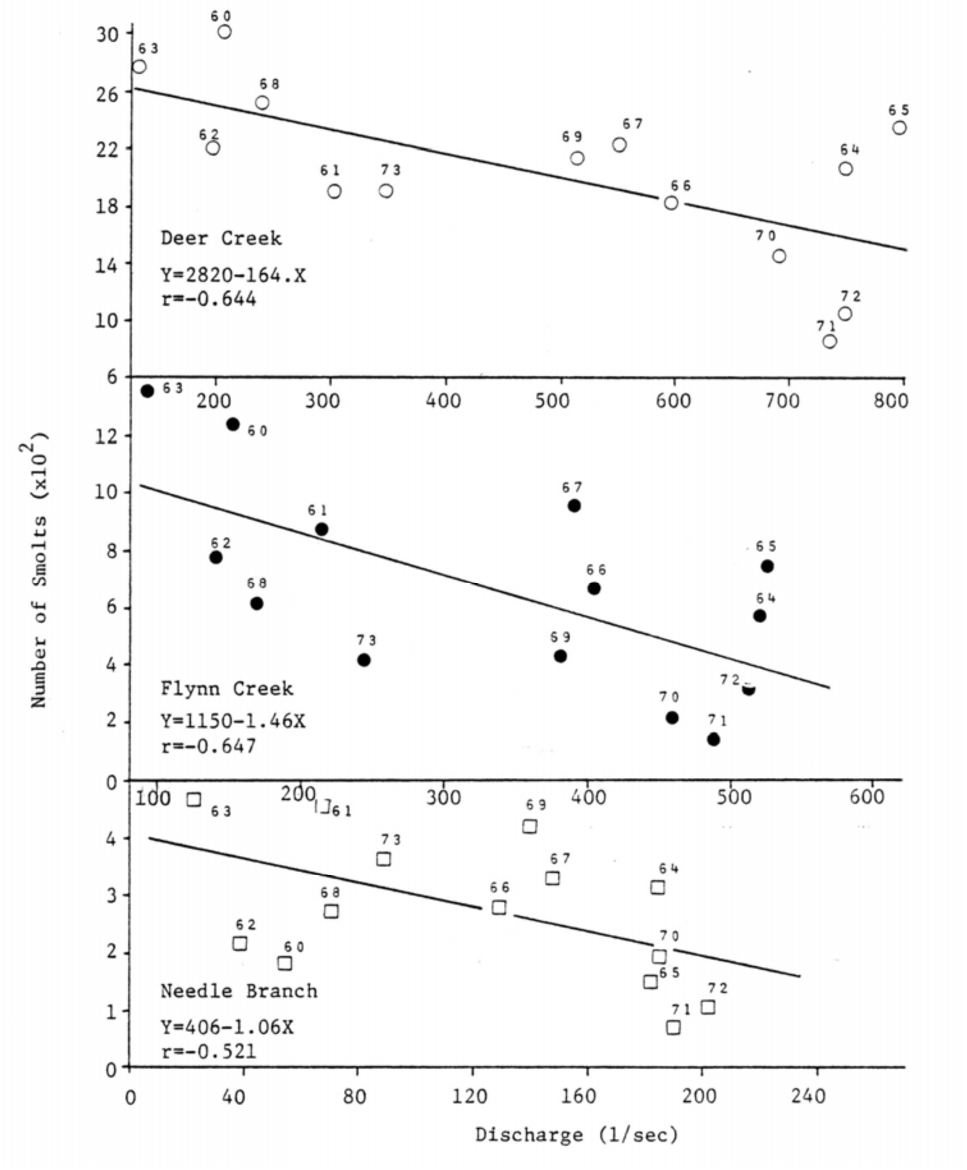

Figure 56. Relationships between coho smolt yields and mean January discharge during the overwintering life stage in Deer Creek, Flynn Creek, and Needle Branch within the Alsea River system (Oregon Coast). Data labels indicate smolt year. The three streams were subject to different levels of logging. The Needle Branch watershed was clearcut in 1966, leaving no buffer strip along the stream. The Deer Creek watershed was patchcut (three patches) with 25% of the area being logged in 1966. Partial buffer strips were left. Flynn Creek was not logged and served as a control watershed during the study period. From Knight (1980).

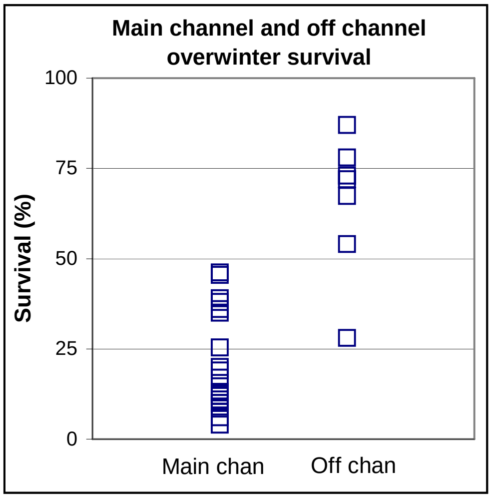

Figure 57. Comparison of overwinter survival estimates for juvenile coho in main stream habitats and off-channel habitats. See Table 3 for a list of studies used to create the chart.

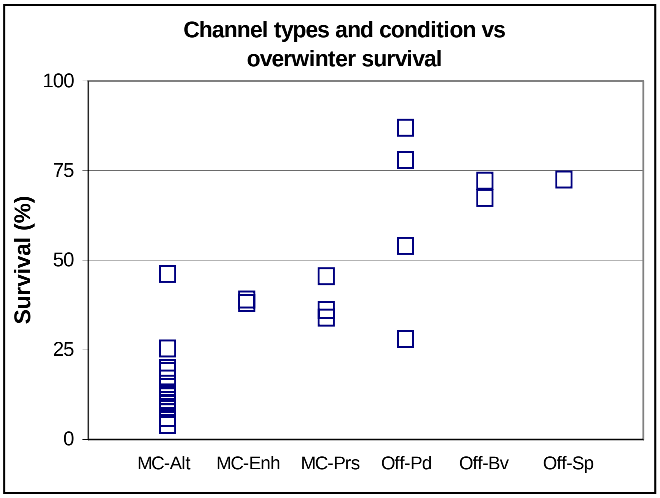

Figure 58. Comparison of overwinter survival estimates for juvenile coho in altered main stream habitats (MC-Alt), enhanced main stream habitats (MC-Enh), pristine main stream habitats (MC-Prs), off-channel ponds (Off-Pd), off-channel beaver complexes (Off-Bv), and off-channel spring sites (Off-Sp). See Table 1 for a list of studies used to create the chart.

Table 4. Summary of estimated overwinter survival rates for juvenile coho salmon in streams of Alaska, British Columbia, Washington, Oregon, and California.

Channel type	Basin	Status	Region	Survival	Source	Comment
In channel	Alsea R.	Previously logged; pre treatment	Oregon Coast	0.13	Solazzi et al. (2000)	Two year mean
In channel	Alsea R.	Previously logged; reference-pre treatment	Oregon Coast	0.17	Solazzi et al. (2000)	Two year mean
In channel	Alsea R.	Previously logged; post treatment	Oregon Coast	0.38	Solazzi et al. (2000)	Two year mean
In channel	Alsea R.	Previously logged; reference-post treatment	Oregon Coast	0.20	Solazzi et al. (2000)	Two year mean
In channel	Nestucca R.	Previously logged; pre treatment	Oregon Coast	0.11	Solazzi et al. (2000)	Two year mean
In channel	Nestucca R.	Previously logged; reference-pre treatment	Oregon Coast	0.19	Solazzi et al. (2000)	Two year mean
In channel	Nestucca R.	Previously logged; post treatment	Oregon Coast	0.39	Solazzi et al. (2000)	Two year mean
In channel	Nestucca R.	Previously logged; post treatment	Oregon Coast	0.10	Solazzi et al. (2000)	Two year mean
In channel	WF Smith R.	Previously logged	Oregon Coast	0.04 - 0.13	J. Ebersole personal communications	Survivals of groups from 9 locations
In channel	Big Beef Cr.	Previously logged	Hood Canal	0.25	Quinn and Peterson (1996)	High flow winter
In channel	Big Beef Cr.	Previously logged	Hood Canal	0.46	Quinn and Peterson (1996)	Moderate flow winter
In channel	Sashin Cr.	Pristine	SE Alaska	0.35	Crone and Bond (1976)	Three year mean
In channel	Carnation Cr.	Pristine	Vancouver Is.	0.35	Bustard and Narver (1975)	One year
In channel	Prairie Cr.	Pristine	North CA	0.45	Brakensiek (2002)	One year; estimate for standardized fish length
In channel			Mean	0.20		

Channel type	Basin	Status	Region	Survival	Source	Comment
Off channel – beav ponds	Carnation Cr.	Pristine	Vancouver Is.	0.72	Tschaplinski and Hartman (1973)	Mean of several years
Off channel – beav ponds	Carnation Cr.	Post logging	Vancouver Is.	0.67	Tschaplinski and Hartman (1973)	Mean of several years
Off channel - spring creek	Wilson R.	Not known	Oregon Coast	0.72	Skeesick (1970)	Mean of nine years (range 0.46-0.91)
Off channel - pond	Clearwater R.	Pristine	Wash Coast	0.78	Peterson (1982)	One year; deep pond
Off channel - pond	Clearwater R.	Pristine	Wash Coast	0.28	Peterson (1982)	One year; shallow pond
Off channel - pond	Coldwater R.	Not known	Fraser R.	0.54	Swales et al. (1986)	One year
Off channel - pond	Coldwater R.	Not known	Fraser R.	0.87	Swales et al. (1986)	One year
Off channel			Mean	0.66		

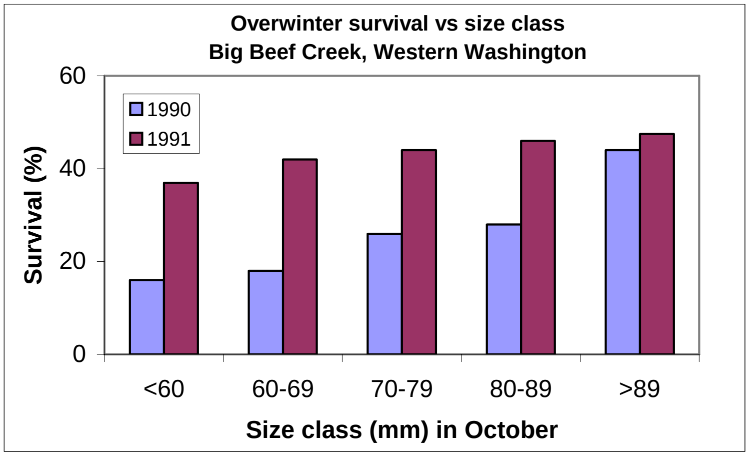

Figure 59. Overwinter survival of juvenile coho of different sizes tagged at the end of summer in Big Beef Creek (Western Washington) in 1990 and 1991. From Quinn and Peterson (1996).

Figure 60 summarizes in graphic form effects of environmental factors on the overwinter survival of juvenile coho salmon. Most of these factors relate to how easily juvenile coho can find low velocity habitats during winter.

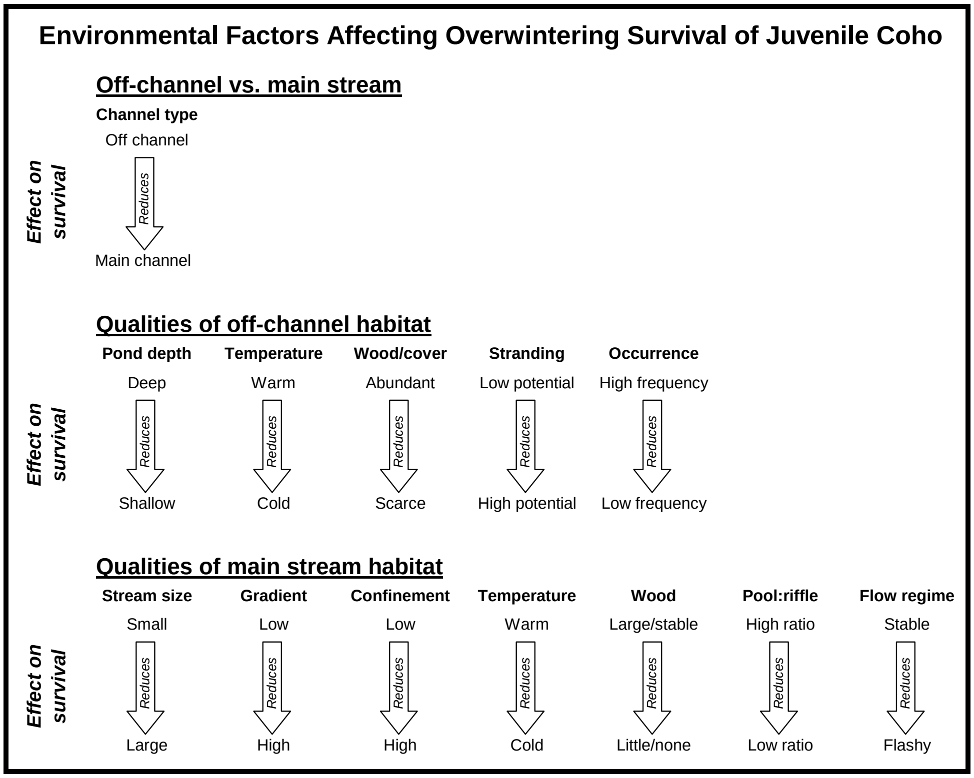

Figure 60. Summary of factors that affect overwinter survival of juvenile coho salmon.

3.2.7 Smolt Migration

Juvenile coho salmon that attain a certain size by late winter or spring undergo smoltification—the physiological transformation necessary for surviving at sea. Minimum fork length needed during this time period to facilitate the transformation appears to be 75-80 mm based on studies cited by Sandercock (1991). Fish that do not reach this size within the critical time window delay their outmigration until the next year. As noted earlier in this document, the fate of especially small yearling migrants associated with the margin-backwater foraging type described by Nielsen (1994) remains unknown. The large majority of coho smolts in California, Oregon, and Washington are yearlings.

Smoltification and the corresponding smolt migration begins earlier in the southerly part of the species' geographic range (Sandercock 1991; Spence 1995). Shapovalov and Taft (1954) reported that in California the outmigration of smolts begins as early as mid March, peaking in mid May. Similar timing patterns exist in Oregon and Washington streams (Au 1972; Seiler et al. 2004). In contrast, in the Resurrection Bay area of Alaska, the mid point of the outmigration can occur in mid June (Sandercock 1991 citing McHenry 1981). Spence (1995) suggests that one reason for the relationship between smolt timing and latitude is that ocean upwelling and seasonal increase in productivity occurs progressively later with increasing latitude. Also, migrations of northern populations tend to be of short duration (majority migrating over a 5-10 day period), while 50% of the fish from southern populations migrate over a 2-5 wk period. Spence (1995) suggests that the migration of southern populations spans a greater time period because greater variation occurs in the timing of increased spring-time ocean productivity in the southern end of the species' range. While positive relationships between smolt timing and latitude are strong, considerable variation in timing has been observed among populations at any given latitude (Spence 1995). This variation may be partly the result of the type of streams where data has been collected within the data set that Spence used in his analysis.

Of particular interest for this review is the wide range of smolt outmigration patterns that can occur in a single watershed within the overall critical time window for smoltification. While the onset and duration of smoltification are largely controlled by day length and water temperature (Hoar 1976), both migration timing and rate of migration can be affected by smolt size, location in the watershed at the start of the migration, migration distance, and stream flow (Quinn 2005). This overview is focused primarily on free-flowing rivers. It is beyond the scope in this report to consider factors affecting migration timing and travel rates through reservoirs, such as in the Columbia system, though some information from that system is included here where useful.

Larger salmonid smolts, for several species including coho salmon, generally begin their migration earlier than smaller ones, presumably because smaller ones require additional time to gain size necessary for smoltification and for improved marine survival (Irvine and Ward 1989; Seiler et al. 2004; Quinn 2005). This pattern is seen in the Queets River system on the Washington coast (the Clearwater River seen in Figure 2 is a major tributary to the Queets River). Studies have been underway in this river system since 1981 to annually assess natural coho smolt yields from various tributaries and from the watershed as a whole. The studies provide a means to assess outmigration timing, rates of migration, and production of wild smolts originating in various habitats around the basin (Lestelle and Curtwright 1988; Lestelle et al. 1993a).

The coho smolt migration in the Queets system typically begins first for fish emigrating from riverine ponds, followed by fish from runoff tributaries (Figure 61). Smolts coming from off-channel ponds are consistently larger than fish that overwinter and emigrate from runoff tributaries and small groundwater channels (Figure 62). Consequently, the emigration from overwintering ponds occurs earliest and ends well before it is completed in runoff streams. While emigration timing from ponds is earlier than runoff streams, considerable variability can exist between ponds (Figure 63). Differences in timing seen in Figure 63 are not due to variation in smolt size because both the earliest and latest patterns shown consisted of exceptionally large fish of comparable size.

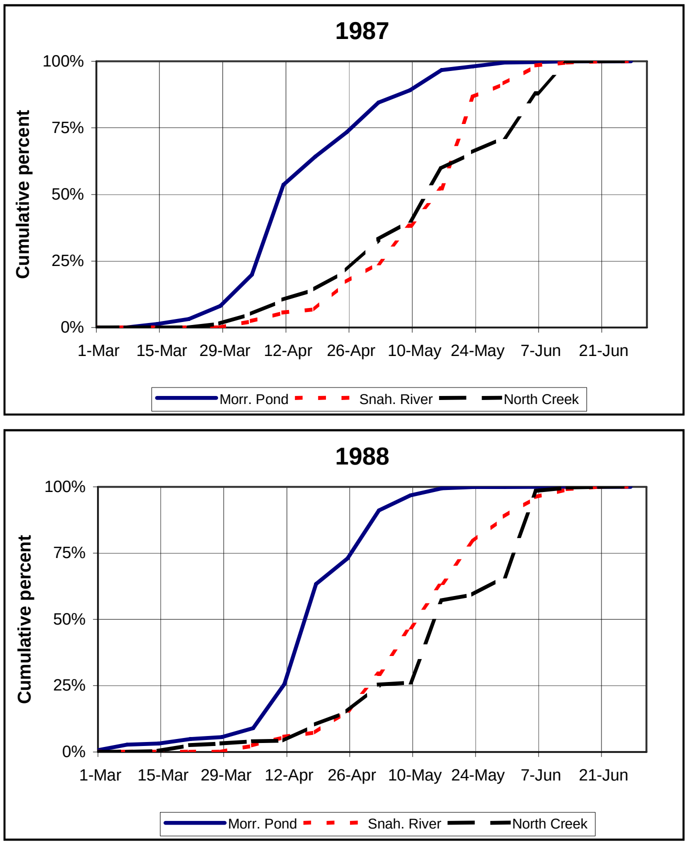

Figure 61. Timing of coho smolt emigration from three channel types in the Queets River system in 1987 and 1988: a riverine pond (Morrison Pond), a runoff stream (Snahapish River), and a groundwater fed stream (North Creek). Data from Lestelle and Curtwright (1988) and QDNR (1989a).

Another pattern usually seen with Queets coho smolts shows that early emigrants, though large, move downstream more slowly than fish that emigrate late in the migration. Figure 64 illustrates this pattern, comparing the timing of wild fish marked when they departed either a pond or a runoff tributary with their recapture timing at a seining site near the head of tidewater. The pond and runoff tributary trap sites where marking occurred were 6.8 and 27.6 miles upstream of the seining site, respectively. Travel rates computed using the median dates when smolts were marked and released, then recaptured near the head of tidewater were 0.6 and 5.5 miles per day for pond and runoff tributary fish respectively (1.0 and 8.9 km/day). A different depiction of this pattern is seen by comparing the release timing of all marked fish to their recapture timing at a scoop trap near the mouth of the Clearwater River (Figure 65). Smolts departing tributary streams and ponds later in the season migrated more quickly to the scoop trap than earlier migrants. It bears noting that more rapid migration of later-timed fish in this river occurs during a receding hydrograph—the flow regime is rainfall dominated with winter peak flows.

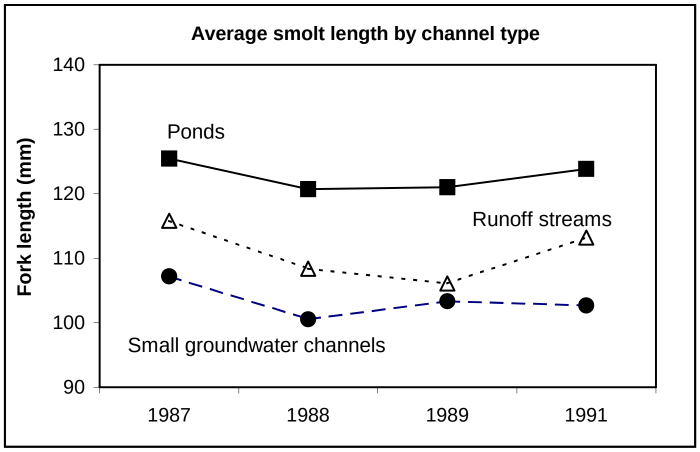

Figure 62. Average lengths of coho smolts emigrating from ponds, runoff streams, and small groundwater channels in the Queets River system in 1987, 1988, 1989, and 1991. Data for 1990 in the sequence of years shown were not used here due to experimental supplementation fish present that year. Multiple trapping sites for each channel type are included. Data from Lestelle and Curtwright (1988) and QDNR (1989a, 1989b 1992).

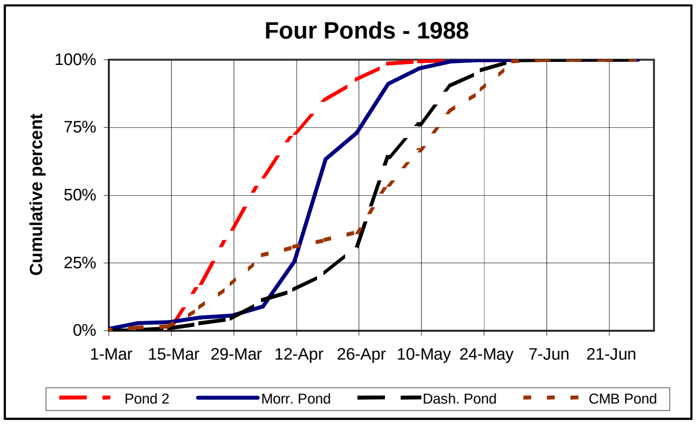

Figure 63. Timing of coho smolt emigration from four riverine ponds along the Clearwater River (Queets River system) in 1988: Pond 2, Morrison Pond, Dashers Pond, and Coppermine Bottom Pond (CMB). Data from QDNR (1989a).

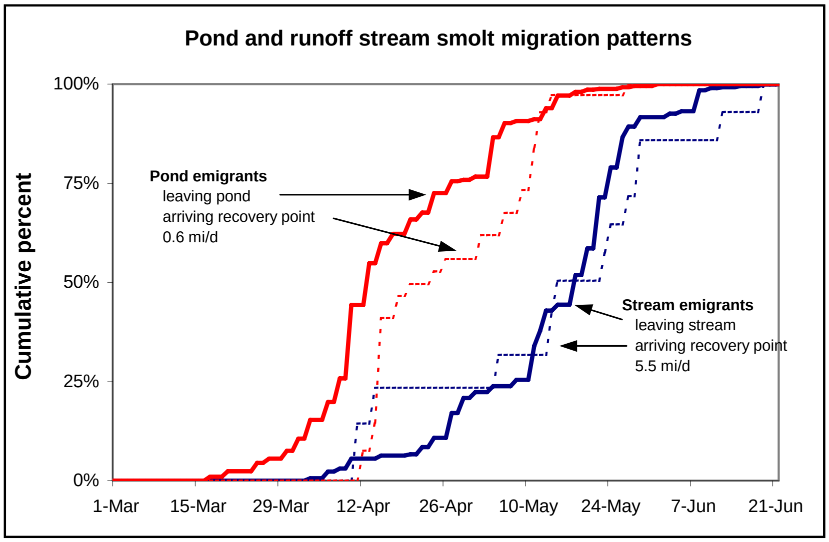

Figure 64. Emigration timing patterns of marked coho smolts from a riverine pond (Morrison Pond) and a runoff tributary (Snahapish River) in the Clearwater watershed and recapture patterns of the same marked smolts at the Queets River seining site near the head of tidewater in 1987. Computed average migration rates associated with the times of 50% of marks released and marks recaptured are shown in miles traveled per day. The trap sites where smolts were marked are located 6.8 and 27.6 miles upstream of the seining site respectively. Adapted from Lestelle and Curtwright (1988).

This pattern of early migrating smolts moving more slowly downstream than later migrants has been documented elsewhere and it appears to occur for salmonid species in general (Quinn 2005). Dawley et al. (1986) documented the pattern for hatchery coho salmon released at Ice Harbor Dam on the Snake River. Fish released later in the season migrated more quickly than those released earlier (Figure 66). Similar results were reported by Giorgi et al. (1997) for hatchery and wild yearling Chinook smolts and steelhead smolts in the Columbia River and by Pyper and Smith (2005) for spring Chinook yearling and coho smolts in the Yakima River.

Another factor that can affect migration rate of salmonid smolts is migration distance to the river mouth (Quinn 2005). Smolts that begin their migration far from the estuary generally travel downstream much faster than those that begin closer. A multiple regression analysis of coho smolt release data in Dawley et al. (1986)(Table 18 in that report-excluding releases prior to March 15 and after June 15) for the Columbia River shows significant effects (P<0.05) of both date released (Julian day) and distance between release site and the recovery point on travel time. Similarly, data presented here in Table 6 show the same type of effects for wild coho smolts in the Clearwater River—though the scale in distance being traveled by smolts is much less in this case. Multiple regression analysis between release date (Julian day) and distance to the recapture site as independent variables and travel time (dependent variable) shows significant effects (P<0.05) for both independent variables in combination ($R^2 = 0.73$). This effect of distance on travel time is intriguing—Quinn (2005) states that it raises the question of whether there is a genetic adaptation in travel time to the distance that a population has to migrate.

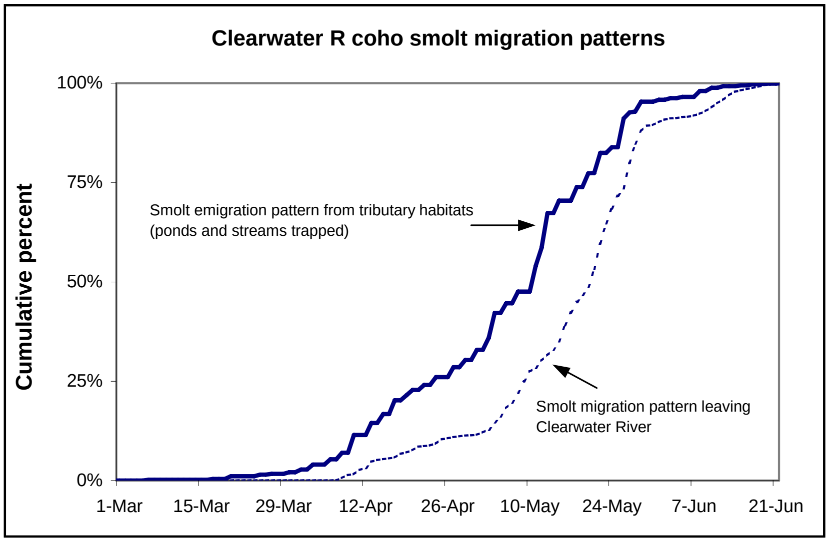

Figure 65. Emigration timing patterns of marked coho smolts released at all tributary trap sites combined and at a scoop trap near the Clearwater River mouth in 1987. Adapted from Lestelle and Curtwright (1988).

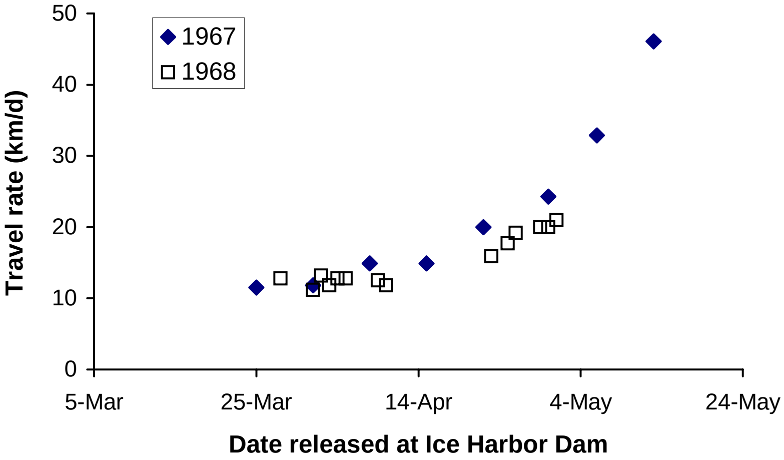

Figure 66. Travel rate of coho salmon smolts released at Ice Harbor Dam on the Snake river and captured at Jones Beach on the lower Columbia River (463 km downstream—288 miles). Data from Dawley et al. (1986); figure recreated from Quinn (2005).

Flow is another factor that can affect migration timing and migration rate (Fast et al. 1991; Berggren and Filardo 1993; Williams et al. 2005; Quinn 2005). The effect of flow on smolt migration patterns through the reservoir system of the Columbia is reasonably well established—river flow has been demonstrated to make the greatest contribution to explaining smolt travel time among various factors examined (Berggren and Filardo 1993). Williams et al. (2005) summarized available information relating flow level to smolt migration rates of yearling

Chinook under pre-dam and post-dam conditions on the Columbia and Snake rivers (Figure 67). Flow levels are shown as affecting travel time between Lewiston, Idaho and Bonneville Dam (317 miles) under both pre-impoundment and post-impoundment conditions. Travel time over this distance prior to dams during high flow conditions was estimated to be approximately half the time required during low flow conditions (based on Raymond 1979).

Factors that can affect the survival rates of migrant smolts in fresh water have been extensively studied in the Columbia and Snake rivers—and intensely debated. Much of the debate has focused on the relationship between mainstem flow and outmigrant survival. It is well known that predation can be high on juvenile salmonids as they outmigrate through impounded systems such as the Columbia River (Beamesderfer et al. 1996) and in systems with multiple water diversions with fish bypasses like the Yakima River (Fast et al. 1991). These rivers have large populations of northern pikeminnow (*Ptychocheilus oregonensis*) and exotic predatory fishes. It has often been assumed in these cases that the travel rate of smolts, affected by flow, determines predation rates by regulating the amount of time that juvenile migrants are exposed to the predators. More recent research, however, indicates that while migration rate is affected by flow, survival appears to be largely a function of migration distance and not travel rate (Muir et al. 2001; Smith et al. 2002; Williams et al. 2005). This is particularly the case for yearling and older smolts (as reported for yearling Chinook and yearling and older steelhead)(Anderson 2003a; Williams et al. 2005).

Anderson (2003b) explains that the effect of predatory fishes on yearling and older smolts acts essentially through a gauntlet effect: “observations on migrating prey (juvenile salmon) through a field of predators (pisivors) reveals that mortality depends mostly on distance traveled and only weakly on travel time…At the other extreme, if prey and predators move randomly within an enclosed habitat, mortality is time dependent.” The latter case could be applied to the effect of predators on subyearling Chinook as they move slowly seaward through a large river like the Columbia River, consistent with conclusions of Anderson (2003a).

Within the mainstem Columbia River hydrosystem, another factor shown to be important to the survival of outmigrant yearling smolts is water temperature (Anderson 2003a; Conner et al. 2003; Smith et al. 2003). Anderson (2003a) suggests that for yearling spring Chinook smolts that temperature operates mainly by affecting the activity of predatory fishes. As water temperatures rise, feeding rates of predatory fishes typically increase (within temperature limits tolerable to the species).

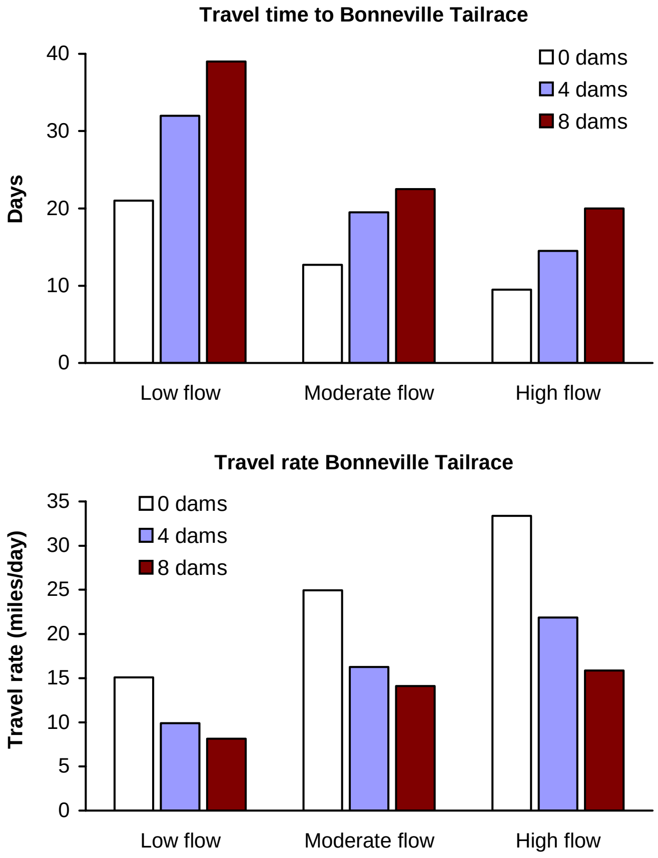

Figure 67. Estimated average travel times (top) and travel rates (bottom) for yearling Chinook smolts through the section of the lower Snake and Columbia rivers now inundated by mainstem dams (approximately from Lewiston, Idaho to Bonneville Dam). Estimates for the 0- and 4- dam scenarios are derived from Raymond (1979). Data for 8 dams were derived from PIT-tagged fish between 1997 and 2003. Top chart is from Williams et al. (2005). Bottom chart was adapted from the top chart.

The effect of migration distance on yearling smolt survival has also been demonstrated for free-flowing streams upstream of Lower Granite Dam on the Snake River. A strong inverse relationship exists between survival and migration distance for hatchery spring Chinook smolts released at various hatchery sites in the Snake River system (Figure 68)(Williams et al. 2005). The fish experienced only free-flowing river conditions from their points of release until they arrived at the top end of the Lower Granite Dam reservoir—they were assessed for survival just below the dam. Williams et al. (2005) also reported survival rates for PIT-tagged wild and hatchery yearling Chinook released at two sites upstream of Lower Granite Dam (Table 5). It is important to note that the free-flowing section of the Snake River below the tributaries where these releases were made, the lower ends of the tributaries, and the Lower Granite reservoir contain northern pikeminnow and other exotic predatory fish species. Anderson (2003b) concluded that water temperature during the period of migration did not help explain mortality within the free-flowing tributaries to the Snake River, suggesting that temperature has a stronger role in the prey-predator dynamics within the extensive reservoir system downstream. Anderson (2003b) determined that only migration distance affected smolt survival to Lower Granite Dam.

Table 5. Summary of average survivals for wild and hatchery yearling Chinook smolts released at two sites upstream of Lower Granite Dam (LGD) on the Snake River, 1993-2003. Fish released at the Salmon River trap experienced free-flowing river conditions until they arrived at the Lower Granite reservoir. Fish released at the Snake River trap at the head of the reservoir experienced impounded water conditions to the point of tag detection at the dam. Data from Williams et al. (2005).

Release site	Distance to LGD (km)	Survival to LGD	
		Hatchery	Wild
Salmon River (White Bird) trap	233	77.7%	86.2%
Snake River trap – head of LG reservoir	52	92.9%	93.5%

Less data exists on predation rates on free-flowing rivers in the Pacific Northwest where pikeminnow and exotic predators are not present. One example is for streams on Vancouver Island where mergansers are the primary predator on migrant smolts. Wood (1987) reported maximum estimates of mortality rate due to adult mergansers to be less than 2% for hatchery coho salmon during their seaward migration in the Big Qualicum River.

Lestelle and Curtwright (1988) evaluated survival of wild coho smolts during their migration downstream from traps within the Clearwater River system on the Olympic Peninsula. This river, like those reported on by Wood (1987), is used extensively by mergansers. Groups of wild coho smolts captured in tributary traps were uniquely branded to identify recaptured fish at a scoop trap located near the mouth of the river. A total of 18 mark groups in nine pairs were released to learn whether survival was affected by release time (day or night) or release site (distance traveled)(Table 6). No significant differences in recapture rates were found between release sites nor between day and night releases. The results suggested that little or no mortality occurred between release and recapture for all groups. The closest release site was 1.3 miles upstream of the scoop trap, while the most distant site was 22.6 miles upstream. It is noteworthy that this river, as the name implies, is a clear water river and generally has very low turbidity through much of the smolt migration. It is a rainfall-dominated stream and is moderately confined over much of its length. During the smolt migration, the river has virtually no flooded shorelines containing grasses and willows that might provide cover. It also has a relatively low wood load, unlike the Queets River, which it joins.

Taken together, the studies described above for free-flowing rivers suggest that smolt survival during their outmigration is typically very high. The data reported in Table 5 for the Snake River, combined with results in Table 6, are construed to mean that most or all of the mortality on fish released at the head of the Lower Granite Dam was due to the presence of pikeminnow and exotic fishes inhabiting the impoundment. This suggests that survival with distance is much higher in the absence of pikeminnow and for entirely free-flowing reaches than seen in Table 5.

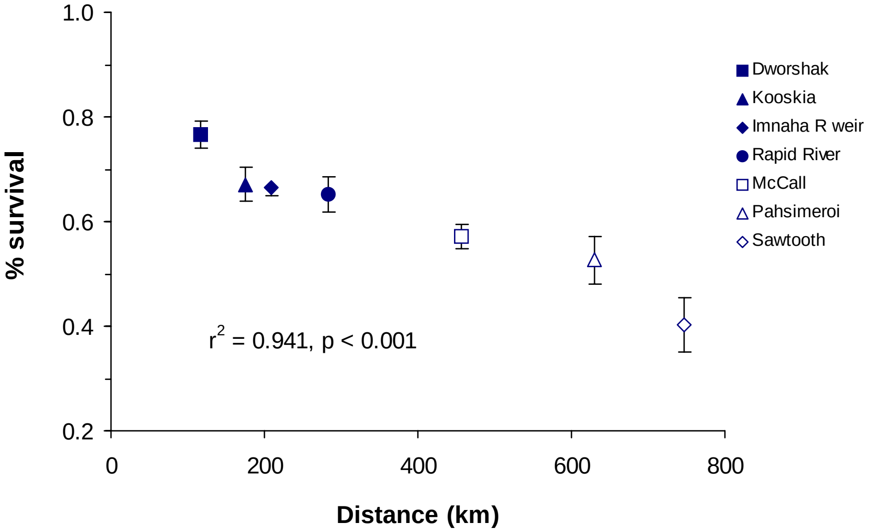

Figure 68. Estimated survivals (+/- SE) of yearling Chinook smolts from release at Snake River basin hatcheries to Lower Granite Dam tailrace, 1993-2003, versus distance (km) to Lower Granite Dam. Correlation between survival and migration distance is shown. From Williams et al. (2005).

The results of the marking experiments in the Clearwater River (Table 6) show another pattern worth noting. Smolts emigrating from an individual tributary on any given date exhibited wide ranges in the number of days that it took to arrive at the river mouth. For example, smolts trapped and released on May 14 at the mouth of Miller Creek, 11 miles above the downstream scoop trap, took between 1 to 28 days with a median of 13 days to travel that distance. For all groups combined, the range in days required to migrate to the scoop trap was 1 to 37 days. These results show that smolts tended not to travel rapidly between the tributary of origin and the point of departure from the mainstem river. These findings are consistent with patterns of wild coho smolt migrations seen elsewhere.

In Carnation Creek (Vancouver Island), McMahon and Holtby (1992) reported that coho smoltification and associated downstream emigration occurs progressively within a stream system, even small ones as Carnation Creek. Fish emigrating from tributaries moved progressively—as if in stages—downstream as smoltification developed. Smolts were typically aggregated in groups >5 fish, with aggregation size increasing significantly over the course of the smolt run. Smolts exhibited few agonistic interactions. The groups exhibited a high degree of cohesiveness. Typically, fish were quite secretive, milling about in dark, low velocity areas under cover with occasional forays to the edge of cover to feed on invertebrate drift. The most often used cover type was large woody debris associated with pools. Movement downstream in this short stream required several weeks once movement had been initiated. These findings indicate that smolt emigration by individual fish is not rapid once initiated, but occurs progressively with fish continuing to forage and use instream cover during periods of rest and short-term residency at stop-over sites. McMahon and Holtby stated that shelter from high velocities during spring freshets is likely important to prevent premature displacement.

Table 6. Summary results of mark-recapture experiments with wild coho smolts captured in outmigrant traps in tributaries to the Clearwater River in 1982. All groups were marked with unique brands. Fish were released within 24 hrs of their capture at the tributary traps to test for differences in recapture rates between day and night release. Recaptures were made at a scoop trap near the mouth of the river. Table is recreated from Lestelle and Curtwright (1988). No significant (*P*>0.05) differences in recapture rate were found between any release site.

Release site	mi from scoop trap	Release group				Recapture				
		Pair no.	Date	Time	No. released	No. recaptured	Percent recaptured	Days from release		
								First	Median	Last
Hurst Cr.	1.3	1	14-May	day	211	52	24.6%	1	3	23
			15-May	night	101	14	13.9%	2	5	22
		2	25-May	day	213	56	26.3%	1	5	19
			26-May	night	205	58	28.3%	1	3	12
Miller Cr.	11.0	3	14-May	day	166	39	23.5%	1	13	28
			15-May	night	88	17	19.3%	2	13	28
		4	25-May	day	244	73	29.9%	1	7	23
			26-May	night	245	72	29.4%	1	8	23
Christmas Cr.	12.5	5	15-May	day	30	6	20.0%	3	7	18
			15-May	night	30	8	26.7%	4	10	24
Bull Cr.	18.5	6	15-May	day	37	15	40.5%	9	33	37
			15-May	night	37	5	13.5%	3	25	32
Snahapish R.	22.6	7	14-May	day	212	41	19.3%	4	17	25
			15-May	night	141	19	13.5%	4	15	27
		8	25-May	day	501	134	26.7%	5	14	24
			25-May	night	343	88	25.7%	5	14	23
		9	3-Jun	day	215	40	18.6%	5	7	11
			3-Jun	night	213	50	23.5%	5	8	16
		Total day releases			1,829	456	24.9%			
		Total night releases			1,403	331	23.6%			
		Grand total releases			3,232	787	24.4%			

Quinn (2005) described the downstream migration of coho smolts as not continuous but interspersed by periods of holding. Radio tracking of wild coho smolts in the Chehalis River (Western Washington) suggested that migrants spent about 40% of the time moving and 60% holding during their outmigration (Moser et al. 1991). Smolts rested in back eddies and even in off-channel habitats, consistent with observations of McMahon and Holtby (1992).

A multi-year study is being conducted in the Klamath River by the U.S. Fish and Wildlife Service to investigate coho smolt emigration patterns and associated survivals using radiotelemetry. First year results (Stutzer et al. 2006) have shown an outmigration pattern similar to those described above where wild smolts display periods of holding interspersed with downstream movement. While smolts were found to hold in a variety of habitat types, they appeared to prefer those with low water velocities. Unlike juvenile coho at younger life stages, however, fish were frequently found to be occupying velocity shear zones. Moreover, unlike the observations of McMahon and Holtby (1992) in Carnation Creek where fish were found in close association with shelter, smolts in the mainstem Klamath River were more removed from margin cover when holding. Holding smolts were generally still associated with shoreline habitats, 75% of habitat use was within 20 ft of the shoreline. The migration rate of smolts was also found to accelerate as fish moved further down the river.

McMahon and Holtby (1992) described the progressive downstream movement pattern of smolts as one of transitioning to a behavior adapted to open-water life (i.e., away from cover)—a pattern seen in the Klamath River observations. It is logical to expect that as smolts leave small streams (such as the size of Carnation Creek) and emigrate down large rivers, their association with instream cover would diminish.

4.0 Discussion and Conclusions

Two underlying questions have been considered throughout this report as they relate to how coho salmon utilize physical habitats within a watershed. How similar are coho life history patterns across the species' range? And what kinds and extent of variation occur with respect to these patterns, particularly as variation might relate to the SONCC Coho ESU and Klamath River coho?

These questions relate to Moyle's statements about coho salmon in his book "Inland Fishes of California":

> "…evolutionary forces keep coho salmon (and other salmon) surprisingly uniform in morphology and life history throughout their range, while producing runs that show strong, genetically based adaptations to local or regional environments. In California coho populations are the southernmost for the species, and they have adapted to the extreme conditions (for the species) of many coastal streams."

The extensive coverage of coho life histories in Sandercock (1991), augmented by the works of Moyle (2002) and Quinn (2005), provide much material that addresses the two questions of primary interest here. This report provides additional information, mostly as it pertains to how physical habitat is used and associated survival rates. Variations in life history traits that relate to habitat use have been described here to the extent that information is available.

On its surface, Moyle's statement may seem contradictory. He concludes that coho salmon show a high degree of uniformity (or similarity) in life history patterns across their range, yet he asserts there is also significant variation and local adaptation. In context, Moyle is saying that coho salmon—like other salmonid species—exhibit significant variation in life histories, but the range of variation remains within what he sees as unifying life history themes for the species. The central themes of life history similarity are morphology, age structure, spatial distribution within a watershed, general timing patterns of migrations and other movements, development and growth patterns, foraging patterns, effects of environmental stressors, and habitat use patterns—among others. But significant variations exists within these unifying themes, enabling considerable adaptation to local conditions.

One unifying theme in the freshwater life history of juvenile coho is their affinity for slow velocity habitats in all life stages. Body morphology, fin sizes, and behavior are generally adapted to life in these habitats—notwithstanding variations that exist between stream-type and lake-type fish and coastal and interior forms (discussed further below). Their affinity for slow water is evident across the species' range—in both northern and southern regions and coastal and interior regions. Juveniles in all life stages—though to a lesser extent during the smolt stage—primarily rear and seek refuge in slow velocities associated with pools, channel margins, backwaters, and off-channel sites (alcoves, ponds, and groundwater channels). This tends to segregate them to some degree from juvenile Chinook and steelhead, though overlaps in space occur. Their affinity for low velocity water is strongest during the fry (very young fry) and overwintering life stages.

This association with low velocity habitats tends to result in several patterns of distribution within a watershed. Juvenile rearing—particularly in summer—occurs to a large extent within the natal streams. These streams usually tend to be relatively small and low in gradient, thus they often have a substantial amount of low velocity habitat. Emergent fry generally remain relatively close to their natal areas, though some dispersal downstream typically occurs. The maximum extent that dispersal occurs downstream is not known. Spawning which occurs in higher gradient streams appears to result in a greater downstream dispersal of fry. In that case, the young move—or are displaced by high velocity flows—to low velocity habitats in reaches of lower gradient.

Another related distribution pattern is the association that juvenile coho have for physical cover. Cover types within the water column or overhead are preferred (wood, rooted macrophytes, roots, overhead structure), as opposed to substrate cover provided by cobbles or turbulence cover associated with velocity shears. Preferred cover types provide shelter from high water velocities and predators, and match feeding behaviors keyed to aquatic drift and terrestrial organisms on the water surface (instead of benthos feeding). In smaller streams, cover is not a strong determinant of habitat selection in summer, though association with it grows by summer's end. Physical cover appears to be a much greater determinant of habitat selection in large rivers, probably due to the likelihood for higher water velocities and more predators.

The affinity for low velocity habitats is particularly strong during winter. This season often brings rapidly changing, adverse conditions within a stream—both in coastal and interior regions—whether due to flow fluctuations or extreme cold and icing. Survival appears to be strongly related to how successful juvenile coho are in locating suitable refuge from harsh conditions. One characteristic of coho seen throughout their range is for some individuals within the population to move during fall to sites that offer some degree of refuge. The number of fish that move, and the extent of their movement, appears to be related to the suitability of their locations to provide shelter from high velocities. Movement seems to be volitional, or when flows are high, due to displacement. In dynamic rivers, redistribution to overwintering sites can be quite dramatic in terms of distances traveled and numbers of fish that move. Off channel sites (alcoves, ponds, groundwater channels) are particularly desirable overwintering habitats throughout the Pacific Northwest and California. These provide the highest survival rates compared to other habitats. Low velocity locations within main stream channels having undercut banks with exposed root masses or sites of large wood accumulations also provide refuge habitat. Side channels with low velocities and some form of cover are also used. Juvenile coho rarely use cobble substrate for overwintering cover, as commonly occurs for juvenile steelhead.

Lestelle et al. (2005) considered how these patterns of distribution would be manifested in a large river system, one with a fairly extensive floodplain along the mainstem river. For the sake of illustration, they compared the expected distribution pattern of coho salmon to one that could be expected for ocean-type Chinook (i.e., fall Chinook). The patterns, shown in Figures 69 and 70, are based on a summary of habitat use patterns given in that paper. The patterns are those that would be expected in a largely unaltered watershed. They are consistent with the conclusions being presented here.

Another set of utilization patterns showing how species use a stream system has been derived using the Intrinsic Potential Method (Agrawal et al. 2005). The method assumes that three indicators of landform and hydrology—channel gradient, valley width (degree of confinement), and mean annual discharge—constrain channel morphology and hence the potential of a reach to express habitat characteristics favorable for specific salmonid species and life stages. The method was originally developed for coho and steelhead in watersheds draining the Coast Range of Oregon (Burnett 2001; Burnett et al. 2003). Burnett's (2001) study was conducted in the Elk River (Southern Oregon), which is encompassed by the SONCC Coho ESU. Figure 71 displays suitability of stream reaches to support coho, Chinook, and steelhead using this method. If these patterns were to be recast in the form of Figures 69 and 70, they would yield similar patterns as seen in those figures.

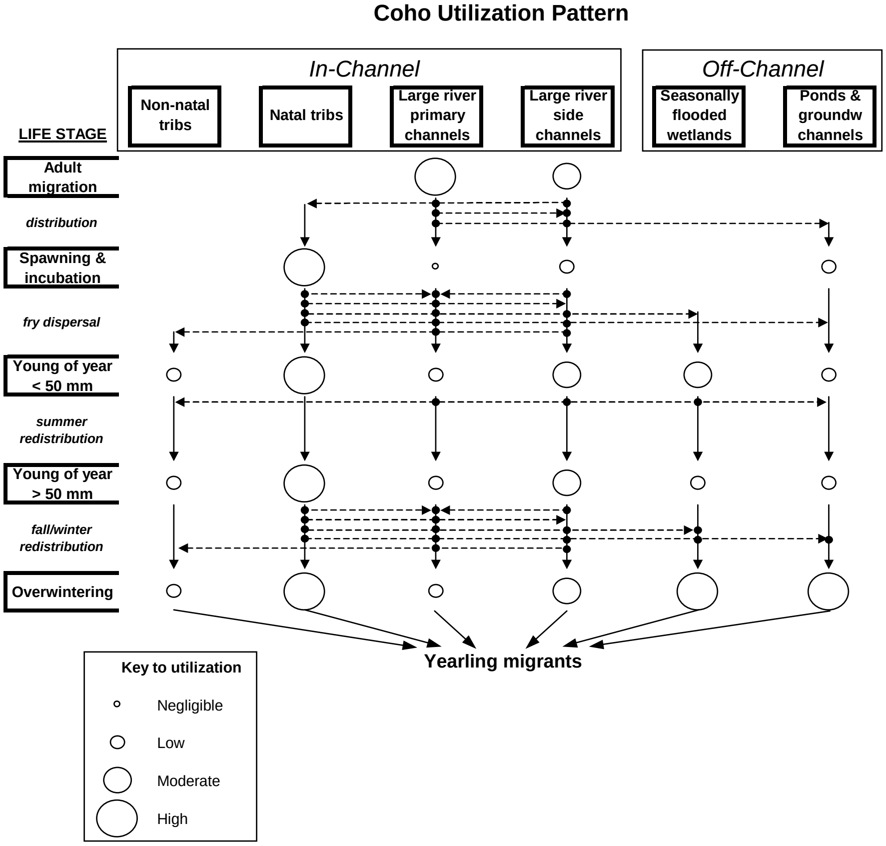

Figure 69. Summary of expected habitat utilization pattern for coho salmon in a generally unaltered large river system. A moderate to high spring runoff is assumed. It is assumed that the mainstem river is flowing across a wide floodplain. Circle size reflects relative amounts of production attributed to each area. Dashed lines show movements of fish from one area (dot) to another area (arrow). From Lestelle et al. (2005).

Variations on the central themes of coho life history exist and several types could affect habitat utilization patterns. Juvenile coho in the southern part of the range can exhibit a summer movement pattern different from what is seen further north. This movement pattern appears to be a redistribution to find thermal refugia. There is no evidence that fish in the southern region have a higher thermal tolerance than fish further north, though some greater tolerance may exist. Little or no movement by juveniles in mid summer is typically seen in more northern populations, but temperatures are less severe. Trapping in some streams in California and Oregon show that substantial numbers of fish can move in early to mid summer during periods of increasing temperature. While the fate of these fish has not been determined, some do successfully arrive at cooler water sites. It is unknown what level of mortality or loss in other performance measures might occur while moving to refugia or the distance that fish can travel. Nielsen (1992a, 1994) described a foraging phenotype (termed “early-emerging”) in Northern California that appears to provide some measure of adaptation to high temperature. These fish display no obvious dominance hierarchy and have a crepuscular (i.e., associated with dawn or twilight) foraging pattern, where they move out from refuges to feed then return. Nielsen (1992a) concluded that this foraging phenotype is the dominant one during periods of drought, when streams are particularly warm with limited flow. Perhaps this phenotype is suited for movement during early to mid summer to seek out refugia. Their larger size than other foraging phenotypes would be advantageous for such movement. Habitat utilization in warm water streams will reflect overlapping areas of tolerable temperatures and water velocities.

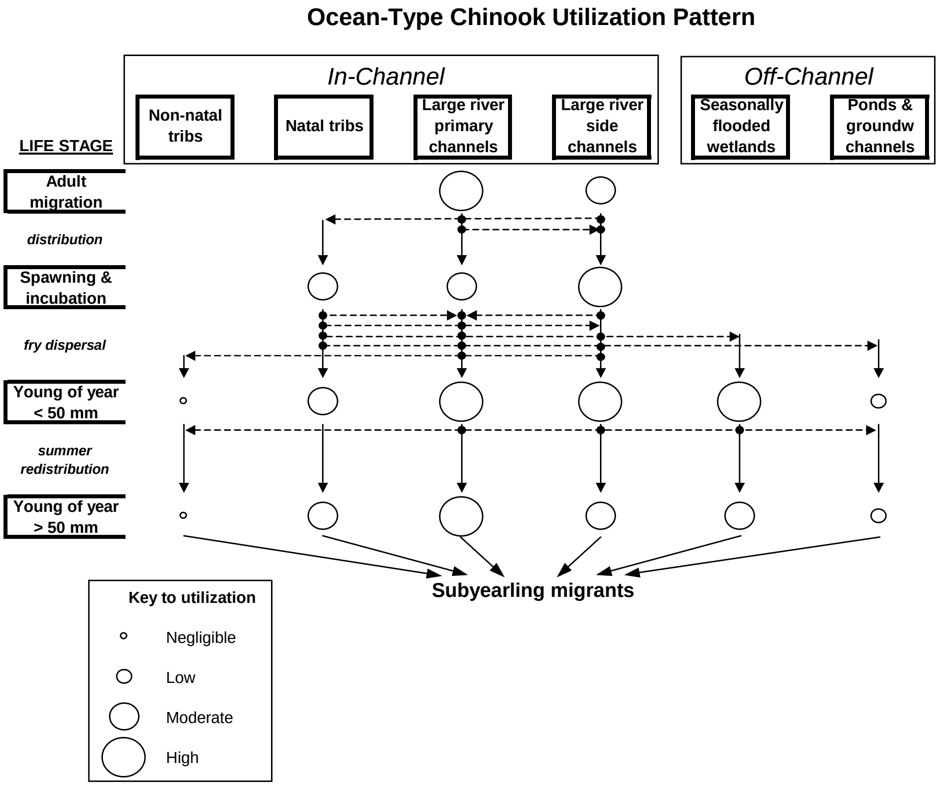

Figure 70. Summary of expected habitat utilization pattern for ocean type Chinook salmon in a generally unaltered large river system. A moderate to high spring runoff is assumed. It is assumed that the mainstem river is flowing across a wide floodplain. Circle size reflects relative amounts of production attributed to each area. Dashed lines show movements of fish from one area (dot) to another area (arrow). From Lestelle et al. (2005).

Another life history variation is seen in differences in body morphology and fin sizes between coastal and interior populations and associated swimming performances (see Taylor 1985a and b). It is not known how far south such a coastal-interior distinction might extend. Do both forms exist within the Klamath River basin? There is no evidence that these morphological forms have different habitat requirements, i.e., does the interior form, which has greater swimming stamina, have less of an affinity for slow water habitats than the coastal form? Or do cover type preferences differ between the forms? Evidence shows that both forms exhibit the same selection for slow water habitat types and cover types (e.g., Bratty 1999). Taylor and McPhail (1985a and b) suggest that the adaptive benefit of these variations to interior coho (more streamlined body, smaller fins, greater swimming stamina) is in their ability to negotiate long in-river migrations, both as smolts and adults. Richard Bailey's (Fisheries and Oceans Canada, *personal communications*) hypothesis that Thompson River juvenile coho travel from the upper Thompson River to the lower Fraser River to overwinter recognizes that these fish may be adapted for a fall redistribution on such a scale. An interior-type body form would presumably aid upper Klamath River coho in their movements within the mainstem Klamath River, if this body form occurs there. This author, on seeing the nature of the mainstem Klamath River downstream of the Scott River, wondered whether juveniles could successfully negotiate the distance and turbulent water conditions to travel to the very lower parts of the river to overwinter. In light of what Thompson River fish would encounter during a fall redistribution of the scale mentioned, the Klamath scenario would be much more feasible. A multi-year study was initiated in fall 2006 to investigate the fall redistribution and overwintering patterns of juvenile coho in the lower Klamath River and the lower reaches of its small tributaries.[29]

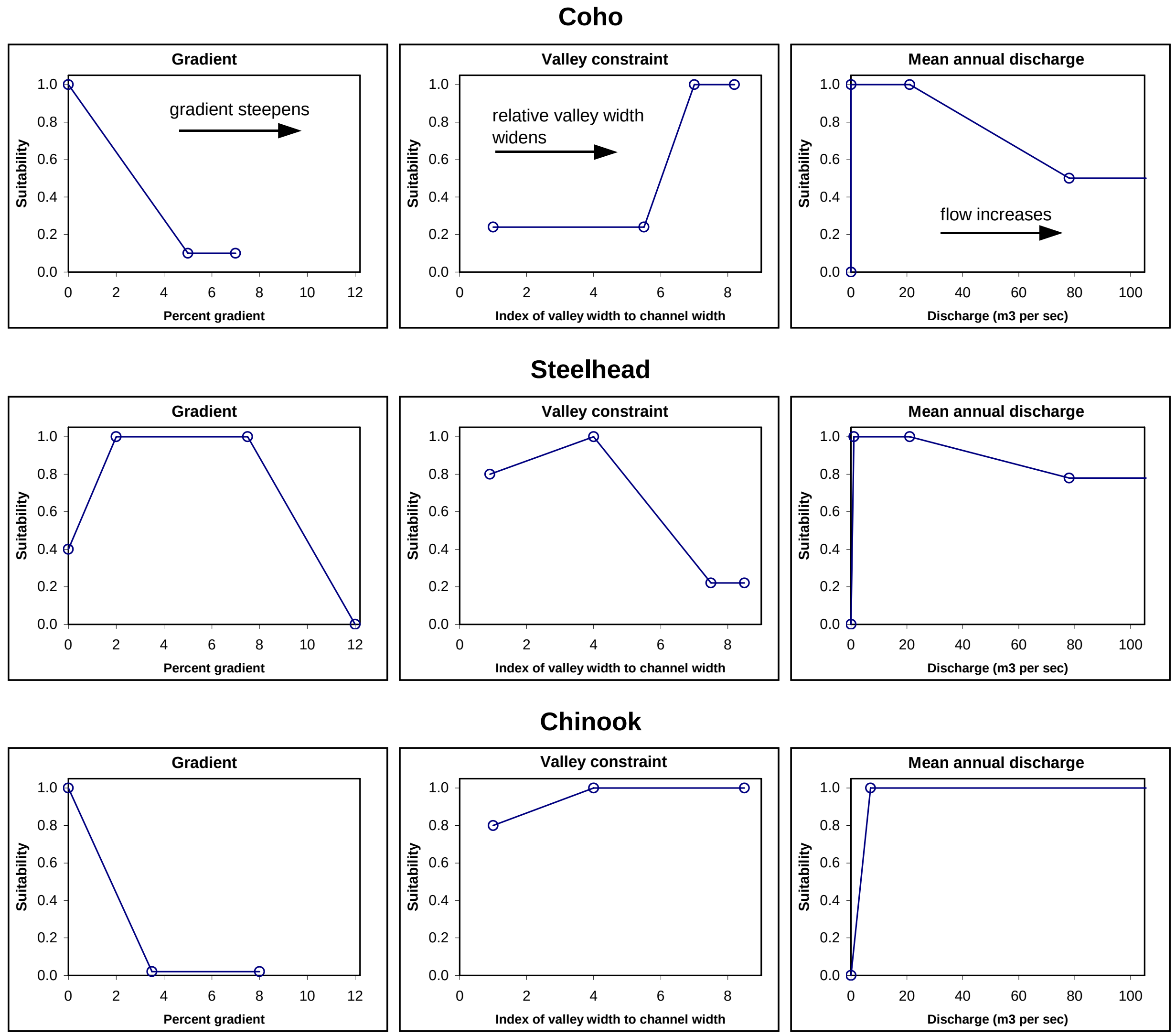

Figure 71. Suitability curves for each of the three components of the Intrinsic Potential Method (gradient, valley constraint, and discharge) for coho, steelhead, and Chinook juveniles. Recreated from Agrawal et al. (2005).

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[29] / The study is being conducted by the technical staffs of the Yurok and Karuk tribes and is funded by the Bureau of Reclamation.

Perhaps the most obvious variation in life history patterns seen in southern coho populations is their ability to delay river entry timing during periods of drought or late arriving rainfall, particularly when sand bars are formed that block entry. In the extreme, river entry can apparently be stalled several months. This would thereby delay spawning and would presumably have cascading effects on emergence timing and subsequent growth and habitat use patterns. This may be a factor in variation of freshwater age structure seen in Prairie Creek (see Bell et al. 2001). Sand bars can often block entry to smaller streams in Northern California but on occasion also form on large rivers in that region such as the Klamath River. While these features may only rarely delay entry timing into rivers like the Klamath (Walt Duffy, Humboldt State University *personal communications*), it is noteworthy that delayed rainfall can affect the ability of adult coho to enter spawning tributaries in such large rivers. In such cases, delayed rainfall can force adults to spawn to a greater extent in the mainstem; spawning maturation would likely not be delayed.[30]

Coho salmon exhibit a wide variety of life history patterns in large, diverse watersheds. These patterns are phenotypic expressions of the interaction of genotype and environmental factors. Among others, these factors include flow characteristics, gradient, water temperature, and habitat structure. Diverse phenotypic expressions enable the species to utilize a wide variety of physical habitats across a range of gradients, habitat sizes, and qualities—but within limits set by the species' genetic blueprint. To understand the performance of a species in any watershed requires a life history perspective, seen across the full cycle (Lichatowich et al. 1995).

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[30] / Once adult coho enter freshwater, maturation would probably develop on a normal schedule (see Hodgson and Quinn 2002).

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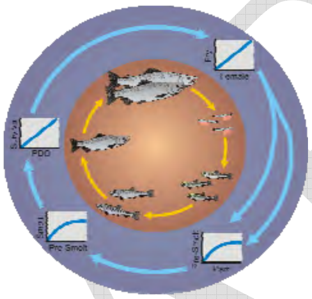
Appendix 3-B

Klamath Coho Integrated Modeling Framework, Draft Version 1.1 Model Report Prepared by: Cramer Fish Sciences and submitted to the Bureau of Reclamation, Klamath Basin Area Office, October 17, 2007.

Klamath Coho Life-Cycle Model

Draft Version 1.1 Model Report



Prepared by:

Cramer Fish Sciences

Submitted to:

The Bureau of Reclamation, Klamath Basin Area Office

October 17, 2007

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Introduction

Purpose

The Klamath coho life-cycle model was developed by an expert team of fisheries scientists at Cramer Fish Sciences (CFS) to predict the effects of Bureau of Reclamation (Reclamation) operation of the Klamath Project on natural production of coho salmon within the Klamath Basin. These predictions are needed to evaluate how different water management scenarios might affect production and sustainability of Klamath River coho salmon, which are listed as “Threatened” under the U.S. Endangered Species Act (ESA). Data collection efforts on salmonid populations and stream conditions in the Basin have been scattered among numerous tribes, government agencies, and resource conservation districts. Until now, comprehensive analysis of salmonid population dynamics to distinguish the effects of Reclamation flow management on coho salmon was not possible. Such an analysis is needed for the ESA consultation between Reclamation and NOAA Fisheries to demonstrate with clear substantiating evidence that Reclamation will apply a flow management strategy that will not jeopardize the continued existence of coho salmon.

Life-cycle modeling was chosen to provide a quantitative framework that can accumulate effects of flow on multiple life-stages of coho salmon that occur at a variety of times and locations in the basin. By tracking the abundance and survival of coho through successive life-stages, life-cycle modeling makes it possible to integrate effects at specific times and places to examine their cumulative effect at the population level. Most naturally-produced coho in the Klamath Basin spawn and rear in tributaries, but all must migrate to and from the ocean via the mainstem Klamath River. Thus, the model tracks spatially and temporally explicit information, such that tributary populations and the factors affecting them can be distinguished from the effects of flow and temperature on coho in the Klamath mainstem.

This report accompanies Version 1.1 of the model and provides an overview of the Klamath coho life-cycle model structure, a synopsis of the supporting biology used to develop the model structure, results demonstrating model outputs and sensitivity analyses. The Klamath coho life-cycle model is intended to evolve over time along with the growing body of best available science. Reclamation has planned for annual updates following analysis of data from ongoing studies. This report and Version 1.1 of the model should be viewed as drafts because the model structure and some parameters will be revised as part of the continuing public review process.

Review Process

A series of eight technical memorandums were released, each describing a piece of the life-cycle model, to agencies, tribes and Klamath research entities in an attempt to solicit as much feedback as possible during model development. CFS provided response to comments via Technical Response Briefs (TRBs). In total, eight TRBs were disseminated. Reviewers will also provide feedback on Version 1.1 of the model and the Version 1.1 Report. CFS will consider any timely comments received for inclusion in future versions of the model. A workshop will also be held to discuss version 1.1 of the Klamath coho life-cycle model with external reviewers. Figure 1 provides a timeline of the model review process. For more information on the technical review process, visit the project website at: http://www.fishsciences.net/projects/klamathcoho/index.php

Figure 1. Klamath coho life-cycle model review timeline.

Version 1.1 Report Structure

This report is structured to guide the reader through the Klamath coho life-cycle model by life-stage from adults entering the river, parr production and dispersal, smolts reaching the estuary and adult recruits returning to the river. At the beginning of each report section you will find a detailed diagram highlighting the components of that section. An overview of the complete model is given in Figure 2. This overview should help readers orient the fit of more detailed diagrams for specific life-stages into their context within the full life-cycle.

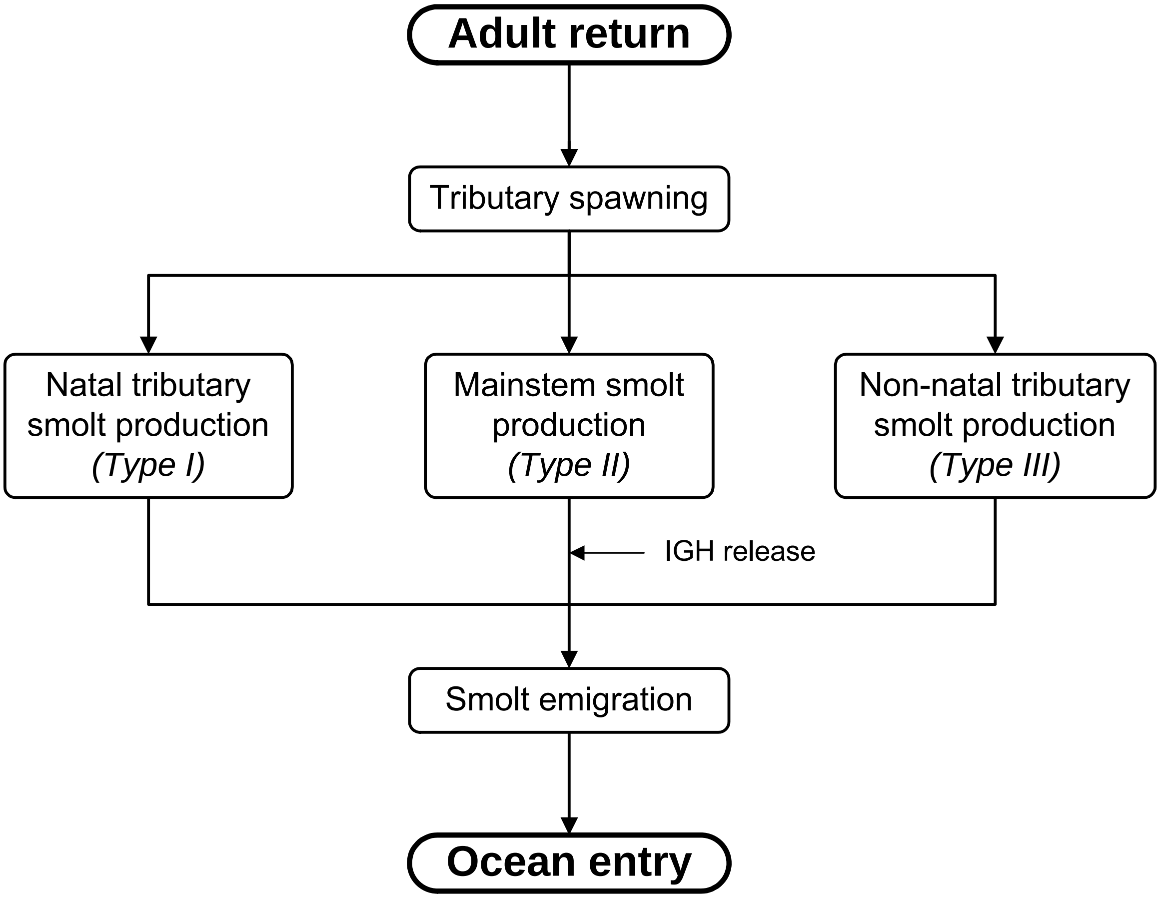


Figure 2. Overview diagram of major Klamath coho life-cycle model components.

Klamath Coho Life-Cycle Model Summary

The Klamath coho life-cycle model integrates a series of mathematical equations which calculate life-stage survival and abundance based on current coho population structure and the influence of certain environmental variables such as flow and temperature. The entire Klamath coho life-cycle model structure is outlined in Figure 3. A complete list of the equations and parameter values used in the model are identified in Appendix 2. The geographic extent of the Klamath model is from Iron Gate Dam to the estuary and includes all the major tributaries that occur in-between (hereafter referred to as the Lower Klamath Basin). The model examines the effect of different environmental variables on specific life stages including: adult, parr, and smolts. The model breaks the coho life-cycle into specific life-stages so that effects of water management can be evaluated for each life-stage. Change in coho production at each life-stage is the metric used to evaluate project effects.

The model divides the Lower Klamath Basin into reaches. Dividing the lower basin into reaches provides sufficient spatial resolution to capture the different flow and thermal regimes experienced by fish in different portions of the project area. We focused on the effects of temperature and flow in the mainstem Klamath because that is the area directly influenced by the project.

Certain functions within the model operate on what we term a “cohort” basis. We use the term “cohorts” to refer to specific groups of fish that spawn, rear, or emigrate together on a weekly or biweekly time-step. For example, we refer to adult coho that spawn between October 1 and 6 as one cohort, and those that spawn between October 7 and 13 as another cohort. This convention helps us describe the effects of temperature and flow on temporally explicit groups of fish. The time period for each cohort, and the proportion of the population within that cohort are defined by either spawner migration timing, or smolt emigration timing distributions.

The remaining sections of this report provide additional detail about the model structure and supporting biology used to develop model functions.

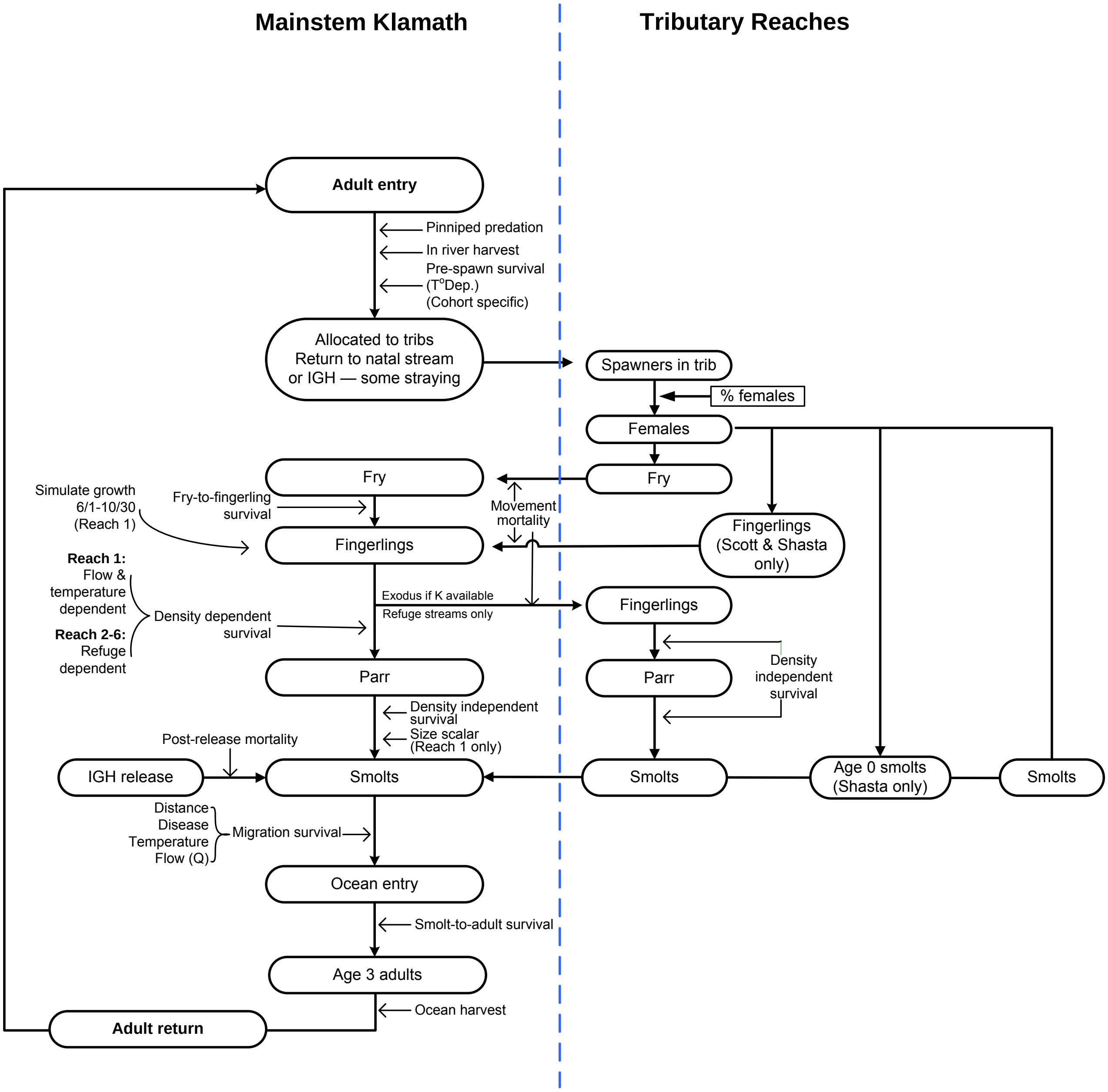


Figure 3. Conceptual diagram of the Klamath coho life-cycle model. Red indicates values that are scaled within the model depending on temperature and/or flow conditions. Green indicates survival rates set prior to model runs.

Model Spatial Structure

The Klamath coho life-cycle model tracks coho production in 16 spatial units (i.e. model reaches; Figure 4). The six mainstem reaches are: 1) Iron Gate to Shasta River, 2) Shasta River to Scott River, 3) Scott River to Portuguese Creek, 4) Portuguese Creek to Salmon River, 5) Salmon River to Trinity River and, Trinity River to Klamath River at Turwar. Distances from the river mouth to the midpoint of each model reach are given in Table 1. The model accounts for tributaries by lumping small tributaries into groups and treating those groupings as separate units. There are six miscellaneous tributary units, one per mainstem reach. These are referred to as: Mainstem Tributaries 1-6 (MST1, MST2, etc.). Finally, the four large tributaries that flow into the lower basin are treated separately in the model and include the Shasta, Scott, Salmon, and Trinity Rivers (Figure 4). Temperature and flow effects on coho survival are estimated at the model unit scale before being accumulated for the entire Klamath coho population. Model spatial units are based on the historic coho population structure (Williams et al. 2006) and changes in temperature and flow near major tributary entry points (Figure 5, Figure 6 and Figure 7).

Table 1. Distance from the river mouth to the midpoint of each model reach.

Reach	Rm	Rkm
MS1	184	296
MS2	160	257
MS3	136	219
MS4	97	156
MS5	55	89
MS6	24	39

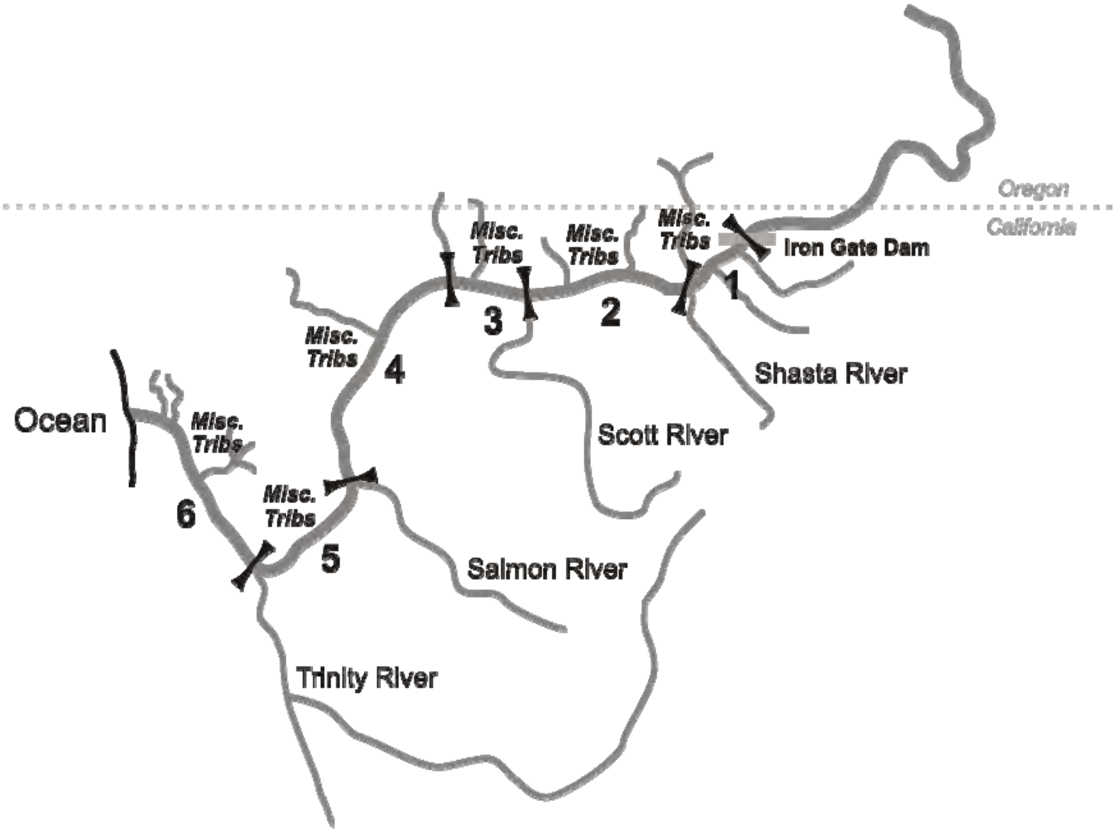


Figure 4. Map of the Lower Klamath River Basin denoting the 16 model reaches.

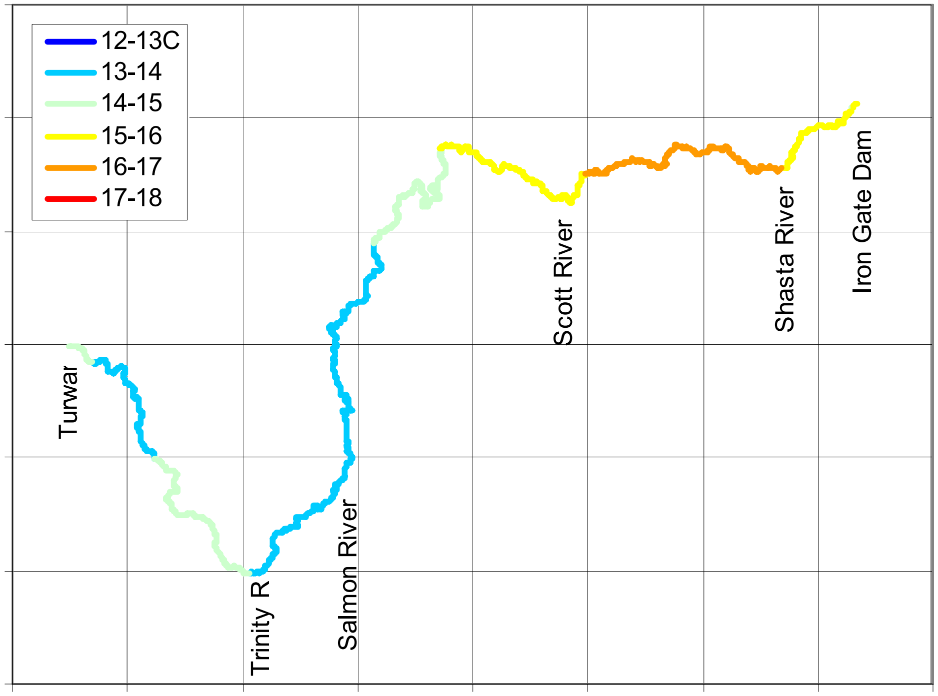


Figure 5. Plan view of daily mean water temperatures in the Klamath River from Iron Gate Dam to Turwar, modeled for June 1, representing average water and weather conditions.

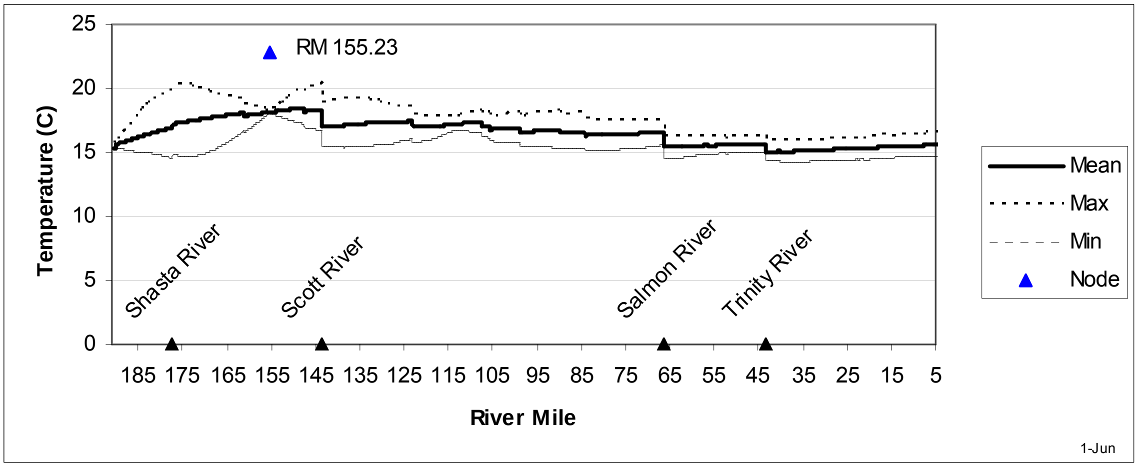


Figure 6. Example of longitudinal temperature plot: Klamath River on June 1, 2004, temperature scale from 0 – 25°C

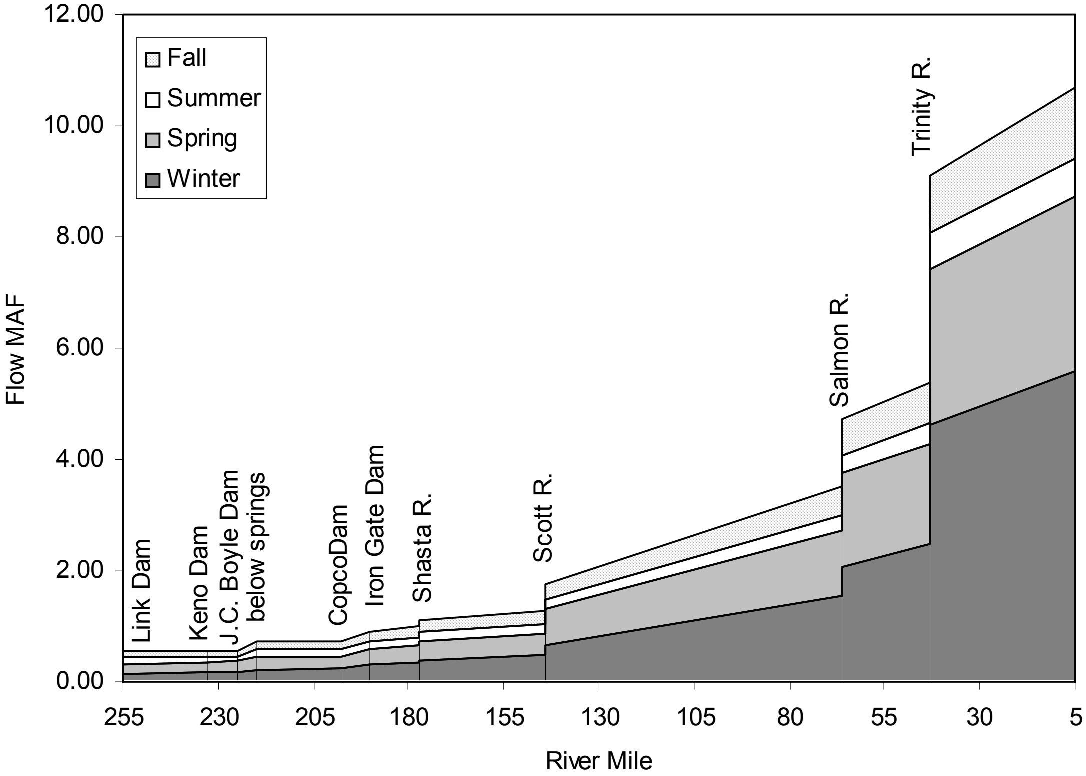


Figure 7. Example of flow simulation: seasonal flows in the Klamath River from Link Dam to Turwar Creek: 2004.

Spawner Survival

Losses in spawner survival accumulate incrementally as adult coho migrate from the estuary to their natal spawning grounds. The model accounts for these losses by assigning different mortality rates from pinniped predation, in-river tribal harvest, and temperature-dependant pre-spawning survival (Figure 8). Figure 9 provides spatial context for application of the adult life-history functions within the model.

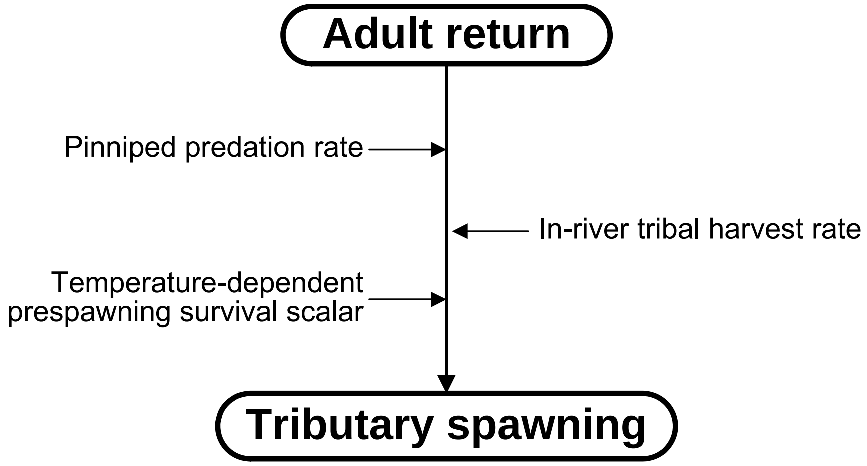


Figure 8. Summary of spawner survival component of the Klamath coho life-cycle model.

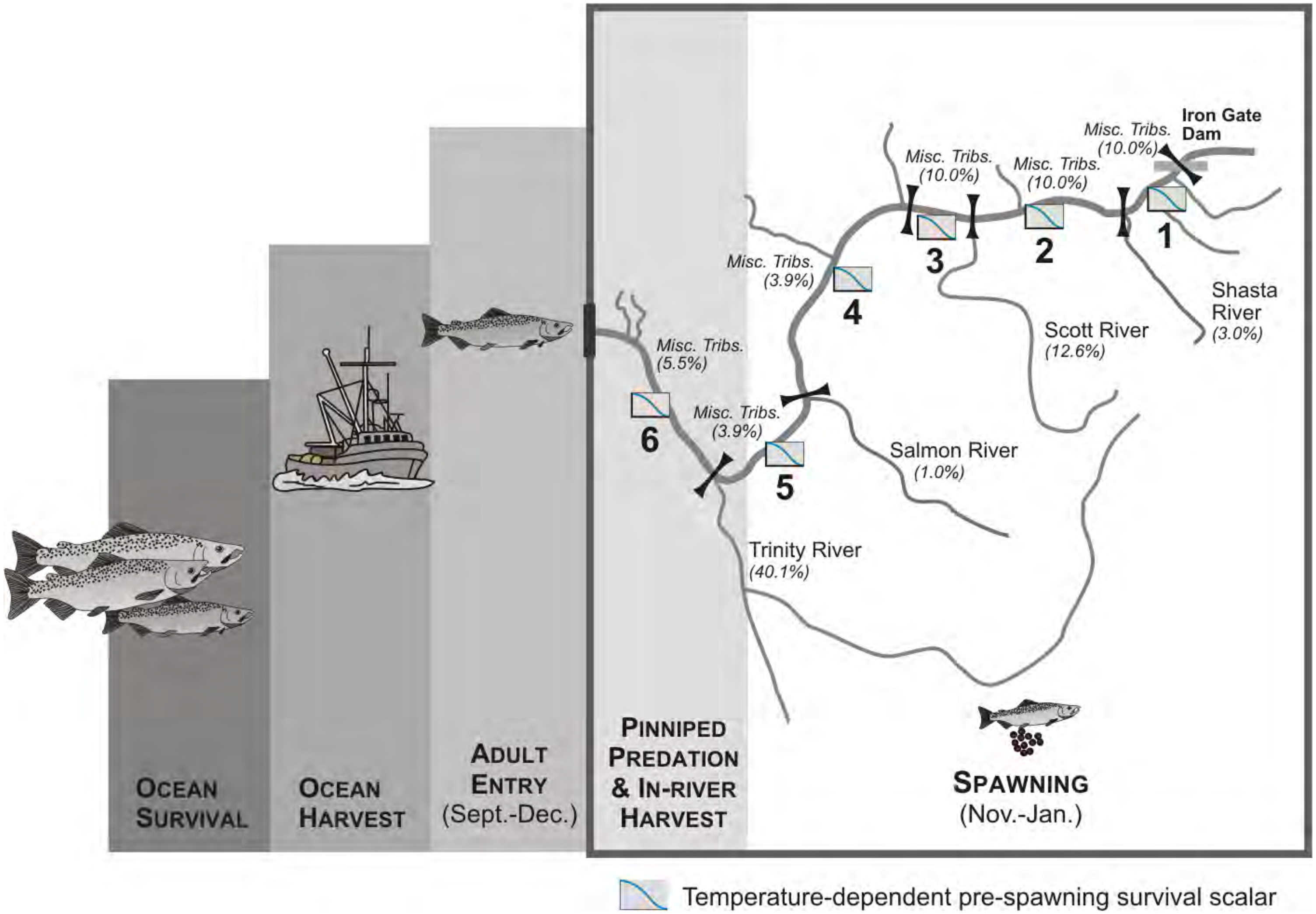


Figure 9. Spatial application of functions within the Klamath coho life-cycle model affecting adult survival. Percentage values represent the proportion of the spawning population allocated to each model reach during the first three brood cycles.

Adult Entry and Migration

The model tracks "weekly cohorts" of adults as they enter the Klamath River between September and December. Dates of passage are important, because they determine the exposure temperatures, which determine the mortality rate before spawning. These weekly cohorts refer to groups of fish that enter the river and migrate through the mainstem during the same week. Thus, coho that enter the river in the first week of September are assigned a different temperature experience than those that arrive in the first week of October (Table 2).

Table 2. Default peak migration timing through the Klamath River mainstem for adult coho by reach of spawning tributary location used in the coho life-cycle model.

Spawning tributary location	Peak Klamath mainstem passage timing	
	Week of river entry	Exit week from mainstem to tributary
Reach 1	October 5 - 11	November 9 – 15
Reach 2	October 19 - 25	November 16 – 22
Reach 3	October 12 - 18	November 2 – 8
Reach 4	October 12 -18	November 2 – 8
Reach 5	October 12 – 18	October 26 – November 1
Reach 6	September 28 - October 4	October 5 - 11

The temporal distribution of coho passage through each mainstem reach was estimated on a weekly time step by comparing timing of hatchery coho salmon in the Lower Klamath River (Yurok Tribal harvest data, unpublished) with passage of hatchery fish at Willow Creek weir (Trinity River) and Iron Gate Hatchery (IGH). Overall passage timing of marked and unmarked coho through the tribal fisheries in the lower Klamath River were similar (Technical Memorandum 1). Little information is available regarding the timing of unmarked fish into the upper reaches of the mainstem, so hatchery fish timing at IGH is used as a surrogate. Approximately 50% of the harvest of Trinity River hatchery fish in the Lower Klamath River occurs by the first week of October, and the migration of hatchery fish through the Willow Creek weir occurs about one week later (Figure 10, top). About 50% of the harvest of IGH coho salmon in the lower Klamath River occurs by the second week of October, and the timing at IGH occurs about 5 weeks later (Figure 10, bottom). This information suggests that 1) coho destined for spawning areas in the upper basin tend to enter the river later than those in the lower basin (e.g. Trinity River); and 2) coho salmon take about a week to migrate up to the Trinity River, and about 5 weeks to migrate from the estuary to Iron Gate Dam.

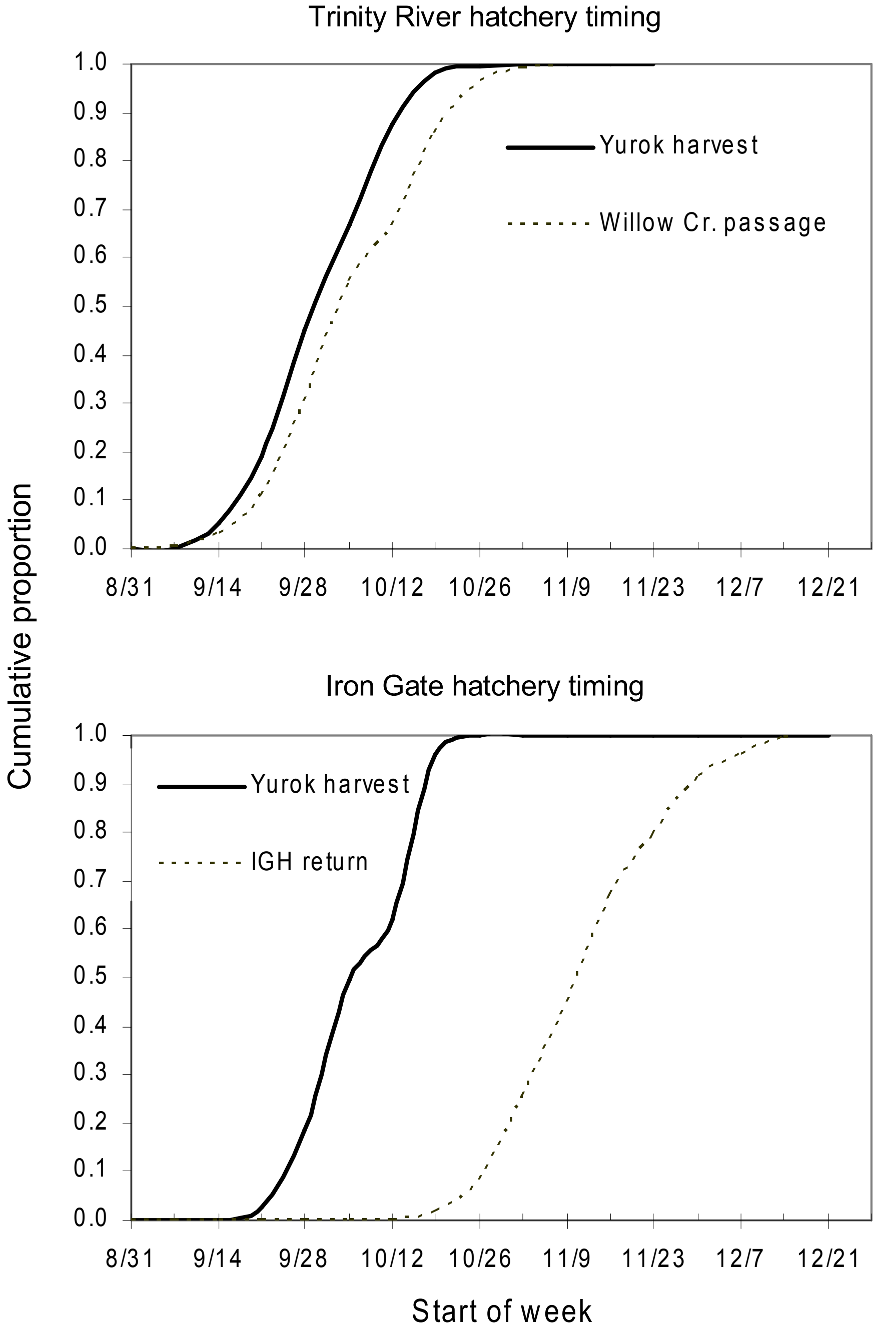


Figure 10. Cumulative proportion of Trinity River hatchery and Iron Gate hatchery coho harvest in the Yurok tribal fishery compared to the return at Willow Creek weir (top), and Iron Gate hatchery (bottom), 2000-2005. IGH data from 2002 was excluded because no IGH hatchery coho were sampled in the fishery due to low numbers of coho returning to IGH that year.

The timing of coho migrating from the mainstem Klamath into a reach tributary was based on data from adult radio telemetry studies, Willow Creek weir counts, Shasta River weir counts, Bogus Creek weir counts, and Iron Gate Hatchery returns. Specifically, we used Willow Creek weir counts to determine the migration timing into the Trinity River (Reach 6). Limited data was available for migration timing between the Trinity and Scott Rivers (Reaches 3-5). Based on limited coho telemetry data from the middle Klamath (Karuk Tribal data, unpublished), and timing of IGH fish (Figure 10), we assumed that coho took one week to migrate from the Trinity River to Portuguese Creek (Reach 5), and then one more week to arrive at the next two reaches (Reaches 3 and 4). Thus, all weekly cohorts from the earliest to the latest at river entry were lagged by weekly amounts to represent their passage through upstream reaches. The full temporal distribution of passage through each reach was represented by a normal curve with a mean equal to the assumed peak passage date and standard deviation as observed at the Willow Creek Weir.

Passage timing through Reach 2 (Scott to Shasta River) was based on Shasta River weir counts. The migration timing from Shasta River up to Iron Gate Dam was determined using Iron Gate Hatchery return data. Figure 10 provides the weekly proportion of the adults entering spawning tributaries.

The temporal distribution of river entry for specific groups of coho returning to different portions of the Basin was back calculated from the time of arrival to the vicinity of the spawning area. Transit time through downstream reaches was assumed to be as previously described. For example, the peak week of river entry for coho destined to spawn in reach 1 spawning tributaries occurs during the week starting October 5 (Table 2). That cohort will migrate through the Klamath for 5 weeks prior to reaching their spawning tributary during the week of November 2 (Figure 11-1; Table 2).

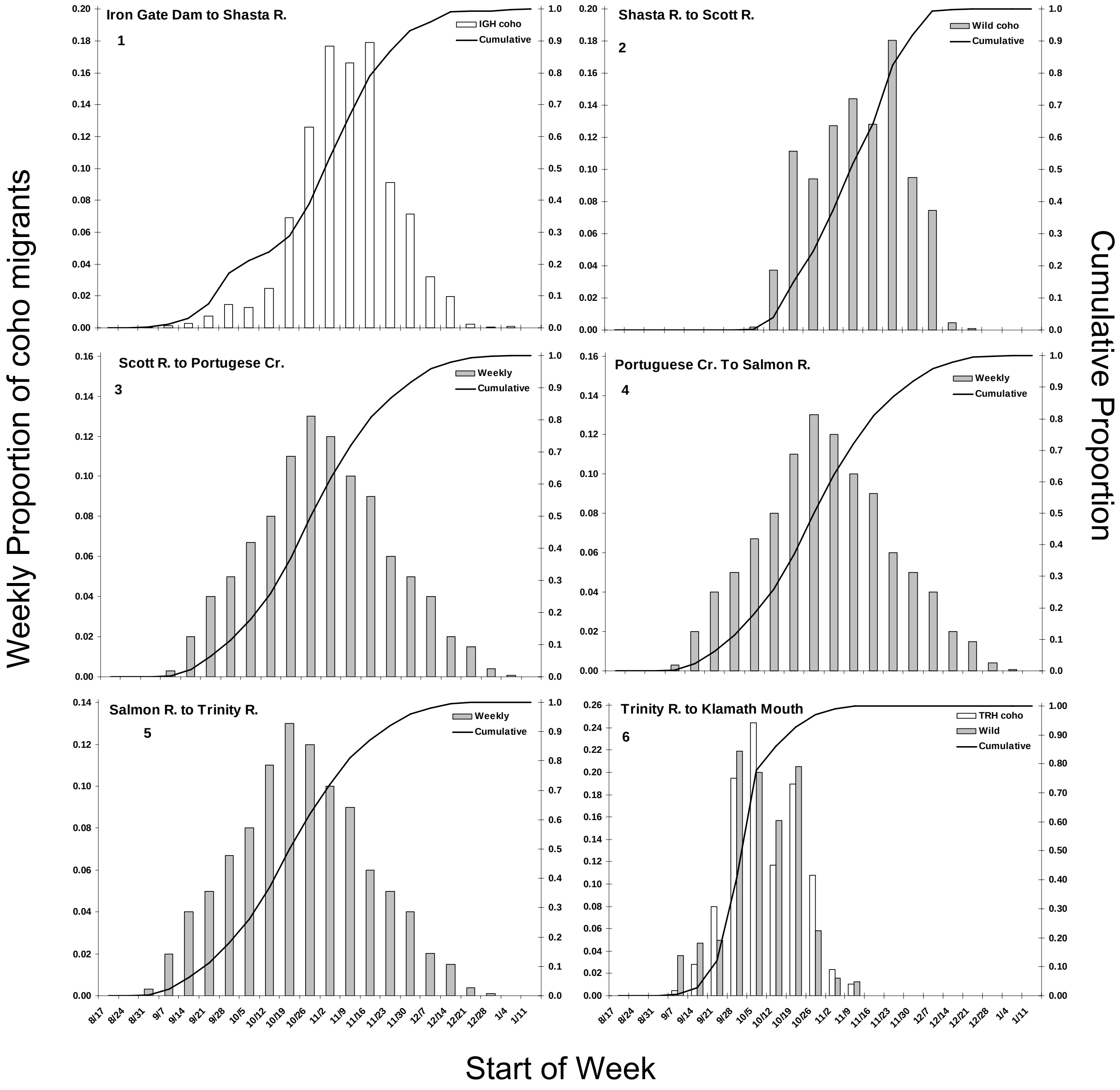


Figure 11. Average weekly timing of coho into spawning tributaries located within the six mainstem reaches of the Klamath River.

Pre-spawning Mortality

Pre-spawn survival rates for coho are defined by a logistic function with a lower temperature threshold of 16°C (temperature at which survival is 95%, Figure 12). Survival decreases rapidly above 16°C, approaching an upper lethal temperature threshold of 26°C (survival is 5%). Survival rates are applied to each weekly cohort as they migrate through the Klamath mainstem. Each cohort is assigned the highest mean weekly temperature experienced during migration. We chose 16°C as the lower threshold because it represented a midpoint of adult threshold temperatures effects compiled by Marine (1992) and others cited in USEPA (2001). The upper lethal temperature at which survival approaches zero was set at 26°C based on Marine (1992) and USEPA (2001). The function for the effect of temperature on pre-spawning survival is:

Equation 1)
$$S_{Prespawn,i} = \frac{1}{1+e^{-12.37+0.59T_i}}$$

where T_i is mean water temperature in week *i,* the warmest week experienced by the cohort.

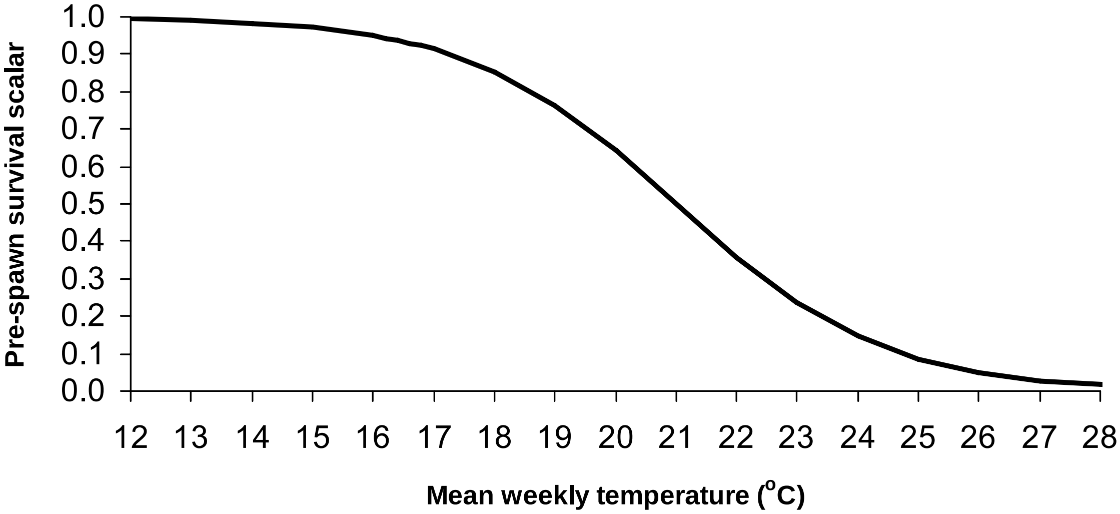


Figure 12. Function representing the simulated effect of temperature on pre-spawning survival. Temperature is the maximum mean weekly temperature experienced during migration.

In-River Harvest and Predation

Adult cohort survival rates are decremented to account for pinniped predation, in-river Yurok Tribal harvest, and Karuk Tribal harvest. Karuk Tribal harvest only applies to fish migrating upriver of Ishi Pishi Falls. The default mortality settings are 1.7% for pinniped predation, 4.2% for Yurok Tribal harvest, and 0.3% for the Karuk Tribal harvest. Yurok Tribal harvest was estimated by averaging the maximum harvest rates from 1992 through 2004 (Williams and Hillemeier 2005). Ishi Pishi Falls harvest rates were more difficult to quantify. We selected the default value from a range of unpublished harvest estimates (0.0% - 0.35%). Finally, we averaged estimates from 1997 (Hillemeier 1999) and 1999 (Williamson and Hillemeier 2001) to establish the default pinniped predation rate in the model.

Spawner Distribution

The model distributes spawners back to their natal tributary or IGH. The model was seeded with three years of coho spawner abundance (Table 3) to initiate simulations. The abundance and distribution of these spawners was taken from observations described in Tech Memo 1 (CFS 2006). After the first three years, natural spawners were distributed within the basin in proportion to the smolt production in each spawning tributary, as described in the smolt production section of this report. The percentage of female spawners is set at 55%.

The model assumes a 10% stray rate for IGH fish. Of those, 70% are distributed to Reach 1 tributaries, 10% to the Shasta River, and 20% to Reach 2 miscellaneous tributaries. These hatchery strays are then mixed with the natural spawners, but their production is discounted by 50% to account for reduced fitness of hatchery fish. Trinity River Hatchery fish are assumed to only stray within the Trinity Basin.

Table 3. Summary of initial numbers of spawners and distribution by model reach. These values were used to populate the model for the first brood cycle (i.e. years 1-3).

Model Reach	Natural Adults	IGH Strays
Total Adults Entering	5,000	120[a]
MST1	0.100	0.700
MST2	0.100	0.200
MST3	0.100	0.000
MST4	0.039	0.000
MST5	0.039	0.000
MST6	0.055	0.000
SHASTA MS2)	0.030	0.100
SCOTT (MS3)	0.126	0.000
SALMON (MS5)	0.010	0.000
TRINITY (MS6)	0.401	0.000
TOTAL	1.000	1.000

[a] This estimate was based on an assumed 10% stray rate applied to an average IGH return of 1,200 fish.

Spawning in the Klamath mainstem is sparse and assumed not to be sustainable due to low survival of eggs and juveniles. Therefore, the model does not accumulate production from mainstem spawning into future generations. Coho salmon spawn mainly in small streams or side channels to larger rivers (Edie 1975, Lichatowich 1999, Behnke 2002, Moyle 2002, Lestelle 2007). These locations typically have smaller channels (3-14 m) and lower flows with moderate gradient; mostly 1-2% but as high as 4% (Edie 1975, Lestelle 2007). A small number of coho salmon spawn in the mainstem of the Klamath River each year, but the origin of these fish and the survival of their eggs are unknown. Between 2001 and 2005, a total of 46 coho redds (ranging between 6 and 21 per year) were counted in the Klamath River mainstem. All of the redds were located within 1.5 km of a tributary, and most were concentrated within 20 km downstream of Iron Gate Dam (Magneson and Gough 2006). The close proximity of IGH to Iron Gate Dam, and similar observations of mainstem spawners close to hatcheries immediately downstream of dams in other rivers (McPherson and Cramer 1981, Lestelle 2007) suggests that these fish are likely hatchery strays. Others have suggested that these are natural fish attempting to utilize historic spawning habitat now blocked by Iron Gate Dam (Magneson and Gough 2006). Regardless of the origin of these fish, their scarce and fluctuating occurrence suggest their contribution to the coho population is negligible.

Smolt Production

The model accounts for three juvenile rearing pathways that lead to natural production of smolts; juveniles that rear within their natal tributary until they reach smolting (type I smolts), juveniles that emigrate from tributaries as fry or fingerlings to rear in the mainstem Klamath River (type II smolts), and juveniles that emigrate from tributaries into the mainstem Klamath but then enter non-natal tributaries of the Klamath to rear until smolting (type III smolts) (Figure 13). More detailed diagrams are provided within each section describing the different types of smolt production. Various life stages of juvenile coho including fry, fingerlings, parr and smolts are frequently referred to within the text of this section and are treated distinctly in the model. Table 4 summarizes the periodicity of these life-stages and distinctions made in the model.

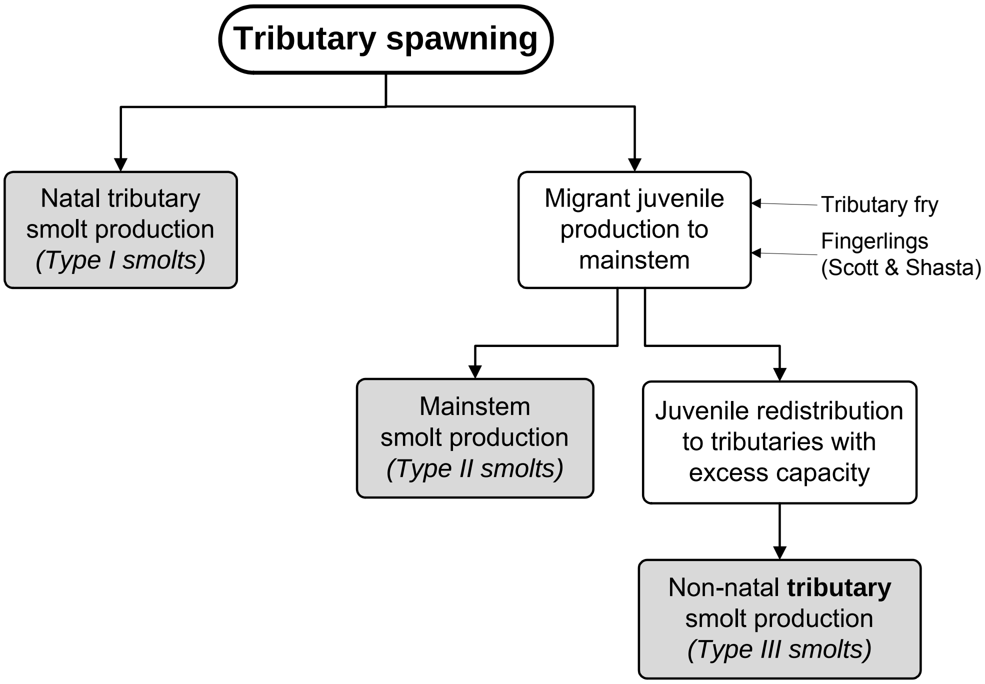


Figure 13. Overview diagram of the three smolt production pathways within the Klamath coho life-cycle model.

Table 4. Juvenile coho life stages distinguished within the Klamath life-cycle model.

Life-stage	Time period	Model Distinctions
Fry	February-April	newly emerged
Fingerling	May-June	juveniles migrating at the onset of summer habitat constriction
Summer Parr	July-October	summer age-0 rearing
Winter Parr	November-February	presmolts in winter
Smolt	March-May	active migrants enroute to ocean

The number of smolts produced from each of these life-history pathways is assumed to be limited by the capacity of the habitat and the productivity, or survival rate, of the fish until they reach smolting. Capacity and productivity are parameters used to describe a stock-recruitment function. Values for these parameters are typically estimated statistically by fitting a relationship between a time series of paired smolt and spawner abundance estimates. However this data is lacking in the Klamath Basin, so parameters had to be estimated by other methods. The capacity was estimated from stream habitat information in the Klamath Basin, to which we assigned the densities of juvenile coho that a given quality of habitat could support. The productivity, or number of smolts produced per spawner, was deduced from estimates of smolts per spawner across many other coho populations in the region.

We begin by describing the derivation of the baseline parr capacities within the basin because these form the basis for the stock-recruitment functions that follow. Next, we describe the stock-recruitment functions for the three types of smolt production: natal tributary smolts; non-natal production in the Klamath mainstem; and, non-natal production in tributaries. Spawners in tributaries are the source of juveniles for all of these life-history pathways.

Baseline Summer Parr Capacity (K_{parr})

We estimated the baseline summer parr capacity (K_{parr}) for all tributaries and mainstem reaches included within the potential range of coho rearing using the modified Habitat Limiting Factors Model (HLFM) originally described by Nickelson et al. (1993) and Nickelson (1998). This model was used to assign maximum summer rearing densities to each habitat unit type (e.g. pools, glides, riffles, cascades). These densities were multiplied by the unit area to determine the maximum number of parr supported within each unit type. The latest version of HLFM (Version 6.1) applies a scalar that assigns progressively lower rearing densities with increasing wetted width of the habitat. This scalar is described by the equation:

Equation 2) $W = 59.75 * \text{width}^{2.54}$.

This scalar is based on summer snorkel survey data collected by the Oregon Department of Fish and Wildlife (ODFW) in Oregon coastal basins. Because the HLFM was based on mark-recapture estimates (Nickelson et al. 1992), we divided the ODFW snorkel densities by 0.47 to calibrate them to mark-recapture estimates (Rodgers et al. 1992). We then used rearing densities in monitoring areas where the average density in streams <10m in width had average densities of at least 1 fish/m^2, the conditions assumed to represent full seeding by Nickelson et al (1992). This approach assumes that if small streams of a basin are fully seeded, then the ratios between densities in large streams and the small streams will reflect differences due to stream size and not seeding level.

The potential range of coho rearing was determined by refining the historical distribution of Klamath coho as defined by NOAA Fisheries (Williams et al. 2006), which excluded any habitat upstream of reaches with greater than 7% gradient. First we removed stream sections upstream of anthropogenic barriers such as dams and impassable culverts. In addition, we excluded any habitat that fell within the 21.5 ˚C temperature mask assigned by NOAA Fisheries (Williams et al. 2006) except in areas where coho are known to rear. We also removed any streams from the potential distribution of coho rearing that were not included in Hassler et al. (1991) or Brownell et al. (1999), which describe the current distribution of coho salmon in the Klamath Basin. Finally, we removed any streams with an intrinsic potential (IP) less than 0.3, which resulted in removal of 49 reaches totaling 133 km or < 4 % of the total potential coho distribution in the Klamath based on the NOAA IP database. This latter IP mask was an attempt to remove small headwater streams that are likely dry during summer.

Natal Tributary (Type I) Smolt Production

Smolts produced exclusively within natal tributaries (Figure 14) comprise a significant component of the total smolt production in the basin. These smolts are nearly all age-1 fish but a unique population of age-0 smolt is known to occur in the Shasta River (Chesney et al 2007). Within the coho life-cycle model we account for both forms of type I smolts.

Smolt capacity is typically limited by either summer or winter rearing habitat. We assumed that smolt capacity of the tributaries in the more arid interior portions of the Klamath basin was limited by summer habitat (low streamflow and temperature). This assumption is supported by Nicholas et al. (2005) who found that summer temperatures limited smolt capacity in the interior portions of the Umpqua Basin. In contrast, we assumed that smolt capacity of the coastal tributaries of the Lower Klamath population was limited by winter habitat, similar to most Oregon coastal streams (Nickelson 1998, Nicholas et al. 2005).

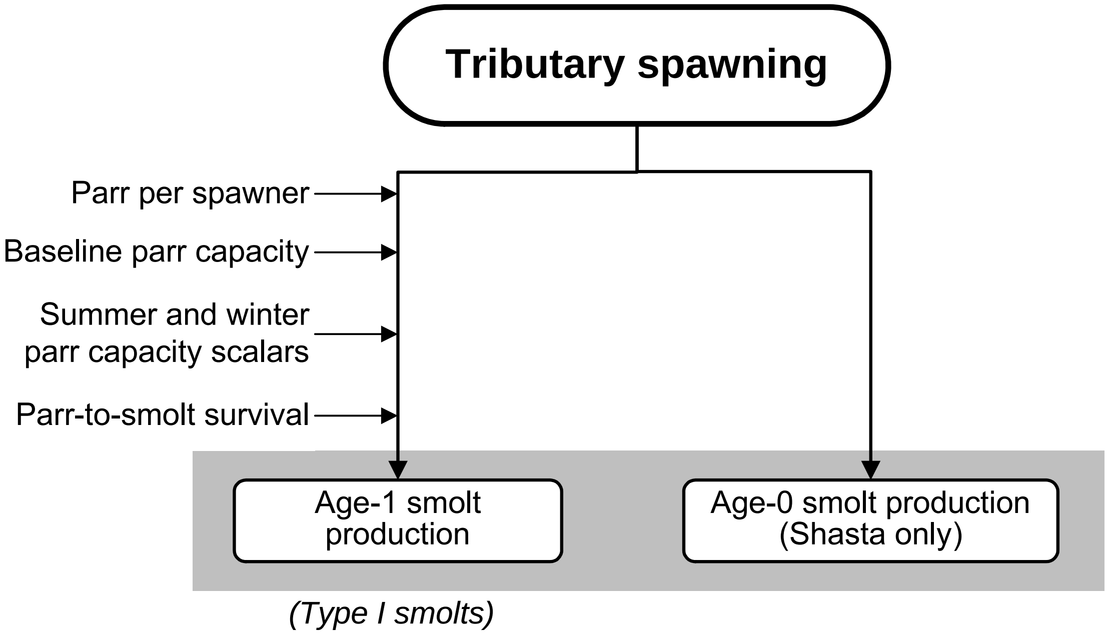


Figure 14. Diagrammatic representation of tributary (Type I) smolt production within the Klamath coho life-cycle model.

Summer limited capacity (K_{Summer})

Carrying capacity for coho parr during summer in the Klamath Basin is also affected by stream temperatures that exceed the optimum range preferred by juvenile coho. Several studies of fish assemblages in streams spread over a broad geographic area showed salmon and trout were consistently found at highest densities where stream temperatures in summer were near their physiological optimum of 12° to 16°C (Huff et al. 2005; Ott and Marret 2003; Waite and Carpenter 2000). These studies showed that salmonids still persisted in stream reaches with temperatures above this range, but at lower densities. Although densities declined with increasing temperature, we did not find consistent evidence that mortality rate of rearing fish increased until temperatures reached incipient lethal levels. However, we did find evidence of mechanisms that would cause increasing competition among fish for food and space as temperature increased, thereby causing a reduction in carrying capacity.

A substantial body of evidence indicates that the final preferred temperature for fish, given a choice, agrees closely with the temperature that results in their maximum growth (Magnuson et al. 1979). Accordingly, we assumed that peak densities can be sustained as long as the temperature and food regime enable fish to achieve optimum growth. A review of field studies indicated that the temperature range for optimum growth of salmonids generally extends from 10-16°C (Poole et al. 2001). Temperatures vary over the course of a summer, and the temperature metric in wide use and strongly associated with juvenile salmonid rearing densities was the maximum weekly average temperature (MWAT). We deduced from the scientific literature that capacity declines as MWAT increases from 16° to 23°C, with essentially all fish having to seek out thermal refugia in order to persist at temperatures >23°C. Eaton et al. (1995) compiled data on fish presence and temperatures from throughout the United States, and found that 95% of average weekly temperatures where coho were found fell below 23.4°C. In the Klamath River Basin, Sutton et al. (*In Press*) noted significant movements by juvenile salmonids into cool water refugia as daytime mainstem Klamath River temperatures reached 22-23°C. Belchik (2003) concluded that all, or nearly all, juvenile salmonids utilize thermal refugia on the Klamath River during periods of the day when temperatures are highest, and that the mainstem may not sustain juvenile salmonids without these refugia.

We evaluated an independent data set to determine the response of juvenile coho salmon density (#/m^2) to stream temperature in 44 sampling sites along the Oregon coast from 2003 to 2006. For each site, we used coho salmon rearing density estimates provided by ODFW (pers. comm., Dave Jepsen, ODFW), and continuous stream temperature monitoring data from Oregon Department of Environmental Quality (pers. comm., Robb Keller, DEQ). Sites were selected based on the criteria that the coho sampling location and the temperature monitoring location were within 2 km of each other on a single stream segment. The analysis suggests that juvenile coho rearing densities were highest at MWAT temperatures between 14-16°C (Figure 15). The highest MWAT at which coho were observed was 23°C. The data suggest that mean densities at an MWAT of 20°C are approximately 30% of those at optimal temperatures.

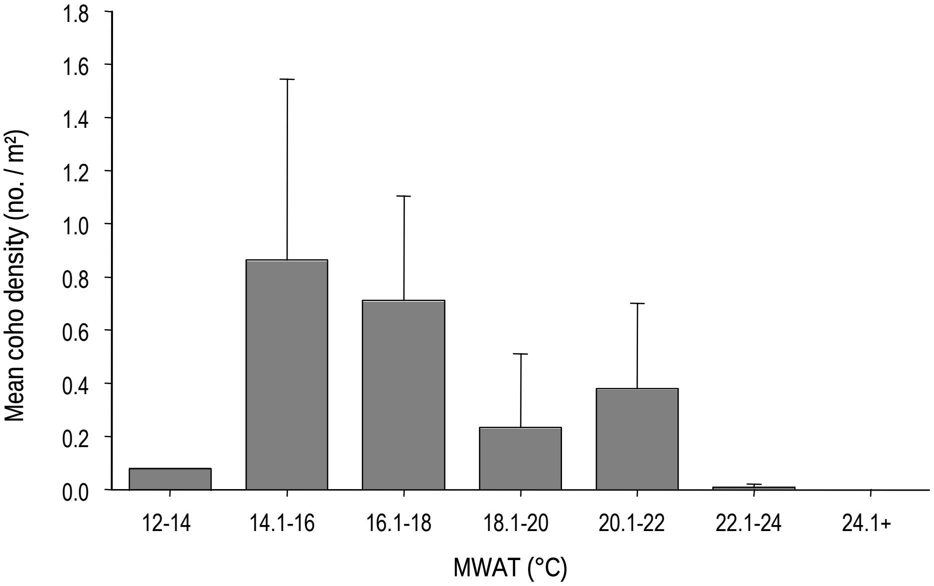


Figure 15. Mean coho salmon density grouped by 2˚C increments of maximum weekly average temperature (MWAT) in 44 Oregon coastal survey sites during the summer, 2003-2006. Error bars represent 2 standard errors.

Based on these findings, we developed a scalar to account for decreasing densities of coho as stream temperatures exceeded their optimum range. We have included three options for the temperature-capacity scalar in the model to allow users to evaluate model sensitivity to variation in the assumed threshold values associated with the temperature capacity scalar. The default function assumes that capacity declines as temperature increases from 16 to 23˚C, with essentially all fish having to seek out thermal refugia in order to persist at temperatures > 23˚C. The default scalar is specified as a logistic function that passes through values of 0.95 at WAT = 16°C and 0.05 at WAT = 23°C. The alternative temperature capacity scalars represent shifts in the scalar function along the x-axis, whereby the upper and lower temperature thresholds were adjusted by plus and minus 1˚C (Figure 16). The temperature capacity scalar (D_{Tr}) is described by the equation:

Equation 3) $$D_{Temp} = \frac{1}{1+e^{-a-bT}},$$

where the T = MWAT, b = -0.84, and a = 16.40 (default thresholds 16-23˚C), 15.56 (thresholds 15-22˚C), or 17.25 (thresholds 17-24˚C).

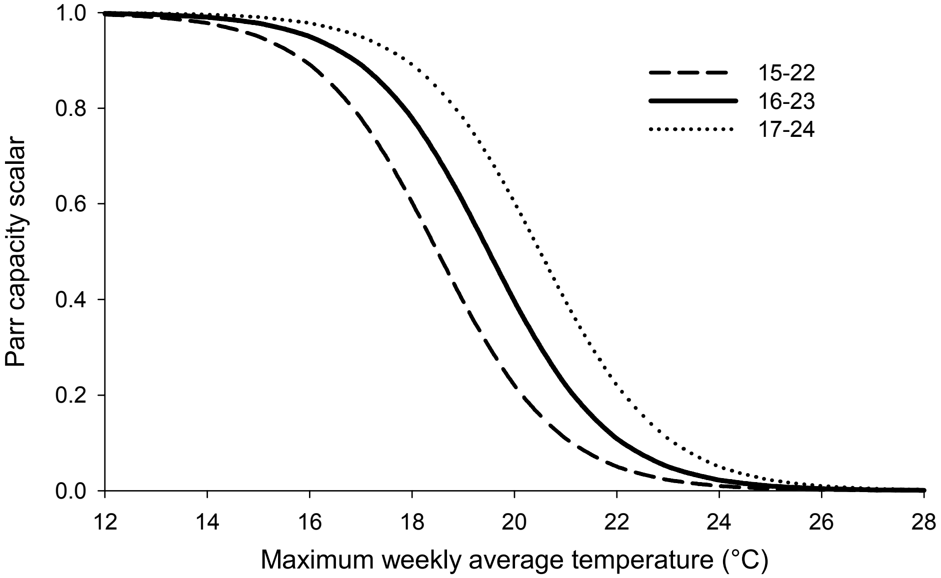


Figure 16. Effect of temperature on capacity used within the Klamath coho life-cycle model. The solid line represents the default scalar used in the model and has lower and upper temperature thresholds of 16 and 23˚C respectively. Alternative temperature-capacity scalars are shown in dashed and dotted lines and have temperature thresholds of 15 and 22˚C and 16 and 24˚C Temperature expressed as WAT and applied on a weekly basis.

The summer-limited capacity of most streams was adjusted for temperature effects using data from the individual stream or, if no data was available, by assuming similarity to nearby streams with data. After estimating the summer parr capacity within each tributary, we applied a constant parr-to-smolt survival rate of 0.45 to calculate the smolt capacity. The resulting smolt capacity estimate is referred to as the summer-limited smolt capacity (K_{Summer}) and is estimated by the equation:

Equation 4) $$K_{Summer} = K_{parr} * D_{Temp} * 0.45.$$

Winter limited capacity (K_{Winter})

Ideally, to estimate winter capacity using the HLFM, habitat data should be collected at winter base flow. Unfortunately winter habitat data are not available for Klamath basin streams. This is also true for the majority of Oregon coastal streams where the HLFM was developed. To address this lack of data, Kim Jones of the Oregon Department of Fish and Wildlife developed an algorithm to estimate winter parr capacity based on 218 stream segments having both summer and winter habitat inventories (Nicholas et al. 2005). We used this algorithm, which predicts winter parr capacity (Parr/km) as a function of the optimal summer parr capacity (K_{parr}), stream active channel width (ACW), and percent of stream area in alcoves and beaver ponds (P). We then applied a 90% winter parr-to-smolt survival rate (as in Nickelson 1998) to estimate the smolt capacity. The resulting smolt capacity estimate is referred to as the winter-limited smolt capacity (K_{Winter}) and is estimated by the equation:

Equation 5) $K_{Winter} = [0.19 * K_{parr} + 14.51 * (ACW) + 10.47 * P - 1] * 0.9.$

Smolt productivity (α)

In addition to estimating smolt capacity (*K*), we estimated the number of smolts per spawner at low spawning densities, or productivity (α) for each tributary. These parameters were then utilized in stock-recruitment functions to predict the number of smolt produced from each tributary. The default form of the stock-recruitment function used in the model was a hockey-stick form as described by Barrowman and Myers (2000) using the equation:

Equation 6) $Smolts = \min(Female\ spawners * \alpha,\ K)$

In this form of the stock-recruitment function the number of smolts per spawner (α) is constant until smolt capacity is reached (Figure 17). The inflection point in the hockey-stick function occurs at N^*, the minimum number of female spawners needed to fill the available smolt capacity (*K*).

Because of the lack of reliable spawner and recruitment data from the Klamath River Basin and the associated uncertainty in productivity parameters for individual tributaries, we included alternative stock recruitment options to evaluate model sensitivity to different assumptions about the productivity of tributary populations. Two variations of the hockey-stick model are provided as options: the first assumes that N^* is a function of stream length and $\alpha = K/N^*$; and the second assumes that α is a fixed value (default = 40 smolts per spawner). The first variation (model default) is based on the concept that as streams get larger, they get wider and, up to a point, need more females/km to fully seed the habitat with juveniles. Bradford et al. (2000) found the value for N^* for coho was positively correlated to stream length (km). That is, more spawners per kilometer are required to fully seed a stream of greater length. This concept is consistent with the reduced density of parr and smolts in larger streams estimated by the HLFM width scalar. The equation used to estimate the minimum number of female spawners N^* needed reach smolt capacity (*K*), was derived using data in Bradford et al. (2000) (Figure 18):

Equation 7) $N^* = \text{stream length} * (4.2008 * \text{stream length}^{0.4849})$

An alternate form of the stock-recruitment function included in the model predicts smolt production using a modification of the Beverton-Holt function (Beverton and Holt 1957). Under this form of the model, the number of smolts per spawner is curvilinear until the spawning capacity is reached (Figure 17). This form of the model predicts greater numbers of smolt at low spawner abundance than the hockey-stick form, and therefore allows for greater resiliency of the population at lower spawning levels. The modification of the Beverton-Holt stock-recruitment function is described by the equation:

Equation 8) $$Smolts = \min\left(\frac{Female\ spawners * a}{1 + {}^{a}\!/_{b} * Female\ spawners},\ K\right)$$

where

Equation 9) $a = c * \alpha$

thus *c* is a scalar of productivity (set to 1.5 as the model default), and

Equation 10) $$b = K\left(\frac{c}{c-1}\right)$$

to constrain the Beverton-Holt function to match the hockey-stick inflection point (i.e. *K* smolts at *N** female spawners).

Thus, there are four stock-recruit options available in the model to estimate tributary smolt production (Table 5). These include two variations of the hockey-stick function and two of the Beverton-Holt function.

Table 5. Optional stock-recruitment functions used in the model to predict tributary smolt production.

	Stock-recruit form	Spawners at full seeding (N^*)	Smolts per spawner at low seeding (α)
Option 1 (default)	Hockey-stick	Function of stream length	$\alpha = K/N^*$
Option 2	Hockey-stick	$N^* = K/\alpha$	Fixed α (default 40 smolts/spawner)
Option 3	Beverton-Holt	Same as Option 1	Scaled value of Option 1 ($a = c^*\alpha$)
Option 4	Beverton-Holt	Same as Option 2	Scaled value of Option 2 ($a = c^*\alpha$)

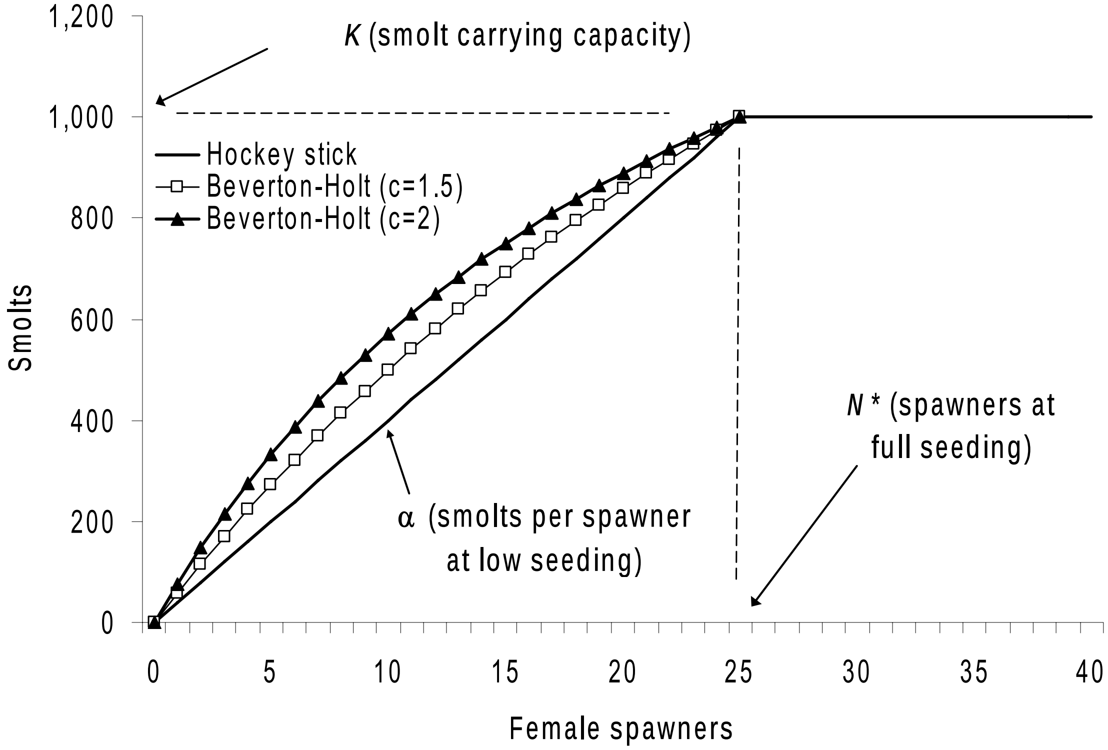


Figure 17. Examples of Beverton-Holt and hockey-stick functions that describe the number of smolts produced per spawner. Values of "c" specify translation of the hockey-stick slope into the slope for a Beverton-Holt function, as described in text.

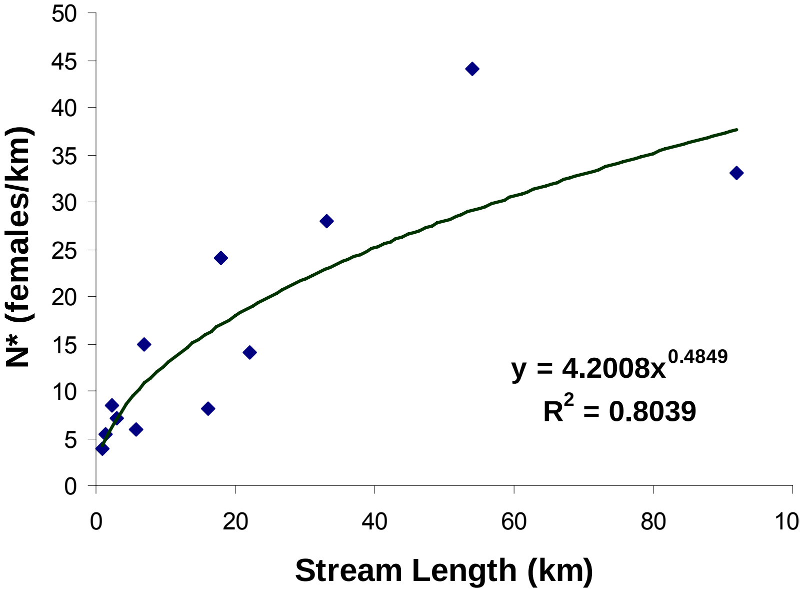


Figure 18. Relationship between the minimum density of female spawners needed for full seeding (N) and stream length based on data from Table 1 of Bradford (2000).*

Shasta smolt production

Natal smolt production from the Shasta River is treated separately in the model for two reasons. First, this is only tributary to the Klamath where there are paired estimates of wild spawners and smolt production (Chesney et al. 2007). In this special case, we estimated smolt capacity and smolt production functions based on available data. Age-1+ smolt capacity was set at 11,100 (the average of 11,052 and 11,155), the maximum estimated to date, as this abundance was produced by estimated adult runs of 220 and 410. Assuming a 50:50 sex ratio, N^* was assumed to be 110 female spawners (Figure 19). Second, the Shasta River produces a unique population of age-0 smolts in addition to yearling smolts (Chesney et al. 2007). Conditions in the Shasta River drainage enables some juvenile coho to surpass 80 mm fork length by late May, and these fish are presumed to migrate to the ocean as age-0 smolts. Evidence of this unique population of age-0 smolts is described by Chesney et al. (2007). The model predicts age-0 smolt production from the Shasta River as a linear regression on the predicted number of emigrant fingerlings (described below) according to the equation:

Equation 11) Age 0 smolts = 0.28 * Migrant fingerlings + 436.

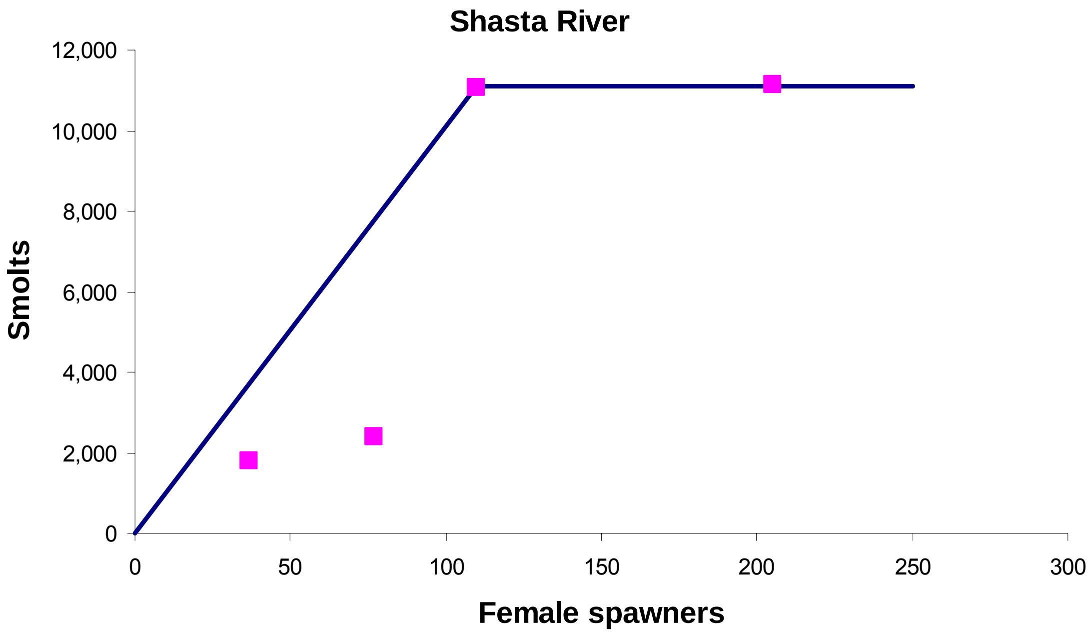


Figure 19. Hockey-stick yearling smolt production relationship for the Shasta River based on smolt years 2003-2006.

Non-Natal (Type II and III) Smolt Production

The two types of non-natal smolt production treated in the model result from juveniles migrating out of their natal stream into the mainstem of the Klamath River (Figure 20). In addition to age-0 smolts produced from the Shasta River, there are two types of age-0 juvenile migrations from tributaries into the Klamath mainstem in the spring and early summer. First are fry, which have grown little since emergence, and their dispersal is usually complete in April, sometimes extending to mid-May (Julian week 19). A second emigration of coho parr, generally 60–80 mm fork length (i.e. fingerlings) is generally observed from both the Shasta and Scott Rivers (Chesney et al. 2003, 2004, and 2007).

Movement of these fish is likely triggered by increasing temperatures and decreasing flows, as has been observed in other streams (Kruzik 1998; Lestelle 2007). Once the juveniles enter the Klamath mainstem, the model allows them to continue rearing in the mainstem (Type II) or migrate into non-natal tributaries with available rearing capacity (Type III) (Figure 20). Because the two types of non-natal smolt production originate from fry and fingerling migrations from the tributaries, we first explain how the model predicts these migrations.

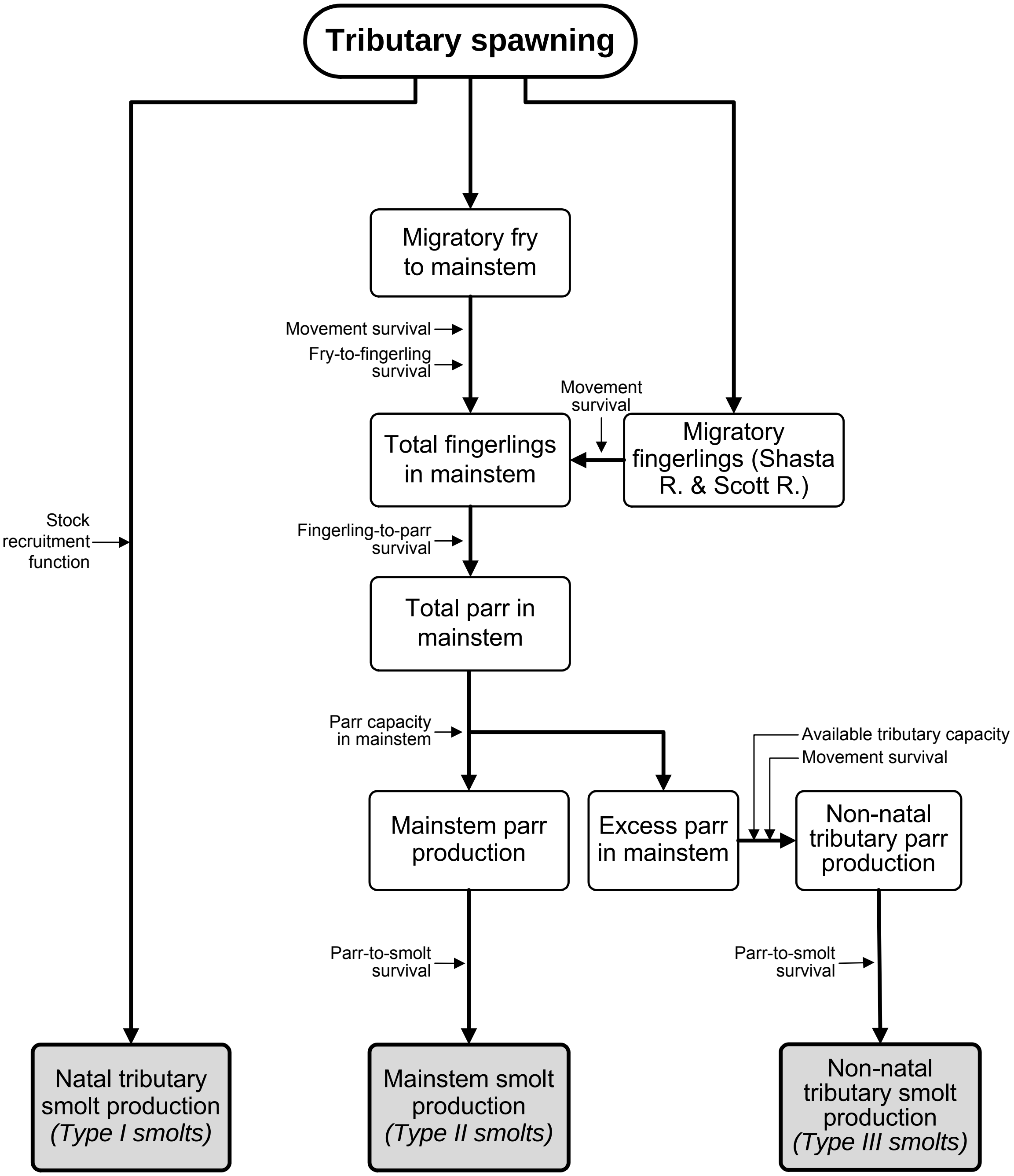


Figure 20. Diagrammatic representation of non-natal (Type II and III) smolt production within the Klamath coho life-cycle model.

Fry and fingerling migrations

Downstream dispersal of fry from tributaries into mainstem habitats has been widely observed (Quinn 2005, Jepsen et al. 2006, and Lestelle 2007). Each of the spawning tributaries in the model contributes fry to the mainstem Klamath. We simulated that movement by predicting the percentage of fry from each tributary that would enter the mainstem reach. With no empirical basis for allotting tributary fish among mainstem reaches, we assumed that all fry emigrating from a tributary would move into the nearest mainstem reach (or the downstream reach if the tributary is located at a reach break).

To determine the number of fry that would be expected to leave their natal basin, we examined data from the Oregon Coast where both spawner densities and estimates of fry emigration have been made. Our findings were similar to those of Bradford et al. (2000) who found that there was a clear relationship between female spawner density and the number of emigrating fry per kilometer of habitat. The slopes of these regressions indicated that the number of fry per spawner that arrived at the trap decreased as the km of habitat in the basin upstream of the trap increased (Figure 21).

We interpret the probable cause of this relationship to be that coho tend to spawn high in the basin, and fry disperse to the nearest downstream area where they find suitable habitat. Thus, the further down the basin a migrant trap is fished, the smaller the proportion of coho fry that will reach that trap before finding suitable habitat. In the life-cycle model, the number of coho fry migrating from a tributary is predicted by the equation:

Equation 12) Migrant fry = (female spawners) * 549.28 * (km of habitat$^{-0.5972}$)

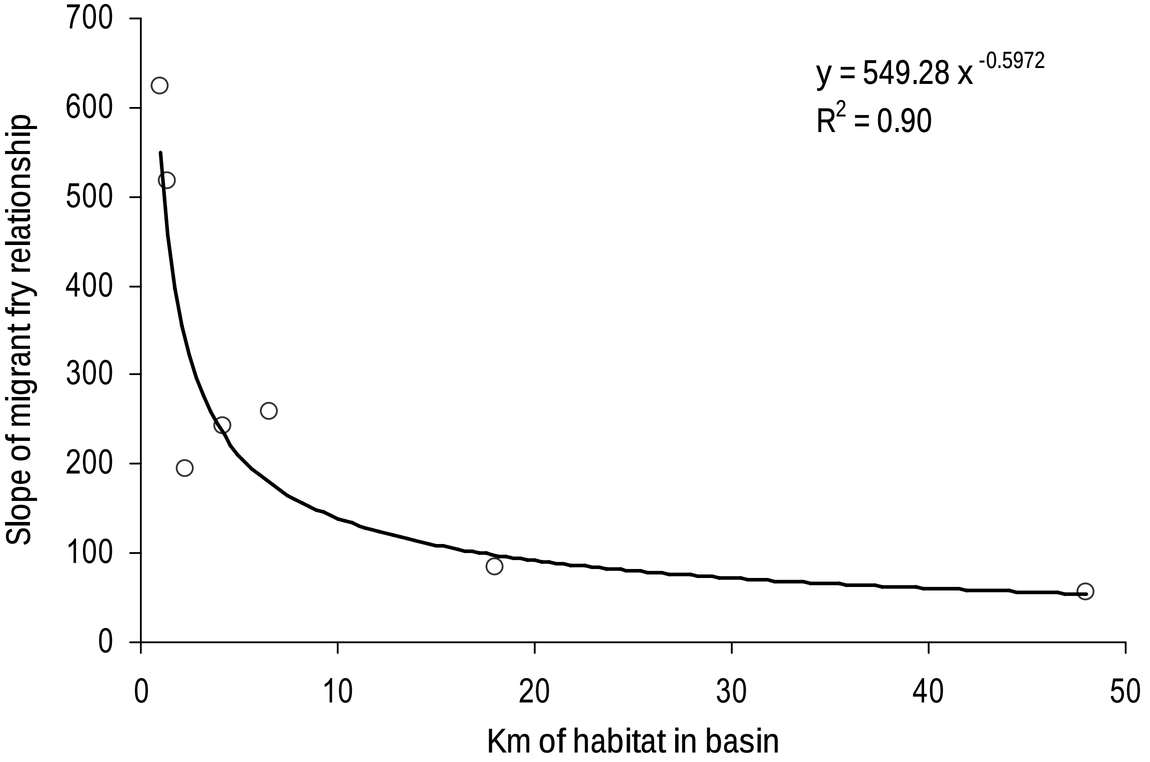


Figure 21. Relationship between the slope of the migrant fry per female spawner relationship to the kilometers of coho habitat in the basin upstream of the trap. Points represent different basins on Oregon coast.

However, this method did not accurately predict the number of migrant fry from the Shasta River. Low dissolved oxygen levels and elevated water temperatures in the Shasta River have resulted in "degraded water quality conditions that do not meet applicable water quality objectives and impair designated beneficial uses" (North Coast Regional Water Quality Control Board 2006). In addition, stream diversions have resulted in a loss of suitable habitat and displacement of rearing coho salmon in the lower Shasta River (Chesney et al. 2007). As a result we analyzed the Shasta River data to provide a better means to simulate fry movement out of this tributary. The number of migrant fry generated from up to 100 female spawners is very low, but then increases exponentially with increasing spawners (Figure 22). However, spawner abundance above the range of existing data would yield exponentially greater numbers of migrant fry. To prevent this unrealistic situation, the model uses this relationship only when the predicted value is less than that predicted by Equation 12. The resulting equation for migrant fry from the Shasta River is:

Equation 13)

$$Shasta\,migrant\ fry = \min\left[\left(female\,spawners * 549.28 * km\,habitat^{-0.5972}\right), \left(6.065 * e^{0.0285*female\,spawners}\right)\right]$$

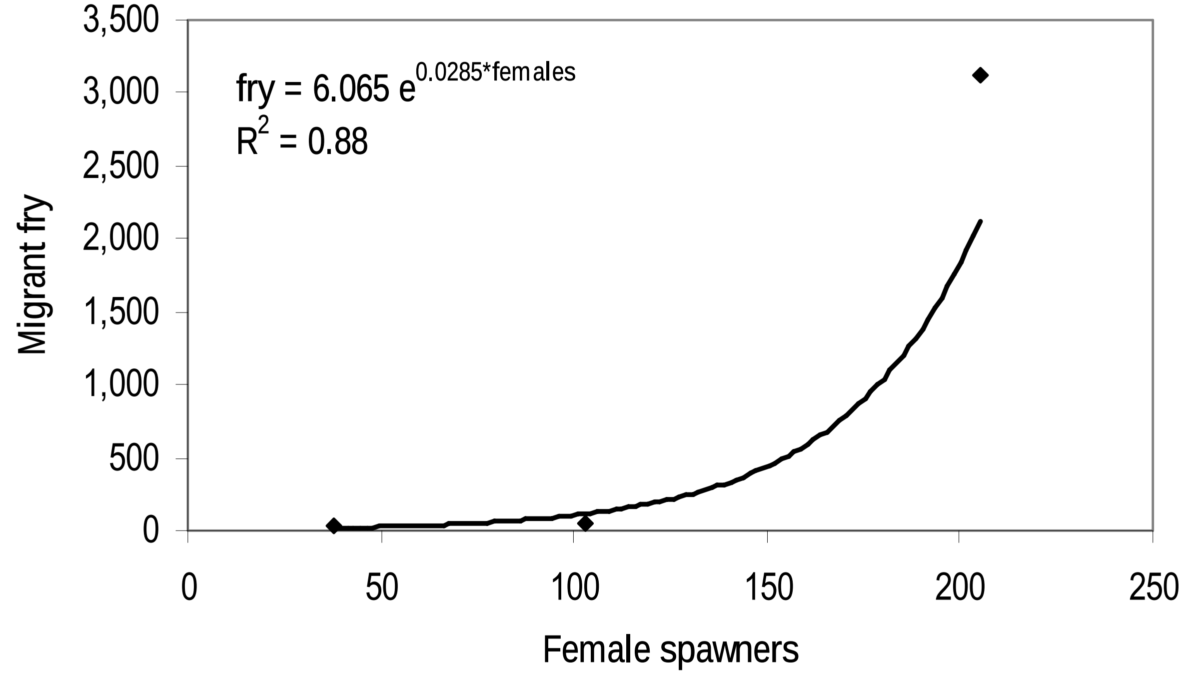


Figure 22. Relationship between migrant fry and female spawners in the Shasta River, brood years 2003 to 2005.

Fry emigrating from tributaries are likely to experience mortality from predation and exposure to new environmental conditions as they migrate into the mainstem Klamath River in search of suitable habitat. Estimates of mortality rates associated with this migration period are not available for the Klamath Basin. Therefore, we assumed a movement mortality rate of 0.10, and have provided a user option in the model to adjust this rate as new information becomes available. In addition to mortality incurred during movement, we assigned a density-independent fry-to-fingerling survival rate of 0.81 based on findings of Lestelle (2007).

The number of juvenile coho migrating into the Klamath mainstem from the Shasta and Scott Rivers as fingerlings was predicted by linear regression on the number of migrant fry leaving these rivers with the following equation:

Equation 14*)* Migrant fingerlings = 2.589 * Migrant fry

This function was generated from downstream migrant trapping data from the Scott and Shasta Rivers during 2004-2006 (Figure 23). The model assumes that fingerling movement from the Shasta River occurs in mid-May (week 20) and from the Scott River in mid-June (week 23). Fingerlings emigrating from the Shasta and Scott Rivers are then subjected to a movement mortality rate of 0.10. All fingerlings in the mainstem, including those that emigrated from the Shasta and Scott and those that emigrated as fry from each of the tributaries are then subjected to a fixed survival to parr of 0.86, based on data from Lestelle (2007).

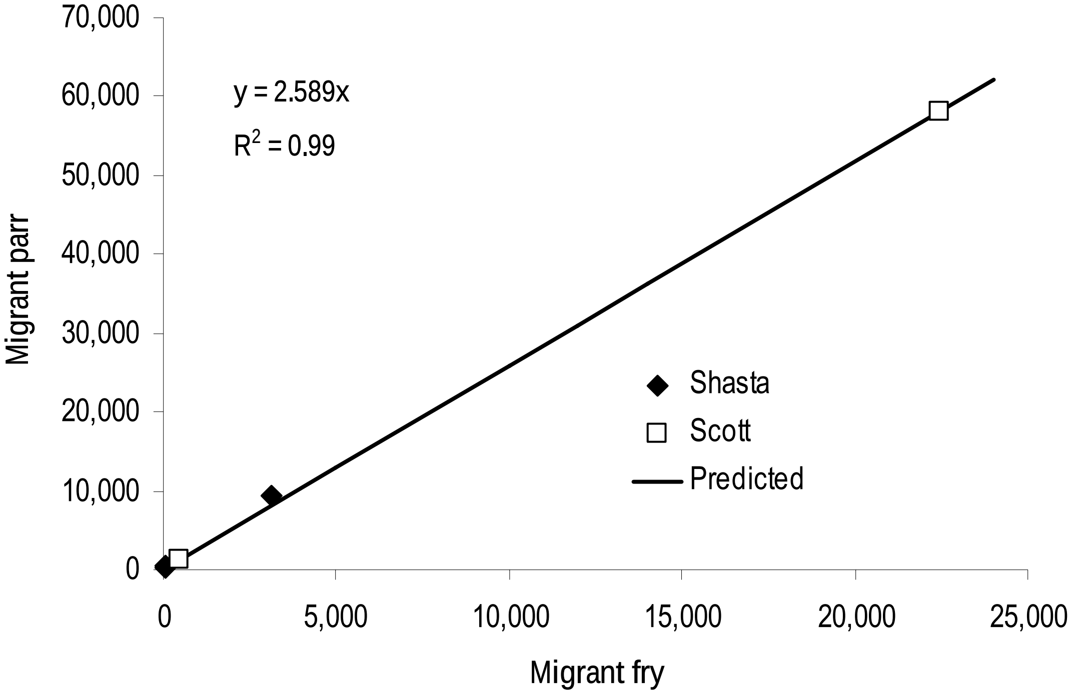


Figure 23. Relationship between migrant parr and migrant fry for the Scott (2005 and 2006) and Shasta Rivers (2004-2006).

Mainstem (Type II) smolt production

We classified the reaches of the mainstem Klamath River into two categories: 1) reaches where capacity is determined by mesohabitat availability, flow, and temperature; and 2) reaches where capacity is determined by the availability of thermal refugia. Observations from studies within the Klamath River, and temperature modeling of the Klamath River suggest that downstream of the Shasta River, for at least some period during the summer, juvenile coho are obligated to use thermal refugia (Sutton et al. *In Press*; Belchik 2003). Mean weekly temperatures during the warmest portion of the summer, based on simulated data for 2004, were greater than 22°C downstream of the Shasta River. Therefore, we classified all mainstem reaches downstream of the Shasta River as "refuge dependent".

MAINSTEM REACH 1 CAPACITY

Between IGD and the Shasta River (Reach 1), capacity was determined by mesohabitat availability, flow, and temperature because: 1) temperatures in this reach may be suitable for non-refuge rearing, and 2) no thermal refugia have been documented in this reach. Although smolt production from this reach is likely small, this reach is most affected by Reclamation operations at IGD. For this reach of the mainstem, the model will operate on a weekly time-step in the summer (July 1 to Sept 31) so that capacity was determined by the week where rearing capacity is lowest. The overall parr rearing capacity in Reach 1 is described by:

Equation 15) $K_{MS1} = \min(K_{Parr} * D_{Temp} * D_{Qflowi})$,

where K_{parr} was the baseline parr capacity (determined by HLFM), D_{Temp} was the temperature scalar (Equation 3) and D_{Qflowi} was the weighted flow scalar for week i. Therefore the baseline parr capacity is scaled by temperature and flow conditions of the reach that week. To predict baseline parr capacity in the mainstem, we used mesohabitat typing data collected by the USFWS (data provided by USFWS, personal communication, Tom Shaw) to populate the HLFM Version 6.1. These are the same habitat-typing data used by Hardy and Addley (2006) and Bartholow and Henriksen (2006) in their evaluations of the effects of flow on salmonid populations in the Klamath River. The weighted flow scalar was defined by:

Equation 16) $D_{Qflowi} = 0.46\ Q_{Mi} + 0.50\ Q_{Sidei} + 0.04\ Q_{Spliti}$

where Q_{Mi} is the flow scalar for the main channel in week i, Q_{Sidei} is the flow scalar for side channels in week i, and Q_{Spliti} is the flow scalar for split channels in week i. Flow scalars for each channel type were determined through the equation:

Equation 17*)* $Q_{ij} = (WUA_{ij} / WUA_{Bj})$,

where Q_{ij} is the flow scalar for channel type j in week i, WUA_{ij} is the weighted usable area for channel type j in week i determined from PHABSIM, and WUA_{Bj} = weighted usable area for the channel type j under baseline flows (827 cfs at IGD).

Like temperature, flow was used to scale the capacity of a reach in each week between July 1 and September 30. The range of our scalar for flow on capacity was based on relationships between discharge and juvenile coho weighted usable area (WUA). WUA is an index of the area of a reach at a given flow that is suitable for rearing of a target species and life stage (Bovee et al. 1998). WUA was calculated by combining the physical characteristics (velocity, depth, and cover/substrate) of a specific stream site with the relative suitability of those characteristics to the species of interest. Thus, WUA for a given discharge requires both the physical data and a suitability curve for each physical attribute included in the analysis. WUA by discharge was predicted with a model termed PHABSIM (see Bovee et al. (1998) for a complete description of WUA).

The habitat calculations portion of PHABSIM controls how habitat suitability criteria (HSC) will be combined. In each cell, the composite suitability factor was calculated using a method that weighted the suitability factor based on cover. This relatively new approach in PHABSIM places the cover variable outside the geometric mean calculation used to calculate the suitability factor. This technique implies that one variable (e.g., cover) has a greater effect than the others. The composite suitability factor (CSF) was calculated by:

Equation 18) $\mathbf{CSF = (HSC\ (velocity) * HSC\ (depth))^{0.5} * HSC\ (cover)}$

Figure 24 illustrates how site-specific hydraulic data is integrated with HSCs to develop the habitat-discharge relationship output from PHABSIM.

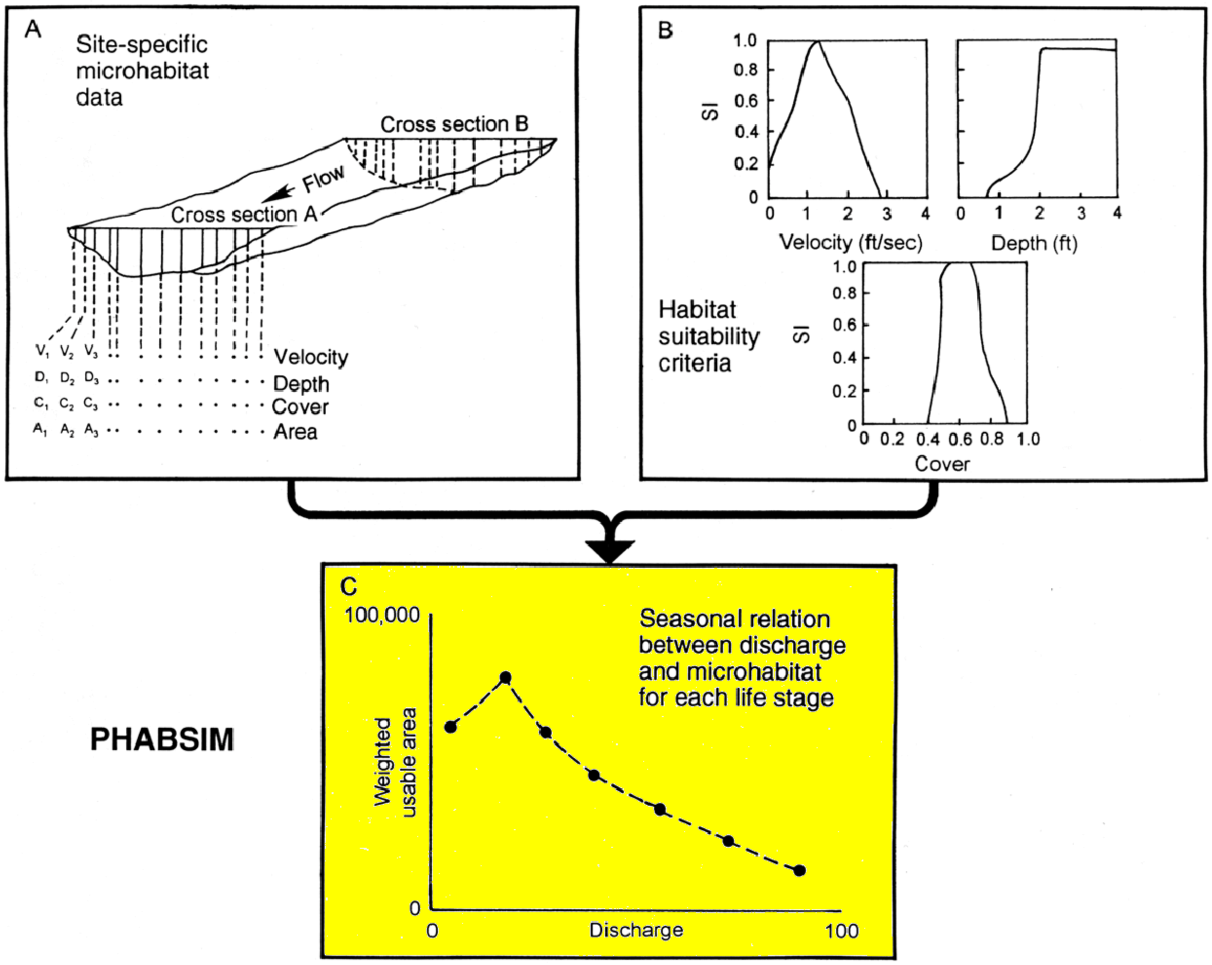


Figure 24. PHABSIM process of integrating hydraulic data with habitat suitability criteria to develop a habitat-discharge relationship.

We developed curves predicting the relationship between discharge and WUA at four sites in the mainstem Klamath River between IGD and the Shasta River. These sites were surveyed as part of the USGS/USFWS SALMOD study (Bartholow and Henricksen 2006) and include River Ranch, KRCE, Cottonwood, and Yellow House study sites. Data from those sites served as the physical data component for predicting WUA. We used habitat suitability curves for depth and velocity based on observations of juvenile coho depth and velocity preferences in the Klamath and Trinity Rivers (USFWS and Hoopa Valley Tribe 1999; Sutton *In press*) (Figure 25 and Figure 26). The composite curves were developed by deriving the mean suitability between the two curves at depth (ft) and velocity (ft/s) nodes from the curves presented in Sutton (*In press*).

After establishing a habitat-discharge relationship using PHABSIM, we developed a flow-capacity scalar by determining the amount of WUA in a given week (or at a given flow level) relative to the amount of WUA at the flow level when the habitat data used to predict baseline capacity were collected (827 cfs). This method can be described by Equation 17. To account for potential differences in rearing capacity among different channel types within Reach 1, we calculated flow scalars for each channel type separately, and then combined them by summing each flow scalar weighted by the proportion of the total baseline capacity in each channel type (Equation 18)).

The number of parr surviving through the summer (typically equal to K_{MS1}) was then subjected to the parr-to-smolt survival rate to predict smolt production in mainstem Reach 1. Because survival is related to size of the fish, the baseline parr-to-smolt survival rate of 0.45 was scaled based on winter parr size using the equation:

Equation 19) $$D_{size} = 1 + \left(Len_{Pred} - Len_{Base}\right) * 0.02$$

Where Len_{Base} is the baseline length of winter parr and Len_{Pred} is the predicted length of winter parr determined via a simulation of juvenile growth between June 1 and October 30 based on results from a bioenergetics model described in Sullivan et al. (2000). Growth is predicted using an initial starting weight of 1.4g based on Klamath outmigrant sampling data and the following equations:

Equation 20) $$g = \chi_0 + \chi_1 T + \chi_2 T^2 + \chi_3 C + \chi_4 C^2 + \chi_5 CT + w$$

Where $\chi_0 = -0.010649$

$\chi_1 = 0.00096624$

$\chi_2 = -0.00008312$

$\chi_3 = 0.450620$

$\chi_4 = -3.02056$

$\chi_5 = 0.01677$

T = daily mean temperature

w = initial weight

C = food consumption described by the equation:

Equation 21) $$C = w^{-0.275}\left(\lambda_0 + \lambda_1 T + \lambda_2 T^2 + \lambda_3 T^3\right)$$

Where $\lambda_0 = -0.1419$

$\lambda_1 = 0.0544$

$\lambda_2 = 0.0061$

$\lambda_3 = -0.0003$

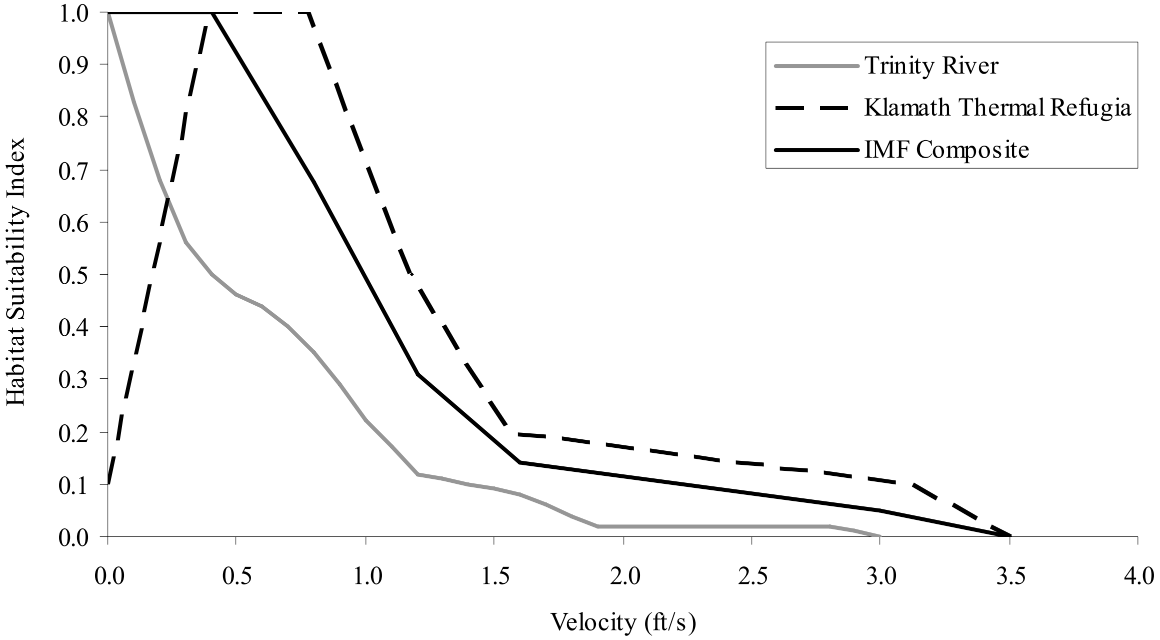


Figure 25. Habitat suitability indices for juvenile coho for velocity from the Trinity River (USFWS and Hoopa Valley Tribe 1999), Klamath River thermal refugia (Sutton In Press), and the composite curve use in the Klamath coho life-cycle model.

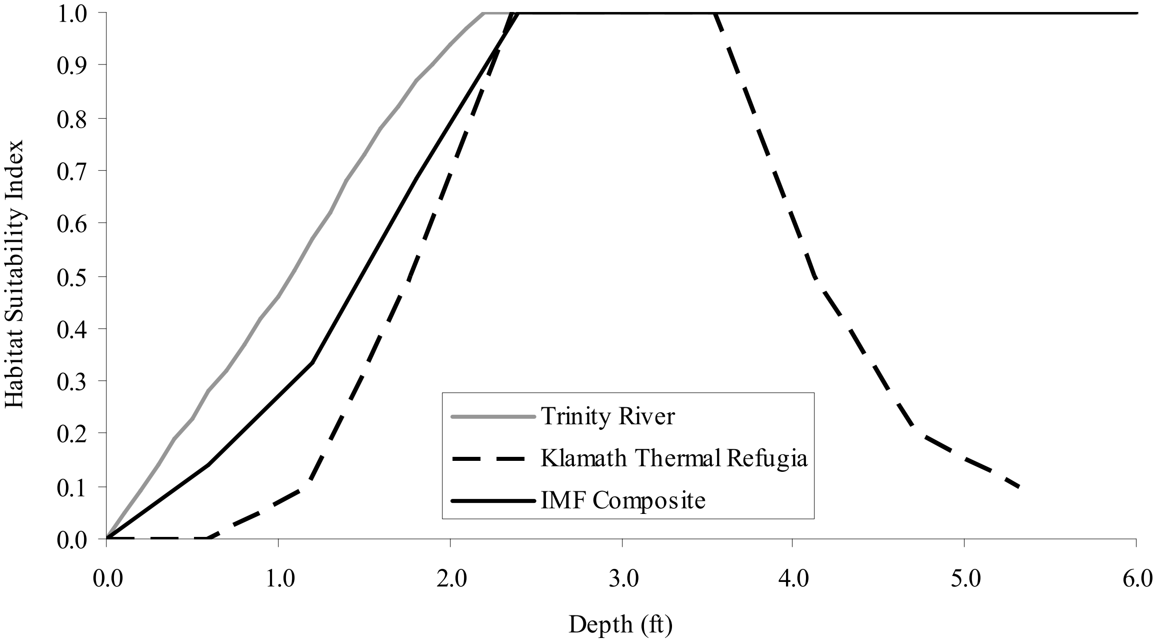


Figure 26. Habitat suitability indices for juvenile coho for depth from the Trinity River (USFWS and Hoopa Valley Tribe 1999), Klamath River thermal refugia (Sutton In Press), and the composite curve for use in the Klamath coho life-cycle model.

MAINSTEM REFUGE-DEPENDENT CAPACITY

We assumed that juvenile coho salmon inhabiting the mainstem Klamath River downstream of the Shasta River must rely on thermal refugia near the mouths of tributaries to persist through the summer (Belchik 2003; Sutton et al. *In Press*). We developed a list of potential refugia based on a list developed by the USFWS (data compiled by Tom Shaw, USFWS). We removed the confluences of Shasta River and Humbug Creek from the original list because these tributaries did not provide thermal refugia.

We used two different methods to estimate rearing capacity in thermal refugia; the corresponding capacity estimates from these two methods are available as options in the model home page. In the first method, we assumed that the capacity of a given refuge was determined by the capacity of habitat units in the surrounding mainstem when river temperatures were cool enough to allow such rearing. We used HLFM to estimate the rearing capacity in these habitat units and assigned the appropriate capacity estimate to the thermal refuge site according to the following rules:

1. Identify the location of the tributary confluence with the mainstem Klamath River (for tributaries that produce refugia).
2. If the tributary enters at transition between 2 units (i.e. the top or bottom of a unit) sum the capacity of both the upstream and downstream mesohabitat unit.
3. If the tributary enters a riffle/rapid, include the unit downstream, unless the unit downstream is a riffle/rapid and the unit above is a pool, then include the capacity estimate from the upstream pool.
4. If the tributary enters a pool, include the unit upstream unless another pool is present downstream.

The second method for estimating parr rearing capacity in thermal refugia was based on the maximum number of juvenile coho observed during snorkel surveys (Belchik 2003; Deas et al. 2006; Unpublished survey data from 2002 provided by Tom Shaw, USFWS). The maximum number of fish observed was adjusted for observation efficiency by dividing the snorkel estimate by 0.40 (Rodgers et al. 1992). The total parr capacity in each reach was simply the sum of the rearing capacity in all thermal refugia within a given reach.

The estimated summer parr capacity in the mainstem Klamath River was used to determine the maximum number of fish able to find suitable habitat and rear in the river until smoltification and emigration during spring. Because the number of fish that spawn in the mainstem Klamath is very small, and because redds within the mainstem are likely scoured by relatively high flows in some years, we assumed that mainstem smolt production is dependent on subyearling migrations from the tributaries. Large number of fry and fingerlings migrate from tributaries during the late spring and early summer, where they rear until the following spring. The number of parr residing in the mainstem until smolting is ultimately limited by the available mainstem parr capacity. Fish unable to find available mainstem capacity must move into non-natal tributaries or perish. A parr-to-smolt survival rate of 0.45 is applied to surviving parr in refuge-dependent mainstem reaches to predict the number of emigrant smolts in the spring.

Non-natal tributary (Type III) smolt production

As water temperatures increase during the summer, the Klamath River becomes increasingly inhospitable to juvenile salmonids and mainstem rearing capacity becomes limited. The coho life-cycle model allows non-natal parr in excess of mainstem rearing capacity to migrate into tributary streams with available capacity. By July 1, daily maximum temperatures throughout the Klamath mainstem from Iron Gate Dam to the mouth begin to exceed 20°C and reach 25°C in many areas (see Appendix 3). Within the Klamath River mainstem, coho parr are then restricted to a limited number of thermal refuge sites (Belchik 1997, Sutton et al. *In Press*, Deas and Tanaka 2006). Observations by biologists in the basin suggest that as the mainstem Klamath warms, juvenile coho also seek refuge in cooler non-natal tributary streams typically associated with thermal refuge sites.

When capacity remains available in “refuge streams” (tributary streams that have connectivity to the mainstem throughout the summer), mainstem parr are allowed to move a finite distance to fill the available capacity. A movement mortality of 0.10 is applied to parr seeking refuge streams. Because of the relatively small size of parr in the early summer, the model default allows parr to fully utilize the lower 1.6 km of rearing habitat in those tributaries. This assumption is supported by observations in smaller tributaries of the Klamath River with no known spawning populations. While parr could move further upstream in larger tributaries with lower gradient, these tributaries are more likely to provide spawning habitat and be seeded by natal fish. The model assumes that habitat in streams with coho spawning will be seeded first by natal fish, and non-natal fish can only utilize habitat capacity not fully seeded by natal fish. To do this the first model calculates the available capacity in the tributary, then scales the available capacity by the proportion of the capacity in the lower stream (approximated in the default as 1.6 km/total length of habitat in stream). The model allows users to define the distance parr can move upstream to examine the sensitivity of the model results to this parameter. Density independent parr-to-smolt survival rates are applied to parr that fill available capacity in the “refuge streams” to determine the number of non-natal smolt produced.

Optional Alkalinity Scalar

We developed a scalar to account for differences in stream productivity in the Klamath basin and Oregon coastal basins based on a multiple regression model described by Ptolemy (1993). His model, which included fish size and alkalinity, explained 86% of the variation observed in salmonid density in 226 streams in British Columbia. Alkalinity was highly significantly correlated to fish density (P= 0.0001). We used the findings by Ptolemy (1993) to derive a function that scaled the productivity of different portions of the Klamath Basin against each other, and against the Oregon Coast. Essentially, the function assigns greater rearing capacity to streams with higher alkalinity:

Equation 22) $D_{alk} = (K_{alk})^{0.45}/(OR_{alk})^{0.45}$,

Where K_{alk} is mean alkalinity of the stream reach and OR_{alk} is the mean alkalinity of Oregon coastal streams. This function was included as an option in the model, but is not included under the default model settings.

Iron Gate Hatchery Smolt Releases

The model simulates a 100,000 release of IGH smolts into the Klamath River (into mainstem Reach 1). These releases experience an initial 0.50 post release mortality before being lumped together with the rest of the emigrant smolt population. We assume that IGH smolts do not rear in the Klamath River and therefore do not affect survival of naturally produced smolt.

Smolt Emigration Survival

All smolts produced in the Klamath River Basin migrate through the mainstem on their way to the ocean. Their survival is a function of the temperature and flow conditions encountered and total distance traveled through the mainstem (Figure 27). These processes are all simulated in the model and described by the equation:

Equation 23)

$$S_{Total} = S_{Base}{}^{d/100} * \left(\prod_{i=1}^{n} D_{MTemp,i} * D_{MFlow,i} \right)$$

Where:

S_{Total} = total survival estimate for each cohort through all model reaches,

d = total migration distance (km) of the cohort,

S_{Base} = baseline smolt survival per 100 km,

$D_{MTemp,i}$ = temperature survival scalar in reach *i,* and

$D_{MFlow,i}$ = flow survival scalar in reach *i*,

*Note: the symbol **Π** denotes the product.*

For each biweekly cohort migrating through a particular reach, survival was scaled by the relative temperature and flow effects. The “baseline” survival rate, defined as the maximum survival rate per 100 km for a given cohort under optimal temperature and flow conditions, was then adjusted by the total migration distance and the product of the reach-specific survival scalars to determine the overall survival estimate for each cohort.

Because temperature and flow can change during the spring, migration timing can have a significant effect on emigration survival. Therefore, we discuss smolt migration timing through the Klamath River before discussing the effects of temperature, flow and distance.

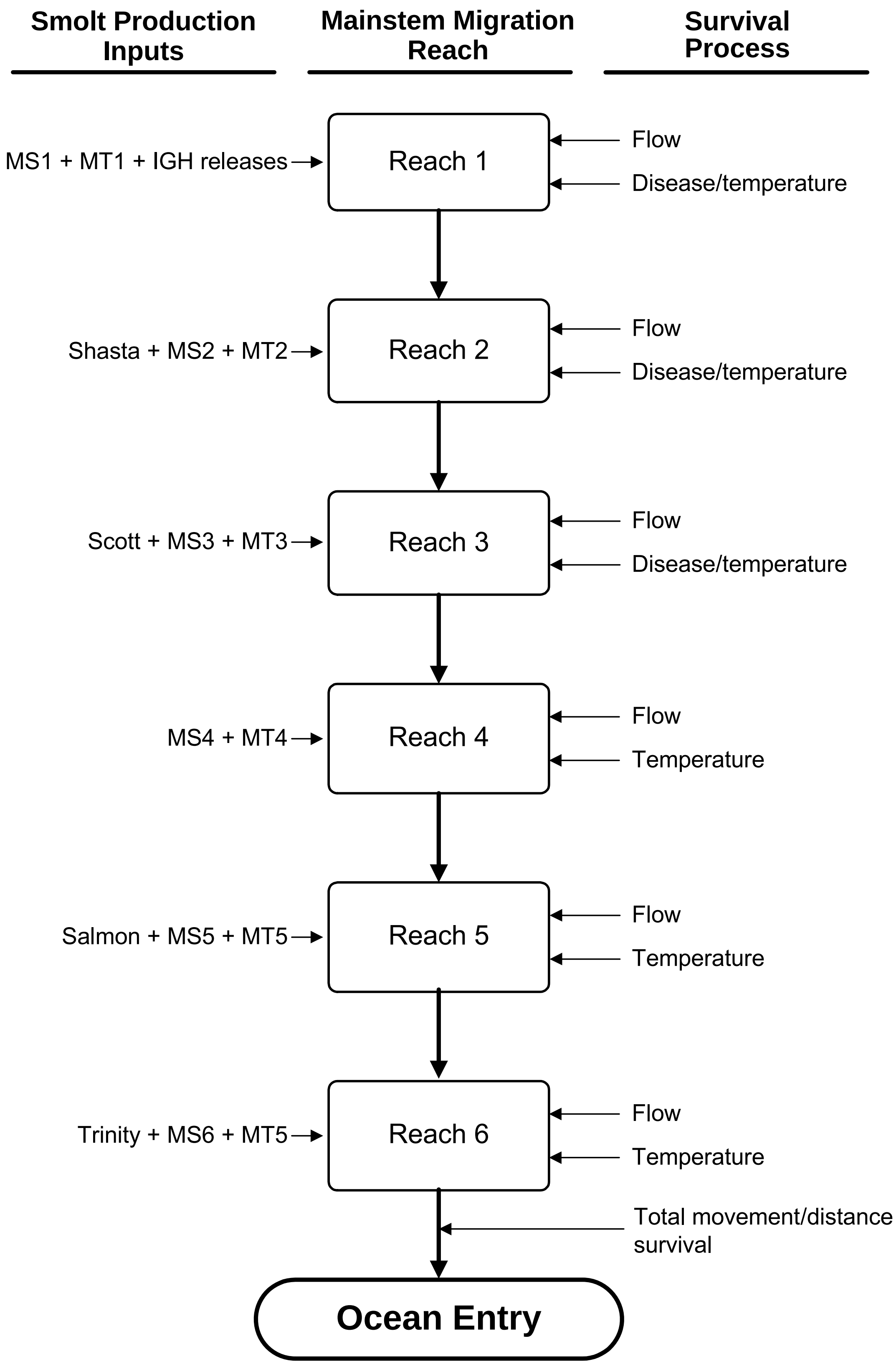


Figure 27. Diagrammatic representation of the smolt emigration component of the Klamath coho life-cycle model.

Migration Timing

Stream conditions such as temperature and flow, and their potential influence on survival of migrating smolts, are likely to change dramatically over the course of the smolt migration period. To account for the temporal variation in stream conditions and their effects on smolt survival, the model divides the total number of coho smolts entering the mainstem into biweekly cohorts that correspond to passage timing distributions determined from sampling at downstream migrant traps. Table 6 provides the proportion of smolts in each model reach passing during each biweekly time period.

Passage timing distributions for each reach were estimated from smolt trapping data collected in various tributary and mainstem locations from 1997-2006 (Figure 28). Smolt traps were fished in the mainstem Klamath River, Trinity River, Salmon River, Happy Camp, Elk Creek, Seiad Creek, and Horse Creek by the Arcata office of the US Fish and Wildlife Service (AFWO). Additional traps were fished on the Scott and Shasta rivers from 2000-2006 by the California Department of Fish and Game (CDFG). Data from the Salmon River and Elk Creek trap sites were not used to determine passage timing due to the low number of coho smolts captured at these locations. For each reach in the model, we used data from the nearest trap to characterize passage timing (Table 7).

We calculated an index of abundance by weighting weekly trap catches by the flow each week to estimate the average smolt migration timing at each trap location. This abundance index was similar to the method used by the AFWO in which the total daily catch is divided by the proportion of flow sampled (USFWS 2001). Because we did not have estimates of flow sampled at most of the trap sites, it was not possible to use the AFWO method. In addition, mark-recapture estimates of abundance were not available for most of the trapping sites.

This index of abundance yielded similar estimates of peak migration timing of age-0 fry as the AFWO index at two trapping sites (Figure 29). Age-0 fry were used for comparison because too few smolts were captured in most years to estimate trap efficiency. The estimated median passage week was generally similar (within 1-2 weeks) between the two abundance index methods. Peak passage timing estimated from the abundance indices were generally earlier than that from raw count data. This trend is not surprising given that flow tended to be higher early in the year and trap efficiency is assumed to be inversely related to flow.

The abundance index was based on the assumption that trap efficiency is inversely proportional to flow. While the relationship between trap efficiency and flow is probably not linear and may be complicated by other factors such as fish size and turbidity, the general negative relationship between trap efficiency and flow is commonly observed in downstream migrant studies. For example, we observed a strong negative relationship between flow and catch rate of juvenile Chinook salmon in a rotary screw trap in the Stanislaus River (Figure 30). Therefore, the expanded abundance indices likely provide a more realistic estimate of migration timing than simple count data. The abundance index was not used to estimate abundance but to examine patterns in migration timing.

Table 6. Estimated proportion of age-1+ coho smolt passage through the Klamath mainstem for biweekly cohorts originating from the 16 model reaches and IGH.

Biweek		Production Reach															
start date	IGH	MS1	MS2	MS3	MS4	MS5	MS6	MST1	MST2	MST3	MST4	MST5	MST6	SHASTA	SCOTT	SALMON	TRINITY
5-Feb	0.000	0.000	0.000	0.000	0.034	0.000	0.000	0.000	0.005	0.013	0.013	0.013	0.013	0.000	0.002	0.004	0.000
19-Feb	0.000	0.000	0.001	0.001	0.070	0.000	0.000	0.000	0.034	0.056	0.056	0.056	0.056	0.000	0.011	0.018	0.000
5-Mar	0.000	0.000	0.010	0.010	0.118	0.000	0.000	0.001	0.129	0.149	0.149	0.149	0.149	0.001	0.045	0.058	0.001
19-Mar	0.034	0.034	0.055	0.055	0.163	0.000	0.000	0.087	0.267	0.248	0.248	0.248	0.248	0.026	0.122	0.130	0.009
2-Apr	0.498	0.498	0.173	0.173	0.184	0.001	0.001	0.603	0.302	0.262	0.262	0.262	0.262	0.187	0.216	0.206	0.054
16-Apr	0.444	0.444	0.296	0.296	0.168	0.033	0.033	0.300	0.187	0.175	0.175	0.175	0.175	0.420	0.256	0.232	0.169
30-Apr	0.024	0.024	0.277	0.277	0.126	0.253	0.253	0.009	0.063	0.074	0.074	0.074	0.074	0.297	0.200	0.187	0.292
14-May	0.000	0.000	0.142	0.142	0.077	0.472	0.472	0.000	0.012	0.020	0.020	0.020	0.020	0.066	0.104	0.106	0.279
28-May	0.000	0.000	0.040	0.040	0.038	0.216	0.216	0.000	0.001	0.003	0.003	0.003	0.003	0.004	0.036	0.043	0.146
11-Jun	0.000	0.000	0.006	0.006	0.015	0.024	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.012	0.042
25-Jun	0.000	0.000	0.001	0.001	0.005	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.007
9-Jul	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
23-Jul	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

MS = mainstem reach; MST = miscellaneous mainstem tributaries.

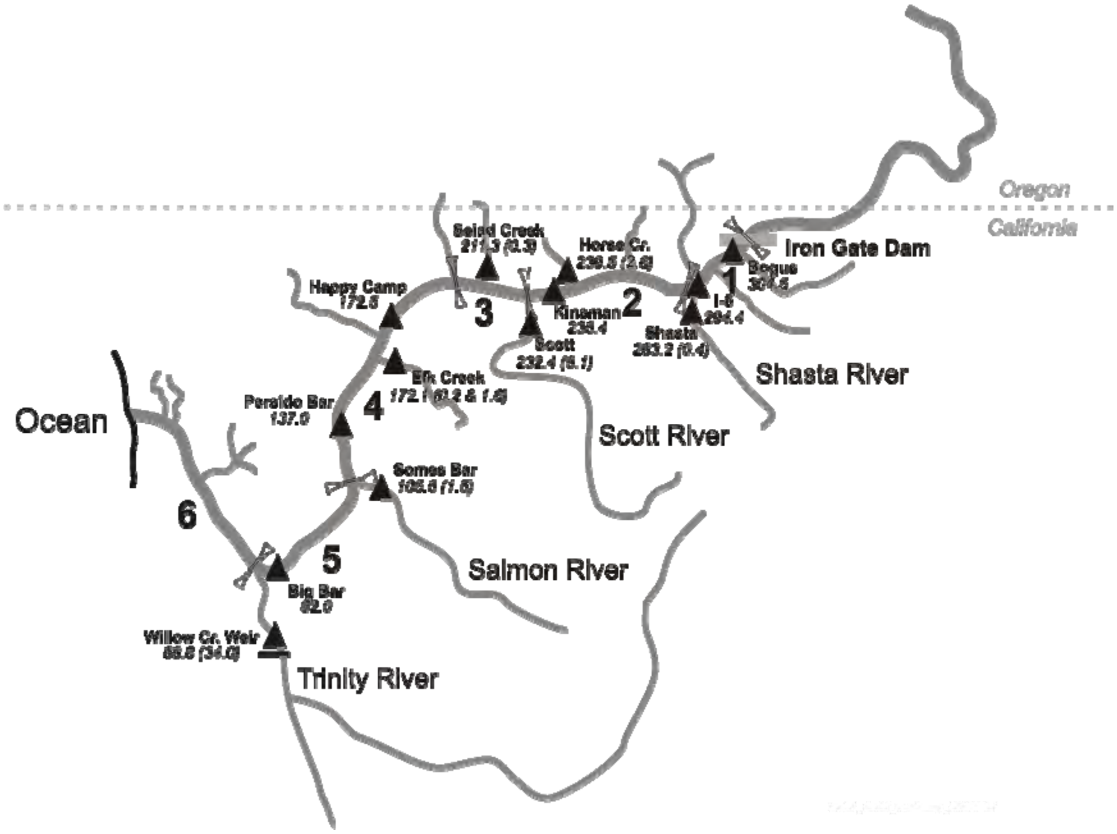


Figure 28. Map of the Klamath River Basin showing model reaches (bold numbers) and downstream migrant trapping locations (triangles).

Table 7. Description of migrant trapping data used to represent smolt emigration timing for each model reach.

Model reach	Representative trap site(s)	Klamath rkm (tributary rkm)	Monitoring agency	Year(s)
IGH & MS1	Klamath R. @ Bogus Cr.	304.5	USFWS	2002-2005
	Klamath R. @ I-5	294.4	USFWS	2002-2005
MS2 & MS3	Klamath R. @ Kinsman Cr.	236.4	USFWS	2002-2005
MS4	Klamath R. @ Happy Camp	172.5	USFWS	2004
	Klamath R. @ Persido Bar	137.0	USFWS	2004
MS5 & MS6	Klamath R. @ Big Bar	82.0	USFWS	1998-2004
MST1	Klamath R. @ Bogus Cr.	304.5	USFWS	2002-2005
MST2	Horse Cr.	239.5 (2.6)	USFWS	1997
MST3-MST6	Seiad Cr.	211.3 (0.3)	USFWS	2004
Shasta	Shasta R.	283.2 (0.4)	CDFG	2005-2006
Scott	Scott R.	232.4 (8.1)	CDFG	2000-2006
Salmon	Seiad Cr.	209 (0.2)	USFWS	2004
Trinity	Trinity R. @ Willow Cr.	68.8 (34)	USFWS	1998-2005

MS = mainstem; MST = mainstem tributary.

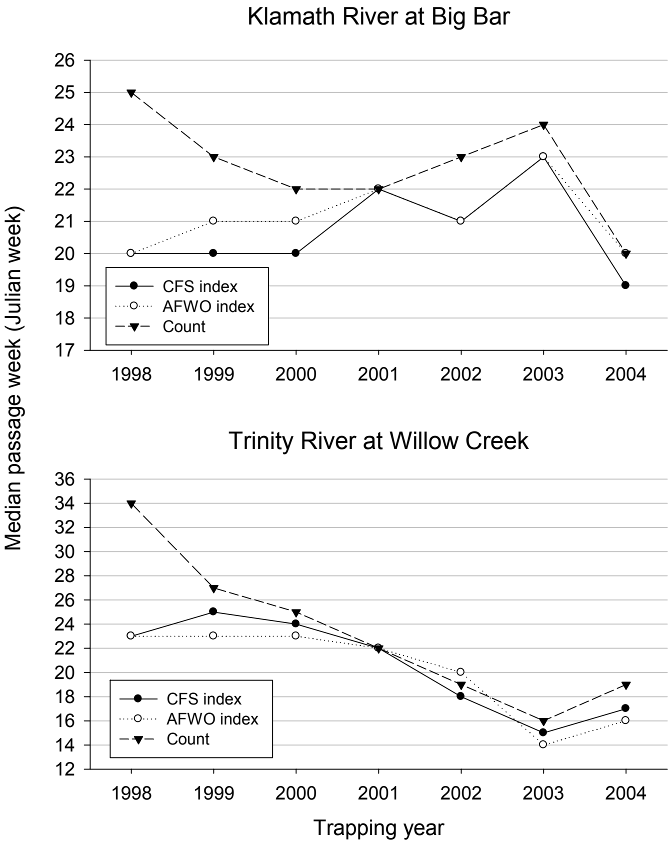


Figure 29. Comparison of peak passage timing of age-0 coho salmon passing the Klamath River at Big Bar and Trinity River at Willow Creek trap sites estimated from raw count data, abundance index data based on proportion of flow sampled (AFWO index), and abundance index data based on direct proportionality to flow (CFS Index).

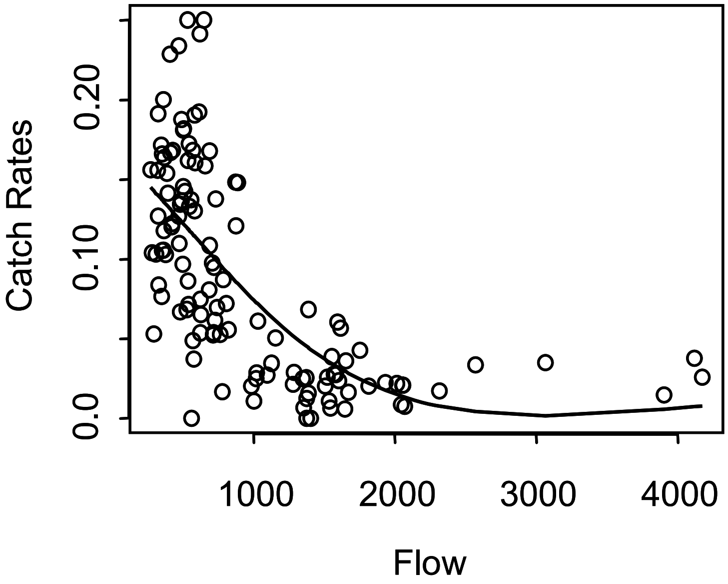


Figure 30. Catch rates of juvenile Chinook salmon as a function of flow for 122 day-specific mark-recapture releases at the Caswell trap location on the Stanislaus River. The solid line is an exploratory fit of a smoothing spline.

CDFG estimated abundance of emigrating juvenile coho salmon in the Scott and Shasta Rivers using mark-recapture techniques in 2003-2006 (Chesney et al. 2007). However, very few marked fish were recaptured in 2003 and 2004, resulting in unreliable abundance estimates in those years. Therefore, we estimated fish passage timing in 2003 and 2004 with the flow-based abundance indices, and with abundance estimates in 2005 and 2006.

We developed normalized smolt passage timing distributions for trapping locations to simulate smolt migration through the mainstem. The number of age-1+ smolts captured per year in downstream migrant traps was generally low, ranging from 0 to 3,828 (mean = 207 across all years and trapping locations) (Table 8). The number of fish captured was particularly low for mainstem trap sites, averaging only 12, 30, and 10 fish per year at Bogus Creek, Kinsman Creek, and Big Bar respectively. Because of the relatively small number of coho smolts captured in mainstem traps, we assumed that normalized passage timing distributions, as opposed to passage distributions based on raw data, would best represent average passage timing. At each trapping location, we calculated the mean passage date and associated standard deviation for each year of available trapping data. We then averaged the mean passage dates and standard deviations across all years and fit a normal curve to the data in order to approximate the average passage distribution that may be expected over a large number of years. These normal curves were used to estimate the proportion of fish from a production reach expected to pass through the mainstem by biweekly period (Table 6).

The resulting passage of coho salmon smolts in the mainstem Klamath River peaks progressively later moving downstream (Figure 31). This spatial variability emphasizes the importance of including distinct passage timing for each reach in the life cycle model. We assumed that all fish from a given cohort would migrate to the estuary within a 2-week period. This assumption is generally consistent with the median migration rate of 21.7 km/day for wild radio-tagged coho smolts reported by Stutzer et al. (2006).

The model does not currently incorporate interannual variability in passage timing. Migration timing of coho smolts is likely to vary with fluctuations in environmental conditions, particularly stream temperature. For example, Roper and Scarnecchia (1999) found the median migration date for Chinook salmon emigrating from tributaries in the Umpqua River occurred approximately one month earlier as spring water temperatures increased by 5˚C. However, available data on migration timing of coho smolts in the mainstem Klamath River does not provide a clear relationship between environmental conditions and interannual variability in migration timing (Technical Memorandum 4, Appendix A), although our ability to detect a relationship was likely reduced by the low abundance of smolts in recent years. Future analysis may include examination of the relationship between stream temperature and migration timing of coho smolts in the Klamath and other areas to determine if there is basis for incorporating a function that shifts the migration timing of coho smolts in response to spring water temperature or flow into a later version of model.

Table 8. Total number of age-1+ coho captured in downstream migrant traps in the mainstem Klamath River and various tributaries by year.

Trap site	Klamath rkm (tributary rkm)	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
Klamath @ Bogus Cr	304.5					1	6	35	6		48
Klamath @ I-5	294.4					15	2	4	4		25
Shasta R	283.2 (0.4)								409	797	1,206
Horse Cr	239.5 (2.6)							88			88
Scott R	232.4 (8.1)			832	19	11	1,473	93	248	3,828	6,504
Klamath @ Kinsman Cr	236.4					8	64	12	35		119
Seiad Cr	211.3 (0.3)							65			65
Klamath @ Happy Camp	172.5							17			17
Elk Cr	172.1 (0.2 & 1.6)							2			2
Klamath @ Persido Bar	137.0							3			3
Salmon @ Somes Bar	105.6 (1.5)					0	2	0			2
Trinity @ Willow Cr	68.8 (34)	32	77	48	54	574	78	65	33		961
Klamath @ Big Bar	82.0	1	3	9	9	25	8	16			71
Total		33	80	889	82	634	1,633	400	735	4,625	9,111

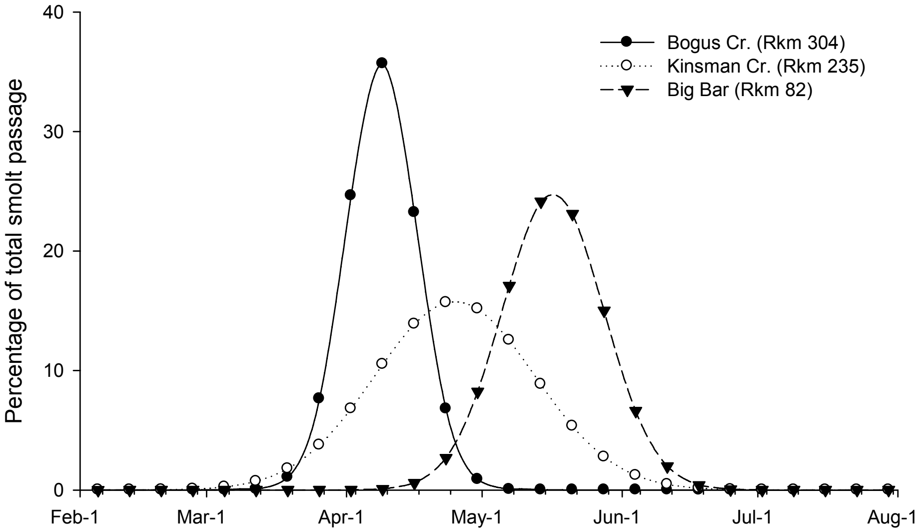


Figure 31. Passage timing distributions of coho salmon smolts at three mainstem Klamath River Trapping locations. Mean passage dates and associated standard deviations for all available years of trapping data (1998-2005) were used to derive the normal distributions shown here.

Effect of Migration Distance (*d*) on Survival

Distance of migration is perhaps the most influential variable affecting smolt emigration survival. There are few examples in which smolt survival has been tracked over long distances of free-flowing rivers for coho, so we examined data on yearling Chinook smolts for reference. Williams et al. (2005) found that survival of yearling Chinook salmon released from Snake River Basin hatcheries to the tailrace of Lower Granite Dam from 1993-2003 was closely and negatively related to migration distance ($R^2 = 0.941$, $P < 0.001$; Figure 32). Total migration survival was highest (0.765) from Dworshak National Fish Hatchery (116 km from Lower Granite Dam), and lowest (0.403) from Sawtooth National Fish Hatchery (747 km from Lower Granite Dam). Muir et al. (2001) demonstrated that survival through the free flowing Snake River and its tributaries is a function of distance from the hatchery where the fish were released. Similarly, Anderson (2003) found that survival of all PIT-tagged groups passing though free-flowing reaches of the Snake River Basin was best accounted for as a function of distance.

In order to determine the effect of migration distance on survival, independent of temperature and flow effects, it was necessary to determine a baseline or maximum survival rate for coho smolts migrating to the ocean. Because there is little data on coho smolt survival in the Klamath River, we reviewed studies elsewhere in the Pacific Northwest to establish a credible range of survival estimates for emigrating smolts. Migration survival of yearling Chinook and coho smolts has been estimated in free flowing (unimpounded) sections of the Yakima river (Pyper and Smith 2005) and partially impounded sections of the Snake River (i.e. release to Lower Granite Dam; Williams et al. 2005). We used survival estimates from yearling Chinook salmon as a surrogate for coho salmon because data on emigration survival of coho salmon is largely lacking in the literature and because the life history characteristics (i.e. size and migration timing) of yearling Chinook salmon closely resembles that of juvenile coho salmon.

In order to compare survival rates of fish from different rivers across varying migration distances, we standardized all survival estimates by the migration distance using the following formula: Survival per 100km = $\text{Survival}^{(100/\text{total distance})}$. We found that the highest survival estimate per 100 km from these data was 0.95 and the lowest was 0.62 (Table 9). The majority of the survival estimates per 100 km for the

Columbia River ranged between 0.80 and 0.95. We used the maximum survival estimate of 0.95 to define the survival rate for coho smolts under optimal conditions in the mainstem Klamath River.

The migration distance used to estimate emigration survival for each cohort of smolts was defined as the distance from the midpoint of each reach of origin to the Klamath River estuary. For example, smolts migrating from the mouth of the Shasta River (rkm 284) to the mouth of Portuguese Creek (rkm 205) will travel approximately 79 km. Smolts originating in a mainstem reach, or in one of the miscellaneous tributary reaches will be assumed to start emigration at the mid-point in their mainstem reach.

The relative effect of migration distance on survival was described by:

Equation 24) $\text{Distance Effect} = \left(S_{Base}\right)^{d/100}$;

Where:

S_{Base} = baseline (i.e. maximum) survival rate per 100 km under optimal temperature and flow conditions (default = 0.95),

d = migration distance from the midpoint of the starting reach to the estuary (km).

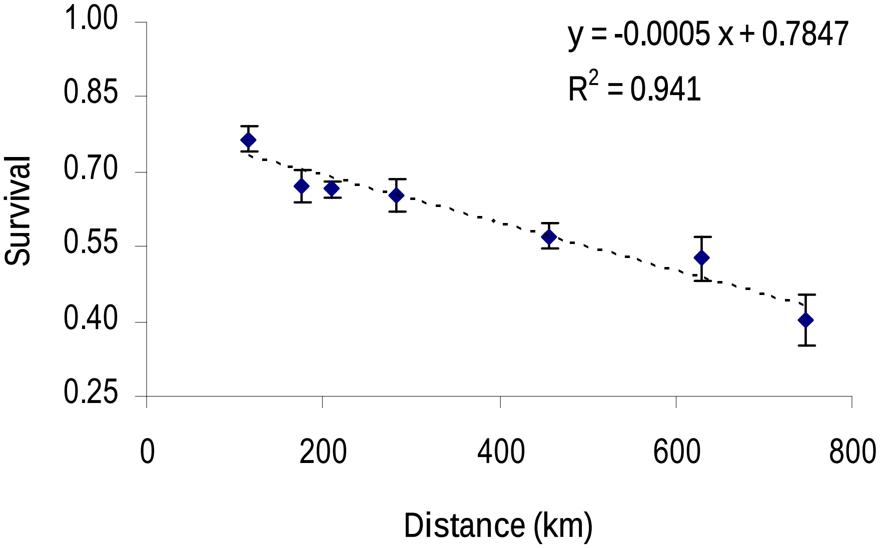


Figure 32. Mean survival rates for yearling Chinook salmon from Snake River hatcheries to the tailrace of Lower Granite Dam, 1993-2003. Modified from Williams et al. (2005).

Table 9. Snake River yearling Chinook survival rates per 100 km from Snake River hatcheries to Lower Granite Dam, Yakima River juvenile spring Chinook and coho survival from Prosser Dam to McNary Dam, and Klamath River 2006 coho survival estimate. Data was modified from Williams et al. (2005), Pyper and Smith (2005) and John Beeman USGS (personal communication) using the following formula to calculate survival per 100 km: Survival$^{(100/total\ distance)}$.

	Snake River Yearling Chinook							Yakima River		Klamath River			
Year	Dworshak	Kooskia	Imnaha River weir	Rapid River	McCall	Pahsimeroi	Sawtooth	Spring Chinook	Coho	Coho	Mean	Max	Min
1993*	0.687	0.809	0.820	0.868	0.859	0.883	0.833	—	—	—	0.823	0.883	0.687
1994*	0.805	0.850	0.834	0.797	0.879	0.836	0.811	—	—	—	0.830	0.879	0.797
1995***	0.859	0.872	0.794	0.893	0.867	0.833	0.821	—	—	—	0.848	0.893	0.794
1996***	0.804	0.845	0.762	0.829	0.871	—	0.754	—	—	—	0.811	0.871	0.754
1997***	0.622	0.634	0.793	0.712	0.829	0.896	0.913	—	—	—	0.771	0.913	0.622
1998**	0.857	0.784	0.833	0.863	0.889	0.874	0.934	—	—	—	0.862	0.934	0.784
1999***	0.855	0.785	0.824	0.902	0.910	0.918	0.899	0.907	0.913	—	0.879	0.918	0.785
2000**	0.861	0.839	0.836	0.902	0.922	0.930	0.922	—	—	—	0.887	0.930	0.836
2001*	0.778	0.732	0.870	0.877	0.915	0.927	0.917	0.743	0.790	—	0.839	0.927	0.732
2002**	0.842	0.873	0.824	0.905	0.892	0.940	0.881	—	—	—	0.879	0.940	0.824
2003**	0.753	0.719	0.852	0.878	0.885	0.949	0.933	0.792	0.834	—	0.844	0.949	0.719
2004**	—	—	—	—	—	—	—	—	—	—	—	—	—
2005*	—	—	—	—	—	—	—	—	—	—	—	—	—
2006***	—	—	—	—	—	—	—	—	—	0.865	—	—	—

*Low Flow Year

**Moderate Flow Year

***High Flow Year

Temperature Survival Scalar

Temperature has consistently been found in studies along the West Coast to be negatively correlated with smolt emigration survival (Kjelson and Brandes 1989; Baker et al. 1995; Anderson et al. 2003). These studies generally show that increasing stream temperatures have little influence on migration survival at low to moderate temperatures, but have a dramatic negative effect when temperatures exceed a specific threshold (Williams et al. 2005; Pyper and Smith 2005). Here we use findings from such studies to derive a function for use in our model to predict reach specific temperature effects on emigrant survival.

We developed a logistic function to describe the relationship between emigration survival and average stream temperature whereby the survival scalar (value 0 to 1) is given by:

Equation 25) $$D_{MTemp,i} = \frac{1}{1+e^{-a-bT_i}};$$

Where:

$D_{MTemp,i}$ = emigration survival scalar in reach *i*,

a= intercept of logit($D_{Temp,i}$) = 14.07,

b = slope of logit($D_{Temp,i}$) = -0.65, and

T_i = mean daily water temperature for each biweekly period in reach *i*.

The parameters for this function were calculated by defining two temperature thresholds: a lower temperature threshold of 17˚C beyond which survival decreases rapidly; and an upper lethal temperature limit of 26˚C where survival approaches zero. We chose the 17˚C threshold because it represented an approximate midpoint of the threshold temperatures observed in a number of field studies (Kjelson and Brandes 1989; Baker et al. 2003; Williams et al.2005; Pyper and Smith 2005). An upper lethal temperature at which survival approaches zero was set at 26˚C based on laboratory studies of juvenile coho salmon showing that upper lethal temperatures ranged from 25 to 26 ˚C (Brett et al. 1952; Beschta et al. 1986; Bjornn and Reiser 1991). This functional relationship should be refined as additional information about the relationship between stream temperature and survival becomes available. The resulting survival curve is very similar to that described by Baker et al. (2003), which was also used in the SALMOD model to simulate the thermal effects on survival of juvenile Chinook salmon in the Klamath River (Bartholow and Henriksen 2006).

The biological justification for a temperature survival scalar stems from the consistent relationship between temperature and smolt survival in the available data and research on this topic. Warmer stream temperatures may increase metabolic costs associated with rearing and migration (Groot et al. 1995) and also increase predation rates by elevating the metabolic demand of predators (Vigg et al. 1991). Kjelson and Brandes (1989) reported that survival of juvenile Chinook migrating through the Sacramento-San Joaquin Delta declined steadily as temperature increased from 16 to 21˚C, and Baker et al. (1995) estimated the upper incipient lethal temperature was 23˚C for these fish.

Similarly, Pyper and Smith (2005) found that the “best” logistic model for coho salmon in the Yakima River, Washington included the variables *temperature*, *log(flow)*, *year*, *day* and *travel time*. The dominant explanatory variable was *temperature*, which had a negative association with survival. The fit of a GAM (generalized additive model) model strongly suggested that the relationship between temperature and logit(survival) was nonlinear, with temperature having a pronounced negative effect above roughly 19.4˚C. For yearling Chinook salmon emigrating through the Lower Snake and Columbia Rivers from Lower Granite Dam to McNary Dam from 1996-2003, general additive models and multiple regression models indicated that temperatures below 13˚C did not influence survival, but that survival decreased with increasing temperatures above this threshold (Williams et al. 2005).

Comparison of the relationships between temperature and emigration survival of juvenile salmonids from various basins indicates considerable variation in both the magnitude and range of the temperature effect (Figure 33). Clearly, physical differences among river basins such as stream gradient and discharge, channel morphology, and climate as well as differences among fish species and life history characteristics will influence the biological response to stream temperature. Some of the observed differences between the temperature and survival functions may also be attributed to the form of temperature measurement used in the analyses. For example, Williams et al. (2005) and Baker et al. (2003) used 7-day average temperature in their analysis while Pyper and Smith (2005) used daily average temperatures. Despite these differences, these data suggest that emigration survival declines sharply at stream temperatures above 20˚C, and may begin declining at temperatures as low as 13˚C under some circumstances.

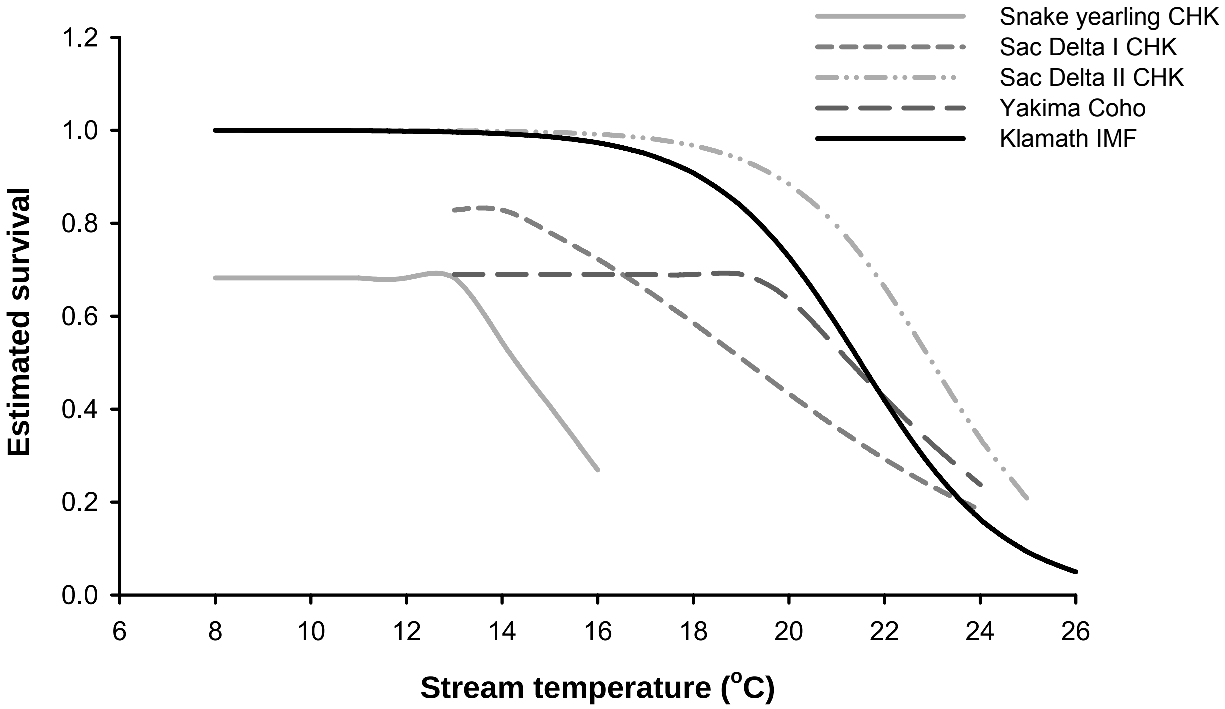


Figure 33. Relationship between stream temperature and emigration survival of yearling Chinook salmon (CHK) in the Snake and Columbia Rivers (Williams et al. 2005), juvenile Chinook salmon in the Sacramento-San Joaquin Delta (I. Kjelson and Brandes 1989; II. Baker et al. 2003), and juvenile coho salmon in the Yakima River (Pyper and Smith 2005).

Accounting for disease effects on smolt survival

The model accounts for disease effects on smolt survival between IGD and the Portuguese Creek (Reaches 1-3) by shifting the temperature survival scalar to encompass lower temperature thresholds (Figure 34). This shift is accomplished by substituting 16.69 for the intercept *a* and -0.98 for the slope *b* in Equation 25. The revised temperature scalar is based on 14^{o}C and 20^{o}C for the lower and upper thresholds. We chose a lower temperature threshold based on observations that disease effects on salmon become evident at approximately 14^{o}C (Foott et al 2004). Udey (1975) observed approximately 85% mortality at 20.5^{o}C for juvenile coho exposed to *Ceratomyxa shasta*.

Though juvenile coho in the Klamath River have likely adapted to local disease conditions, they will be exposed to a suite of pathogens in the mainstem from Iron Gate Dam to Portuguese Creek. *Myxozoan* pathogens will have the greatest effect and will likely result in notable mortality at 16˚C and above (Foott et al. 2004). Thus, high temperatures have a greater effect on smolt survival in the upper mainstem reaches than in lower reaches.

Inclusion of a disease effect on smolt survival in the upper reaches was justified because disease conditions in the mainstem Klamath River between Iron Gate Dam and the Portuguese Creek are having unusually high impacts on juvenile salmonid survival. This conclusion is drawn from several sources of empirical data including parasite concentration sampled in the mainstem Klamath in the spring of 2005 (Jerri Bartholomew, unpublished data) and infection prevalence (Figure 35; Stocking and Bartholomew 2007). USFWS 2004 screw trap data in the mainstem Klamath further corroborate these findings. Fish trapped at Kinsman, upriver of the Scott River confluence and downriver of Horse Creek, experienced significantly higher mortality compared to those trapped further downriver. Researchers also reported many live fish captured in mainstem traps below Iron Gate Dam exhibiting external signs of disease infection and/or stress (Chamberlain and Williamson 2006). In addition, Beeman (2007) estimated lower smolt survival in mainstem sections above the Scott River (Table 12). Preliminary results from 2007 smolt survival studies reveal similar patterns of reduced survival (John Beeman, Personal Communication).

The life-cycle model applies the average temperatures within each reach over a biweekly period to the logistic temperature function to derive survival scalars. We estimate roughly 50% survival at 17˚C in Reaches 1-3. Survival estimates from radio tracking of coho smolts in the Klamath Basin in 2006 are congruent with how the logistic function would have scaled survival in these reaches. Survival was roughly 0.837 (Beeman 2007) in the mainstem section that corresponds to Reaches 1-3 of the life-cycle model. We estimated temperatures to be an average of 14.4-15.1˚C during the telemetry study. Using the scalar below, a temperature of 15˚C would amount to a scaled effect on survival of approximately 0.88.

Some have suggested that increasing flow reduces the concentration of disease organisms and may reduce salmonid infection rates. In contrast, a recent study indicates that a threefold increase in spring river flows did not effectively reduce parasite infection rates in the Klamath River (Foote et al. 2007). This suggests that increasing spring flows would not reduce parasite infection rates by itself. However, increased flows may increase migration rates thereby reducing the length of time smolts are exposed to parasites. We chose to take a similar modeling approach to that presented in SALMOD and adjust weekly disease-induced coho mortality based on temperature alone; however, though the flow-disease mortality relationship has not been independently parameterized in the model, the flow survival scalar described in the next section accounts for disease-induced smolt mortality along with a suit of other mortality factors related to flow.

The CFS Team intends to propose a study design along with disease experts in the Klamath Basin to explore the relationship between flow, disease concentration, and juvenile salmonid survival. With the right data, we feel confident that the effects of flow, independent of temperature, can be parameterized within the Klamath coho life-cycle model.

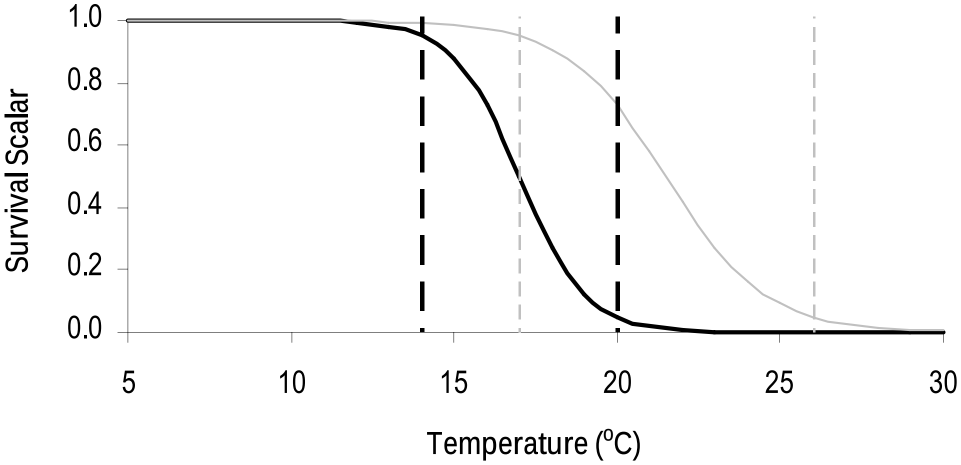


Figure 34. Logistic function used to predict the scaled effect of temperature on mortality of coho smolts migrating in the mainstem Klamath River between Iron Gate Dam and Portuguese Creek (model Reaches 1-3). Dashed vertical lines represent the default lower and upper temperature thresholds of 14˚C and 20˚C. The gray solid line represents the temperature scalar derived for temperature effects on smolt mortality between Portuguese Creek and the Klamath River mouth (model Reaches 4-6). Gray dashed vertical lines represent the default lower and upper temperature thresholds of 17 ˚C and 26 ˚C.

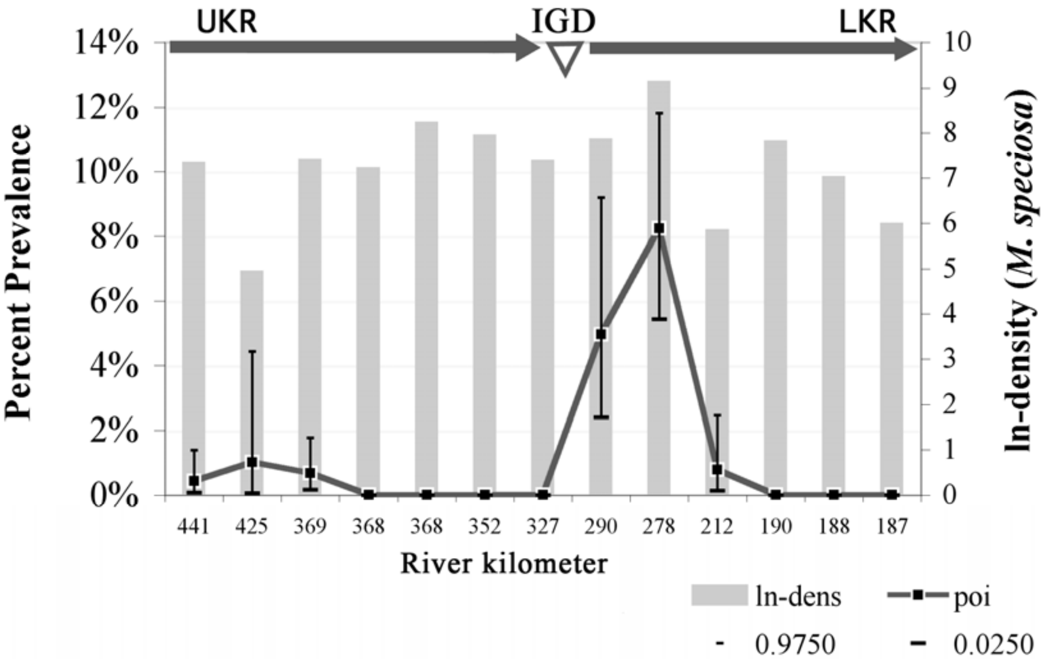


Figure 35. Estimates of Ceratomyxa shasta infection prevalence (poi) and associated 95% confidence intervals within selected populations of Manayunkia speciosa collected from the Klamath River. Sites sorted on the x-axis from Upper Klamath Lake (Rkm 441) going downriver towards the mouth. Abbreviations UKR = Upper Klamath River, IGD = Iron Gate Dam, and LKR = Lower Klamath River (from Stocking and Bartholomew 2007).

Flow Survival Scalar

While there has been some conflicting discussion on the topic of flow effects on emigration survival (Anderson 2003), it is generally accepted that survival increases with discharge in free flowing river reaches. Distinction between temperature and flow effects is difficult because these two variables are often correlated. Lawson et al. (2004) found natural production of coho smolts tended to be greater in years of higher flow during smolt emigration for Oregon coastal rivers. This was one of four environmental variables that together accounted for 52% of variation in smolt production over 30 years of data. Smolt production ranged from 1.3 to 6.5 million from Oregon coastal rivers, and the estimated effect of spring flow from the lowest to highest observations was from minus 1 million to plus 1 million. Similarly, Pyper and Smith (2005) found that flow has a strong effect on survival rates of Yakima River fall Chinook, an intermediate effect for coho, and a minimal effect for spring Chinook.

To model the effects of flow on survival of migrating coho smolts in the mainstem Klamath River, we developed reach-scale logistic functions based on theoretical threshold flow levels and reach-scale survival estimates derived from radio-telemetry studies (Beeman 2007). The relationship between smolt survival and flow in each reach can be described by the following equation:

Equation 26) $$D_{MFlow,i} = \frac{1}{1+e^{-a-bF_i}};$$

where $D_{MFlow,i}$ = emigration survival scalar for reach i,

a = intercept for logit($D_{MFlow,i}$),

b = slope of logit($D_{MFlow,i}$), and

F = mean daily flow (cfs) for each biweekly period in reach i.

The parameters for the flow-survival function were based on assumed values for the intercept (i.e. survival at which flow = 0 cfs) and the expected survival at median spring flows (Table 10). Note that actual flows will never approach zero, so the survival at zero flow does not have biological significance. Rather the zero flow intercept influences the elevation of the survival-flow curve as it passes through flows that are likely to occur. Median flow for each of the mainstem reaches was calculated from March-May, 1998-2007, using USGS flow data at the nearest upstream gauging station (Table 11). The reach-specific flow-survival scalars ($D_{MFlow,i}$) are then multiplied together to derive the cumulative flow survival scalar from the starting point of migration to the estuary.

Table 10. Parameters used to describe the reach-specific flow-survival scalars.

Flow scalar parameters	MS1	MS2	MS3	MS4	MS5	MS6
Scalar @ 0 flow	0.60	0.60	0.70	0.70	0.80	0.80
Scalar @ median flow	0.85	0.85	0.95	0.95	0.99	0.99
logit intercept (*a*)	0.40547	0.40547	0.84730	0.84730	1.38629	1.38629
logit slope (*b*)	0.00058	0.00058	0.00041	0.00028	0.00025	0.00013

Table 11. Median spring flows (March-May) for each model reach indicating the gauging station and years of record used to estimate the median flow. These data were used to specify the expected survival rate at median flow.

Model reach	Median flow (March-May)	Gauging station	Years of record
MS1	2,300	Iron Gate Dam	1998-2007
MS2	2,300	Iron Gate Dam	1998-2007
MS3	5,100	Seiad Valley	1998-2007
MS4	7,400	Seiad Valley * 1.45[a]	1998-2007
MS5	12,700	Orleans	1998-2007
MS6	24,400	Klamath	1998-2007

[a] There was no gauging station near the midpoint of MS4, so we multiplied the median flows at Seiad Valley by 1.45 to estimate the median flow at MS4. This ratio was derived from the average ratio between median flow at the midpoint of MS4 and MS3 from modeled flows in the Klamath River from 2001 and 2004 (personal communication with Mike Deas, Watercourse Engineering, 2007).

Given the dearth of research investigating the relationship between coho smolt survival and flow in the Klamath Basin, we developed hypothetical flow thresholds based on limited survival information from the Klamath River, and from flow-survival relationships from out-of-basin studies.

Analysis of radio-telemetry data indicates that coho smolt survival in the upper reaches of the Klamath River is lower than downstream reaches. A radio-telemetry study examining migration survival of coho smolts in the mainstem Klamath River below IGD during the spring of 2006 indicated that survival in the most upstream section (i.e. release near IGD and the Shasta River to the Scott River) was approximately 84% compared with an average of 95% in other downstream reaches (Table 12; Beeman 2007).

We used capture history data reported in Stutzer et al. (2006) to estimate apparent survival of coho smolts radio-tagged in 2005 using the single-release Cormack-Jolly-Seber model implemented in program MARK (White and Burnham 1999) (Table 13). Survival estimates in 2005 indicated similar relative differences in reach-specific survival estimates compared with survival rates in 2006, although survival rates were considerably lower in most reaches. Specifically, survival was lowest in the most upstream reach (i.e. release near IGD and Shasta River to Trees of Heaven; apparent survival = 0.716) compared with all downstream reaches (range = 0.775-1.0). Preliminary results from a 2007 radio-telemetry study also indicated that the upper reach (release near IGD and Shasta River to Scott River) was substantially lower than in all other downstream reaches (John Beeman, USGS, personal communication).

To develop flow survival scalars for the Klamath River, we began with the assumption that the basic structural form of the function would be curvilinear, with survival approaching an upper limit near a particular flow threshold. The most comprehensive research on smolt emigration survival has shown that there is likely a threshold effect in the relationship between survival and flow. That is, there may be a flow level above which survival remains relatively constant, but below which survival decreases with decreasing flow. Smith et al. (2003) observed a threshold in the relationship between flow and survival of hatchery subyearling fall Chinook salmon in the lower Snake River where survival increased as flows increased to approximately 70.6 kcfs, but did not increase further at flows above that level. Similarly, Williams et al. (2005) estimated that survival of yearling Spring Chinook salmon in the Snake and Columbia Rivers increased as flows increased to approximately 73 kcfs, and then remained relatively constant as flows increased beyond that level. Pyper and Smith (2005) found that the relationship between flow and survival of juvenile coho salmon in the Yakima River was best explained by a logistic function with log(flow) as an independent variable in which survival increased steeply up to about 2000 cfs, and then leveled off rapidly.

Table 12. Estimated apparent survival rates and standardized apparent survival rates (survival per 100 km) for radio-tagged juvenile coho salmon in five study reaches of the Klamath River, spring 2006 (Results from Beeman, 2007).

Reach	Reach distance (km)	Apparent survival	95% CI	Apparent survival/ 100km
Release (IGD (rkm 309) or Shasta River (rkm 263)) to Scott River (rkm 234)	75	0.837	[0.776, 0.893]	0.789
Scott River to Indian Creek (rkm 178)	56	0.916	[0.854, 0.961]	0.855
Indian Creek to Salmon River (rkm 107)	71	0.938	[0.887, 0.973]	0.914
Salmon River to Trinity River (rkm 69)	38	1.000	[0.966, 1.000]	1.000
Trinity River to Steelhead Lodge (rkm 33)	36	0.951	[0.886, 0.997]	0.870
Total (Release to Steelhead Lodge)	276	0.684	[0.613, 0.756]	0.871

Table 13. Estimated apparent survival rates and standardized apparent survival rates (survival per 100 km) for radio-tagged juvenile coho salmon in six study reaches of the Klamath River, spring 2005 (Derived from data in Stutzer et al. 2006).

Reach	Reach distance	Apparent survival	95% CI	Apparent survival/ 100km
Release (IGD (rkm 309) or Shasta River (rkm 263)) to Trees of Heaven (rkm 280.4)	28.6	0.716	[0.636, 0.798]	0.311
Trees of Heaven to Beaver Creek (rkm 263.5)	16.9	0.894	[0.800, 0.956]	0.514
Beaver Creek to Seiad (rkm 213.5)	50.0	0.775	[0.690, 0.847]	0.600
Seiad to Happy Camp (rkm 176.8)	36.7	1.000	[0.914, 1.000]	1.000
Happy Camp to Orleans (rkm 96.6)	80.2	0.770	[0.674, 0.851]	0.722
Orleans to Trinity Confluence (rkm 69)	27.6	0.958	[0.854, 1.000]	0.855
Total (Release to Trinity Confluence)	240.0	0.366		0.658

We chose a logistic function to represent the relationship between survival and flow, as was used to fit actual data on coho survival in the Yakima River (Pyper and Smith 2005). The logistic curve forces the survival probability to an asymptote at a specified flow threshold, which is consistent with previously mentioned studies in the Columbia River basin that have demonstrated a consistent threshold effect of flow on survival. In addition, this function has attractive properties for modeling purposes in that survival is constrained between 0 and 1.

We developed logistic flow survival scalars based on results from emigration survival studies and flow data from the Klamath River from 2005-2007. Because stream reaches used in radio-telemetry studies didn't always match the model reaches defined in this report, it was necessary to approximate survival rates for model reaches where we didn't have corresponding radio-telemetry survival estimates. For example, in 2006 and 2007 radio-telemetry studies, reach 1 was defined as IGD to Scott River, which includes both model reaches 1 (IGD to Shasta R.) and 2 (Shasta R. to Scott R.). To derive separate survival estimates for model reaches 1 and 2, we calculated the square-root of the radio-telemetry survival estimate based on the assumption that the survival rate was constant from IGD to Scott River. We used similar methods to approximate survival rates for reaches 2-5 using radio-telemetry data from 2005.

Next, we removed the distance effect from each survival estimate in order to focus only on the effects of flow. To do this, we calculated the distance effect using the equation: distance effect = $(S_{Base})^{d/100}$; where S_{Base} is the baseline survival rate (0.95 by default), and d is the reach distance in kilometers. We then divided the survival estimate for each reach by the corresponding distance effect to produce reach-specific survival estimates that were independent of migration distance.

Given the small number of reach-specific survival estimates that were available, we made the simplifying assumption that survival scalars were equal for pairs of reaches (Reaches 1-2, 3-4, and 5-6). We set values for the intercept (i.e. survival at which flow = 0 cfs) and the expected survival at median spring flows for each pair of reaches, based on a visual inspection of plots of estimated survival and flows (relative to median flow). The resulting survival scalars are shown in Figure 36. The cumulative flow survival scalars for each reach are shown in Figure 37. These scalars represent the product of each reach-specific scalar, and indicate the cumulative effect of flow on survival from the starting reach to the estuary.

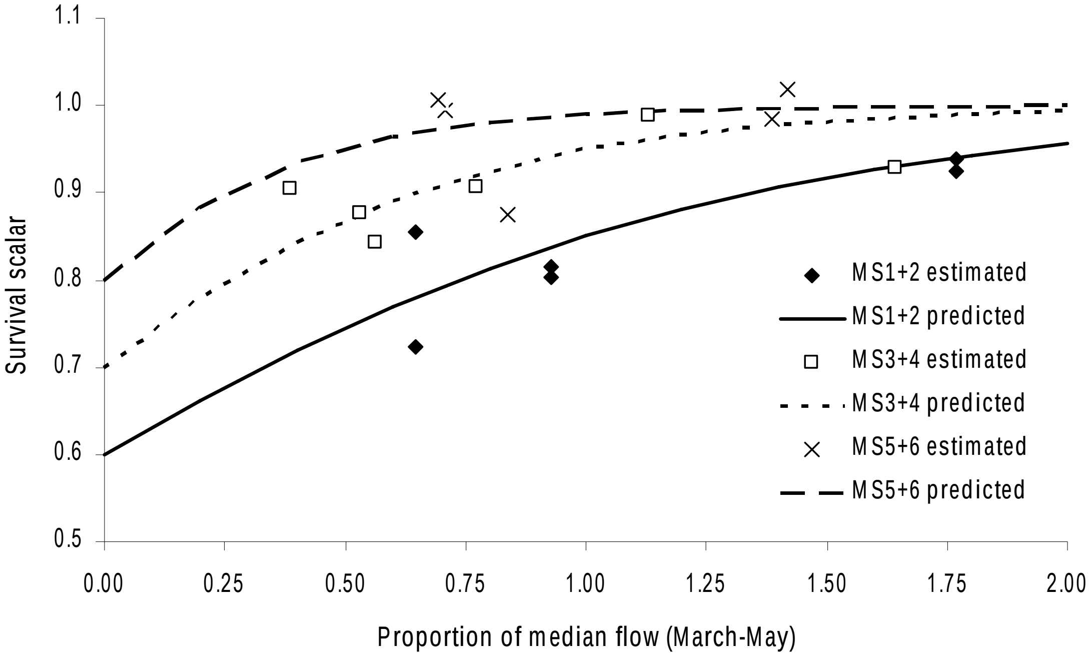


Figure 36. Reach-specific survival scalars as a function of the proportion of median spring flow (March-May, 1998-2007).

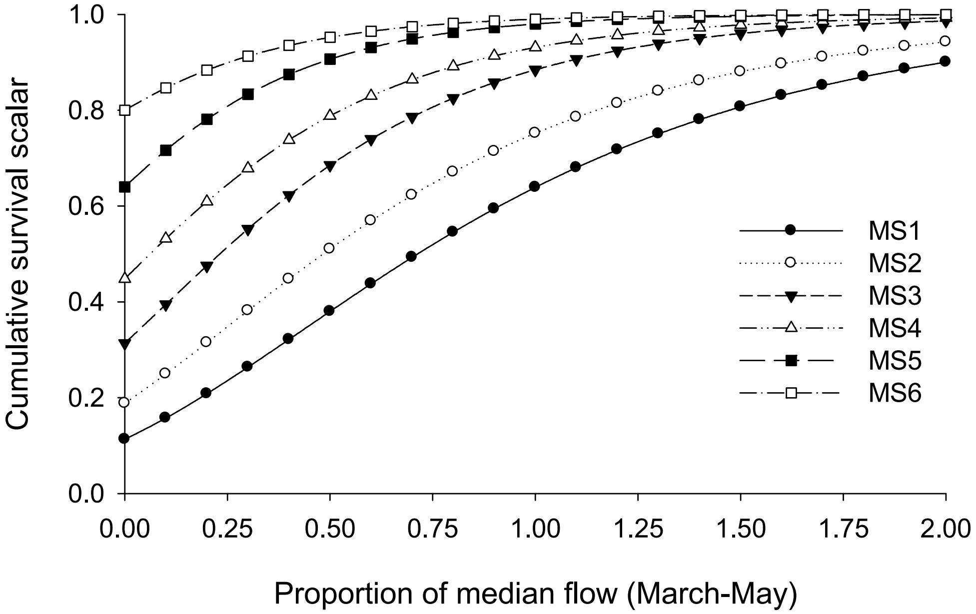


Figure 37. Cumulative survival scalars as a function of the proportion of median spring flow (March-May, 1998-2007).

Marine Survival

The Klamath coho life-cycle model moves smolts entering the ocean through two stages of mortality prior to estimating the total number of adult returns (Figure 38). First, a smolt-to-adult survival rate is applied to the smolts emigrating from the Klamath River. Second, adults undergo an ocean harvest rate to predict the number of adults returning to the mouth of the Klamath River.

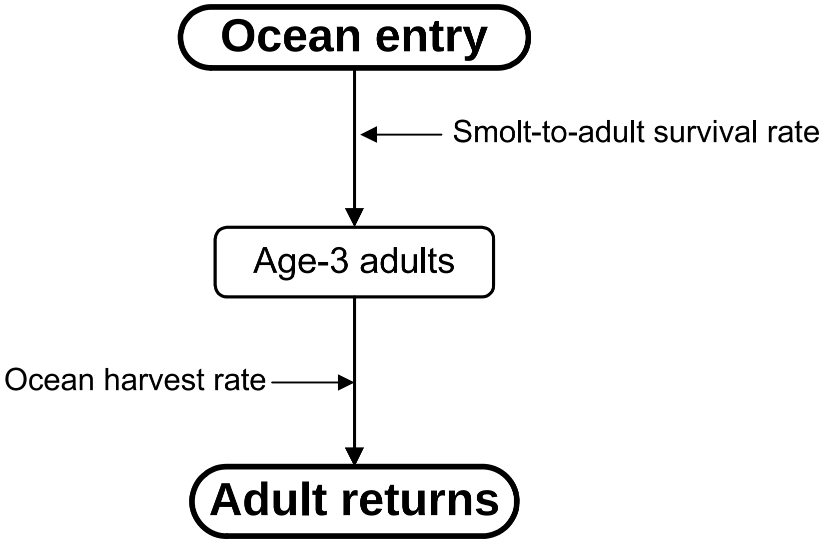


Figure 38. Diagrammatic representation of the marine life-history component of the Klamath coho life-cycle model.

Smolt-to-Adult Survival

We examined the relationship between returns of IGH coho and returns of coho from other hatcheries in the Pacific Northwest to establish a reasonable estimate of smolt-to-adult survival. We discovered a strong correlation between IGH returns to the Klamath River and Cole Rivers hatchery returns to the Rogue River (Figure 39).

The model uses a 4% smolt-to-adult survival rate, or roughly twice the mean predicted IGH survival index (range = 0.12% to 5.7%). Oregon coho hatchery smolts have been shown to survive their first year in the ocean at half the rate of wild smolts (Nickelson 1986, Seiler 1989, Independent Scientific Advisory Board 2003). Similarly, wild smolts were assumed to have ocean survivals twice that of hatchery fish in a model used to investigate the benefits of hatchery supplementation of Oregon coast coho (Oosterhout et al. 2005). We used smolt-to-adult survival rates for coho released from Iron Gate Hatchery for the 1976-2002 broods (CFS 2007, Tech Memo 3), and multiplied each of those survivals by two to determine the percentile distribution of ocean survival expected for naturally-produced coho. Those data indicated that ocean survival of natural coho has varied since 1976 from a 25th percentile value of 2.1% to a 75th percentile valued of 7.6% (Table 14).

Table 14. Percentiles of smolt-to-adult survivals for wild Klamath coho based on return rates of coho released from Iron Gate Hatchery, 1976-2002 broods. Survival of wild fish is assumed double that of hatchery fish.

Percentile	Survival (%)
10%	0.88
25%	2.1
50%	3.8
75%	7.6
90%	9.32

Though marine survival of coho is highly variable, we used a constant value for simulations because future survival of coho populations in the ocean cannot be accurately predicted. As with other forms of uncertainty, the life-cycle model can be used to explore a range of potential ocean effects on coho abundance.

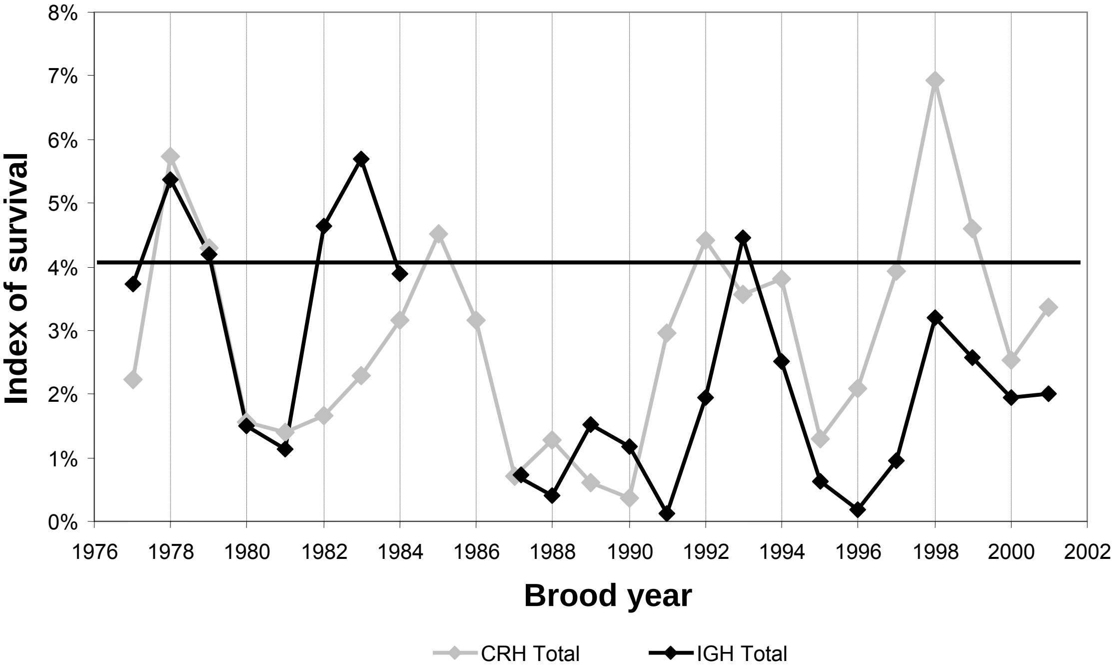


Figure 39. Marine survival trends for Iron Gate hatchery (IGH) and the Cole Rivers hatchery (CRH). Klamath coho life-cycle model default smolt-to-adult survival is set at 4%, which is twice the mean predicted survival for IGH years of record.

Ocean Harvest

The second stage of marine mortality (ocean harvest) occurs when the population reaches 3 years of age. Although retention of all coho is prohibited south of the Oregon/California border, Klamath coho are incidentally harvested north of the border. The Pacific Fisheries Management Council (PFMC) has set a maximum ocean harvest rate for Southern Oregon/Northern California Coast coho (which includes Klamath River coho) at 13%. In recent years, the estimated exploitation rate on Rogue/Klamath coho has ranged between 2.9% and 10.5%. A default 6.5% ocean harvest rate is used in the life-cycle model to account for incidental ocean harvest on age-3 adults prior to freshwater entry (Figure 38). A 6.5% harvest rate represents half the maximum value set by the PFMC and is within the range of recent estimates. As with smolt-to-adult survival, the model can be used to explore a range of ocean harvest values.

Simulation Methods

Inputs

The coho life-cycle model simulates the number of Klamath Basin coho alive at different stages and locations in their life cycle, dependent on the environmental circumstances and management effects they encounter. The variable factors that fish encounter within a simulation year include flow and temperature conditions in the mainstem. These variable factors must be supplied as inputs for each year of simulation, and they include daily values of temperature and flow at the midpoint of each mainstem reach. Because temperature and flow were not measured at each of these points, a hydrodynamic temperature model was used to simulate temperature and flow conditions from Iron Gate Dam to the estuary for a wide range of flow releases at IGD. This model accurately simulates river temperatures at one-hour time steps and 150 m intervals from IGD (RM 190) to Turwar (RM 5). A complete description of this hydrodynamic temperature model including validation with observed temperature data in the Klamath River is provided in Technical Memorandum 7 (CFS 2007) and model outputs are summarized in Appendix 3.

Because tributary flows play a large role in determining downstream flow and temperature, we ran model simulations with two sets of tributary flow conditions; one for a dry water year and one for an average water year. We used weather and tributary flow conditions in 2001 to represent the dry year, and for 2004 to represent the average year. Although flows at IGD during 2001 and 2004 were both below normal, those same years produced 95% and 55% exceedence flows, respectively, from the Salmon River. The Salmon River provides a reasonable index of tributary inputs, because its watershed is located between the Scott and Trinity rivers.

Flows to be released from Iron Gate Dam will vary depending on annual precipitation and the volume of water arriving at the project. Variation in project flow between years was determined from flows recorded over the baseline period, 1961-2006. These flows were used to determine the exceedence probability in each month for any given flow. Flow years were then constructed that represented 10% increments of exceedence probability from 10% up to 90% (Table 15) These flows at progressive points downstream in the Klamath River are shown in Figure 7. We assumed in our simulations that the minimum flow releases from IGD would be those required by the ESA consultation as specified for Phase 3 dry-year condition in the 2002 Biological Opinion (NMFS 2002) (Table 16). Outflows for the baseline data set (1961-2006) had gone below these ESA levels in dry years (Figure 40 and Figure 41).

Flow and temperature data used in model simulations was ultimately determined by a combination of weather and tributary flow conditions (i.e. water year type), and flow inputs from Iron Gate Dam. For a given model simulation, these temperature and flow conditions were held constant for the entire simulation period (i.e. 12 years).

Table 15. Monthly exceedence flows released from Iron Gate Dam, averaged over the baseline period of record, 1961-2006.

% Exceed	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
90%	987	1,065	1,227	1,242	976	1,106	1,236	1,014	722	680	710	910
80%	1,322	1,324	1,435	1,457	1,540	1,776	1,418	1,034	746	719	968	1,035
70%	1,342	1,350	1,532	1,784	1,788	2,041	1,661	1,327	780	729	1,005	1,193
60%	1,357	1,400	1,822	1,907	1,920	2,459	1,813	1,575	857	734	1,016	1,308
50%	1,382	1,710	2,334	2,326	2,398	2,625	2,525	1,777	925	739	1,026	1,321
40%	1,482	1,844	2,859	3,075	3,212	3,567	2,985	2,356	1,073	761	1,033	1,337
30%	1,716	2,237	3,138	3,344	3,629	4,490	3,741	2,807	1,273	811	1,041	1,355
20%	1,801	2,827	3,777	3,885	4,163	5,223	4,676	3,251	1,532	903	1,058	1,405
10%	2,472	3,087	4,019	4,837	5,601	6,615	5,598	3,963	2,049	1,048	1,084	1,593

Table 16. Minimum monthly flow (cfs) targets at Iron Gate Dam as recommended in the 2002 Biological Opinion for a dry water year type.

Month	Flow (cfs)
October	1,300
November	1,300
December	1,300
January	1,300
February	1,300
March	1,450
April	1,500
May	1,500
June	1,400
July	1,000
August	1,000
September	1,000

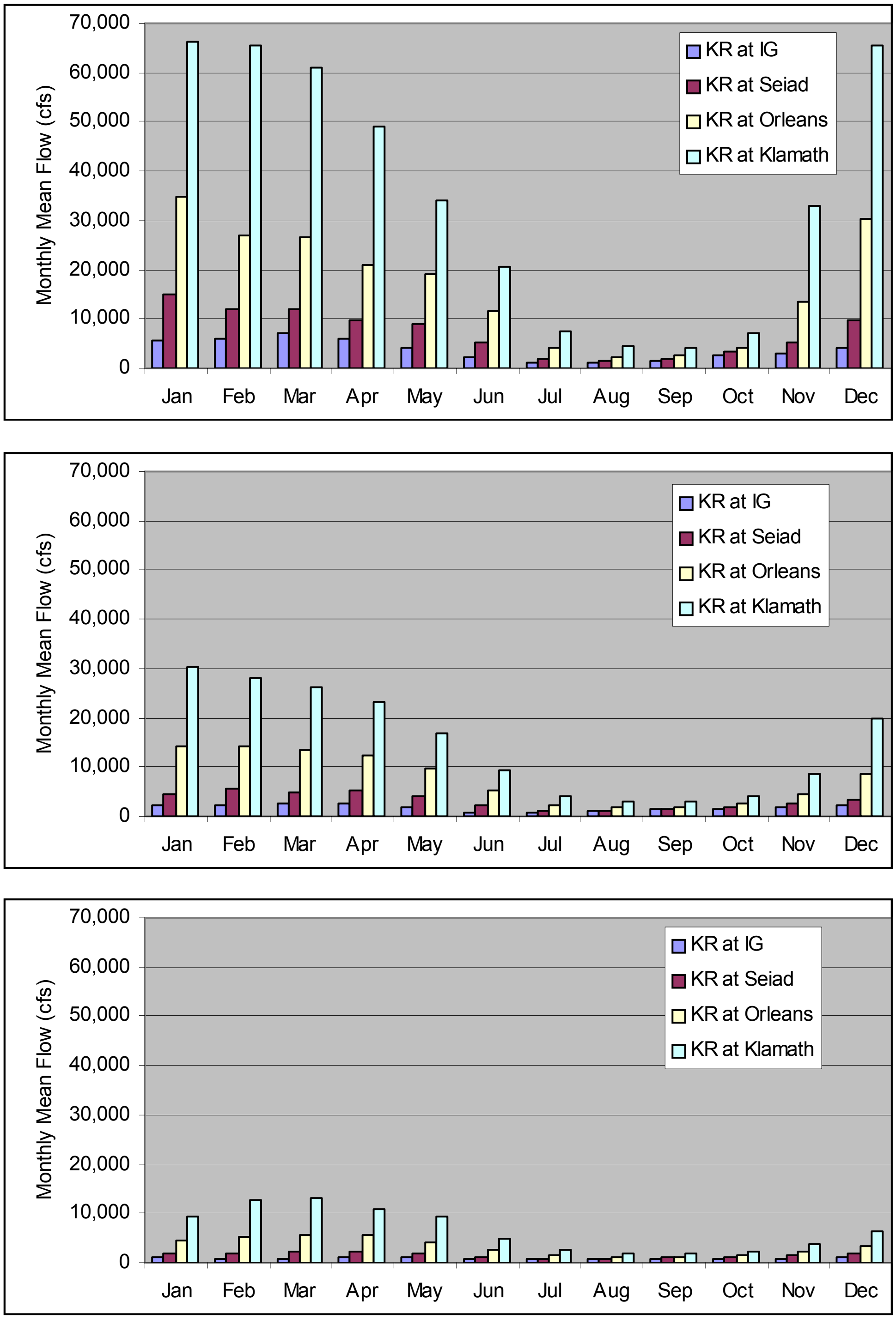


Figure 40. Monthly mean flow exceedence condition of the Klamath River at selected locations for 90%-Wet (top), 50%-median, and 10%-dry years for the 1960-2006 water years at USGS gages.

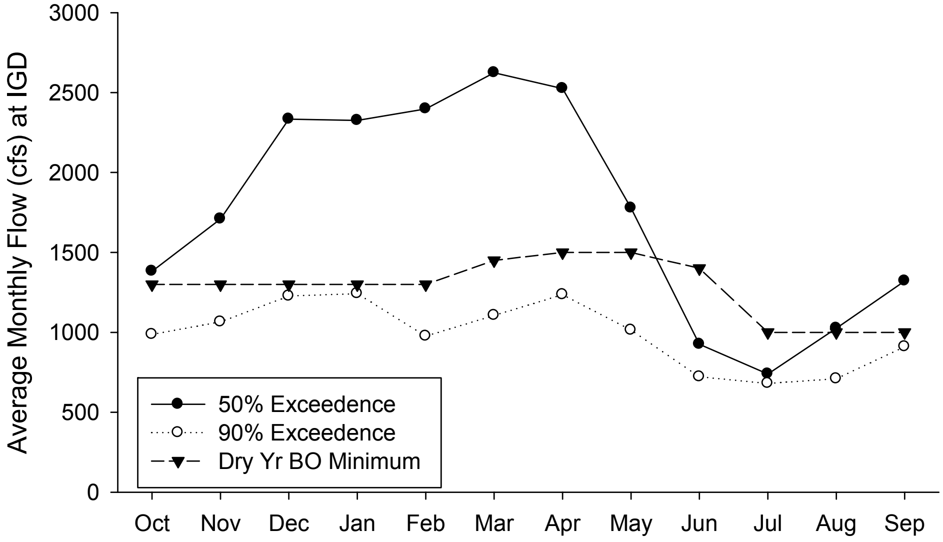


Figure 41. Flows released from Iron Gate Dam at different exceedence levels during the baseline period, 1961-2006, and the minimum now mandated by the ESA Biological Opinion in dry years (Table 16).

Outputs

The model tracks spatially and temporally explicit information, such that outputs can be generated for the distinct tributary and main stem reaches, as well as the specific life stages in each of those reaches, including spawners, subyearling emigrants, parr, and smolts. The model simulates the effects of temperature and flow on 50 spawning populations, through 5 life stages, over a span of 40 weeks for each year. Each model simulation was run for 12 years (3 complete life-cycles) under constant conditions, and results were tabulated for "year 10" of the simulation. Smolt production in year 10 represents the cumulative effects after three generations of a specified change to model inputs or parameters. Smolt production was chosen as the primary metric of interest, because smolt production is what remains after all freshwater effects are accounted for, and this would include effects on adults returning to freshwater through the three generations simulated. As a useful reference point, an increase of 26 ocean smolts is equivalent to one adult return, given minimum outflows at IGD and average marine survival (4.0%) and harvest (6.5%).

The metric used to evaluate Reclamation project influence was the difference in smolt production between a specific operation scenario and the minimum flow condition specified in Table 16. We also examined how this difference in smolt production changed between 2001 and 2004 weather and tributary flow conditions.

Sensitivity Analyses

We evaluated the sensitivity of model results to numerous parameters to assess the relative importance of the parameters (and assumptions) on model outputs. Our analysis focused on parameters of specific interest in the analysis (i.e. thresholds applied in temperature functions), and parameters that tend to exhibit considerable variation (i.e. capacity and life stage survival rates). Where information from the literature suggested a likely range of values, we constrained our analysis to that range. For parameters where the range of likely variation was uncertain, we used professional judgment to set reasonable bounds. These analyses were intended to provide a reconnaissance view of which factors had the greatest effects on model outputs.

Because the model was intended to predict how IGD flows affected coho production, the metric of interest for our sensitivity analysis was the relative change in smolt production when IGD outflow as increased by 500 cfs above the BiOp minimum release (Table 16) for every month of the year. We evaluated how this metric (change in smolt production due to flow increase) was altered when a parameter or variable of interest was changed within the model. We repeated these calculations for the weather and tributary flow conditions downstream for 2001 (dry year) and 2004 (average year). Thus, the sensitivity metric was:

Equation 27) $\textit{relative change in smolt production} = \left(smolts_{+500cfs} - smolts_{base}\right) / \, smolts_{base}$

Where $smolts_{base}$ is the number of smolts that survive to the ocean in simulation year 10 under the minimum outflow from IGD, and $smolts_{+500cfs}$ is the number of smolts that survive in year 10 with flows at IGD increased by 500 cfs during each month.

Findings

Effects of Flow at Iron Gate Dam on Stream Temperature

The influence of Iron Gate Dam releases on downriver temperature and flow changes seasonally. During winter, the reservoir has its least effect on downstream temperatures, and the river warms slightly with progressive distance downstream. In spring, conditions may vary considerably, but the reservoir generally reduces mainstem temperatures down to the Scott River by up to approximately 3^{o}C below equilibrium temperatures. During late spring and early summer the reservoir tends to release waters that are below equilibrium temperature on the order of 2-4^{o}C from Iron Gate Dam to the Scott River, with diminishing effect further downstream. From mid-summer into fall, the large thermal mass of the reservoir tends to create a thermal lag, where temperatures leaving the dam may be warmer than equilibrium temperature. The effects of this thermal lag diminish with distance downstream.

The temperature modeling indicated that tributary inputs and meteorological conditions are the primary temperature drivers throughout the year downstream from the Scott River. Thus, the ability to control temperature in the lower Klamath River through flow management at IGD is limited because heat and water inputs downstream are much larger than those from IGD (Figure 42–Figure 55).

During smolt outmigration, the project has some effect on temperatures downstream of IGD. However, temperatures remain within the optimum range for survival during the majority of the smolt migration for a wide range of flow releases (Appendix 3). Therefore, the project has a limited effect on smolt survival. Later in the summer, temperatures exceed tolerable levels and coho are relegated to thermal refugia throughout most of the mainstem. During summer, releases from IGD have little influence temperatures downriver of the Shasta River. Thus, high temperatures in the Klamath River sharply limit the rearing capacity for coho in the main stem during summer, and heat energy balances dictate that releases of any magnitude from IGD can have little influence below the Shasta River (CFS 2007, Tech Memo 5).

The relationship between discharge at IGD and downstream temperature varied by reach and season. Discharge vs. temperature relationships were of particular interest in the spring, summer and fall because temperature affects survival and rearing capacity for coho during these seasons. Under 2001 meteorological and tributary flow conditions, reaches 1 through 4 generally exhibited decreasing water temperature in October as IGD releases increased (Figure 45). This effect was expected, due the relatively large influence of the cooler discharge water at a time when tributary flows are declining. In contrast, the mainstem water temperature rose in reach 5 as IGD flows increased to approximately 1,800 cfs, then decreased with increasing IGD discharges. For reach 6, water temperature increased throughout the flow range. Both these results for reaches five and six have similar explanations. During the season of low flow in the mainstem, several water tributaries have a cooling influence on the mainstem. Thus increases in mainstem flow can dilute the cool tributary influence.

In April, average temperature at the midpoint of all model reaches in April declined as flow at Iron Gate Dam increased (Figure 46). However, stream temperatures remained within or slightly below the optimum growth range for juvenile salmon and steelhead (~10–15°C), so thermal effects on coho from flow manipulations in April would be slight.

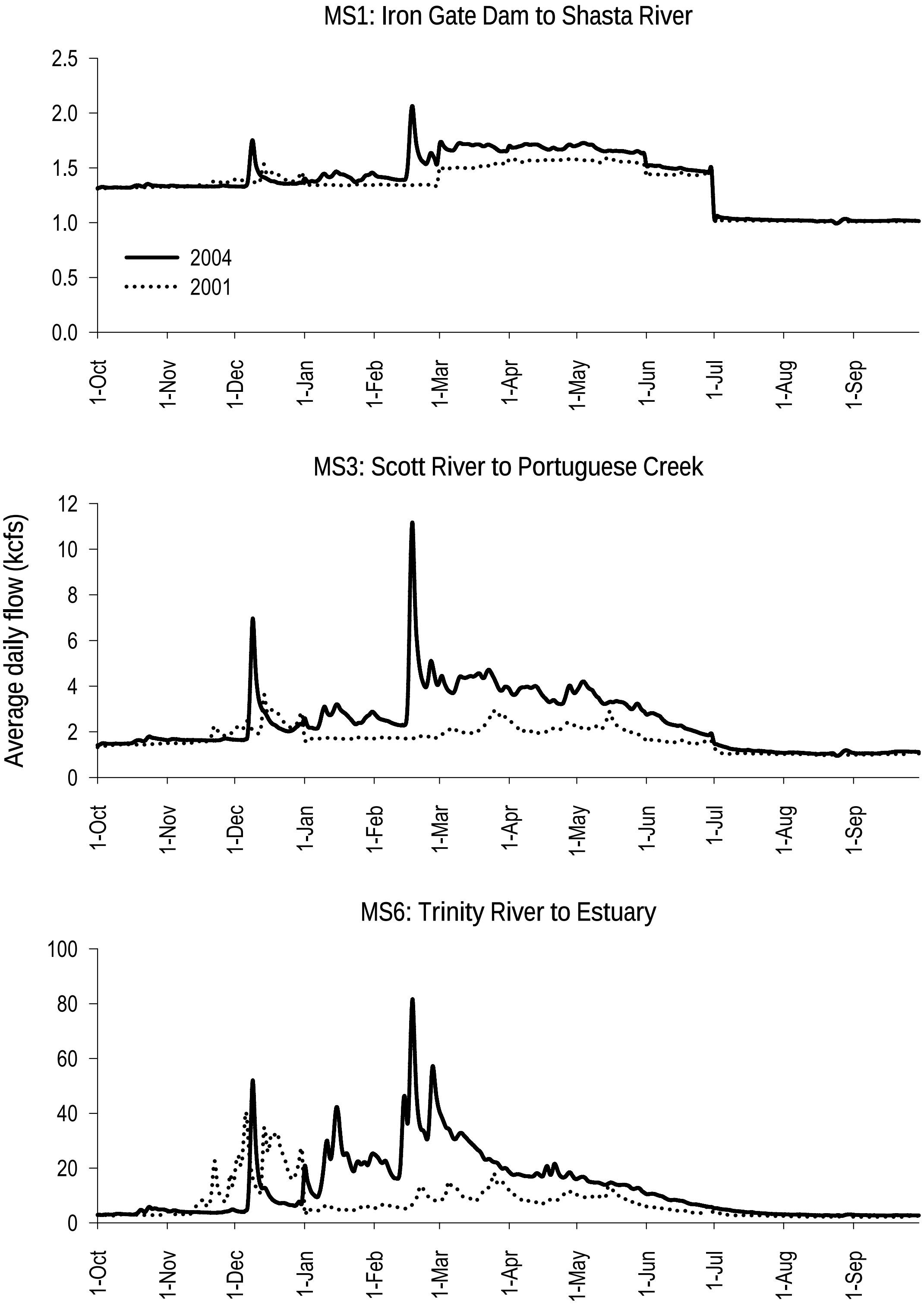
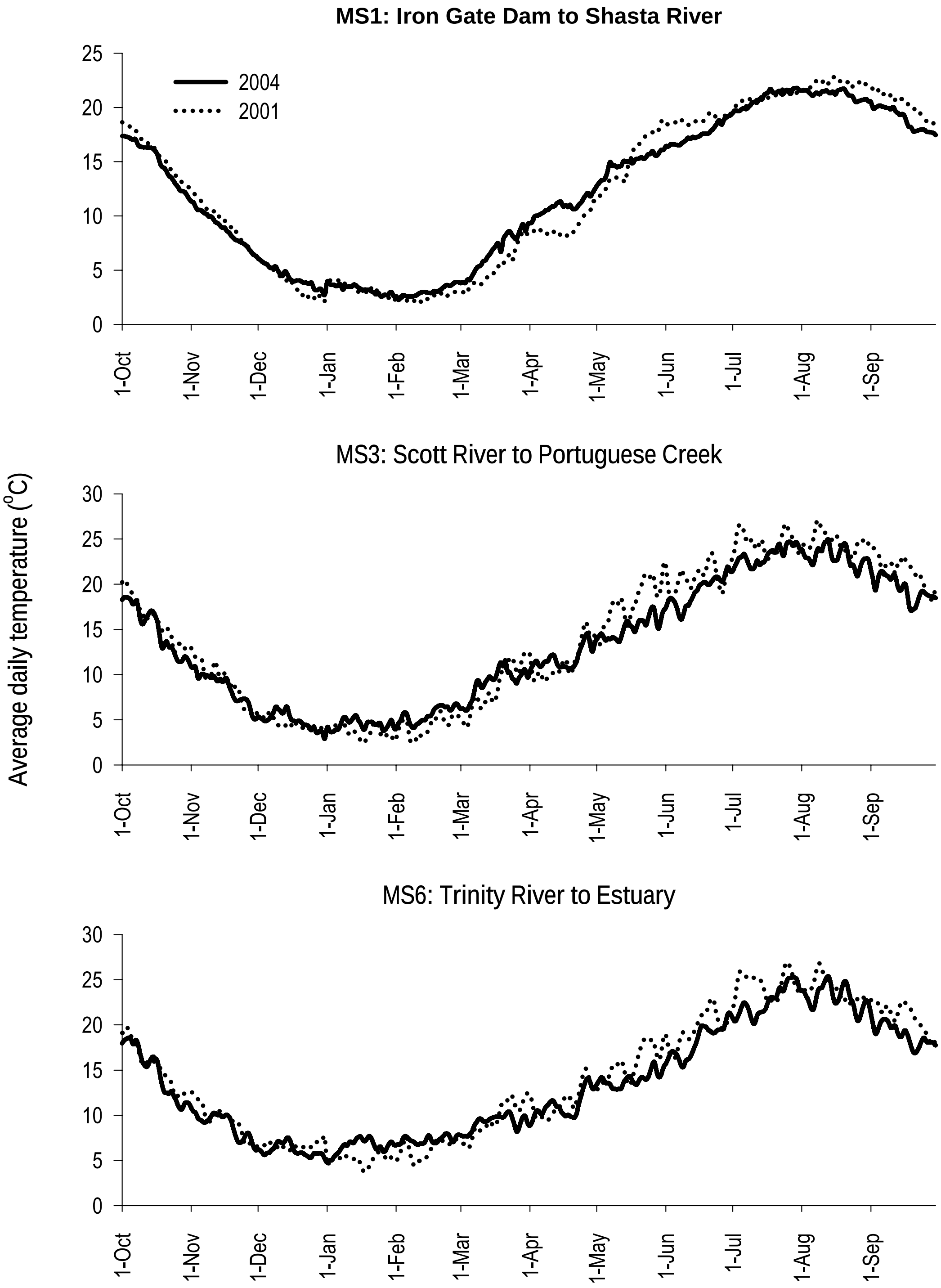


Figure 42. Daily average flows (kcfs) in the Klamath River predicted by the temperature model for the midpoint of model reaches MS1 (rkm 296), MS3 (rkm 219), and MS6 (rkm 38.6). These flows were generated using the BiOp minimum monthly flows at Iron Gate Dam coupled with meteorological conditions and tributary flow data from 2001 (dry year) and 2004 (average year).



MS1: Iron Gate Dam to Shasta River

MS3: Scott River to Portuguese Creek

MS6: Trinity River to Estuary

Figure 43. Daily average stream temperature (˚C) in the Klamath River predicted by the temperature model for the midpoint of model reaches MS1 (rkm 296), MS3 (rkm 219), and MS6 (rkm 38.6). These temperatures were generated using BiOp minimum monthly flows at Iron Gate Dam coupled with meteorological conditions and tributary flow data from 2001 (dry year) and 2004 (average year).

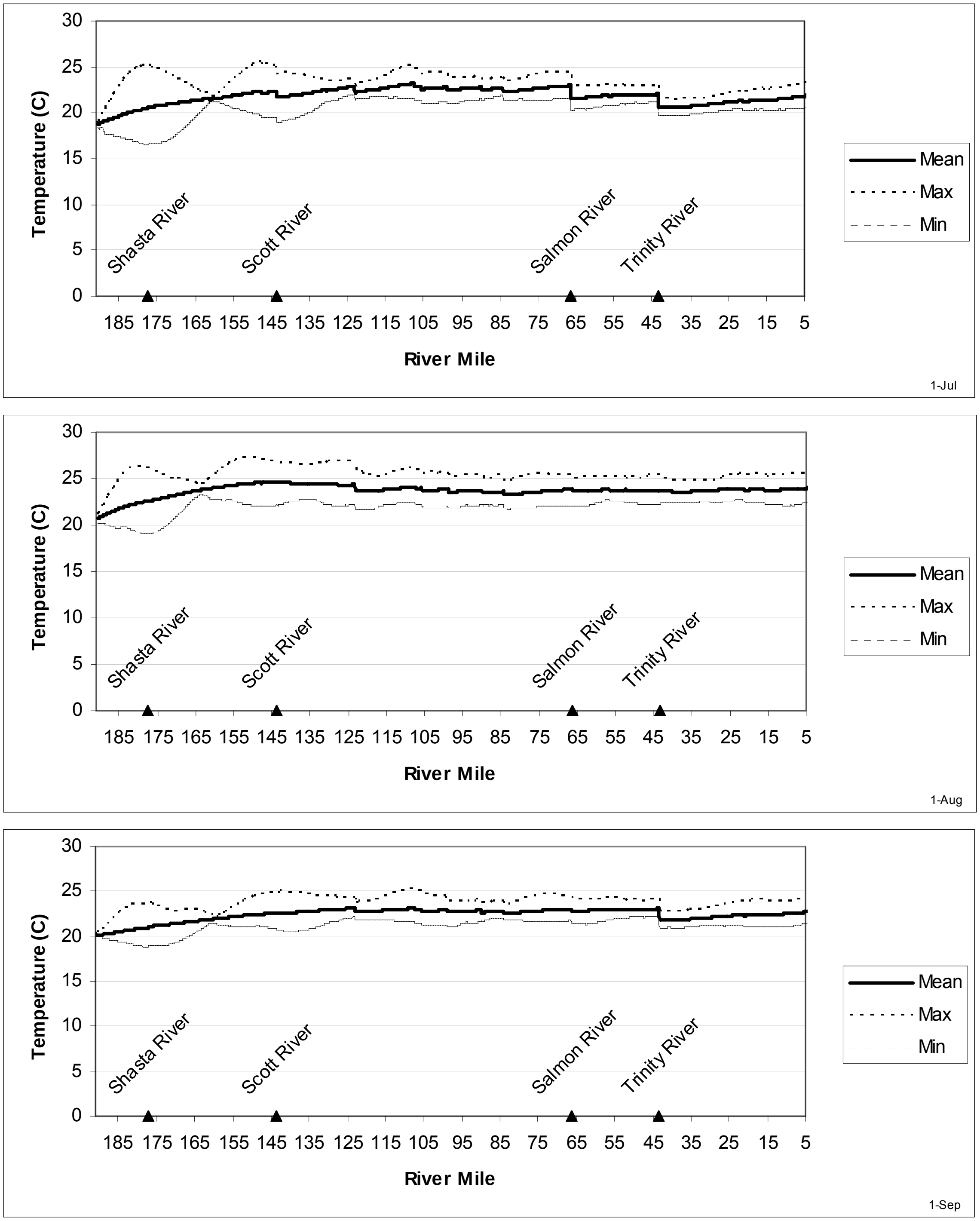


Figure 44. Longitudinal profile of daily maximum, mean, and minimum water temperatures in the Klamath River for July 1, August 1 and September 1, as predicted from the temperature model, given 2001 meteorology and tributary flows.

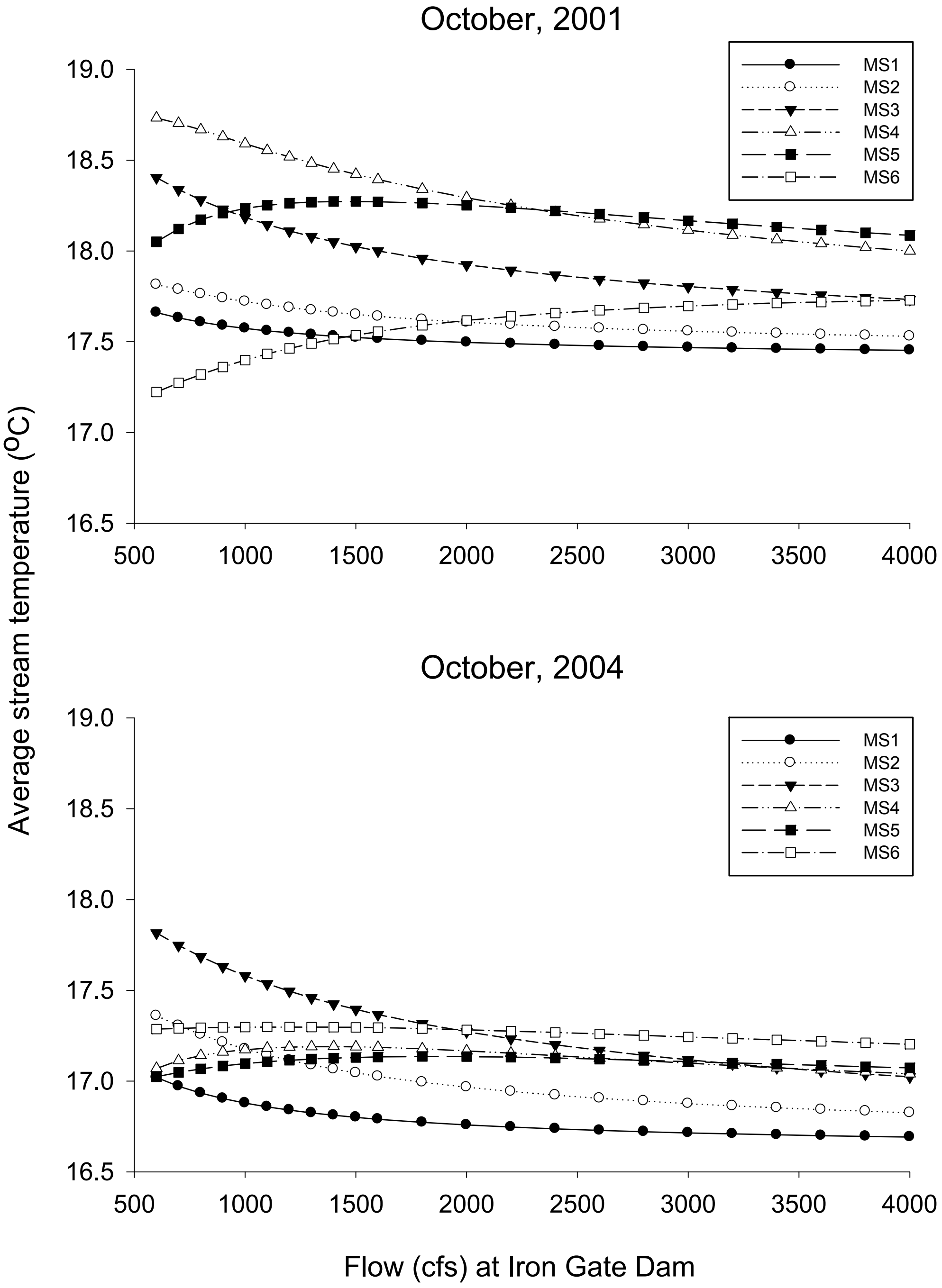


Figure 45. Relationship between average stream temperature (˚C) at the midpoint of each model reach and flow (cfs) at Iron Gate Dam from 1-Oct to 15-Oct using 2001 and 2004 data for tributary flow and weather.

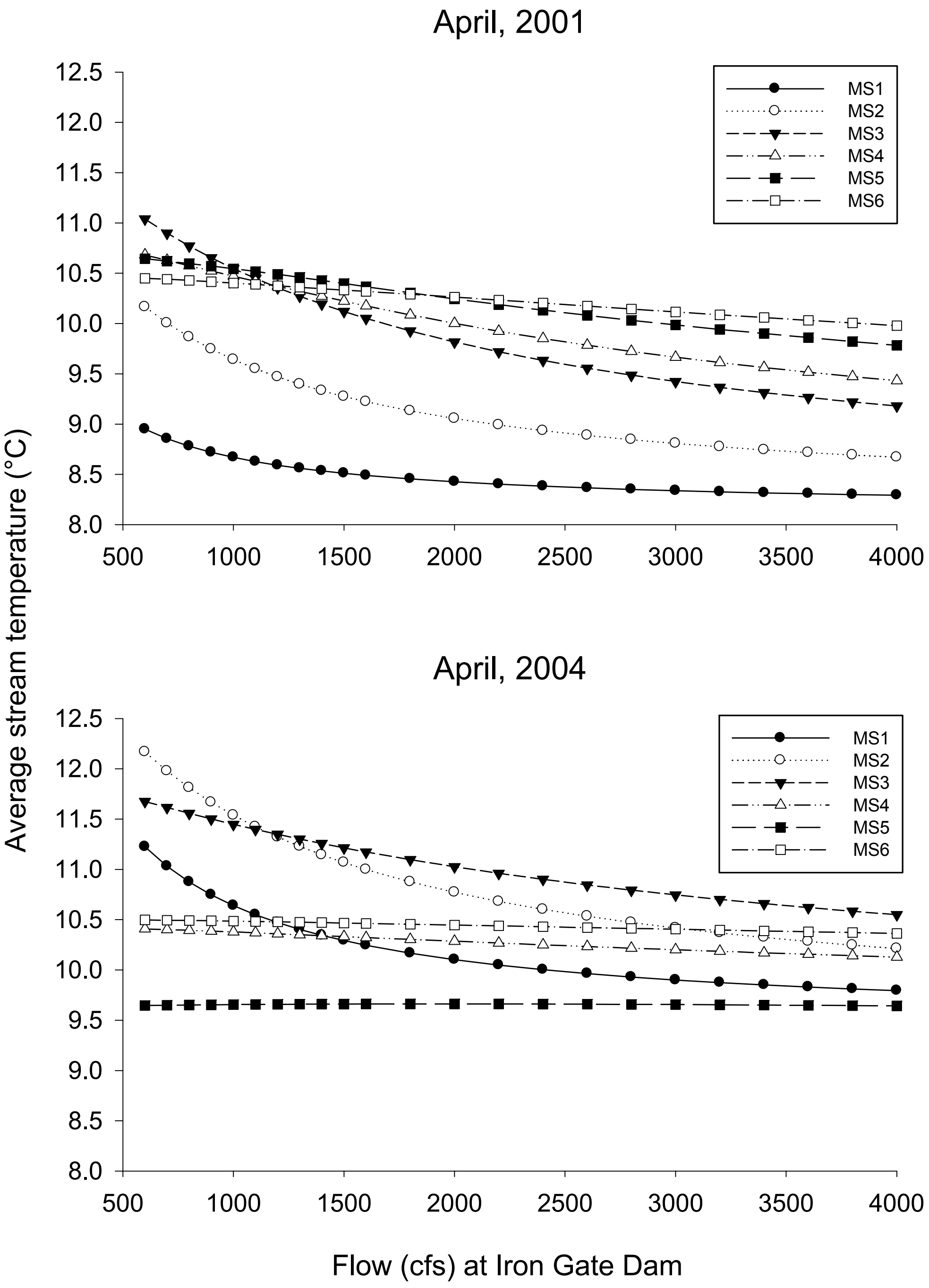
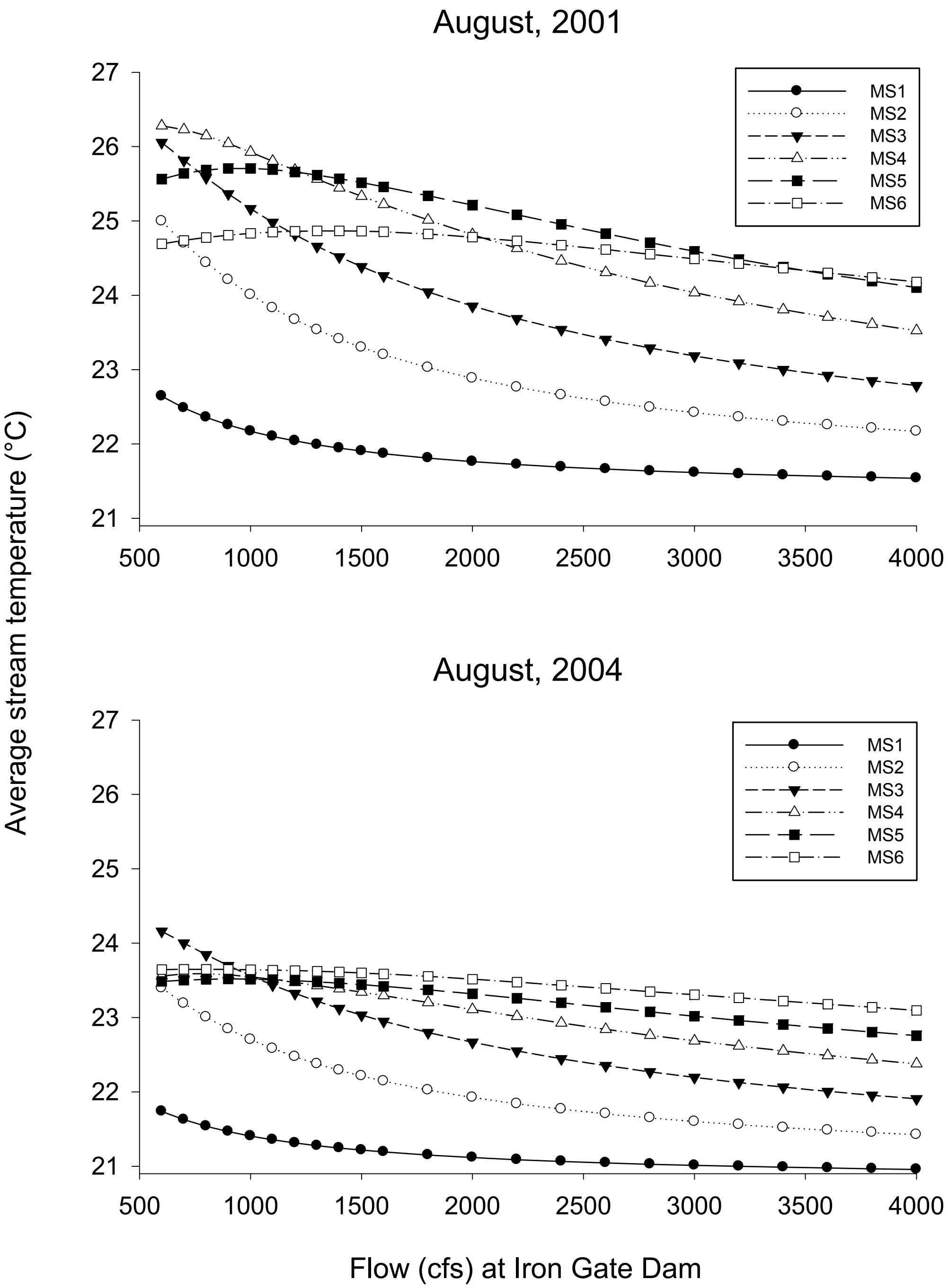


Figure 46. Relationship between average stream temperature (˚C) at the midpoint of each model reach and flow (cfs) at Iron Gate Dam from 1-Apr to 15-Apr using 2001 and 2004 data for tributary flow and weather.


August, 2001

August, 2004

Figure 47. Relationship between average stream temperature (˚C) at the midpoint of each model reach and flow (cfs) at Iron Gate Dam from 1-Aug to 15-Aug using 2001 and 2004 data for tributary flow and weather.

Population Performance

The Klamath coho life-history model predicted significantly different smolt production for various parts of the basin. One way to examine this further was to look at the proportion of smolt produced in each reach (the mainstem reach including all tributaries) by type of smolt. While most the production typically occurred in natal tributaries (Type I smolts), non-natal smolts (Type II and III) contributed a large proportion of the production in some reaches (Figure 48). Type II smolts are those that reared in the mainstem, and Type III smolts are those that moved through the mainstem to enter and rear in non-natal tributaries. Non-natal mainstem (Type II) smolt, accounted for nearly half of the production in reaches 1 and 4. Smolt production in these reaches is greater because of larger summer parr capacities. Reach 1 (IGD to Shasta River) is the only reach where summer parr capacity is not limited to thermal refugia, and reach 4 (Scott River to Portuguese Creek) has the greatest number of thermal refugia.

Across all reaches combined, the model predicts that about 85% of smolts are produced in tributaries, 4% in the main stem Klamath, and 10-12% in non-natal tributaries (Table 17). We repeated the simulations to compare the effects of continuous dry year conditions (2001 with 90% exceedance releases at IGD) with those for continuous average year conditions (2004 with 50% exceedance releases at IGD). After 10 years of these conditions, there was little change in relative contribution of the smolt life history pathways.

Table 17. Total smolt production in year 10 by smolt type for a continuous simulation of dry years (90% exceedance flows at Iron Gate Dam combined with 2001 meteorological and tributary flow downstream), and of average years (50% exceedence flows at Iron Gate Dam combined with 2004 meteorological and tributary flow downstream).

Smolt Type	Smolts produced	% of total
2001 with 90% Exceedence Flows		
Type I (tributary)	53,303	84.7%
Type II (mainstem)	2,217	3.5%
Type III (non-natal tributary)	7,390	11.7%
Total	62,910	
2004 with 50% Exceedence Flows		
Type I (tributary)	88,307	86.1%
Type II (mainstem)	4,367	4.3%
Type III (non-natal tributary)	9,933	9.7%
Total	102,607	

Survival during different life-stages also varied within the Klamath Basin (Figure 49). Adult pre-spawning survival was relatively consistent throughout the basin but was slightly higher for fish migrating into the upper basin. This was because these fish tended to migrate into the Klamath later when temperatures were dropping. Fingerling-to-parr survival was generally low, but higher in reach 1 and in particular in reach 4. This survival was higher due to greater summer parr capacity in these reaches and therefore reduced competition for space. Smolt migration survival was much higher for those migrating from the lower reaches. Lower survival of smolts originating from the upper drainage is due to three factors including higher incidence of disease, lower flows, and greater migration distance. These factors are analyzed further in a subsequent report section.

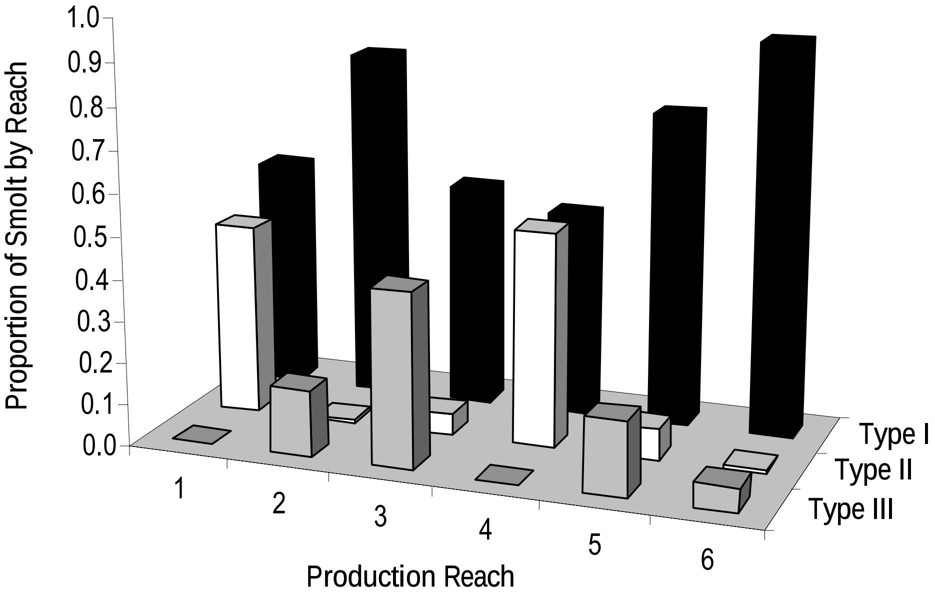


Figure 48. Proportion of coho smolt production by smolt type for each reach of the Klamath River Main Stem. Assumes BiOp minimum flow released from IGH, and weather conditions plus tributary flow as in 2004. Reaches include miscellaneous tributarys enerting that reach. See map in Figure 9.

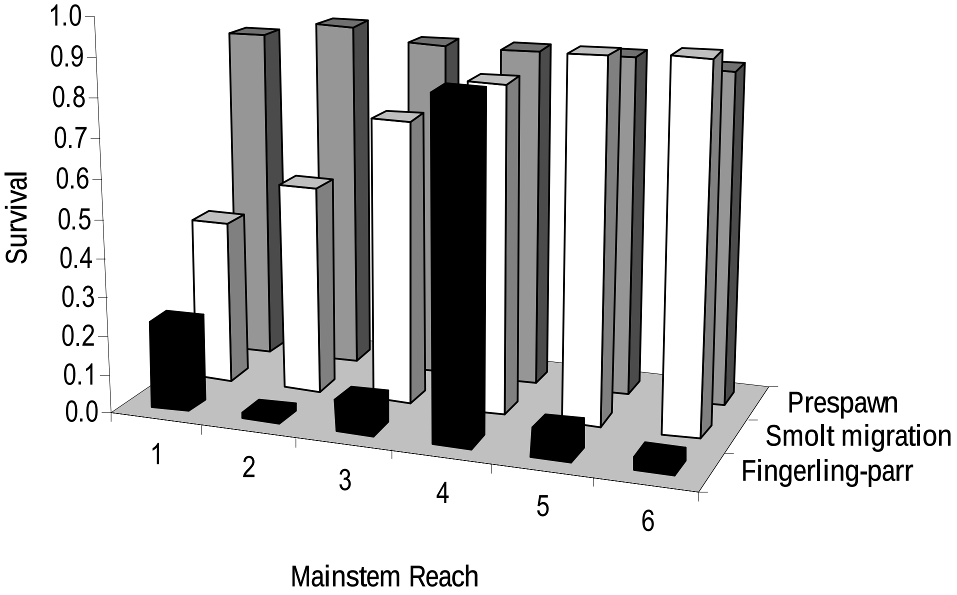


Figure 49. Model-simulated survival during adult pre-spawning, fingerling-to-parr, and smolt migration by mainstem reach. Survivals for each reach account for mortality experienced by fish from that reach as they migrated through other reaches. Assume B1Op minimum flow released from IGD and weather plus tributary flow as in 2004.

Flow and Temperature Effects on Coho

We simulated coho production for a variety of flow manipulations, and the model automatically changed temperature as a function of flows released from IGD and downstream conditions. Because temperature and flow were linked in the model, the focus of our simulations was the influence of flow manipulations. We began by simulating two broad types of flow manipulations: (1) manipulation of IGD outflows while holding downstream flow inputs constant, and (2) changes in downstream flow inputs while holding IGD outflows constant.

In order to compare the influence on smolt production from increased release at IGD to those from increased tributary flow, we ran a 2-by-2 matrix of simulations that gave all combinations of dry and average year outflow conditions (Table 18) matched with dry and average year tributary inputs downstream. The resulting combinations of temperature and flow at the midpoint of each main stem reach are given in Appendix 1. The simulations show that variation in downstream flow inputs has a substantially greater effect on coho smolt production than does variation flow released from IGD (Figure 50). The increase flow at IGD from a dry (90% exceedence) to an average year gave an average 6.6% increase in smolt production, while the increase in downstream tributary flows from a dry to an average condition gave an average 52.9% increase in smolt production. The large difference between effects of IGD flows compared with those found downstream water-year conditions is a reflection of the small percentage that IGD flows composed of Klamath Basin outflow (~10%) on average.

Table 18. Average monthly flow (cfs) at IGD for 90% and 50% annual exceedence probabilities based on historical flow data from 1961-2006. Flows were rounded to the nearest 50 cfs.

Month	90%	50%
October	1,000	1,400
November	1,050	1,700
December	1,250	2,350
January	1,250	2,350
February	1,000	2,400
March	1,100	2,600
April	1,250	2,500
May	1,000	1,800
June	700	950
July	700	750
August	700	1,050
September	900	1,300
Average	992	1,763

Table 19. Total simulated smolt production (to the ocean) in year 10 using 90% and 50% exceedence flows at IGD for both 2001 (dry year) and 2004 (average year) meteorological and tributary flow conditions.

Flow released at IGD	2001 (Dry Yr)	2004 (Avg Yr)
90% Exceedence (low flow)	62,910	96,646
50% Exceedence (median flow)	67,479	102,657

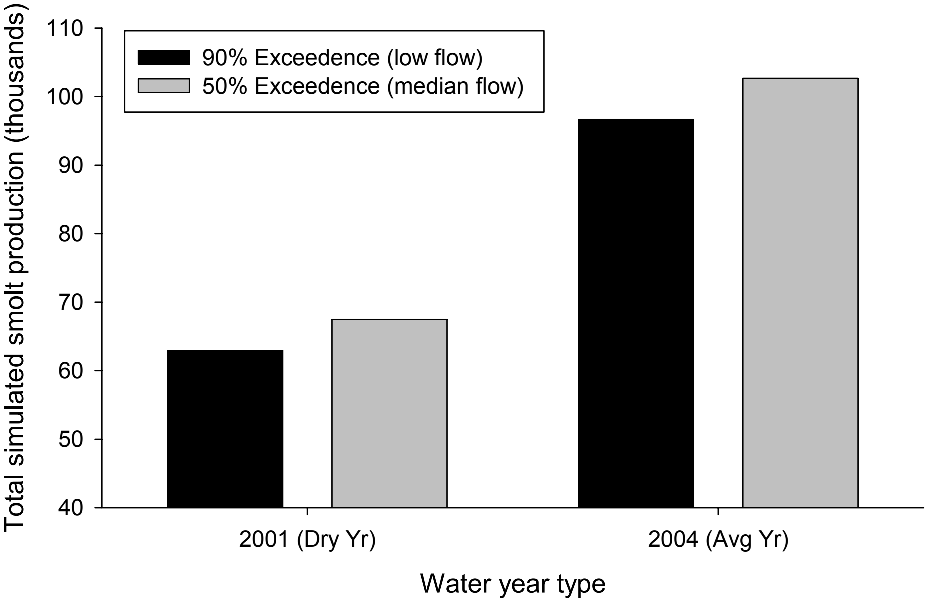


Figure 50. Total simulated smolt production (to the ocean) in year 10 using 90% and 50% exceedence flows at IGD for both 2001 (dry year) and 2004 (average year) meteorological and tributary flow conditions.

The limited capability of flow manipulations at IGD to boost coho production was also evident from simulation of a wide range of exceedence flows historically released from IGD. The downstream effects from a different set meteorology and tributary flows had a far greater effect on smolt production (about 35% increase) than did increasing IGD flows from a 90% exceedence to a 40% exceedence (about 10% increase in smolt production) (Figure 51;Table 20). These results are primarily driven by increased survival of migrating smolts due to higher mainstem flows and lower temperatures in 2004.

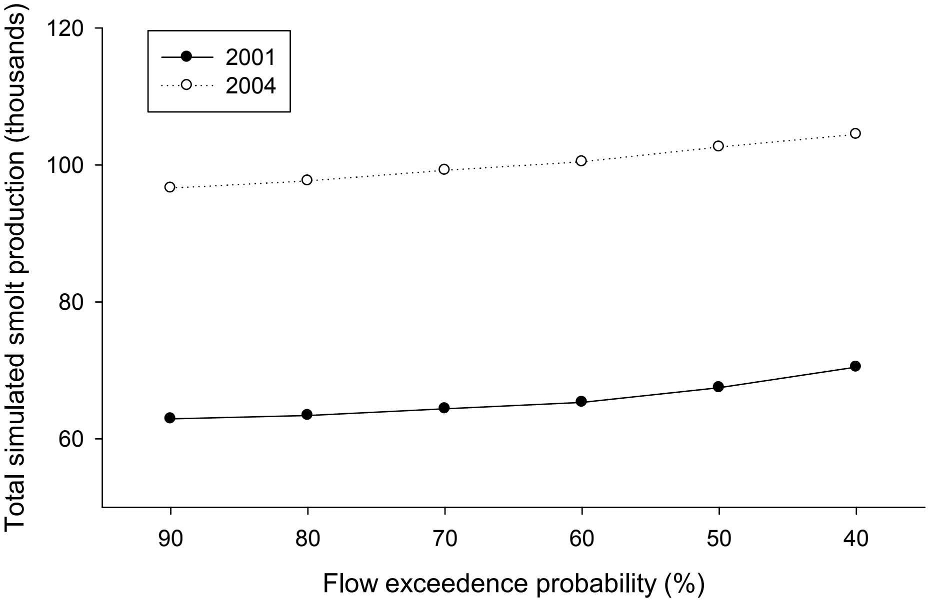


Figure 51. Total simulated smolt production in year 10 by flow exceedence probability at IGD for both 2001 and 2004 water year types. Exceedence flows were calculated from monthly average flows at IGD from 1961-2006.

Table 20. Total simulated smolt production in year 10 by flow exceedence probability at IGD for both 2001 and 2004 water year types. Exceedence flows were calculated from monthly average flows at IGD from 1961-2006.

Exceedence	2001	2004
90	62,910	96,616
80	63,420	97,656
70	64,393	99,212
60	65,329	100,446
50	67,479	102,607
40	70,467	104,440

Effects by month

In order to determine the months in which flow had the greatest effect on coho production, we ran separate simulations for an increase in IGD outflow by 500 cfs for one month at a time and determined the change in smolt production compared to that for minimum flow releases from IGD (Figure 52, Table 19 and Table 22). The 500 cfs increase flow for a given month had a small but similar effect on overall smolt production, between the two water years (Figure 52). In general, increasing the flow at IGD during March-May had the greatest benefit to smolt production primarily due to better smolt migration survival. Increasing flows in the fall, tended to reduce smolt production through increased adult pre-spawning survival. As one would expect, increasing flow in a dry year such as 2001, had a greater relative effect on smolt production than in a normal year such as 2004 (Figure 52).

Increasing springtime flows tended to have the greatest benefit to smolt production in the upper basin and least to the lower basin. The Shasta River showed the greatest increases in smolt production when flow was increased in March-May. Smolt production in the Shasta increased 64% given a 500 cfs increase at IGD above 2001 minimum flow conditions and 34% above 2004 conditions. In comparison, the same increase flow increased Trinity River smolt production only 4% for 2001 conditions and 1% for 2004 conditions. Although smolt production increased in mainstem reach 1 (IGD to the Shasta River) with greater spring flows, the greatest benefit in this reach was by increasing summer flows. This was due to an increase in summer parr capacity with higher summer flows in this reach. The increased numbers of smolts were low, but represented a large proportion of the baseline capacity for this reach.

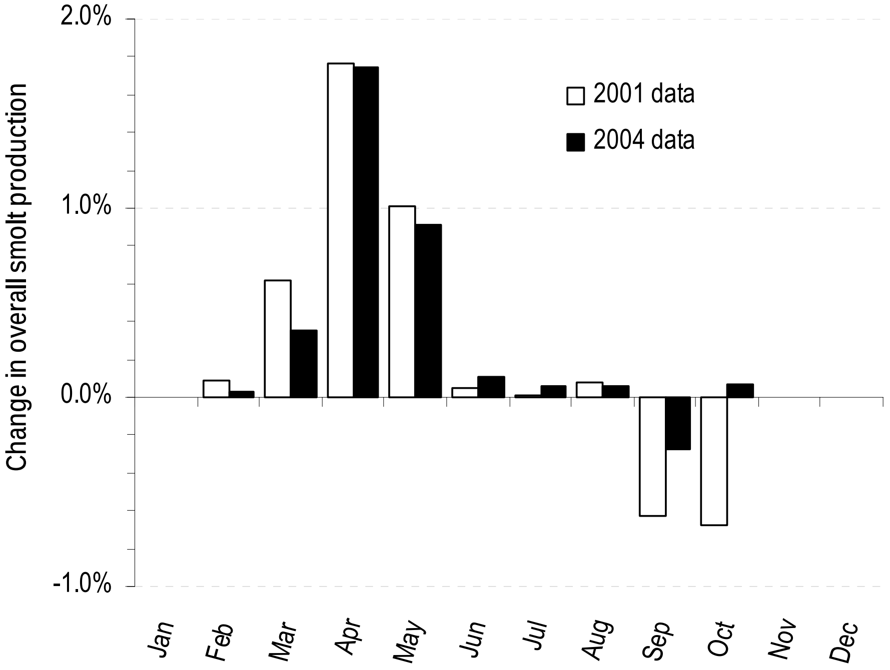


Figure 52. Percent change in overall smolt production in simulation year 10 resulting from increasing daily flow at IGD by 500 cfs over the minimum during the month indicated. Separate results are shown for weather and tributary flows set to either 2001 or 2004.

Table 21. Increase in smolt production in simulation year 10 resulting from increasing daily flow at IGD by 500 cfs during the month indicated. Weather and tributary flow set for 2001 (dry year).

Rearing	Baseline	Increase in Smolt Production											
Reach	Production	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MS1	88	0	0	1	14	0	0	2	46	2	0	0	0
MS2	26	0	0	0	2	2	0	0	0	0	0	0	0
MS3	128	0	0	1	6	7	0	0	0	0	0	0	0
MS4	620	0	8	28	35	13	2	0	0	0	-4	0	0
MS5	777	0	0	0	1	7	1	0	0	0	0	0	0
MS6	695	0	0	0	0	2	0	0	0	0	0	0	0
MST1	184	0	0	5	42	1	0	0	4	0	0	0	0
MST2	1,439	0	9	108	133	22	0	0	0	-1	-1	0	0
MST3	659	0	10	67	86	35	0	0	0	0	-4	0	0
MST4	627	0	7	30	36	10	1	0	0	0	-4	0	0
MST5	9,512	0	12	59	78	20	1	0	0	-9	-10	0	0
MST6	19,802	0	10	48	68	14	0	0	0	-64	-67	0	0
SHASTA (MS2)	1,175	0	0	22	425	234	0	0	0	-4	-5	0	0
SCOTT (MS3)	296	0	2	20	49	39	0	0	0	0	-2	0	0
SALMON (MS5)	117	0	0	1	2	1	0	0	0	-1	-1	0	0
TRINITY (MS6)	27,810	0	0	5	148	241	24	2	0	-323	-337	0	0
Total	63,954	0	58	395	1,127	649	30	5	50	-398	-435	0	0

Table 22. Increase in smolt production in simulation year 10 resulting from increasing daily flow at IGD by 500 cfs during the month indicated. Weather and tributary flows were set for 2004 (average year).

Rearing	Baseline	Increase in Smolt Production											
Reach	Production	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MS1	236	0	0	2	27	1	1	49	48	3	0	0	0
MS2	40	0	0	0	2	2	0	0	0	0	0	0	0
MS3	199	0	0	0	3	3	0	0	0	0	0	0	0
MS4	2,099	0	4	21	38	18	6	0	0	-9	1	0	0
MS5	901	0	0	0	0	4	1	0	0	0	0	0	0
MS6	738	0	0	0	0	1	0	0	0	0	0	0	0
MST1	329	0	0	8	63	1	0	7	7	0	0	0	0
MST2	2,549	0	9	124	157	18	0	0	0	0	0	0	0
MST3	2,687	0	8	74	102	22	1	0	0	-5	3	0	0
MST4	2,068	0	3	23	39	14	4	0	0	-9	1	0	0
MST5	11,585	0	0	7	16	5	1	0	0	-1	0	0	0
MST6	23,474	0	0	12	30	10	1	0	0	-39	9	0	0
SHASTA (MS2)	4,910	0	0	56	1,097	542	3	0	0	-3	2	0	0
SCOTT (MS3)	1,447	0	1	20	67	41	6	0	0	-3	1	0	0
SALMON (MS5)	227	0	0	0	1	1	0	0	0	-1	0	0	0
TRINITY (MS6)	45,340	0	0	2	80	223	83	1	0	-210	48	0	0
Total	98,831	0	26	351	1,722	904	108	58	55	-275	66	0	0

Comparison of 2001 and 2004 using minimum flows

After 10 years of simulation with the 2004 flow and temperature conditions, coho production was approximately 34,900 smolts and 1,300 adults higher than after 10 years of 2001 flow and temperature conditions (Figure 53 and Figure 54). Under both conditions, coho production stabilized after one generation and changed little across years. Such simulations with fixed environments represent extreme cases to reveal how good or bad production will become after extended exposure to the same condition. For example, 2001 was an a 95% exceedence year for the Salmon River, meaning that it would only be expected to recur once in 20 years, and minimum flow recurrence at IGD is on the order of once in 10 years. Thus, a 10 year simulation of 2001 conditions represents a dry year sequence that has virtually no chance of ever occurring (roughly $(0.05)^{10}$). Conditional upon the default parameters assumed in the model (i.e. marine survival= 4%), this result suggests that basin-wide populations would be sustained under constant conditions.

Spatial structure is an important component of population viability for two main reasons: 1) because there is a time lag between changes in spatial structure and species-level effects, and 2) population structure affects evolutionary processes and may therefore alter a population's ability to respond to environmental change (McElhany et al. 2000). A variety of metrics might be used from simulations with the coho model. We present the percentage of natural smolts that are produced from each independent population in the basin (except the three Trinity Basin populations are combined) in Figure 55. This figure shows how the relative distribution of smolt production changes in response to a 10 year extreme drought (top graph) compared to 10 years of average conditions. The Trinity Basin is the largest contributor of smolts, followed by the lower Klamath, and Middle Klamath. This concentration of smolt production in the lower basin, means that most manipulations of IGD flow releases have a limited ability to influence overall production.

Further examination of model outputs at each life-stage revealed that pre-spawning survival was slightly higher under 2004 conditions. Pre-spawning survival averaged 88% in 2001 compared with 93% in 2004. Relative differences in pre-spawning survival (i.e. (Survival_{2004} – Survival_{2001}) / Survival_{2001}) were generally similar among the different model reaches (average = 5.7%), although the difference between years was least for fish destined for tributaries to reach 2 (MST2) including the Shasta River (Table 23). Higher pre-spawning survival for these fish was related to their later passage timing and associated exposure to cooler stream temperatures during upstream migration.

Examination of juvenile life-stages revealed a different pattern. A significant change in parr capacity occurred in mainstem Reach 1 (MS1) between the different flow scenarios. Under 2004 flow conditions, parr capacity in MS1 was 91.7% greater than the 2001 scenario. However, the absolute difference in coho production was modest, because of the low capacity for coho production in MS1. Parr production in MS1 after 10 years of simulation using the 2004 conditions was 1,255 parr compared to 655 for 2001 conditions. These levels of production represented 8.5% and 10.6% of the total parr production for the mainstem under 2001 and 2004 conditions respectively.

The most notable differences between 2001 and 2004 conditions, each with minimum flows released at IGD, occurred during smolt migration. Survival of smolts to the estuary was higher in 2004 compared with 2001 (Figure 56). The overall scalar values applied in the model for the distinct effects of temperature, flow, and distance on survival during the smolt migration reveal the relative role that each of these factors played in affecting the survival difference between the 2001 and 2004 conditions (Table 24). Each scalar value represents the percentage of the optimum survival that was calculated for the factor being scaled. Temperature survival scalars ranged from 0.74 to 0.98 in 2001, and 0.92 to 0.99 in 2004 (Table 24), so warmer temperatures reduced survival of smolts originating from some of the reaches. Flow scalars affected overall survival to a greater degree and ranged from 0.35 to 0.93 in 2001, and 0.49 to 0.96 in 2004. The effects of flow on smolt survival were greatest in the upper three reaches (30% to 40% reduction), and diminished in the lower three reaches (3% to 24% reduction). This effect is supported by results from the radio tracking studies with coho smolts in the Klamath River, although the underlying causes of mortality have not been determined. The temperature scalars only showed an effect in reaches 2 and 3 (Table 24), where disease incidence has been demonstrated to substantially influence survival. In these reaches the model accounts for a drop in survival due to disease at a lower temperature than would reduce survival in other reaches. Temperature became a factor to survival in other reaches later in the migration period, but the majority of the population was out of the mainstem prior to detrimental temperature conditions.

The proportional increase in survival from 2001 to 2004 conditions was greatest for fish originating in mainstem Reaches 2 and 3 (MS2 and MS3) and associated tributaries (MST2 and MST3). Simulated survival in these reaches increased by 55.9% between the two years (Table 24). Similarly high relative increases in survival were observed for fish originating in MS1 and associated tributaries (relative increase = 40.4%). The proportional change in survival from 2001 to 2004 conditions declined for mainstem Reaches 4 through 6 (MS4 – MS6) (Table 24), corresponding with decreasing migration distance and reduced influence of IGD flows on stream conditions.

The total survival for all smolts from MS1 to the estuary was simulated to be 30% for 2001 conditions and 42% for 2004 conditions. These simulated survivals are near the low range of survivals estimated for radio-tagged coho smolts in 2005 through 2007. Lower than average survival rates are consistent with our expectations given that model simulations were populated with minimum monthly flows at IGD, rather than actual flows that would be released in a given water year (see Table 12 for IGD flow exceedence values).

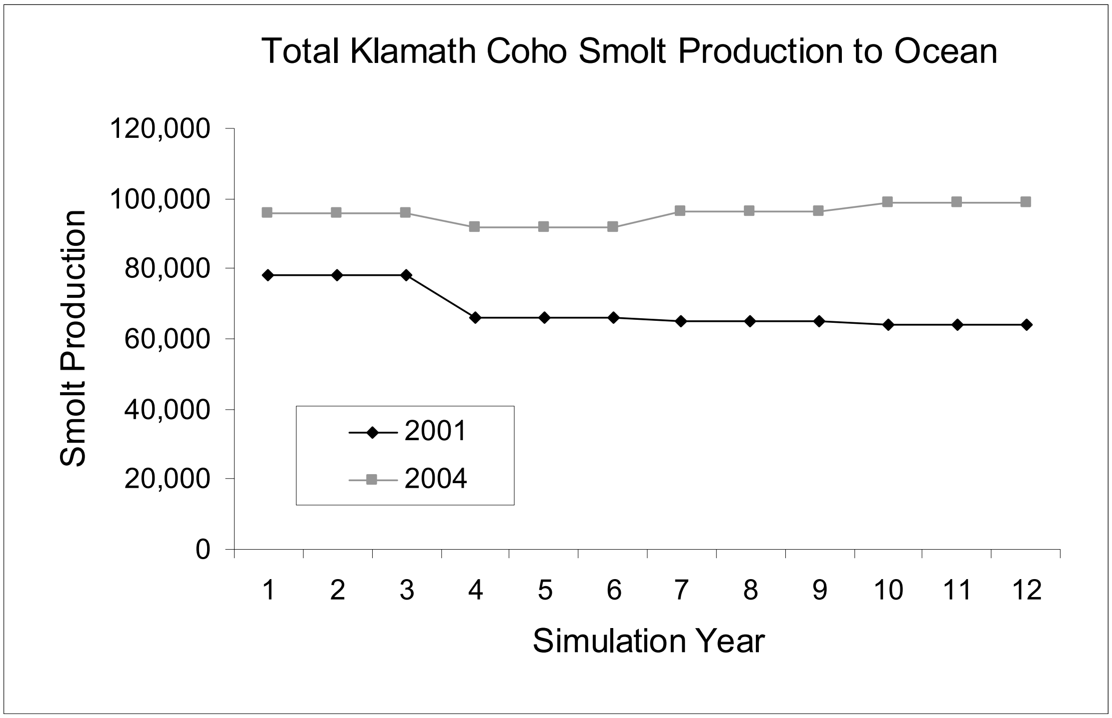


Figure 53. Model simulation of total Klamath coho smolt production using minimum monthly flows at Iron Gate Dam coupled with meteorological conditions and tributary flow data from 2001 (dry year) and 2004 (average year).

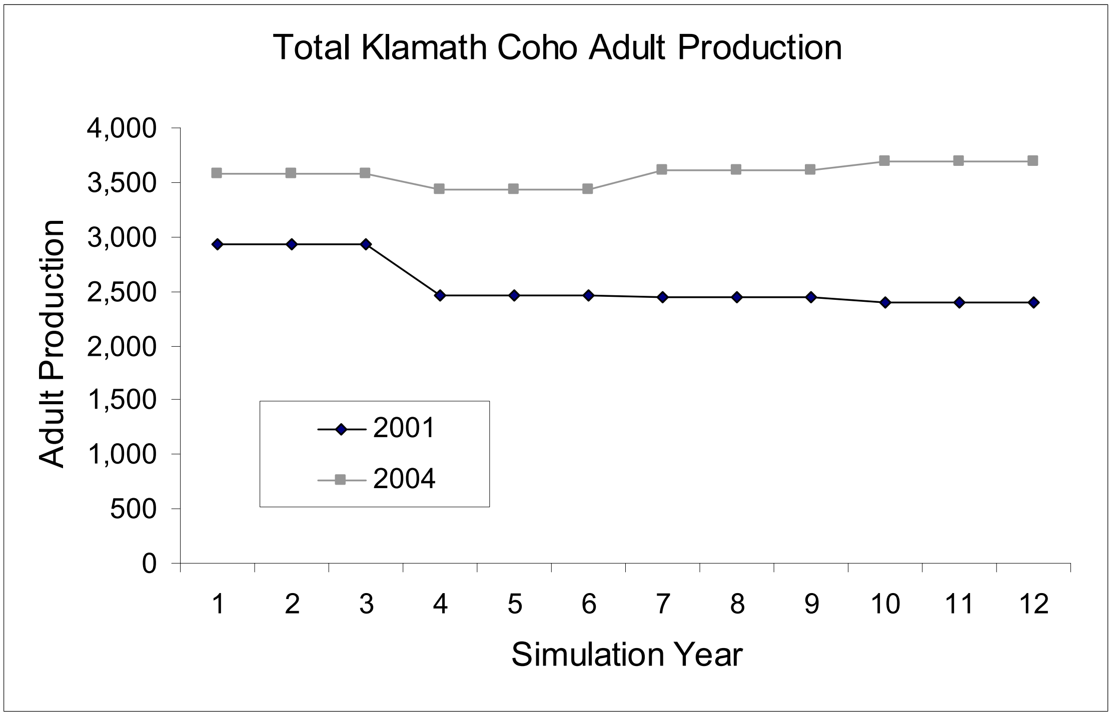


Figure 54. Model simulation of total Klamath coho adult production using minimum monthly flows at Iron Gate Dam coupled with meteorological conditions and tributary flow data from 2001 (dry year) and 2004 (average year).

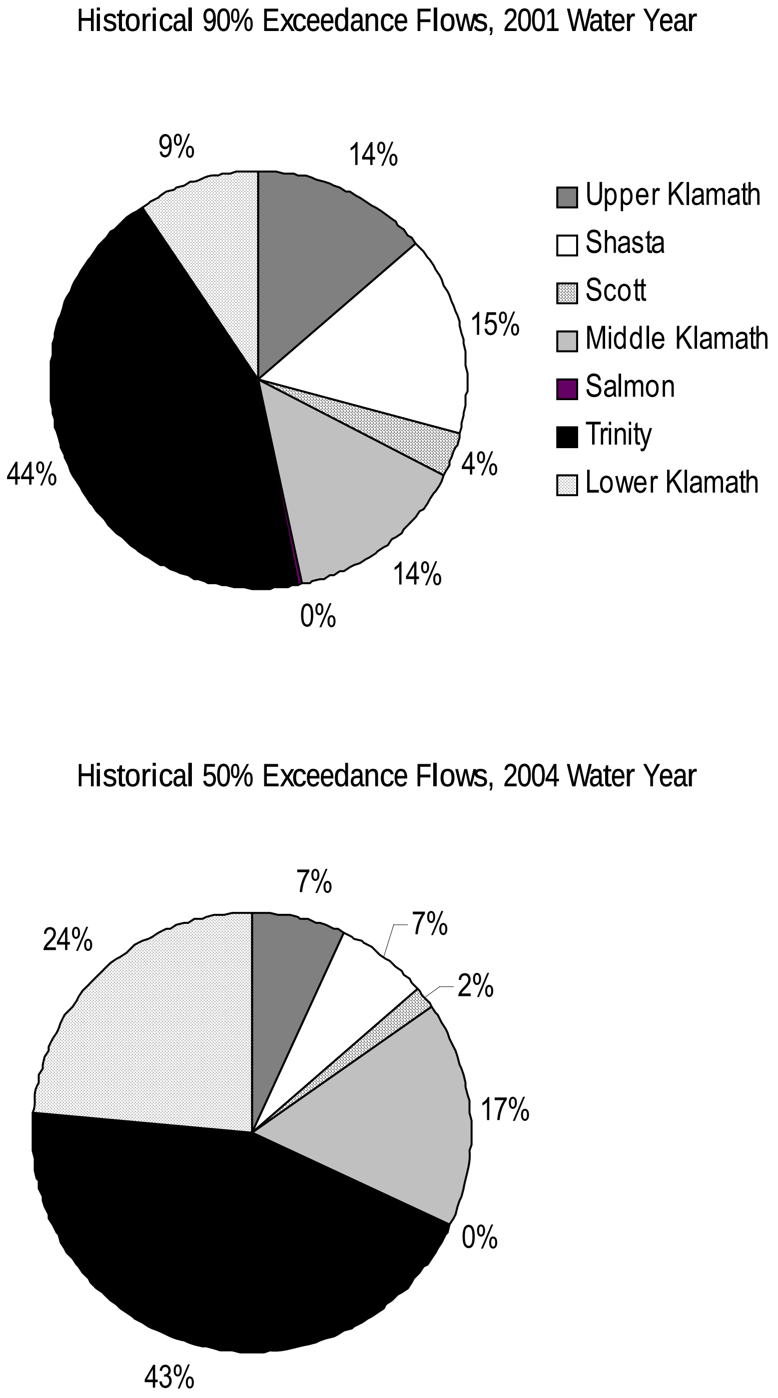


Figure 55. Proportion of simulated smolt production by population of origin for historical 90% exceedence flows using 2001 data, and 50% exceedence flows using 2004 data.

Table 23. Percentage change in pre-spawning survival from 2001 to 2004 conditions by reach.

Destination Reach	2001	2004	% Difference 2004-2001
MST1	0.88	0.92	5.0%
MST2	0.94	0.96	1.6%
MST3	0.86	0.93	7.5%
MST4	0.86	0.93	7.5%
MST5	0.86	0.93	7.3%
MST6	0.86	0.91	6.1%
SHASTA (MS2)	0.94	0.96	1.6%
SCOTT (MS3)	0.86	0.93	7.5%
SALMON (MS5)	0.86	0.93	7.3%
TRINITY (MS6)	0.86	0.91	6.1%
Average	0.88	0.93	5.7%

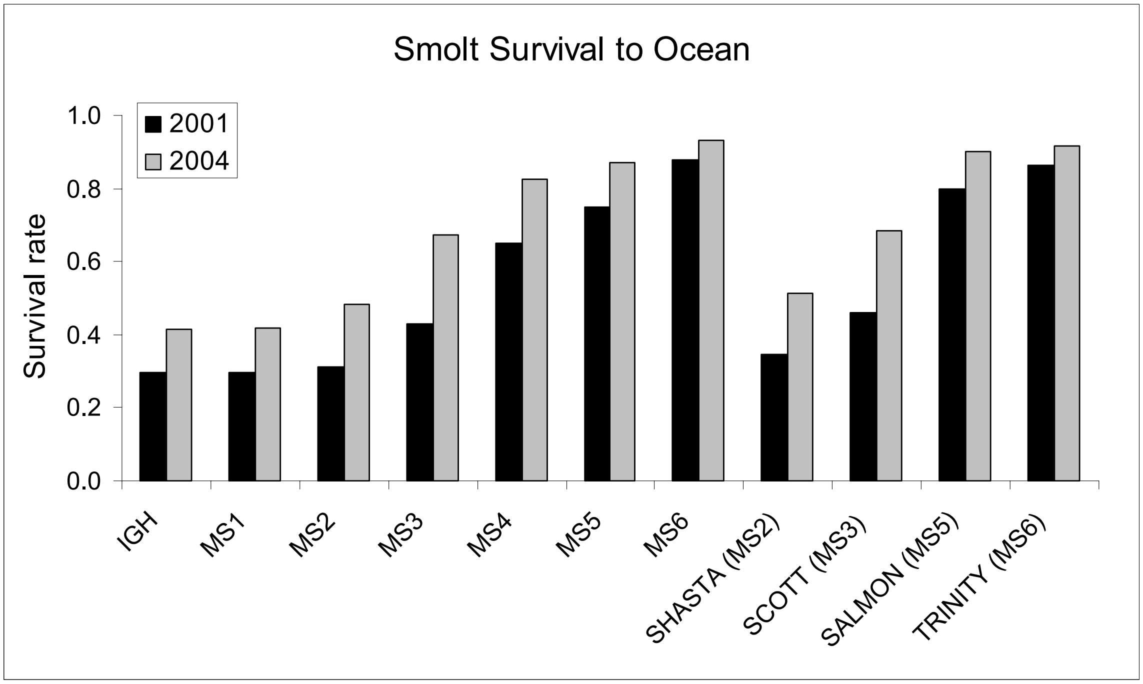


Figure 56. Simulated smolt survival to the river mouth for juvenile coho produced in each of six mainstem reaches and major tributaries. Stream flow and temperature conditions were based on minimum monthly flows at Iron Gate Dam coupled with meteorological conditions and tributary flow data from 2001 (dry year) and 2004 (average year).

Table 24. Summary of model-predicted reach-specific temperature and flow survival scalars and overall smolt survival to the ocean in 2001 and 2004.

		2001			2004			% Change (2004–2001)		
Smolt Origin	Distance Scalar	Temp Scalar	Flow Scalar	Survival to Ocean	Temp Scalar	Flow Scalar	Survival to Ocean	Temp Scalar	Flow Scalar	Survival to Ocean
IGH	0.86	0.98	0.35	0.30	0.98	0.49	0.42	0.0%	40.4%	40.4%
MS1	0.86	0.98	0.35	0.30	0.98	0.49	0.42	0.0%	40.4%	40.4%
MS2	0.88	0.74	0.47	0.31	0.85	0.64	0.48	14.5%	35.4%	55.9%
MS3	0.89	0.77	0.62	0.43	0.92	0.81	0.67	19.6%	30.0%	55.9%
MS4	0.92	0.96	0.73	0.65	0.98	0.91	0.83	3.0%	23.8%	27.2%
MS5	0.96	0.91	0.86	0.75	0.97	0.93	0.87	7.0%	8.7%	15.9%
MS6	0.98	0.96	0.93	0.88	0.99	0.96	0.93	2.7%	3.4%	6.1%
SHASTA (MS2)	0.86	0.85	0.47	0.35	0.92	0.65	0.52	8.1%	36.6%	48.2%
SCOTT (MS3)	0.89	0.82	0.63	0.46	0.93	0.82	0.68	13.8%	31.0%	49.1%
SALMON (MS5)	0.95	0.97	0.87	0.80	0.99	0.96	0.90	2.1%	10.4%	12.6%
TRINITY (MS6)	0.97	0.96	0.93	0.86	0.99	0.96	0.92	2.6%	3.9%	6.5%

Effects of Changes in Flow on Model Results

Under the baseline flow conditions for 2001, a total of 63,954 smolts were projected to survive to ocean entry in simulation year 10 (Table 25). This number increased by 238 smolts (0.4%) when daily flows at IGD were increased by 100 cfs, and by 1,571 smolts (2.5%) for flow increases of 500 cfs.

These increases in smolt production arise from two sources: (1) slight increases in parr capacity in MS1; and (2) increases in smolt migration survival as a function of flow increases. The largest increases in smolt numbers as flows were increased were recorded for the Shasta River and other tributaries to MS2 (Figure 57). However, the relative (percentage) increase in smolt production was greatest for MS1, where the number of smolts surviving to the ocean increased by approximately 90% after flows at IGD were increased by 500 cfs (Figure 58).

Total increases in smolt production resulting from increased flow at IGD were greater under 2004 baseline flow conditions compared with 2001. For 2004, smolt production increased by 610 smolts (0.6%) for flow increases of 100 cfs, and by 3,021 smolts (3.1%) for flow increases of 500 cfs (Table 26; Figure 59 and Figure 60). Greater increases in total smolt production in 2004 compared with 2001 was driven entirely by declines in smolt production in MS6 under the 2001 conditions. In contrast with MS6, relative increases in smolt production were lower in 2004 compared with 2001 in all other reaches (Table 25 and Table 26). For both year types, changes in smolt production were essentially linear with respect to changes in mainstem flow (Figure 61). Smolt production also increased with reduced 1961–2006 exceedence flow probabilities for both water years (Figure 51; Table 20).

Declines in smolt production in MST6 and the Trinity River resulting from increased flow at IGD under 2001 conditions was caused by temperature-related declines in pre-spawning survival. Pre-spawning survival for adult coho migrating to MST6 and the Trinity River declined from 85.6% under 2001 baseline conditions to 85.1% with a 500 cfs increase flow at IGD (relative change = -0.6%). This reduction in survival coincided with elevated stream temperatures in the lower river as flows at IGD were increased (Figure 45). Although the change in pre-spawning survival was very small, the difference was substantial enough to offset the potential benefits of increased flow on migration survival, resulting in declines of 42 smolts in MST6 and 232 smolts in the Trinity River. These declines amounted to almost negligible relative reductions in smolt production of 0.2% and 0.8% in MST6 and the Trinity River respectively.

Table 25. Simulated changes in smolt production (to ocean entry) in simulation year 10 resulting from increases in daily flow (100 cfs increments) at Iron Gate Dam for 2001 weather and tributary flow downstream.

Changes in ocean smolts produced relative to baseline smolt production (2001 data)						
		Simulated Increase in daily flow at Iron Gate Dam				
Production Reach	Baseline smolts	100 cfs	200 cfs	300 cfs	400 cfs	500 cfs
MS1	88	16	32	48	63	79
MS2	26	1	2	3	3	4
MS3	128	3	6	9	12	14
MS4	620	16	32	49	66	83
MS5	777	2	4	5	7	9
MS6	695	0	1	1	2	2
MST1	184	10	21	32	43	55
MST2	1,439	55	110	166	221	274
MST3	659	40	80	121	163	206
MST4	627	16	32	48	66	83
MST5	9,512	29	58	88	119	150
MST6	19,802	-7	-9	-6	0	7
SHASTA (MS2)	1,175	132	270	418	572	735
SCOTT (MS3)	296	22	45	68	91	115
SALMON (MS5)	117	1	1	2	3	4
TRINITY (MS6)	27,810	-97	-166	-211	-234	-249
Total	63,954	238	518	842	1,197	1,571

Percent (%) changes in ocean smolts produced relative to baseline (2001 data)						
		Simulated Increase in daily flow at Iron Gate Dam				
Production Reach	Baseline smolts	100 cfs	200 cfs	300 cfs	400 cfs	500 cfs
MS1	NA	18.1%	36.3%	54.5%	72.3%	89.9%
MS2	NA	3.5%	6.9%	10.2%	13.5%	16.7%
MS3	NA	2.4%	4.7%	6.9%	9.0%	11.1%
MS4	NA	2.5%	5.2%	7.9%	10.6%	13.4%
MS5	NA	0.2%	0.5%	0.7%	0.9%	1.2%
MS6	NA	0.1%	0.1%	0.2%	0.3%	0.3%
MST1	NA	5.6%	11.4%	17.4%	23.5%	29.8%
MST2	NA	3.8%	7.6%	11.5%	15.3%	19.0%
MST3	NA	6.0%	12.1%	18.4%	24.7%	31.2%
MST4	NA	2.5%	5.1%	7.7%	10.5%	13.2%
MST5	NA	0.3%	0.6%	0.9%	1.3%	1.6%
MST6	NA	0.0%	0.0%	0.0%	0.0%	0.0%
SHASTA (MS2)	NA	11.2%	23.0%	35.6%	48.6%	62.6%
SCOTT (MS3)	NA	7.5%	15.1%	22.9%	30.8%	39.0%
SALMON (MS5)	NA	0.5%	1.1%	1.8%	2.5%	3.2%
TRINITY (MS6)	NA	-0.3%	-0.6%	-0.8%	-0.8%	-0.9%
Total	NA	0.4%	0.8%	1.3%	1.9%	2.5%

Table 26. Simulated changes in smolt production (to ocean entry) in simulation year 10 resulting from increases in daily flow (100 cfs increments) at Iron Gate Dam for 2004 weather and tributary flow downstream.

Changes in ocean smolts produced relative to baseline smolt production (2004 data)						
		Simulated Increase in daily flow at Iron Gate Dam				
Production Reach	Baseline smolts	100 cfs	200 cfs	300 cfs	400 cfs	500 cfs
MS1	236	36	72	106	139	170
MS2	40	1	2	2	3	4
MS3	199	1	3	4	6	7
MS4	2,099	16	32	48	64	80
MS5	901	1	2	3	4	5
MS6	738	0	1	1	1	2
MST1	329	19	38	57	76	97
MST2	2,549	64	127	189	251	311
MST3	2,687	44	85	126	166	206
MST4	2,068	15	30	45	60	75
MST5	11,585	6	12	17	23	28
MST6	23,474	3	6	10	17	23
SHASTA (MS2)	4,910	343	692	1,054	1,421	1,652
SCOTT (MS3)	1,447	28	55	82	108	135
SALMON (MS5)	227	0	1	1	2	2
TRINITY (MS6)	45,340	33	72	115	169	225
Total	98,831	610	1,228	1,860	2,509	3,021

Percent (%) changes in ocean smolts produced relative to baseline (2004 data)						
		Simulated Increase in daily flow at Iron Gate Dam				
Production Reach	Baseline smolts	100 cfs	200 cfs	300 cfs	400 cfs	500 cfs
MS1	NA	15.3%	30.3%	44.8%	58.8%	72.0%
MS2	NA	2.0%	3.9%	5.7%	7.5%	9.3%
MS3	NA	0.7%	1.4%	2.1%	2.8%	3.4%
MS4	NA	0.8%	1.5%	2.3%	3.1%	3.8%
MS5	NA	0.1%	0.2%	0.3%	0.4%	0.6%
MS6	NA	0.0%	0.1%	0.1%	0.2%	0.2%
MST1	NA	5.6%	11.4%	17.3%	23.2%	29.4%
MST2	NA	2.5%	5.0%	7.4%	9.8%	12.2%
MST3	NA	1.6%	3.2%	4.7%	6.2%	7.7%
MST4	NA	0.7%	1.4%	2.2%	2.9%	3.6%
MST5	NA	0.1%	0.1%	0.1%	0.2%	0.2%
MST6	NA	0.0%	0.0%	0.0%	0.1%	0.1%
SHASTA (MS2)	NA	7.0%	14.1%	21.5%	28.9%	33.6%
SCOTT (MS3)	NA	1.9%	3.8%	5.7%	7.5%	9.3%
SALMON (MS5)	NA	0.2%	0.3%	0.5%	0.7%	0.9%
TRINITY (MS6)	NA	0.1%	0.2%	0.3%	0.4%	0.5%
Total	NA	0.6%	1.2%	1.9%	2.5%	3.1%

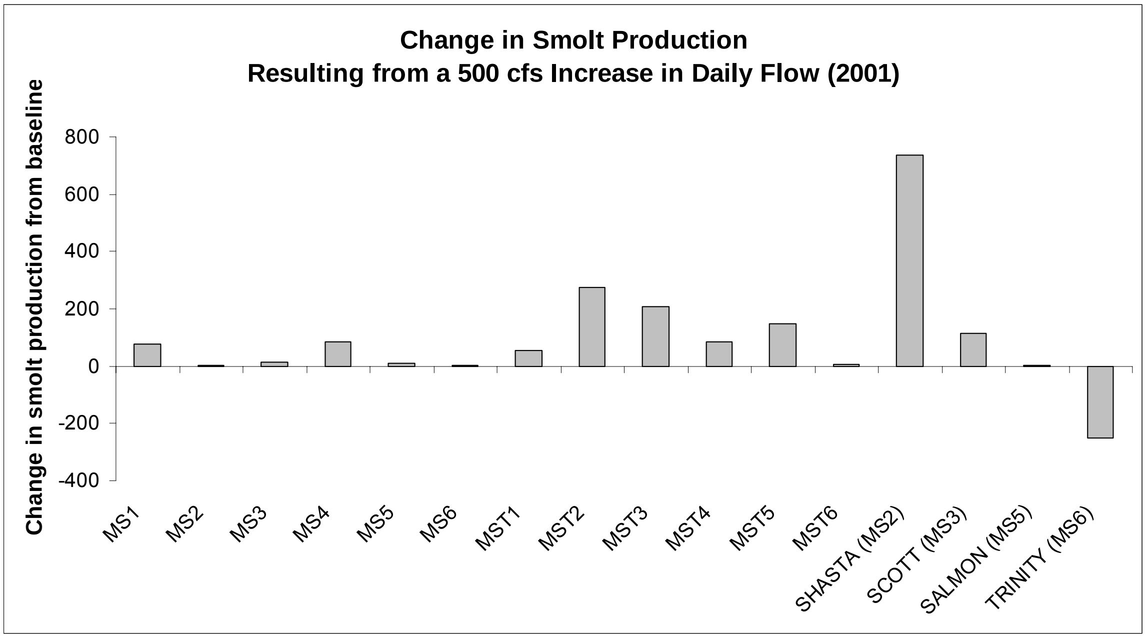


Figure 57. Simulated changes in smolt production (to ocean entry) in simulation year 10 from baseline smolt production resulting from increases in daily flow of 500 cfs at Iron Gate Dam for 2001 weather and tributary flow downstream.

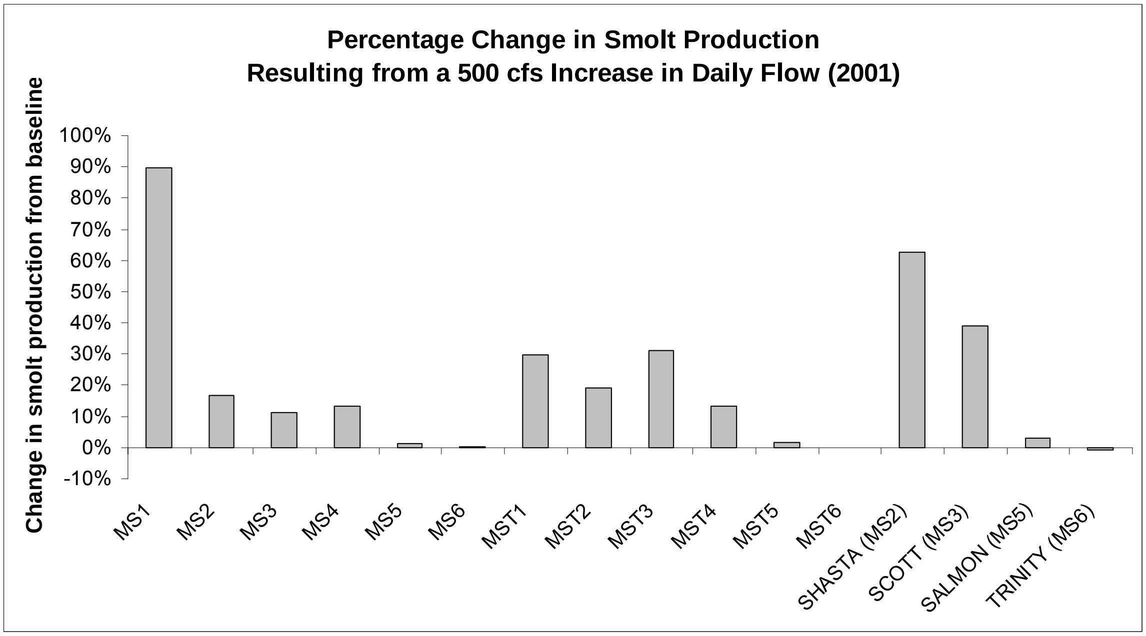


Figure 58. Simulated percentage changes in smolt production (to ocean entry) in simulation year 10 from baseline smolt production resulting from increases in daily flow of 500 cfs at Iron Gate Dam for 2001 weather and tributary flow downstream.

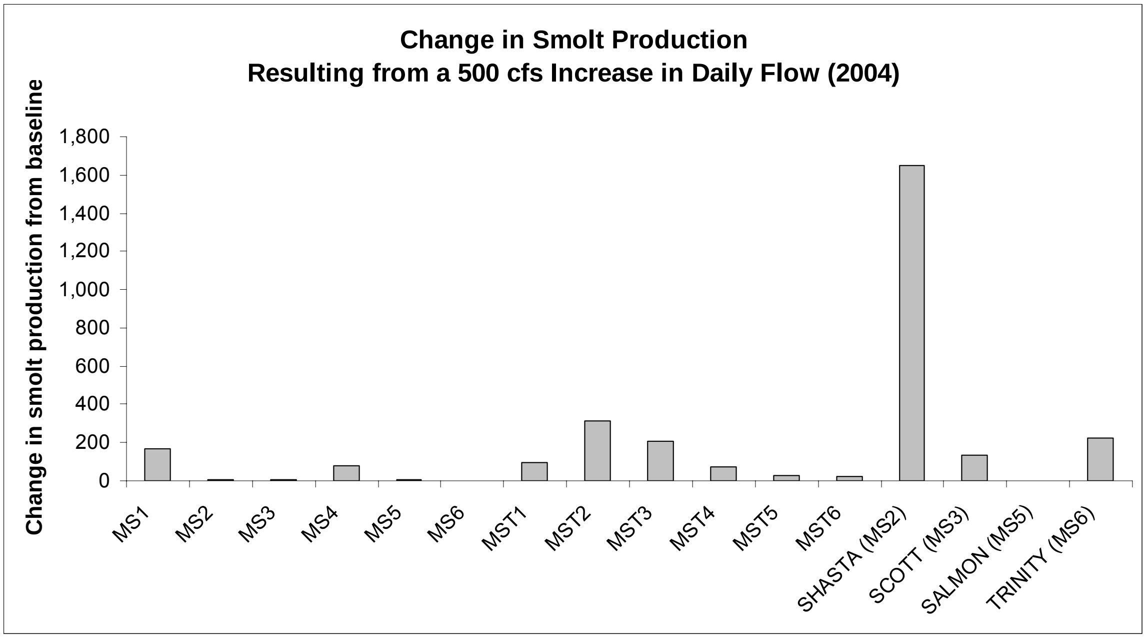


Figure 59. Simulated changes in smolt production (to ocean entry) in simulation year 10 from baseline smolt production resulting from increases in daily flow of 500 cfs at Iron Gate Dam for 2004 weather and tributary flow downstream.

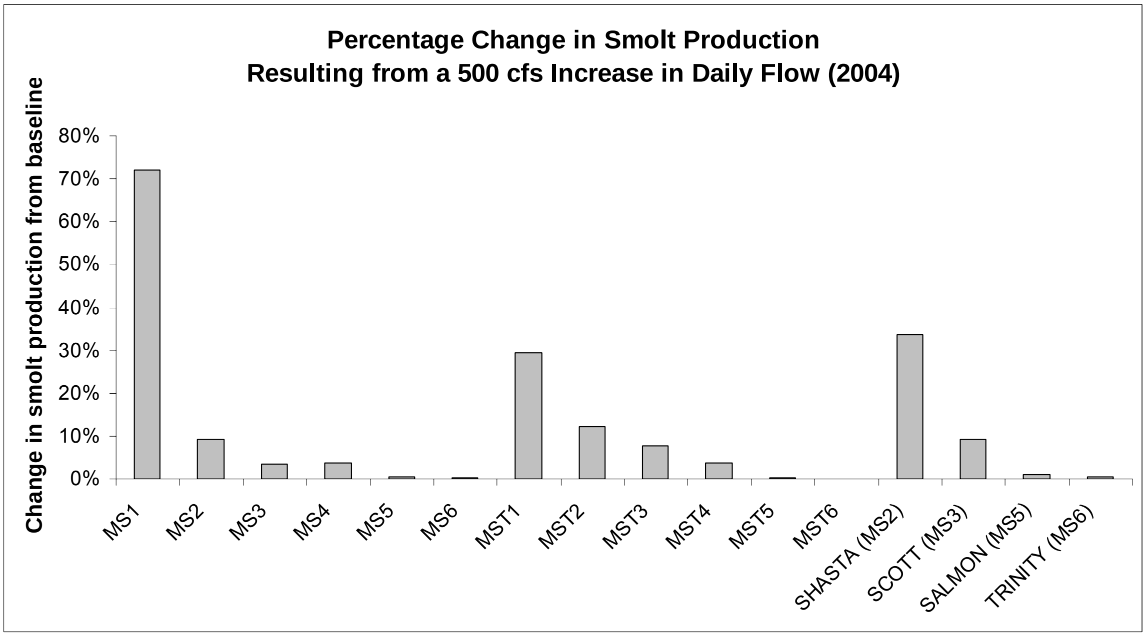


Figure 60. Simulated percentage changes in smolt production (to ocean entry) in simulation year 10 from baseline smolt production resulting from increases in daily flow of 500 cfs at Iron Gate Dam for 2004 weather and tributary flow downstream.

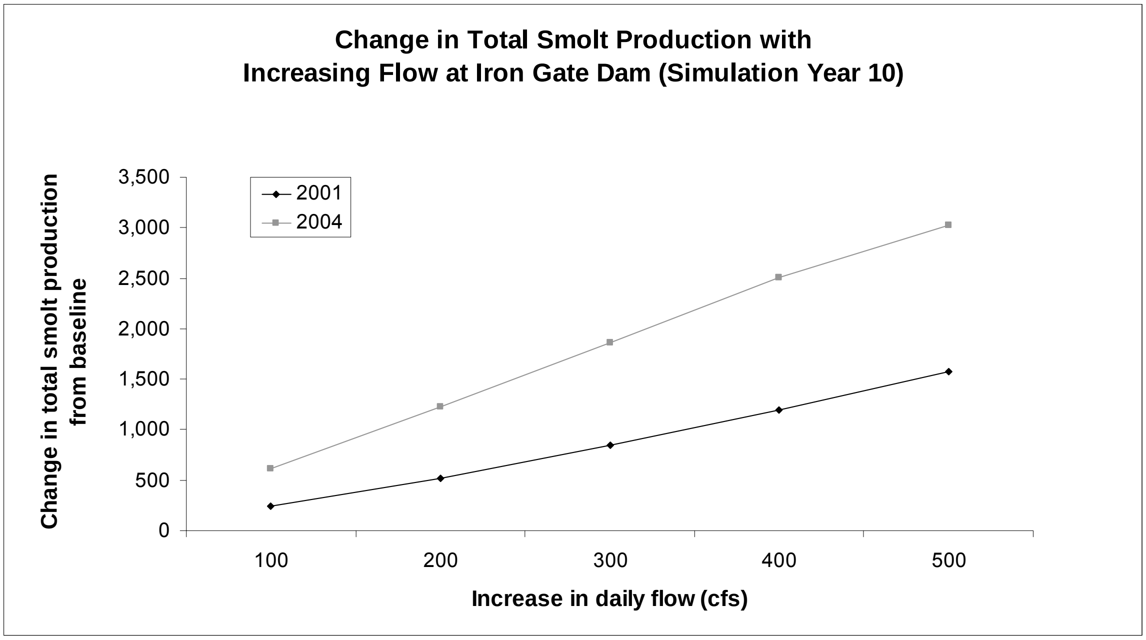


Figure 61. Simulated change in total smolt production to the ocean in simulation year 10 resulting from increases in daily flow (100 cfs increments) at Iron Gate Dam for 2001 and 2004 weather and tributary flow downstream.

Variation in ocean survival is known to have a dramatic effect on coho abundance, so we ran simulations for a constant series of either high, medium, or low ocean survival. We repeated these simulations for dry (2001) and average (2004) hydrologic conditions in the lower basin. Ocean survival for Klamath coho since the 1976 brood has varied from a 25th percentile value of 2.1% to a 75th percentile valued of 7.6%, with a median of 3.8% (Table 14). That range of ocean survivals had a dramatic effect on the simulated smolt production. The ocean survival of 4% combined with minimum release flows at IGD, produced a fairly constant smolt production, whether the years were all dry or average (Figure 62). However, smolt production rose by over 300% if survival was held at the 75th percentile and dropped by about -85% if ocean survival was held at the 25th percentile (Figure 62 and Figure 63). Again, these steady-state simulations represent extremes that would not occur (10 straight years at the 25th or 75th percentiles), but they illustrate why coho populations undergo large variations in abundance. These simulations also demonstrate how rapidly the populations can rebound from depressed to high abundance when ocean survival turns favorable.

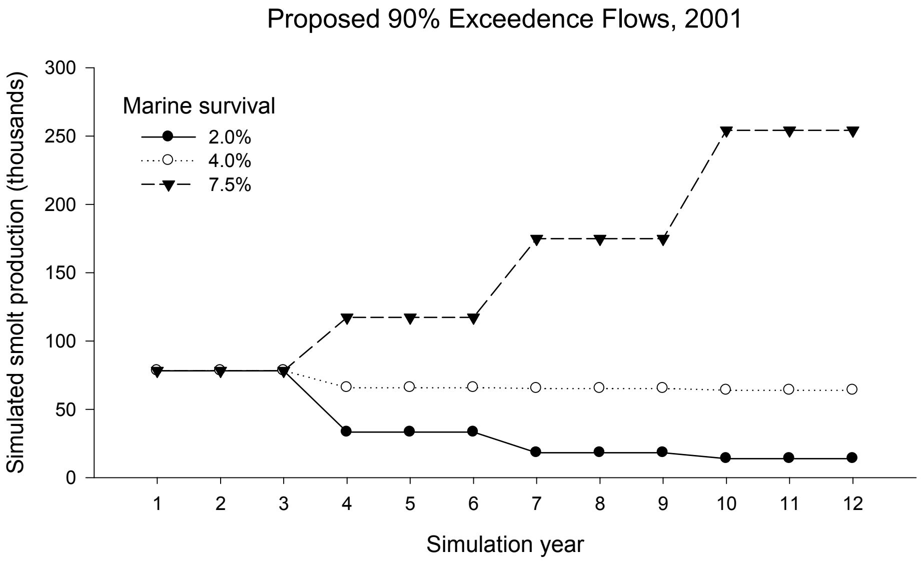


Figure 62. Total simulated smolt production over time under low (2.0%), medium (4.0%), and high (7.5%) marine survival rates using minimum flows released from Iron Gate Dam combined with 2001 meteorological and tributary flow data.

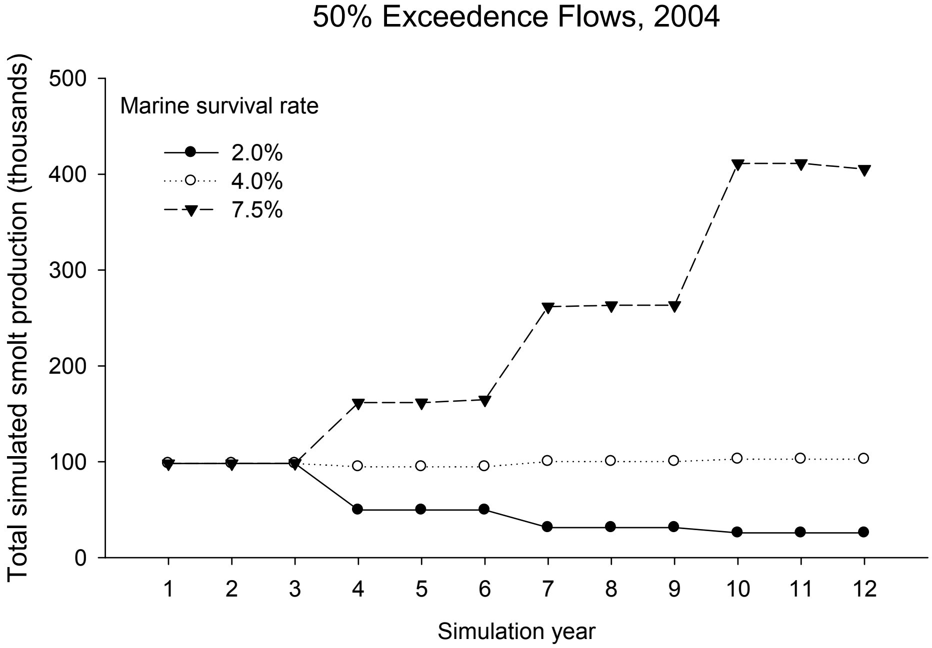


Figure 63. Total simulated smolt production over time under low (2.0%), medium (4.0%), and high (7.5%) marine survival rates using historical 50% exceedence flows (1961-2006) at Iron Gate Dam combined with 2004 meteorological and tributary flow data.

Sensitivity Analysis

We completed a reconnaissance analysis of the sensitivity of flow effects on coho to differences in model parameters and variables. The “flow effect” of interest was the difference in estimated smolt production between two simulations; the first with minimum flows released from IGD and the second with IGD releases increased by 500cfs throughout the year. Thus, we were interested in how the magnitude of the 500 cfs effect would change if parameters in the model changed. We examined 22 different "sensitivity scenarios" consisting of changes to a single model parameter or function from the default model settings (Table 27). Relative changes in smolt production by reach for each sensitivity scenario are presented in Table 28 for 2001 and Table 29 for 2004 data. For each sensitivity scenario, we calculated the difference in the 500 cfs effect on smolt production each reach and for all reaches combined (Table 30 and Table 31).

Estimation of flow effects on smolt production for all reaches combined appeared most sensitive to the assumed stock-recruitment function, smolt-to-adult survival rate (i.e. marine survival rate), and the flow scalar for smolt migration survival (Figure 64). Model results were also sensitive to variation in the baseline smolt migration survival rate and smolt migration timing to a lesser extent. However, model sensitivity to these smolt migration parameters differed considerably by water year type (i.e. 2001 or 2004) and reach of origin.

Table 27. Summary of 22 sensitivity scenarios representing changes in model parameters or functions from the default model settings.

Sensitivity scenario	Changes in model parameters or functions from default
1	Smolt-to-adult survival rate = 2.0% (25th percentile); default = 4.0%
2	Smolt-to-adult survival rate = 7.5% (75th percentile)
3	Delay spawer migration timing by two weeks
4	Accelerate spawner migration timing by two weeks
5	Subtract 1˚C from upper and lower threshods of pre-spawn survival temperature function
6	Add 1˚C to upper and lower threshods of pre-spawn survival temperature function
7	Subtract 1˚C from upper and lower threshods of temperature-capacity function
8	Add 1˚C to upper and lower threshods of temperature-capacity function
9	Turn on alkalinity-capacity scalar
10	Change method for estimating mainstem capacity (MS2-MS6) to snorkel survey estimates; default = HLFM method
11	Stock-recruitment function = Hockey-stick α = 40 (option 2); default = Hockey-stick α = variable (option 1).
12	Stock-recruitment function = Beverton-Holt α = variable (option 3)
13	Stock-recruitment function = Beverton-Holt α = 60 (option 4)
14	Turn off size scalar for parr-to-smolt survival (MS1 only); default = size scalar on
15	Decrease baseline survival rate (i.e. distance effect) by 5% (i.e. baseline survival rate = 0.90 per 100 km); default = 0.95
16	Increase baseline survival rate (i.e. distance effect) by 5% (i.e. baseline survival rate = 1.0 per 100 km)
17	Delay smolt migration timing by two weeks
18	Accelerate smolt migration timing by two weeks
19	Subtract 1˚C from upper and lower threshods of smolt migration survival temperature function
20	Add 1˚C to upper and lower threshods of smolt migration survival temperature function
21	Decrease survival scalar at 0 flow and median flow by 5% for the smolt migration survival flow function (all reaches)
22	Increase survival scalar at 0 flow and median flow by 5% for the smolt migration survival flow function (all reaches)[a]

[a] The survival scalar at median flow was increased from 0.95 to 0.999 for reaches MS3 and MS4 and from 0.99 to 0.999 for reaches MS5 and MS6, because the maximum scalar value for these functions was constrained to < 1.0.

Table 28. Sensitivity to the predicted effect that a 500 cfs increase in flow would have on smolt production if model parameters were altered. Values are the proportionate change in this effect, given that weather and tributary flows were set at 2001values.

Change in Model Parameters from Default	MS1	MST1	MS2	MST2	SHASTA	MS3	MST3	SCOTT	MS4	MST4	MS5	MST5	SALMON	MS6	MST6	TRINITY	Total
Model default	0.899	0.298	0.167	0.190	0.626	0.111	0.312	0.390	0.134	0.132	0.012	0.016	0.032	0.003	0.000	-0.009	0.025
Smolt-to-Adult survival = 2.0%	0.899	0.513	0.167	0.500	0.396	0.400	0.328	0.420	0.134	0.132	0.012	0.044	0.040	0.003	-0.007	-0.009	0.040
Smolt-to-Adult survival = 7.5%	0.899	0.421	0.167	0.260	0.204	0.111	0.167	0.220	0.034	0.167	0.012	0.013	0.034	0.003	0.000	-0.009	0.008
Spawner timing - 2 wks	0.899	0.487	0.167	0.403	0.559	0.111	0.359	0.446	0.139	0.136	0.012	0.014	0.024	0.003	-0.021	-0.045	0.022
Spawner timing + 2 wks	0.899	0.311	0.167	0.192	0.653	0.111	0.305	0.382	0.132	0.130	0.012	0.018	0.037	0.003	0.005	0.006	0.030
Pre-spawn temp f(x) thresholds -1˚C	0.899	0.326	0.167	0.196	0.607	0.111	0.307	0.385	0.125	0.123	0.012	0.015	0.028	0.003	-0.007	-0.019	0.021
Pre-spawn temp f(x) thresholds +1˚C	0.899	0.305	0.167	0.191	0.639	0.111	0.317	0.394	0.142	0.140	0.012	0.017	0.037	0.003	0.002	-0.001	0.027
Temp-K f(x) thresholds -1˚C	0.915	0.390	0.167	0.286	0.627	0.111	0.367	0.444	0.135	0.132	0.012	0.016	0.029	0.003	0.000	-0.009	0.023
Temp-K f(x) thresholds +1˚C	0.865	0.363	0.167	0.195	0.626	0.111	0.299	0.373	0.134	0.132	0.012	0.015	0.032	0.003	0.000	-0.009	0.029
Alkalinity scalar on	0.899	0.374	0.167	0.300	0.625	0.111	0.243	0.309	0.134	0.132	0.012	0.012	0.033	0.003	-0.001	-0.009	0.018
Mainstem K (MS2-MS6) method = snorkel	0.899	0.298	0.167	0.228	0.627	0.111	0.338	0.423	0.034	0.137	0.012	0.016	0.032	0.003	0.000	-0.009	0.026
Stock-recruit f(x) = H-S (α=40)	0.899	0.606	0.167	0.470	0.279	0.111	0.307	0.393	0.134	0.132	0.012	0.038	0.037	0.003	-0.002	-0.009	0.058
Stock-recruit f(x) = B-H (α=variable)	0.899	0.376	0.167	0.239	0.483	0.111	0.279	0.381	0.131	0.124	0.012	0.013	0.034	0.003	0.000	-0.008	0.011
Stock-recruit f(x) = B-H (α=60)	0.899	0.668	0.167	0.469	0.372	0.111	0.230	0.336	0.131	0.126	0.012	0.023	0.033	0.003	-0.002	-0.008	0.041
Size scalar off (MS1)	0.727	0.289	0.167	0.190	0.626	0.111	0.312	0.390	0.134	0.132	0.012	0.016	0.032	0.003	0.000	-0.009	0.024
Baseline smolt survival = 0.90	0.899	0.432	0.167	0.388	0.582	0.111	0.323	0.402	0.134	0.132	0.012	0.017	0.034	0.003	0.000	-0.009	0.022
Baseline smolt survival = 1.0	0.899	0.317	0.167	0.195	0.664	0.111	0.306	0.382	0.134	0.132	0.012	0.016	0.032	0.003	0.000	-0.009	0.034
Smolt timing - 2 wks	0.879	0.290	0.133	0.180	0.487	0.080	0.277	0.306	0.135	0.134	0.013	0.016	0.031	0.004	0.000	-0.008	0.027
Smolt timing + 2 wks	0.988	0.485	0.221	0.393	0.766	0.162	0.421	0.562	0.138	0.136	0.015	0.018	0.036	0.003	0.001	-0.011	0.023
Smolt survival temp f(x) thresholds -1˚C	0.910	0.305	0.191	0.201	0.728	0.132	0.347	0.450	0.136	0.135	0.010	0.016	0.032	0.003	0.001	-0.010	0.024
Smolt survival temp f(x) thresholds +1˚C	0.893	0.295	0.156	0.184	0.565	0.099	0.292	0.356	0.134	0.131	0.012	0.016	0.032	0.004	0.000	-0.008	0.025
Smolt survival flow f(x) values -5%	0.935	0.614	0.182	0.421	0.550	0.119	0.472	0.585	0.153	0.151	0.013	0.019	0.039	0.004	0.000	-0.007	0.014
Smolt survival flow f(x) values +5%	0.817	0.269	0.123	0.139	0.304	0.076	0.113	0.174	0.066	0.063	0.006	0.008	0.013	0.002	-0.003	-0.016	0.029

Table 29. Sensitivity to the predicted effect that a 500 cfs increase_in flow would have on smolt production if model parameters were altered. Values are the proportionate change in this effect, given that weather and tributary flows were set at 2004 values.

Change in Model Parameters from Default	MS1	MST1	MS2	MST2	SHASTA	MS3	MST3	SCOTT	MS4	MST4	MS5	MST5	SALMON	MS6	MST6	TRINITY	Total
Model default	0.720	0.294	0.093	0.122	0.336	0.034	0.077	0.093	0.038	0.036	0.006	0.002	0.009	0.002	0.001	0.005	0.031
Smolt-to-Adult survival = 2.0%	0.720	0.340	0.093	0.210	0.276	0.034	0.112	0.133	0.038	0.036	0.006	0.008	0.010	0.002	0.001	0.005	0.038
Smolt-to-Adult survival = 7.5%	0.720	0.413	0.093	0.200	0.165	0.034	0.074	0.093	0.011	0.016	0.006	0.003	0.009	0.002	0.001	0.005	0.014
Spawner timing - 2 wks	0.720	0.278	0.093	0.120	0.353	0.034	0.073	0.089	0.036	0.034	0.006	0.003	0.007	0.002	-0.002	-0.006	0.028
Spawner timing + 2 wks	0.720	0.309	0.093	0.121	0.206	0.034	0.051	0.065	0.041	0.039	0.006	0.002	0.012	0.002	0.002	0.007	0.023
Pre-spawn temp f(x) thresholds -1˚C	0.720	0.284	0.093	0.121	0.360	0.034	0.075	0.091	0.037	0.035	0.006	0.003	0.008	0.002	0.001	0.004	0.033
Pre-spawn temp f(x) thresholds +1˚C	0.720	0.303	0.093	0.122	0.261	0.034	0.059	0.074	0.039	0.037	0.006	0.002	0.010	0.002	0.001	0.006	0.026
Temp-K f(x) thresholds -1˚C	0.745	0.249	0.093	0.122	0.336	0.034	0.077	0.093	0.038	0.036	0.006	0.002	0.009	0.002	0.001	0.005	0.030
Temp-K f(x) thresholds +1˚C	0.678	0.366	0.093	0.122	0.336	0.034	0.077	0.093	0.038	0.036	0.006	0.002	0.009	0.002	0.001	0.005	0.032
Alkalinity scalar on	0.720	0.416	0.093	0.211	0.335	0.034	0.075	0.092	0.038	0.036	0.006	0.003	0.009	0.002	0.001	0.005	0.024
Mainstem K (MS2-MS6) method = snorkel	0.720	0.294	0.093	0.125	0.335	0.034	0.078	0.095	0.011	0.035	0.006	0.002	0.009	0.002	0.001	0.005	0.031
Stock-recruit f(x) = H-S (α=40)	0.720	0.517	0.093	0.146	0.195	0.034	0.057	0.079	0.038	0.036	0.006	0.004	0.009	0.002	0.001	0.005	0.033
Stock-recruit f(x) = B-H (α=variable)	0.720	0.316	0.093	0.162	0.120	0.034	0.055	0.084	0.011	0.045	0.006	0.003	0.009	0.002	0.001	0.005	0.013
Stock-recruit f(x) = B-H (α=60)	0.720	0.532	0.093	0.185	0.243	0.034	0.063	0.098	0.011	0.039	0.006	0.004	0.009	0.002	0.001	0.005	0.030
Size scalar off (MS1)	0.590	0.276	0.093	0.122	0.336	0.034	0.077	0.093	0.038	0.036	0.006	0.002	0.009	0.002	0.001	0.005	0.030
Baseline smolt survival = 0.90	0.720	0.271	0.093	0.116	0.347	0.034	0.074	0.090	0.038	0.036	0.006	0.002	0.009	0.002	0.001	0.005	0.024
Baseline smolt survival = 1.0	0.720	0.333	0.093	0.135	0.097	0.034	0.052	0.067	0.038	0.036	0.006	0.002	0.009	0.002	0.001	0.005	0.020
Smolt timing - 2 wks	0.706	0.289	0.075	0.110	0.083	0.028	0.046	0.054	0.032	0.030	0.004	0.002	0.006	0.002	0.000	0.003	0.016
Smolt timing + 2 wks	0.746	0.308	0.124	0.144	0.486	0.046	0.091	0.115	0.048	0.045	0.009	0.003	0.014	0.003	0.002	0.007	0.029
Smolt survival temp f(x) thresholds -1˚C	0.728	0.297	0.103	0.131	0.410	0.038	0.080	0.098	0.038	0.036	0.005	0.002	0.009	0.002	0.001	0.005	0.030
Smolt survival temp f(x) thresholds +1˚C	0.717	0.293	0.084	0.116	0.182	0.032	0.075	0.090	0.038	0.036	0.006	0.002	0.009	0.002	0.001	0.005	0.024
Smolt survival flow f(x) values -5%	0.764	0.292	0.113	0.138	0.418	0.047	0.151	0.171	0.067	0.066	0.009	0.009	0.023	0.004	0.004	0.010	0.027
Smolt survival flow f(x) values +5%	0.659	0.268	0.061	0.077	0.066	0.010	0.006	0.018	0.003	0.002	0.002	0.001	0.000	0.001	-0.001	0.000	0.011

Table 30. Difference in relative smolt production from the model default by reach of origin for each sensitivity scenario using 2001 meteorological and tributary flow data.

Change in Model Parameters from Default	MS1	MST1	MS2	MST2	SHASTA	MS3	MST3	SCOTT	MS4	MST4	MS5	MST5	SALMON	MS6	MST6	TRINITY	Total
SAS = 0.02	0.000	0.215	0.000	0.309	-0.230	0.289	0.015	0.030	0.000	0.000	0.000	0.028	0.008	0.000	-0.007	0.000	0.015
SAS = 0.075	0.000	0.123	0.000	0.070	-0.421	0.000	-0.145	-0.170	-0.100	0.035	0.000	-0.003	0.002	0.000	-0.001	0.000	-0.017
Spawner timing - 2 wks	0.000	0.188	0.000	0.213	-0.066	0.000	0.047	0.056	0.004	0.004	0.000	-0.002	-0.008	0.000	-0.022	-0.036	-0.002
Spawner timing + 2 wks	0.000	0.013	0.000	0.002	0.027	0.000	-0.007	-0.008	-0.002	-0.002	0.000	0.002	0.005	0.000	0.004	0.015	0.006
Pre-spawn temp f(x) thresholds -1˚C	0.000	0.027	0.000	0.006	-0.019	0.000	-0.005	-0.005	-0.009	-0.009	0.000	-0.001	-0.004	0.000	-0.007	-0.010	-0.004
Pre-spawn temp f(x) thresholds +1˚C	0.000	0.007	0.000	0.001	0.013	0.000	0.005	0.005	0.007	0.007	0.000	0.001	0.005	0.000	0.002	0.008	0.003
Temp-K f(x) thresholds -1˚C	0.017	0.092	0.000	0.095	0.001	0.000	0.054	0.055	0.000	0.000	0.000	0.000	-0.003	0.000	0.000	0.000	-0.002
Temp-K f(x) thresholds +1˚C	-0.033	0.065	0.000	0.004	0.000	0.000	-0.013	-0.016	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.005
Alkalinity scalar on	0.000	0.076	0.000	0.110	0.000	0.000	-0.070	-0.081	0.000	0.000	0.000	-0.003	0.001	0.000	-0.002	0.000	-0.007
Mainstem K (snorkel)	0.000	0.000	0.000	0.037	0.001	0.000	0.026	0.034	-0.100	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Stock-recruit f(x) = H-S (α=40)	0.000	0.308	0.000	0.280	-0.347	0.000	-0.005	0.004	0.000	0.000	0.000	0.022	0.005	0.000	-0.002	0.000	0.033
Stock-recruit f(x) = B-H (α=variable)	0.000	0.077	0.000	0.049	-0.143	0.000	-0.033	-0.009	-0.003	-0.009	0.000	-0.003	0.002	0.000	-0.001	0.001	-0.013
Stock-recruit f(x) = B-H (α=60)	0.000	0.370	0.000	0.278	-0.254	0.000	-0.082	-0.053	-0.003	-0.006	0.000	0.007	0.001	0.000	-0.003	0.000	0.017
Size scalar off	-0.171	-0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Baseline smolt survival = 0.90	0.000	0.133	0.000	0.198	-0.044	0.000	0.010	0.013	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.000	-0.003
Baseline smolt survival = 1.0	0.000	0.019	0.000	0.004	0.038	0.000	-0.006	-0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009
Smolt timing - 2 wks	-0.019	-0.009	-0.034	-0.010	-0.139	-0.032	-0.036	-0.083	0.001	0.002	0.001	0.001	-0.001	0.001	0.000	0.001	0.002
Smolt timing + 2 wks	0.090	0.187	0.054	0.202	0.140	0.051	0.109	0.173	0.004	0.004	0.003	0.002	0.004	-0.001	0.000	-0.002	-0.002
Smolt survival temp f(x) thresholds -1˚C	0.012	0.007	0.024	0.011	0.102	0.021	0.035	0.061	0.002	0.002	-0.001	0.000	0.000	-0.001	0.000	-0.001	-0.001
Smolt survival temp f(x) thresholds +1˚C	-0.006	-0.003	-0.010	-0.006	-0.061	-0.012	-0.021	-0.034	0.000	-0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.001
Smolt survival flow f(x) values -0.05	0.036	0.315	0.016	0.231	-0.076	0.008	0.160	0.195	0.018	0.019	0.002	0.003	0.008	0.001	-0.001	0.002	-0.010
Smolt survival flow f(x) values +0.05	-0.082	-0.029	-0.044	-0.051	-0.321	-0.035	-0.199	-0.216	-0.068	-0.069	-0.005	-0.008	-0.019	-0.002	-0.004	-0.007	0.005
Minimum	-0.171	-0.029	-0.044	-0.051	-0.421	-0.035	-0.199	-0.216	-0.100	-0.069	-0.005	-0.008	-0.019	-0.002	-0.022	-0.036	-0.017
Mean	-0.007	0.099	0.000	0.092	-0.082	0.013	-0.007	-0.003	-0.011	-0.001	0.000	0.002	0.001	0.000	-0.002	-0.001	0.002
Maximum	0.090	0.370	0.054	0.309	0.140	0.289	0.160	0.195	0.018	0.035	0.003	0.028	0.008	0.001	0.004	0.015	0.033

Table 31. Difference in relative smolt production from the model default by reach of origin for each sensitivity scenario using 2004 meteorological and tributary flow data.

Change in Model Parameters from Default	MS1	MST1	MS2	MST2	SHASTA	MS3	MST3	SCOTT	MS4	MST4	MS5	MST5	SALMON	MS6	MST6	TRINITY	Total
Smolt-to-Adult survival = 2.0%	0.000	0.046	0.000	0.088	-0.061	0.000	0.036	0.040	0.000	0.000	0.000	0.006	0.001	0.000	0.000	0.000	0.008
Smolt-to-Adult survival = 7.5%	0.000	0.119	0.000	0.078	-0.172	0.000	-0.003	0.000	-0.027	-0.020	0.000	0.000	0.000	0.000	0.000	0.000	-0.016
Spawner timing - 2 wks	0.000	-0.017	0.000	-0.002	0.017	0.000	-0.003	-0.004	-0.002	-0.002	0.000	0.000	-0.002	0.000	-0.003	-0.011	-0.003
Spawner timing + 2 wks	0.000	0.014	0.000	-0.001	-0.130	0.000	-0.025	-0.028	0.003	0.003	0.000	0.000	0.003	0.000	0.001	0.002	-0.008
Pre-spawn temp f(x) thresholds -1˚C	0.000	-0.010	0.000	-0.001	0.024	0.000	-0.002	-0.002	-0.001	-0.001	0.000	0.000	-0.001	0.000	0.000	-0.001	0.002
Pre-spawn temp f(x) thresholds +1˚C	0.000	0.008	0.000	0.000	-0.075	0.000	-0.017	-0.019	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.001	-0.005
Temp-K f(x) thresholds -1˚C	0.024	-0.045	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001
Temp-K f(x) thresholds +1˚C	-0.042	0.072	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
Alkalinity scalar on	0.000	0.122	0.000	0.089	-0.002	0.000	-0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.006
Mainstem K (MS2-MS6) method = snorkel	0.000	0.000	0.000	0.003	-0.002	0.000	0.001	0.001	-0.027	-0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Stock-recruit f(x) = H-S (α=40)	0.000	0.222	0.000	0.024	-0.141	0.000	-0.020	-0.014	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.003
Stock-recruit f(x) = B-H (α=variable)	0.000	0.022	0.000	0.040	-0.216	0.000	-0.021	-0.009	-0.027	0.008	0.000	0.000	0.000	0.000	0.000	0.000	-0.018
Stock-recruit f(x) = B-H (α=60)	0.000	0.238	0.000	0.063	-0.093	0.000	-0.014	0.005	-0.027	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000
Size scalar off (MS1)	-0.130	-0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Baseline smolt survival = 0.90	0.000	-0.023	0.000	-0.006	0.011	0.000	-0.002	-0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.007
Baseline smolt survival = 1.0	0.000	0.038	0.000	0.013	-0.240	0.000	-0.024	-0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.010
Smolt timing - 2 wks	-0.014	-0.005	-0.018	-0.012	-0.253	-0.006	-0.031	-0.039	-0.007	-0.007	-0.002	-0.001	-0.003	0.000	-0.001	-0.002	-0.014
Smolt timing + 2 wks	0.026	0.014	0.031	0.022	0.149	0.011	0.014	0.022	0.010	0.009	0.003	0.001	0.004	0.001	0.001	0.003	-0.002
Smolt survival temp f(x) thresholds -1˚C	0.007	0.003	0.010	0.009	0.073	0.003	0.003	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001
Smolt survival temp f(x) thresholds +1˚C	-0.003	-0.001	-0.008	-0.006	-0.154	-0.002	-0.002	-0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.006
Smolt survival flow f(x) values -5%	0.044	-0.002	0.020	0.016	0.081	0.013	0.075	0.078	0.029	0.029	0.004	0.007	0.014	0.001	0.003	0.005	-0.003
Smolt survival flow f(x) values +5%	-0.061	-0.026	-0.032	-0.045	-0.270	-0.025	-0.070	-0.075	-0.035	-0.035	-0.004	-0.002	-0.009	-0.001	-0.002	-0.005	-0.020
Minimum	-0.130	-0.045	-0.032	-0.045	-0.270	-0.025	-0.070	-0.075	-0.035	-0.035	-0.004	-0.002	-0.009	-0.001	-0.003	-0.011	-0.020
Mean	-0.007	0.035	0.000	0.017	-0.066	0.000	-0.005	-0.003	-0.005	-0.001	0.000	0.001	0.000	0.000	0.000	0.000	-0.005
Maximum	0.044	0.238	0.031	0.089	0.149	0.013	0.075	0.078	0.029	0.029	0.004	0.007	0.014	0.001	0.003	0.005	0.008

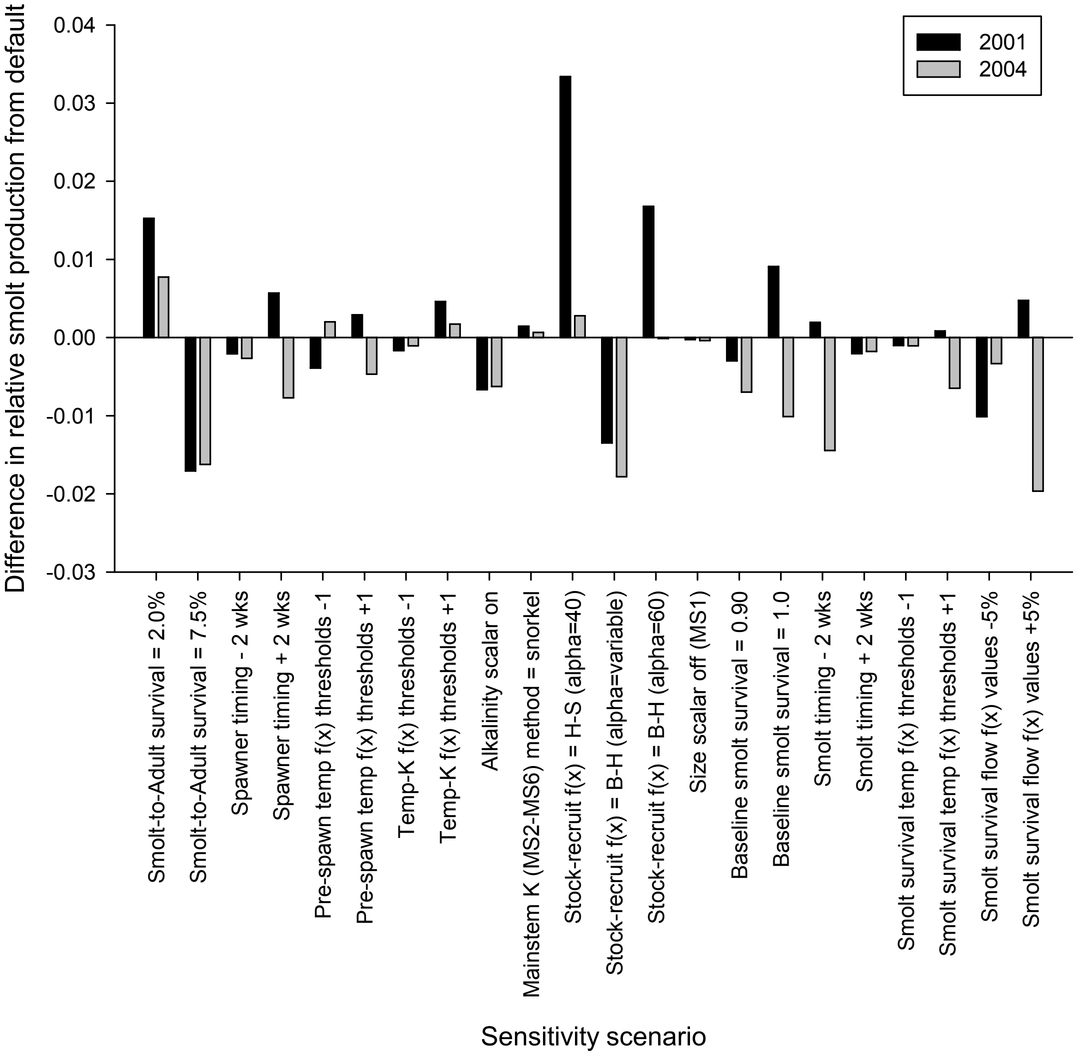


Figure 64. Difference in relative smolt production (all reaches combined) from the model default for each sensitivity scenario. These results are based on 2001 and 2004 meteorological and tributary flow data.

Relative changes in smolt production varied substantially with changes in the stock-recruitment function. The four different functions, as described previously in the smolt production section of the report, include (1) a hockey-stick function with a variable productivity parameter ($\alpha = K/N^*$, where K = smolt capacity and N^* = females at full seeding), (2) a hockey-stick function with a fixed α of 40 smolts per female, (3) a Beverton-Holt function with a variable α, and (4) a Beverton-Holt function with a fixed α of 60 smolts per female. Comparisons were made using temperature and flow conditions from both the 2004 and 2001 years.

The total percentage increase in smolt production to the ocean resulting from a 500cfs increase flow, given minimum outflows from IGD and 2001 conditions, averaged 2.5%, 5.8%, 1.1%, and 4.1% for options 1-4 respectively (Table 28). The relative increase in total smolt production appeared to be most sensitive to differences in the assumed productivity parameter (α), and to a lesser extent to the functional form of the stock-recruitment function (i.e. hockey-stick vs. Beverton-Holt). For example, when α was changed from variable to fixed, the total proportional change in smolt production increased from 2.5% to 5.8% for the hockey-stick function and from 1.1% to 4.1% for the Beverton-Holt function (Figure 65). However, when the stock-recruitment function was changed from hockey-stick to Beverton-Holt, the relative change in smolt production declined slightly from 2.5% to 1.1% for the variable α option, and from 5.8% to 4.1% for the fixed α option. Regardless of the method used to estimate α (i.e. fixed α or variable), the proportional change in smolt production resulting from an increase flow at IGD was generally higher for the hockey-stick function compared with the Beverton-Holt.

Differences in the proportional increase in smolt production among the four stock-recruitment options were driven primarily by changes in MST1, MST2, and the Shasta River, all of which experienced large changes in α (Table 30). Proportional differences were less for the 2004 dataset, although the pattern of differences among the four stock-recruitment options was similar to the 2001 results (Table 31; Figure 66).

Model outputs were also sensitive to changes in marine survival (an input variable). We simulated marine survival value that ranged from the 25th percentile (20%) to the 75th percentile (7.5%). Under 2001 flow and temperature conditions, the relative change in smolt production for all reaches combined increased from 2.5% to 4.0% when the marine survival rate was decreased from 4.0% to 2.0% (Table 28). Increasing the marine survival rate to 7.5% had the opposite effect, with relative smolt production decreasing from 2.5% to 0.8%. Effects of changes in marine survival rate on relative smolt production varied substantially by reach. For example, reducing the marine survival rate from 4.0% to 2.0% resulted in a decrease in relative smolt production of 23% from the Shasta, but resulted in an increase of 21.5% from MST1. With the exception of MS3, differences in relative smolt production from the default were most pronounced in tributary reaches, with relative smolt production generally declining as marine survival increased (Table 30). Similar patterns in model sensitivity to marine survival were observed using 2004 temperature and flow conditions (Table 31).

The relative effect of flow increases at IGD on smolt production was sensitive to changes in the flow scalar for smolt migration survival. Decreasing the flow-scalar intercept and upper limit by 5% resulted in a decrease in the total number of smolts surviving to the ocean, but generally increased the relative change in smolt production resulting from flow increases at IGD. For example, reducing the flow-scalar intercept and upper limit by 5% increased relative smolt production from the Scott River by 19.5% under 2001 temperature and flow conditions (Table 30). This pattern was observed in 13 out of 16 model reaches under 2001 conditions and 15 out of 16 reaches under 2004 conditions. As expected, increasing the flow-scalar intercept and upper limit by 5% had the opposite effect (i.e. decreased relative smolt production).

The effects of increased flow at IGD on relative smolt production were greatest and most variable for fish produced in the most upstream reaches (Figure 67). Effects of flow on smolt production was almost negligible for fish produced downstream of MS4 (i.e. downstream of the Salmon River). The declining effect of flow releases at IGD for fish originating in more downstream reaches is largely due to the decreased influence of additional flow from IGD on stream temperature and total stream flow in the lower river. In addition, flows and temperature scalars for survival of migrating smolts were more severe for the upper reaches, which was consistent with estimated lower survival rates of radio-tagged coho smolts in the upper reaches (Beeman et al. 2007) and higher incidence of disease (Foott et al. 2004).

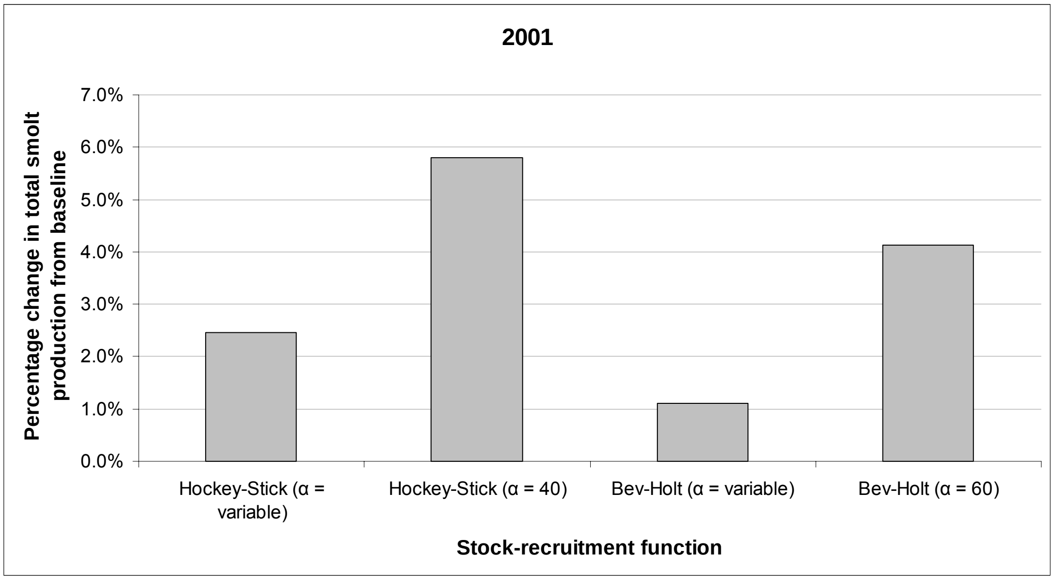


Figure 65. Percentage increase in total smolt production (to the ocean) resulting from a 500 cfs increase flow for 2001 flow and temperature conditions. Results are grouped by the four different options for the stock-recruitment function including the hockey-stick with variable α (option 1, model default), hockey-stick with fixed α (option 2), Beverton-Holt with variable α (option 3), and Beverton-Holt with fixed α (option 4).

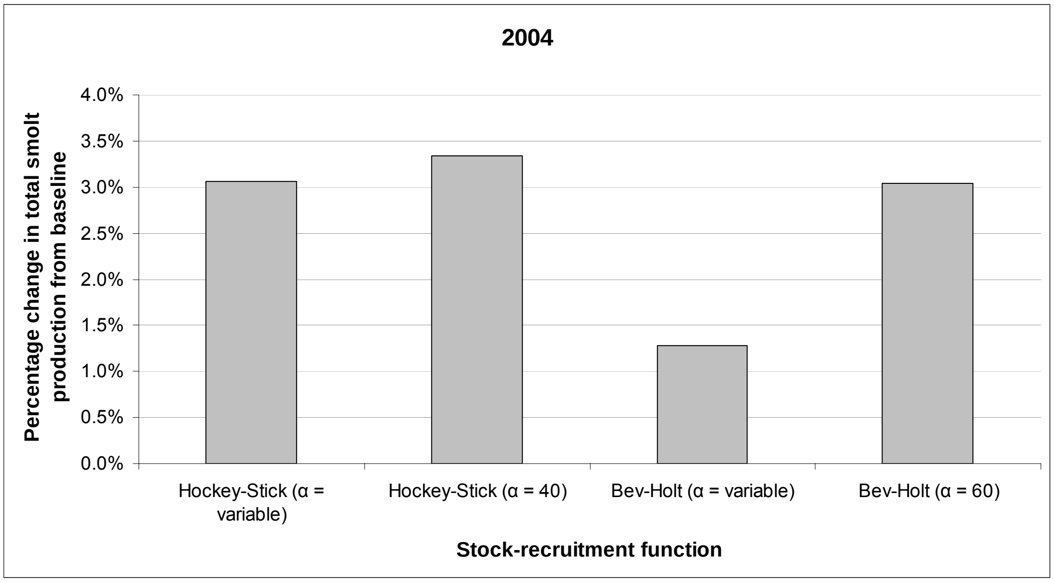


Figure 66. Percentage increase in total smolt production (to the ocean) resulting from a 500 cfs increase flow for 2004 flow and temperature conditions. Results are grouped by the four different options for the stock-recruitment function including the hockey-stick with variable α (option 1, model default), hockey-stick with fixed α (option 2), Beverton-Holt with variable α (option 3), and Beverton-Holt with fixed α (option 4).

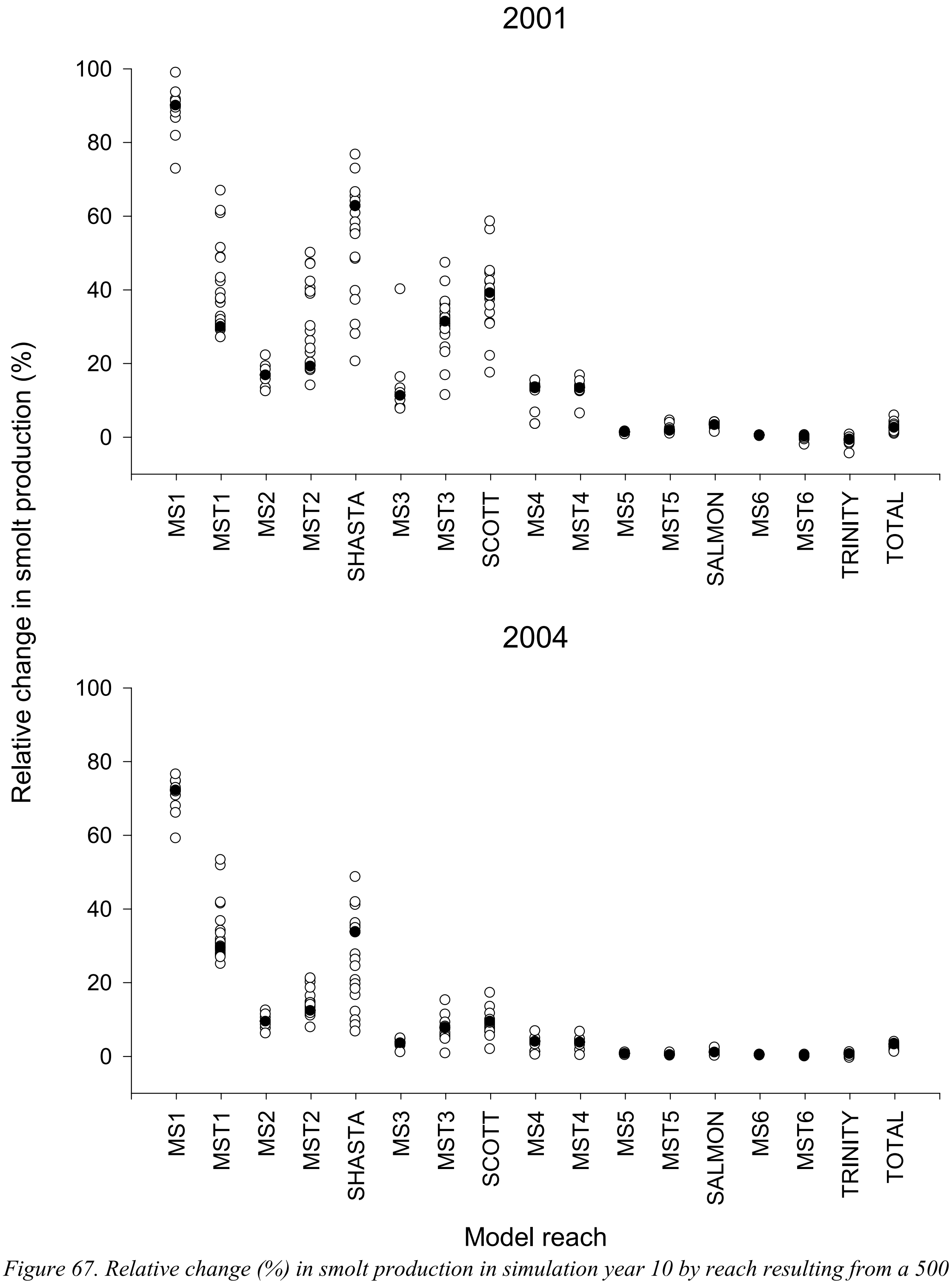


Figure 67. Relative change (%) in smolt production in simulation year 10 by reach resulting from a 500 cfs increase flow at IGD for each sensitivity scenario using 2001 and 2004 meteorological and tributary flow data. Black circles represent relative smolt production under default model settings and white circles represent results under alternative sensitivity scenarios.

Summary of Findings

Effects of Flow at Iron Gate Dam on Stream Temperature

- The ability to control water temperature in the lower Klamath River through flow management at Iron Gate Dam (IGD) is limited because tributary inputs and meteorological conditions are the primary temperature drivers downstream of the Scott River.
- The influence of IGD releases on downriver temperature and flow changes seasonally. The reservoir has its least effect in the winter. During late spring and early summer, the reservoir tends to release waters that are cooler than downstream temperatures. During the late summer and into fall, the large thermal mass of the reservoir above the dam creates temperatures warmer than downstream.
- During summer, releases from IGD are unable to sustain water temperatures under 22°C downstream of the Shasta River. High summer temperatures in the Klamath River sharply limit the rearing capacity for coho in the mainstem.
- During the fall, several lower river tributaries have a cooling influence on the mainstem. However, increasing releases at IGD during these periods of low flows can raise temperatures in Reaches 5 and 6 by diluting the cooler tributary influences.

Population Performance

- Most of the coho smolt production in the Klamath River Basin comes from juveniles that rear in their natal tributaries. After 10 years of simulation under average flow conditions (i.e. 2004 data), approximately 86.1% of the total smolt production came from fish that reared in natal tributaries, while only 4.3% reared in the mainstem and 9.7% reared in non-natal tributaries.
- Juveniles that migrate from natal tributaries and rear in the Klamath mainstem constitute a relatively large proportion of the smolt produced in reaches associated with mainstem Reaches 1 and 4. This is due to the availability of summer rearing capacity of parr in those reaches.
- Adult pre-spawning survival was relatively consistent throughout the basin but slightly higher for fish migrating into the upper basin.
- Mainstem fingerling-to-parr survival was generally low, but higher in reach 1 and in particularly in reach 4.
- Smolt migration survival was much higher for those migrating from the lower reaches than for upper reaches of the basin. Lower survival of smolt originating from the upper drainage is due to three factors: higher incidence of disease; lower flows; and, greater migration distance.

Flow and Temperature Effects on Coho

- In general, variation between years in downstream weather and tributary flow had a substantially greater effect on coho smolt production than did variation in flow released from IGD.
- In general, increasing the flow at IGD had the greatest benefit to coho during March-May through its influence on smolt migration survival.
- Benefits of increased springtime flows tended to be greatest in the upper basin and least to the lower basin.
- Increasing flows in the fall, tended to reduce smolt production because they actually caused temperatures to increase in the lower basin, which reduced survival of returning adults.
- Increasing flow in a dry year such as 2001, had a greater relative benefit to smolt production than in a normal year such as 2004.
- Under either dry (2001) or average (2004) conditions, simulated coho production stabilized after one generation and changed little across years.

- The simulated distribution of total spawners among reaches of the basin was similar between dry or average conditions, but both changed relative to the initial distribution of spawners. The relative proportion of adults returning to the upper half of the basin decreased, while the proportion of adults returning to tributaries in the lower river reaches increased.
- The proportional increase in survival from 2001 to 2004 conditions was greatest for fish originating in mainstem Reaches 2 and 3 (MS2 and MS3) and associated tributaries (MST2 and MST3).
- Variation in ocean survival within the observed range for Klamath coho caused several fold differences in simulated coho abundance. Simulations with minimum IGD outflows and low ocean survival for 10 consecutive years suggested the population could withstand extended periods of poor survival.

Sensitivity Analysis

- Model results were most sensitive to the assumed stock-recruitment function, marine survival, and the smolt migration flow scalar.
- Model results were also sensitive to the baseline smolt survival rate and smolt migration timing to a lesser extent. However, sensitivity to these parameters differed considerably by water year type and reach of origin.

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Appendix 1: Simulated Temperature and Flow by Reach

Table 1-1. Simulated average monthly stream temperature (˚C) at reach midpoints using 90% and 50% exceedence flows at IGD. Simulations were based on meteorological and tributary flow data from 2001.

Month	MS1	MS2	MS3	MS4	MS5	MS6
90% Exceedence Flow at IGD						
October	15.8	15.8	16.1	16.0	15.8	15.3
November	9.4	9.2	9.2	8.4	8.7	9.5
December	3.9	4.1	4.6	4.8	5.4	6.7
January	3.2	3.5	3.7	4.1	4.4	5.1
February	2.6	3.8	4.7	5.4	5.9	6.4
March	5.4	7.4	9.1	9.5	9.7	9.7
April	9.1	10.5	11.7	11.7	11.8	11.6
May	15.6	17.5	18.7	16.7	16.3	15.7
June	19.3	20.9	21.8	21.4	20.5	19.5
July	21.3	23.9	25.4	26.1	25.5	24.4
August	22.5	24.3	25.2	25.4	24.7	23.8
September	20.3	20.9	21.6	22.1	21.8	20.9
Average	12.4	13.5	14.3	14.3	14.2	14.1
50% Exceedence Flow at IGD						
October	15.8	15.8	16.1	16.1	15.9	15.4
November	9.4	9.3	9.3	8.6	8.8	9.5
December	3.8	4.0	4.4	4.7	5.3	6.6
January	3.2	3.4	3.5	3.8	4.2	4.8
February	2.4	3.0	3.6	4.3	5.0	5.8
March	4.9	6.0	7.3	7.9	8.6	9.1
April	8.7	9.6	10.6	10.9	11.3	11.3
May	15.0	16.4	17.6	16.6	16.3	15.8
June	19.1	20.5	21.4	21.3	20.6	19.6
July	21.2	23.7	25.3	26.1	25.5	24.4
August	22.2	23.7	24.6	25.1	24.9	23.9
September	20.2	20.7	21.3	21.9	21.8	21.1
Average	12.2	13.0	13.8	14.0	14.0	14.0

Table 1-2. Simulated average monthly stream temperature at reach midpoints using 90% and 50% exceedence flows at IGD. Simulations were based on meteorological and tributary flow data from 2004.

Month	MS1	MS2	MS3	MS4	MS5	MS6
90% Exceedence Flow at IGD						
October	15.1	14.9	15.1	14.7	14.5	14.8
November	8.8	8.5	8.6	8.5	8.3	8.9
December	4.4	4.5	4.9	5.2	5.5	6.1
January	3.2	3.7	4.5	5.5	5.8	6.6
February	3.2	4.4	5.8	6.4	6.7	7.3
March	6.9	8.4	9.4	8.9	8.5	9.2
April	11.0	12.0	11.9	11.0	10.4	11.1
May	15.2	16.4	15.3	14.6	13.8	13.9
June	18.2	20.0	19.8	19.3	18.5	18.1
July	21.1	22.9	23.6	23.2	22.9	22.6
August	21.4	22.7	23.5	23.1	23.1	23.1
September	19.0	19.3	19.6	19.1	19.1	18.9
Average	12.3	13.2	13.5	13.3	13.1	13.4
50% Exceedence Flow at IGD						
October	15.1	14.9	15.1	14.8	14.6	14.8
November	8.8	8.6	8.7	8.6	8.4	8.9
December	4.3	4.5	4.8	5.0	5.4	6.0
January	3.1	3.4	4.1	5.2	5.6	6.4
February	2.8	3.6	4.9	5.7	6.2	7.1
March	6.2	7.2	8.4	8.4	8.2	9.1
April	10.6	11.2	11.4	10.9	10.4	11.0
May	14.8	15.7	15.1	14.6	13.8	14.0
June	17.9	19.5	19.5	19.2	18.5	18.1
July	21.1	22.8	23.6	23.2	23.0	22.6
August	21.2	22.3	23.0	23.1	23.1	23.1
September	18.9	19.2	19.5	19.2	19.1	19.0
Average	12.1	12.8	13.2	13.2	13.1	13.4

Table 1-3. Simulated average monthly flow (cfs) at reach midpoints using 90% and 50% exceedence flows at IGD. Simulations were based on meteorological and tributary flow data from 2001.

Month	MS1	MS2	MS3	MS4	MS5	MS6
90% Exceedence Flow at IGD						
October	1,016	1,149	1,138	1,188	1,374	2,616
November	1,091	1,331	1,441	2,331	3,782	7,314
December	1,362	1,790	2,407	5,260	10,042	23,681
January	1,292	1,518	1,664	2,068	2,756	5,108
February	1,040	1,270	1,449	2,074	3,044	7,135
March	1,156	1,411	1,891	3,005	4,951	11,378
April	1,316	1,515	1,899	2,704	4,442	8,772
May	1,055	1,187	1,677	2,321	4,181	8,890
June	727	794	875	1,069	1,683	4,057
July	714	754	766	885	1,190	2,540
August	707	726	714	776	942	2,063
September	909	952	931	995	1,139	2,158
Average	1,032	1,200	1,405	2,059	3,301	7,160
50% Exceedence Flow at IGD						
October	1,422	1,548	1,534	1,588	1,765	3,006
November	1,751	1,978	2,087	2,984	4,425	7,944
December	2,478	2,881	3,506	6,363	11,128	24,756
January	2,409	2,610	2,759	3,168	3,829	6,149
February	2,461	2,660	2,842	3,474	4,413	8,461
March	2,678	2,900	3,388	4,508	6,426	12,810
April	2,584	2,755	3,145	3,952	5,661	9,947
May	1,867	1,983	2,472	3,118	4,957	9,638
June	981	1,045	1,122	1,319	1,925	4,294
July	765	805	815	935	1,239	2,589
August	1,062	1,078	1,059	1,127	1,282	2,406
September	1,315	1,352	1,327	1,396	1,529	2,550
Average	1,813	1,964	2,170	2,828	4,054	7,894

Table 1-4. Simulated average monthly flow (cfs) at reach midpoints using 90% and 50% exceedence flows at IGD. Simulations were based on meteorological and tributary flow data from 2004.

Month	MS1	MS2	MS3	MS4	MS5	MS6
90% Exceedence Flow at IGD						
October	1,025	1,219	1,275	1,718	2,322	3,519
November	1,079	1,296	1,405	1,838	2,431	3,788
December	1,347	1,779	2,535	4,584	7,890	11,109
January	1,362	1,784	2,575	5,733	10,560	22,040
February	1,224	2,000	3,645	8,234	15,595	34,599
March	1,337	2,099	3,884	7,685	13,864	27,691
April	1,438	1,925	3,427	6,295	11,163	17,636
May	1,160	1,581	2,929	4,809	8,611	13,692
June	782	1,005	1,594	2,441	4,357	7,455
July	729	813	925	1,312	2,083	3,739
August	712	766	773	1,045	1,474	2,597
September	915	992	996	1,279	1,620	2,667
Average	1,092	1,437	2,159	3,901	6,804	12,475
50% Exceedence Flow at IGD						
October	1,430	1,617	1,671	2,119	2,714	3,906
November	1,739	1,942	2,051	2,487	3,064	4,408
December	2,464	2,871	3,635	5,688	8,977	12,166
January	2,479	2,875	3,673	6,831	11,637	23,101
February	2,645	3,391	5,048	9,638	16,978	35,979
March	2,859	3,586	5,387	9,181	15,334	29,149
April	2,707	3,164	4,678	7,543	12,388	18,834
May	1,972	2,375	3,728	5,606	9,392	14,448
June	1,036	1,255	1,841	2,689	4,598	7,687
July	779	863	975	1,362	2,131	3,787
August	1,067	1,118	1,119	1,395	1,815	2,937
September	1,321	1,392	1,392	1,679	2,009	3,055
Average	1,873	2,200	2,927	4,670	7,558	13,217

Appendix 2: Model Equations

Numerous equations are required to model project effects at each life-stage. The following table is a compellation of equations presented in the body of this report. Page numbers are provided for reference purposes.

Equation 1) $S_{Prespawn,i} = \dfrac{1}{1+e^{-12.37+0.59T_i}}$ 15

Equation 2) $W = 59.75 * \text{width}^{2.54}$........18

Equation 3) $D_{Temp} = \dfrac{1}{1+e^{-a-bT}}$, ...21

Equation 4) $K_{Summer} = K_{parr} * D_{Temp} * 0.45$. 21

Equation 5) $K_{Winter} = [0.19 * K_{parr} + 14.51 * (ACW) + 10.47 * P - 1] * 0.9$. 22

Equation 6) $Smolts = \min(Female\ spawners * \alpha,\ K)$ 22

Equation 7) $N* = \text{stream length} * (4.2008 * \text{stream length}^{0.4849})$ 22

Equation 8) $Smolts = \min\left(\dfrac{Female\ spawners * a}{1 + {}^{a}\!/_{b} * Female\ spawners}, K\right)$ 22

Equation 9) $a = c * \alpha$ 22

Equation 10) $b = K\left(\dfrac{c}{c-1}\right)$ 23

Equation 11) Age 0 smolts = 0.28 * Migrant fingerlings + 436. 25

Equation 12) Migrant fry = (female spawners) * 549.28 * (km of habitat$^{-0.5972}$) 28

Equation 13)

$$Shasta\ migrant\ fry = \min\left[\left(female\ spawners * 549.28 * km\ habitat^{-0.5972}\right), \left(6.065 * e^{0.0285 * female\ spawners}\right)\right]$$

29

Equation 14) Migrant fingerlings = 2.589 * Migrant fry 30

Equation 15) $K_{MS1} = \min(K_{Parr} * D_{Temp} * D_{Qflowi})$, ...31

Equation 16) $D_{Qflowi} = 0.46\, Q_{Mi} + 0.50\, Q_{Sidei} + 0.04\, Q_{Spliti}$ 31

Equation 17) $Q_{ij} = (WUA_{ij} / WUA_{Bj})$, ...31

Equation 18) CSF = (HSC (velocity) * HSC (depth))$^{0.5}$ * HSC (cover) 31

Equation 19) $D_{size} = 1 + (Len_{Pred} - Len_{Base}) * 0.02$ 33

Equation 20) $g = \chi_0 + \chi_1 T + \chi_2 T^2 + \chi_3 C + \chi_4 C^2 + \chi_5 CT + w$ 33

Equation 21) $C = w^{-0.275}\left(\lambda_0 + \lambda_1 T + \lambda_2 T^2 + \lambda_3 T^3\right)$ 33

Equation 22) $D_{alk} = (K_{alk})^{0.45} / (OR_{alk})^{0.45}$, ...36

Equation 23) $S_{Total} = S_{Base}{}^{d/100} * \left(\prod_{i=1}^{n} D_{MTemp,i} * D_{MFlow,i}\right)$ 37

Equation 24) Distance Effect $= (S_{Base})^{d/100}$; 46

Equation 25) $D_{MTemp,i} = \dfrac{1}{1+e^{-a-bT_i}}$; 48

Appendix 3: Temperature Modeling Results

As part of the Cramer Fish Sciences coho life-cycle model, Watercourse Engineering conducted model runs to assess the effects of flow on water temperature downstream of Iron Gate Dam. Watercourse modeled several steady state flow regimes ranging from 600 to 4000 cfs with both, 2001 (dry year) and 2004 (average year) meteorological and tributary flow conditions, to estimate daily average water temperature at several locations downstream of Iron Gate Dam.

This modeling effort yielded results consistent with previous Klamath River temperature modeling efforts, where greater flows downstream of Iron Gate Dam provide modest thermal benefits (cooler water temperatures) that diminish with increased distance from the dam (Watercourse 2007). The modeling effort showed that increased flows from Iron Gate Dam provide cooler water temperatures throughout a larger portion of the Klamath River in a dry year than during an average water year. This is due to less cooling of the main stem Klamath River from tributary flows during dry year conditions. However, when assessing the effect of flow on water temperature you must rely on the 2004 model run, due to the fact that 2001 was a dry water year and water would not be available to sustain the increased flows downstream of Iron Gate Dam that were used for the 2001 model run. Although greater flows from Iron Gate Dam can provide decreased water temperature in the upper and middle reaches of the Klamath River throughout the year, May and June are the only months when daily average temperature stressful to salmon occur and Reclamation's proposed action may deviate from the 2002 NMFS biological opinion. Therefore, the thermal benefits from increased flows can only be attained during the months of May and June.

Table 3-1 and Table 3-2 are the average daily water temperature output tables from the flow and temperature modeling effort conducted by Watercourse Engineering. Figures 3-1 through 3-16 were developed with the data from output Table 3-1 and Table 3-2. The figures show the estimated effects of flow on water temperature for the months of March through June when Reclamation proposes floor flows that diverge from the NMFS 2002 biological opinion recommended flows for below average, average, above average, and wet water year types. However, Reclamation doesn't propose to operate at the floors during all years, rather only during dry years when water supply is limited. During below average, average, above average, and wet water years (years when water is available to provide flows above the floors) the Interactive Management team will provide recommendations as to how to utilize the conservation water supply for suckers and salmon.

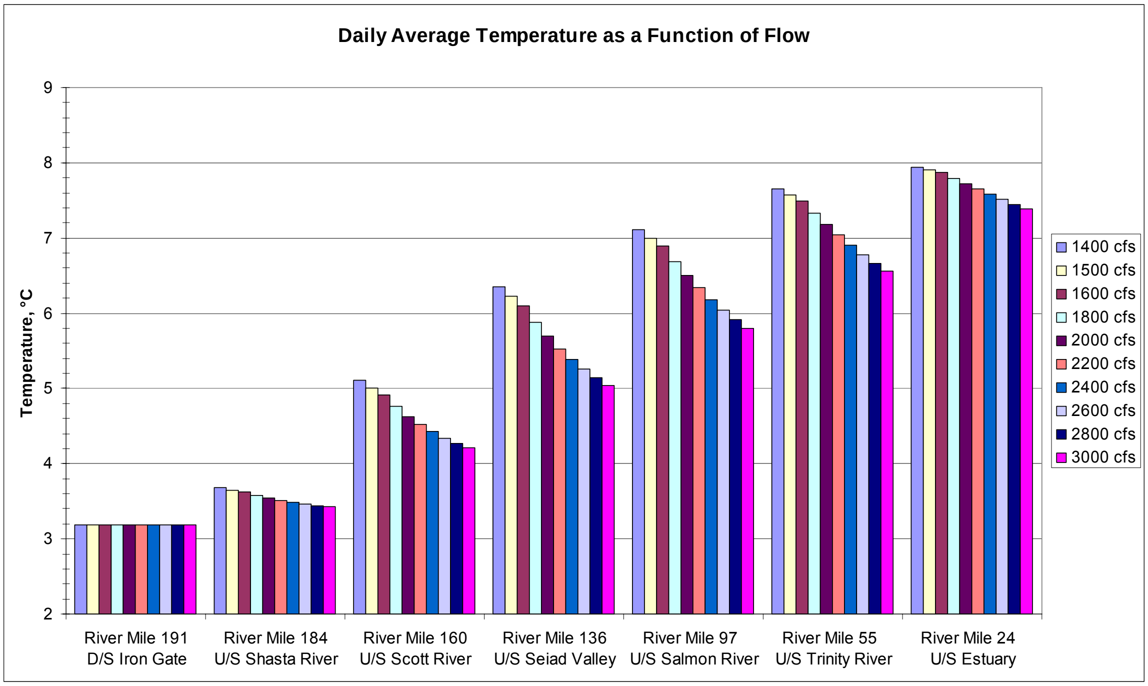


Figure 3-1. March 1 – March 15 for the 2001 Model Run.

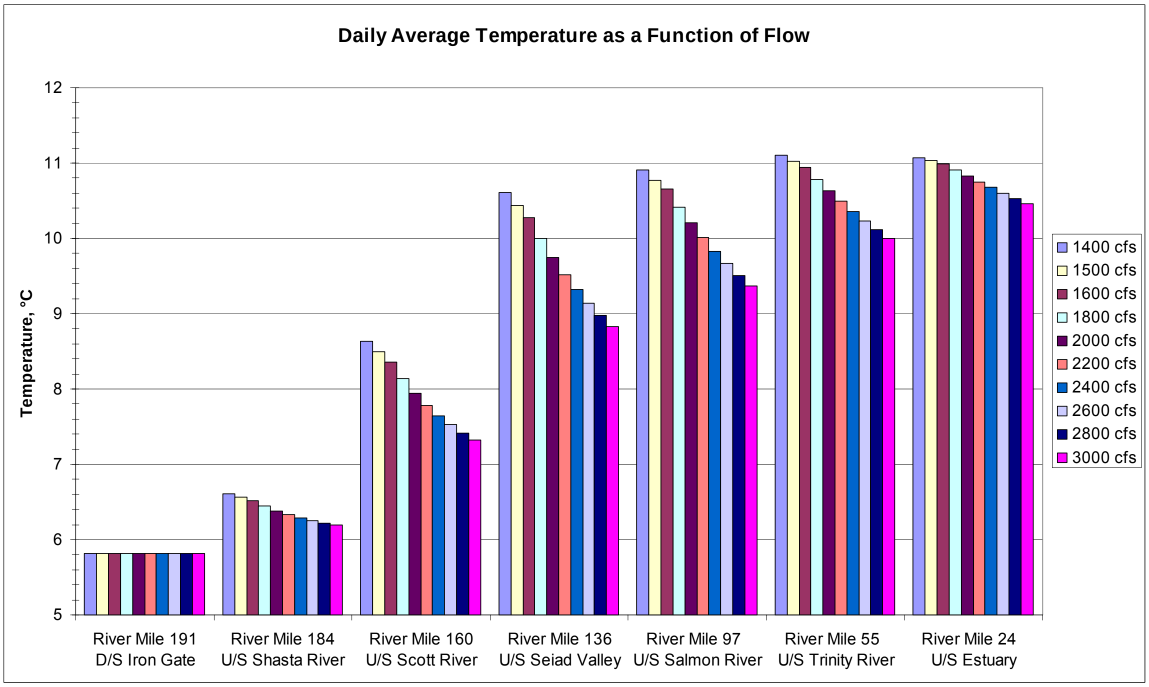


Figure 3-2. March 15 – March 31 for the 2001 Model Run.

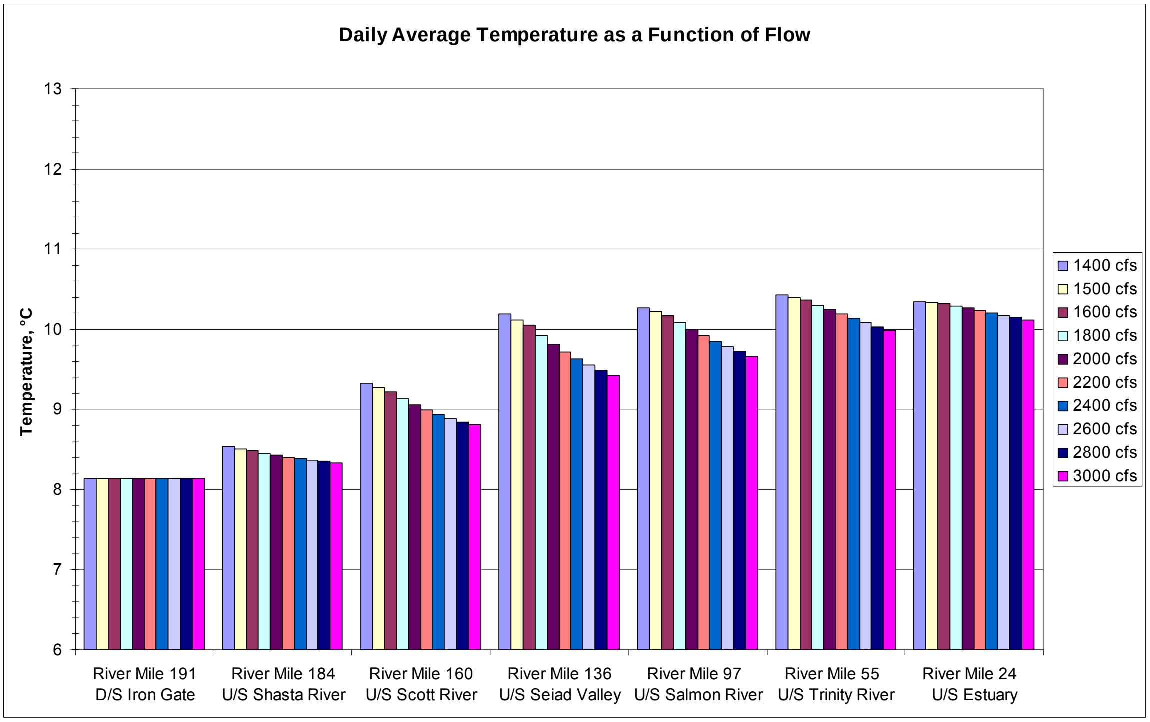


Figure 3-3. April 1 – April 15 for the 2001 Model Run.

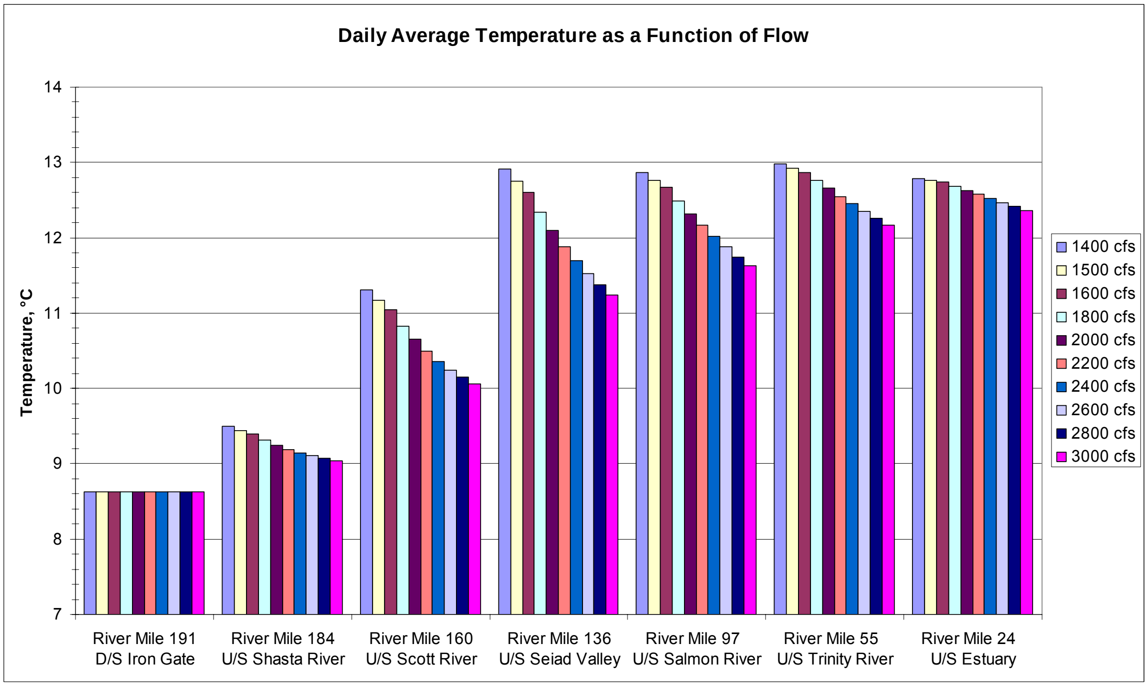


Figure 3-4. April 16 – April 30 for the 2001 Model Run.

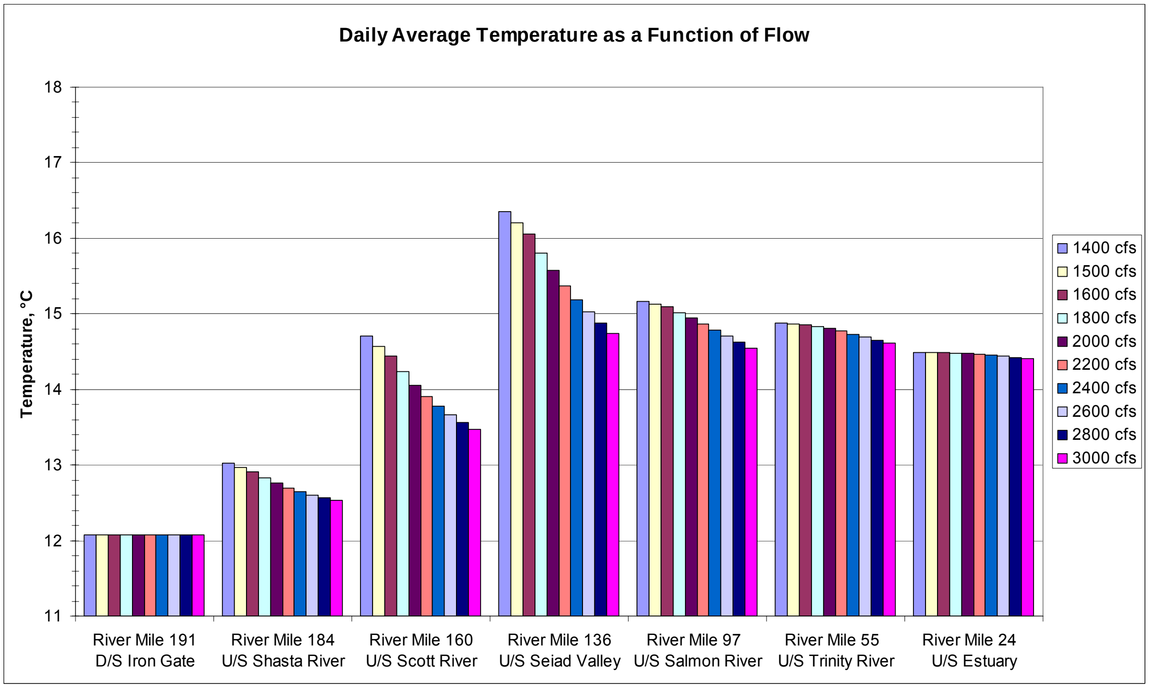


Figure 3-5. May 1 – May 15 for the 2001 Model Run.

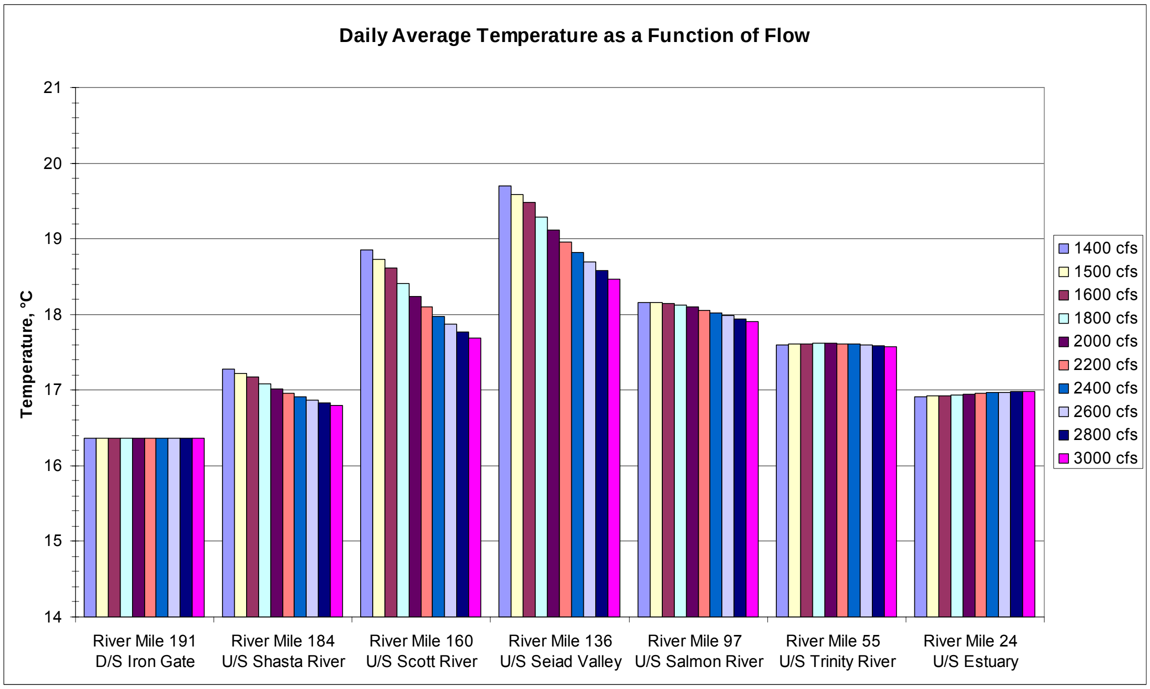


Figure 3-6. May 16 – May 31 for the 2001 Model Run.

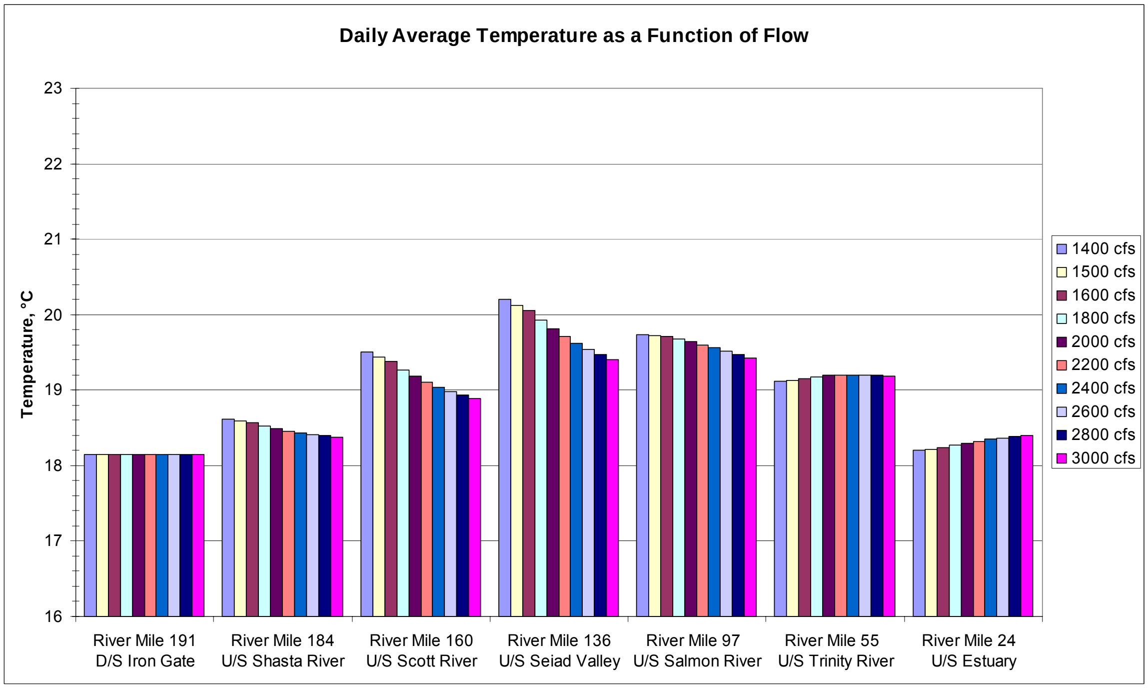


Figure 3-7. June 1 – June 15 for the 2001 Model Run.

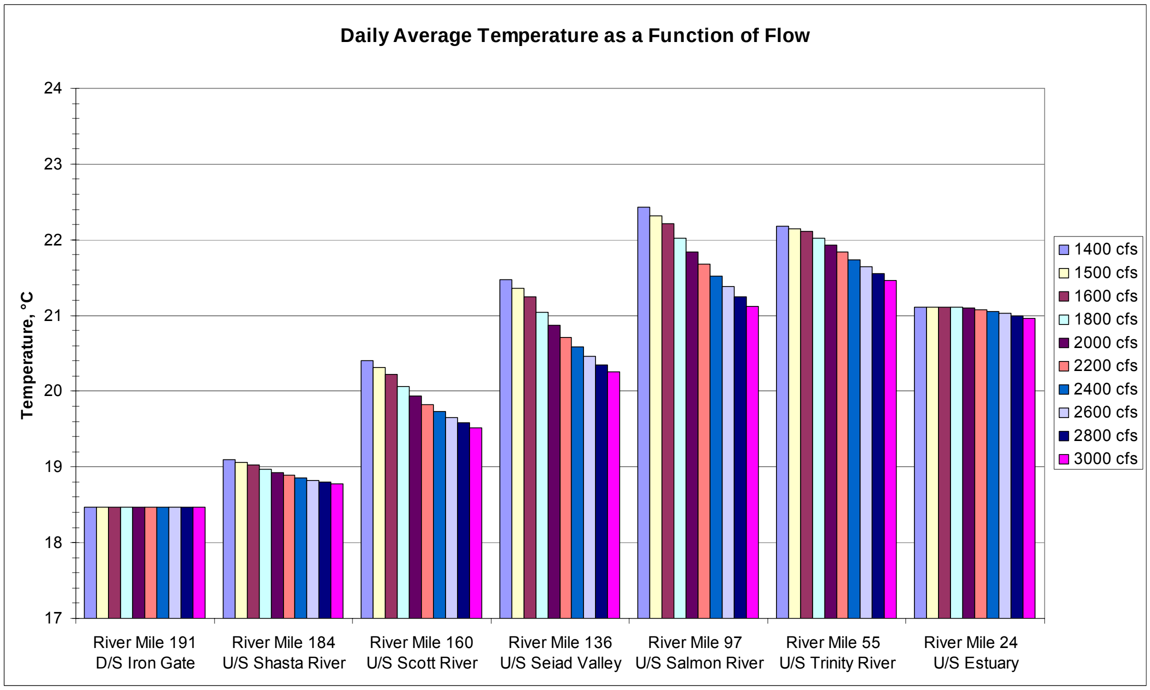


Figure 3-8. June 16 – June 30 for the 2001 Model Run.

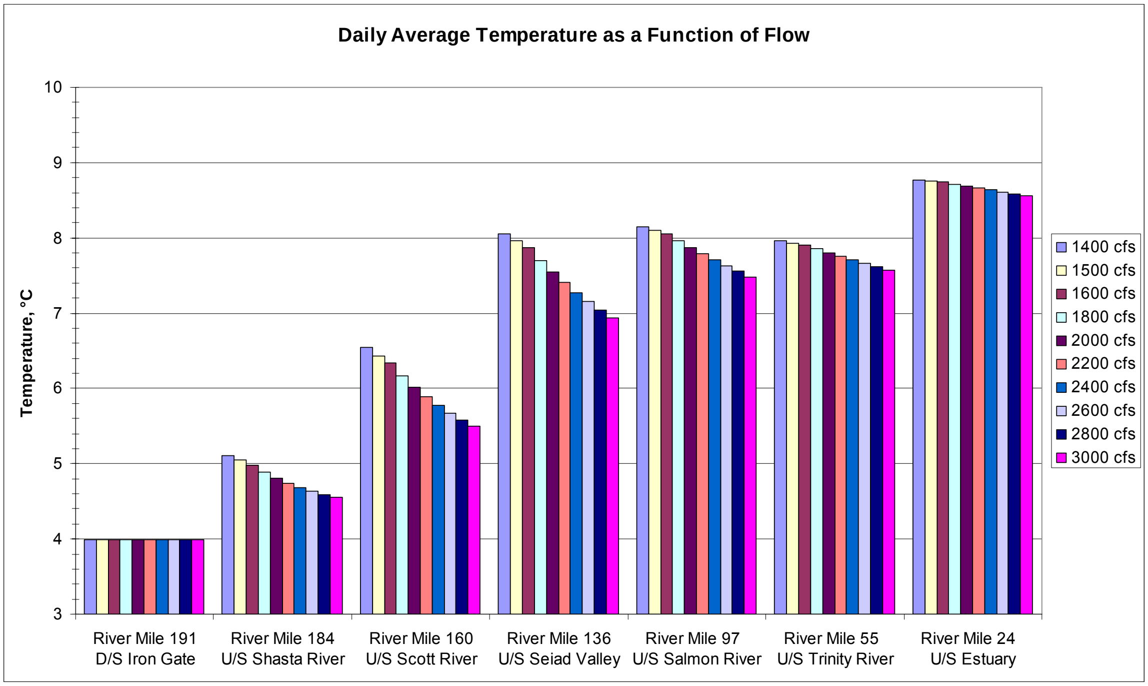


Figure 3-9. March 1 – March 16 for the 2004 Model Run.

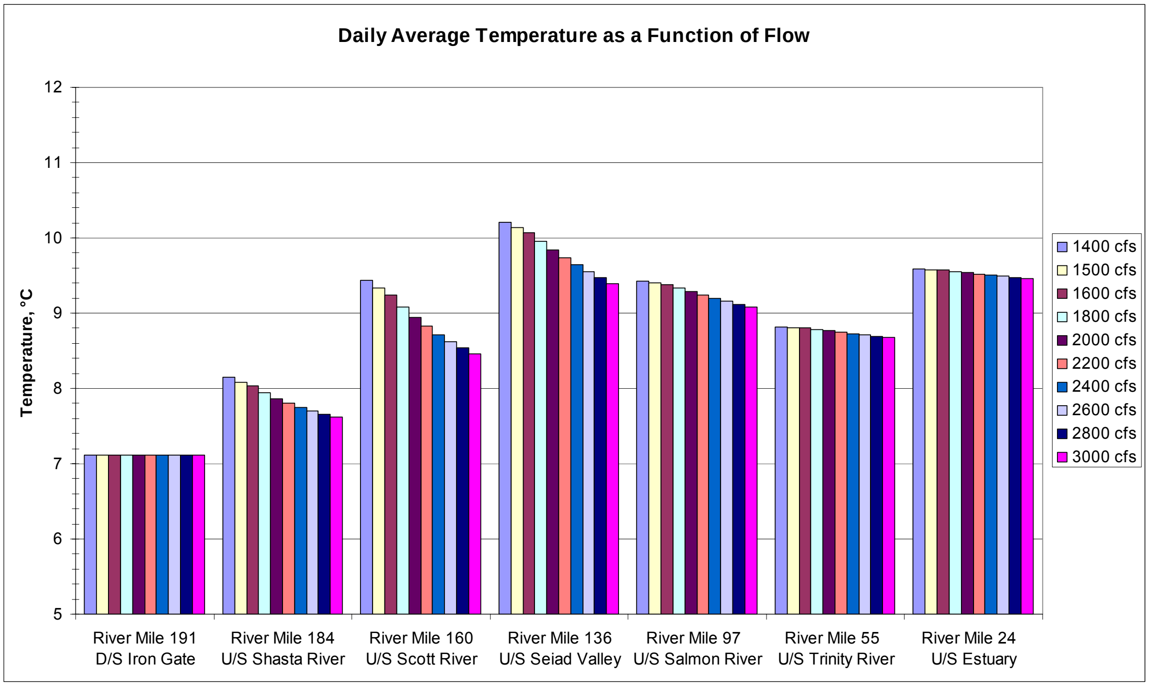


Figure 3-10. March 16 – March 31 for the 2004 Model Run.

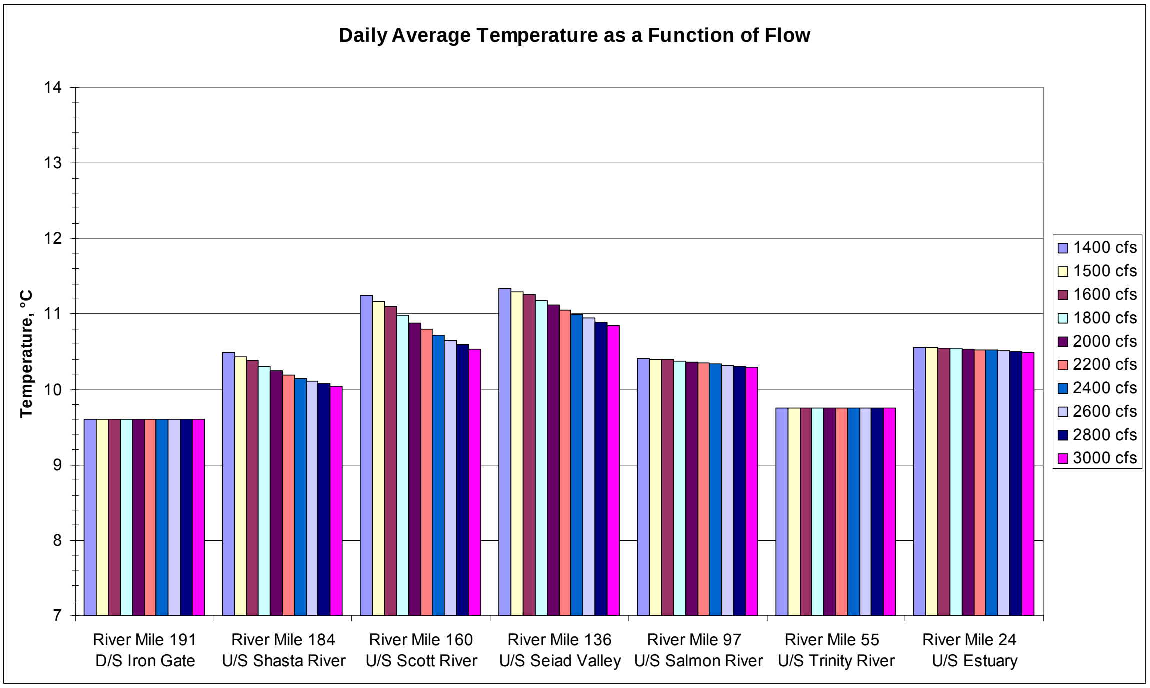


Figure 3-11. April 1 – April 15 for the 2004 Model Run.

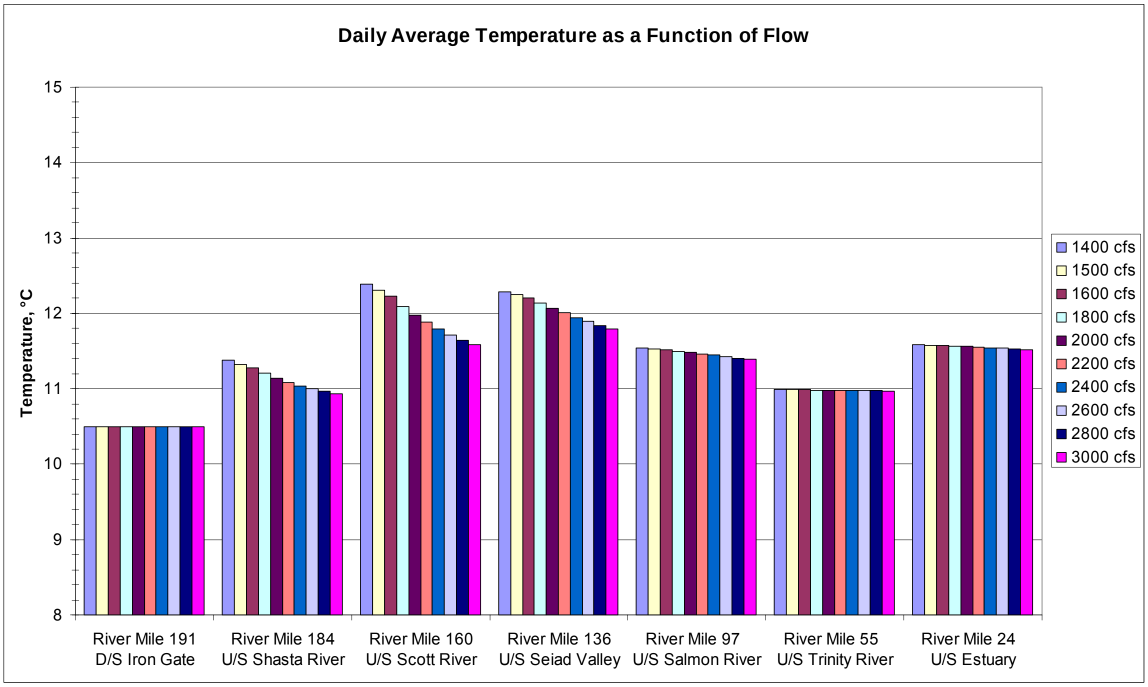


Figure 3-12. April 16 – April 30 for the 2004 Model Run.

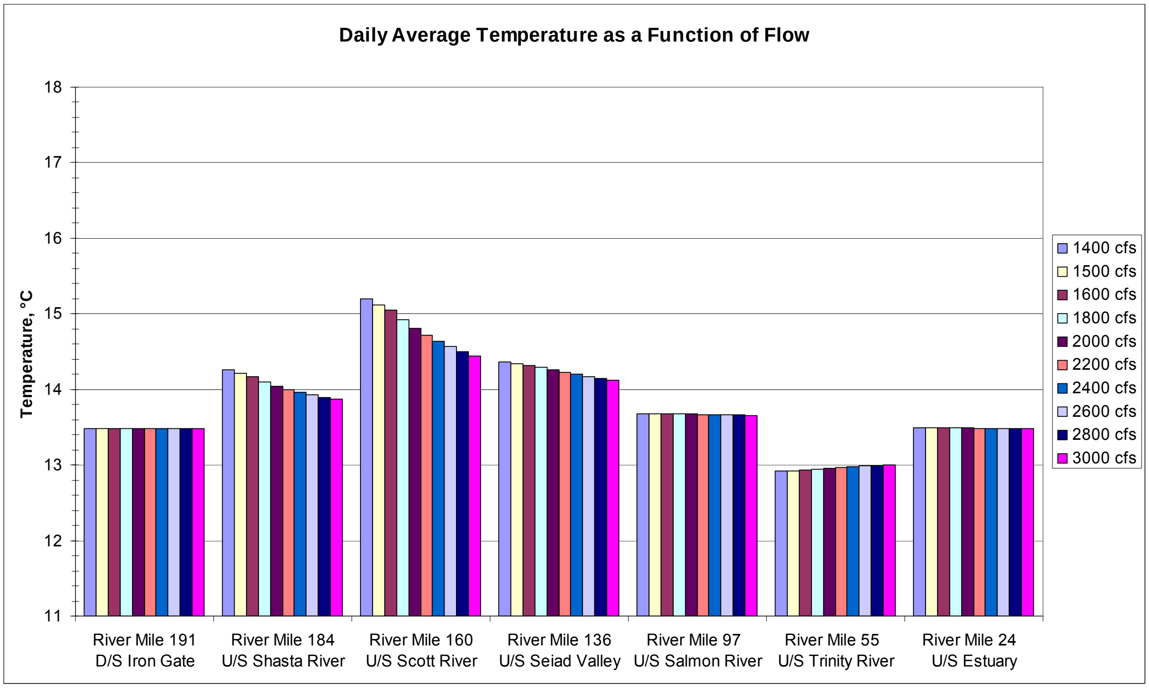


Figure 3-13. May 1 – May 15 for the 2004 Model Run.

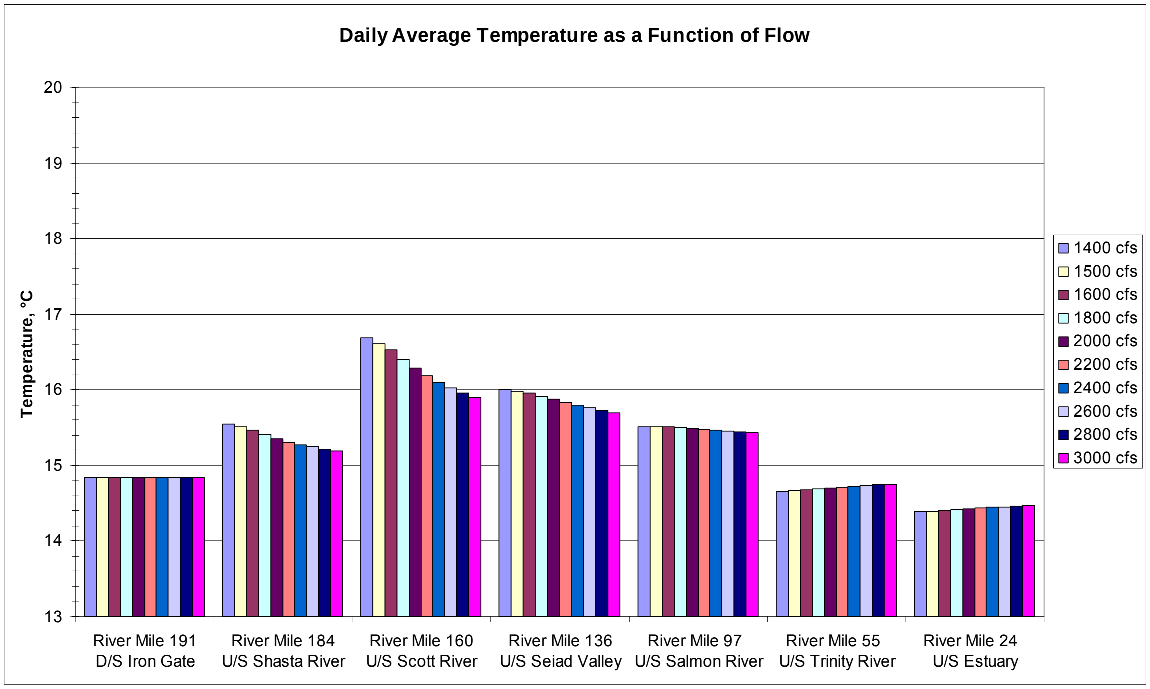


Figure 3-14. May 16 – May 31 for the 2004 Model Run.

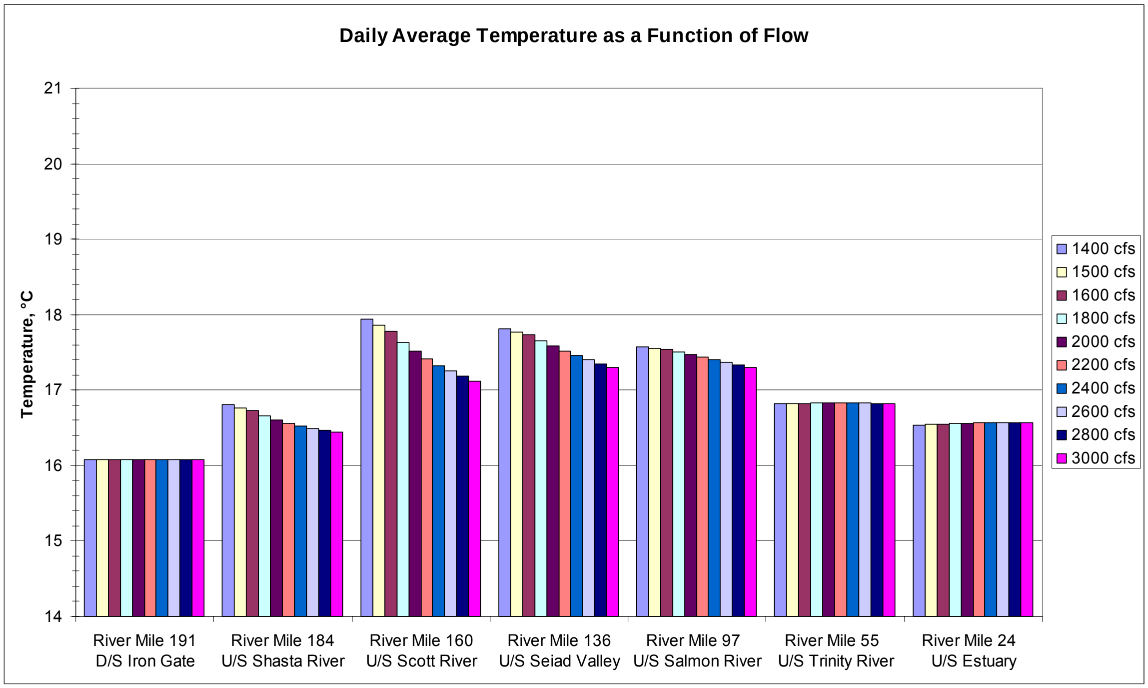


Figure 3-15. June 1 – June 15 for the 2004 Model Run.

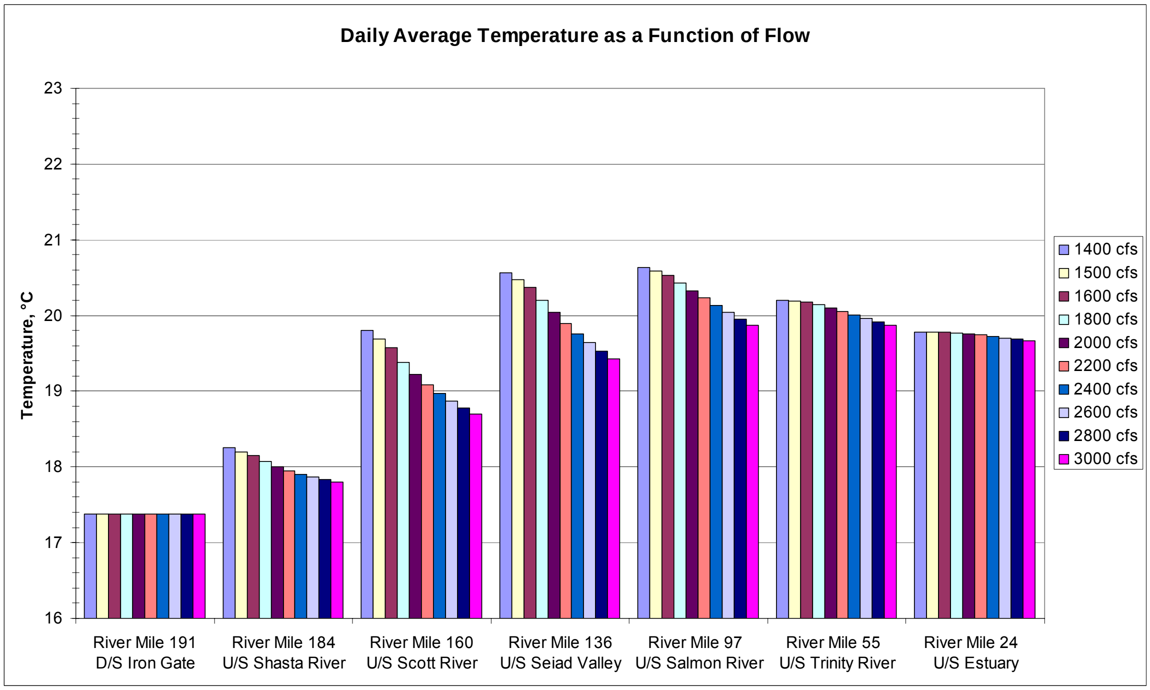


Figure 3-16. June 15 – June 30 for the 2004 Model Run.

Table 3-1. Daily Average Water Temperature Output Table for 2001 Meteorological and Tributary Conditions

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 191 - Immediately downstream of Iron Gate Dam												
Jan 1 - Jan 15	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69
Jan 16 - Jan 31	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63
Feb 1 - Feb 15	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
Feb 16 - Feb 28	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31
Mar 1 - Mar 15	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
Mar 16 - Mar 31	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82
Apr 1 - Apr 15	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14
Apr 16 - Apr 30	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63
May 1 - May 15	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07
May 16 - May 31	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36
Jun 1 - Jun 15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15
Jun 16 - Jun 30	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47
Jul 1 - Jul 15	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30
Jul 16 - Jul 31	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50
Aug 1 - Aug 15	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30
Aug 16 - Aug 31	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68
Sep 1 - Sep 15	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80
Sep 16 - Sep 30	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19
Oct 1 - Oct 15	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39
Oct 16 - Oct 31	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19
Nov 1 - Nov 15	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85
Nov 16 - Nov 30	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06
Dec 1 - Dec 15	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04
Dec 16 - Dec 31	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59

Table 3-1 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 184 - Mid-point between Iron Gate Dam and Shasta River												
Jan 1 - Jan 15	3.80	3.78	3.78	3.77	3.76	3.76	3.75	3.75	3.75	3.74	3.74	3.74
Jan 16 - Jan 31	2.85	2.82	2.80	2.78	2.77	2.76	2.75	2.74	2.73	2.73	2.72	2.71
Feb 1 - Feb 15	2.47	2.43	2.39	2.36	2.33	2.31	2.30	2.28	2.27	2.26	2.25	2.23
Feb 16 - Feb 28	3.30	3.17	3.08	3.00	2.94	2.89	2.84	2.80	2.77	2.74	2.72	2.68
Mar 1 - Mar 15	4.27	4.13	4.02	3.93	3.86	3.81	3.76	3.72	3.68	3.65	3.62	3.57
Mar 16 - Mar 31	7.54	7.33	7.16	7.02	6.91	6.82	6.74	6.67	6.61	6.56	6.52	6.44
Apr 1 - Apr 15	8.95	8.85	8.78	8.72	8.67	8.63	8.59	8.56	8.53	8.51	8.49	8.45
Apr 16 - Apr 30	10.48	10.25	10.07	9.93	9.81	9.71	9.63	9.56	9.50	9.44	9.39	9.31
May 1 - May 15	14.07	13.83	13.64	13.49	13.37	13.26	13.17	13.09	13.03	12.97	12.92	12.83
May 16 - May 31	18.31	18.07	17.89	17.74	17.61	17.51	17.42	17.34	17.28	17.22	17.17	17.08
Jun 1 - Jun 15	19.12	19.01	18.92	18.85	18.78	18.73	18.69	18.65	18.62	18.59	18.57	18.52
Jun 16 - Jun 30	19.78	19.62	19.50	19.40	19.32	19.25	19.19	19.14	19.10	19.06	19.03	18.97
Jul 1 - Jul 15	21.20	20.96	20.78	20.64	20.52	20.42	20.33	20.26	20.19	20.14	20.09	20.01
Jul 16 - Jul 31	21.77	21.62	21.50	21.40	21.32	21.25	21.20	21.15	21.11	21.07	21.04	20.98
Aug 1 - Aug 15	22.64	22.48	22.36	22.26	22.17	22.10	22.04	21.99	21.95	21.91	21.87	21.81
Aug 16 - Aug 31	22.58	22.48	22.39	22.33	22.27	22.22	22.18	22.15	22.12	22.09	22.07	22.03
Sep 1 - Sep 15	21.32	21.26	21.21	21.18	21.15	21.12	21.10	21.08	21.06	21.05	21.03	21.01
Sep 16 - Sep 30	19.58	19.54	19.50	19.47	19.45	19.43	19.41	19.40	19.39	19.38	19.37	19.35
Oct 1 - Oct 15	17.66	17.63	17.61	17.59	17.57	17.56	17.55	17.54	17.53	17.52	17.52	17.51
Oct 16 - Oct 31	14.23	14.23	14.23	14.23	14.23	14.23	14.23	14.23	14.23	14.23	14.23	14.23
Nov 1 - Nov 15	10.93	10.92	10.92	10.92	10.91	10.91	10.91	10.90	10.90	10.90	10.90	10.90
Nov 16 - Nov 30	7.78	7.82	7.85	7.87	7.89	7.91	7.92	7.93	7.94	7.95	7.96	7.97
Dec 1 - Dec 15	4.87	4.89	4.91	4.93	4.94	4.95	4.96	4.96	4.97	4.98	4.98	4.99
Dec 16 - Dec 31	3.01	2.96	2.92	2.89	2.87	2.85	2.83	2.81	2.80	2.79	2.78	2.76

Table 3-1 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 160 - Mid-point between Shasta River and Scott River												
Jan 1 - Jan 15	3.97	3.95	3.93	3.92	3.91	3.89	3.88	3.88	3.87	3.86	3.85	3.84
Jan 16 - Jan 31	3.35	3.30	3.25	3.21	3.17	3.14	3.11	3.08	3.06	3.04	3.02	2.99
Feb 1 - Feb 15	3.54	3.41	3.31	3.22	3.14	3.07	3.01	2.96	2.91	2.87	2.83	2.77
Feb 16 - Feb 28	5.24	5.01	4.81	4.63	4.48	4.35	4.23	4.12	4.03	3.94	3.87	3.73
Mar 1 - Mar 15	6.58	6.29	6.04	5.83	5.64	5.48	5.34	5.22	5.11	5.01	4.92	4.76
Mar 16 - Mar 31	10.72	10.31	9.97	9.67	9.40	9.18	8.98	8.80	8.64	8.49	8.36	8.14
Apr 1 - Apr 15	10.16	10.00	9.87	9.75	9.64	9.55	9.47	9.40	9.33	9.27	9.22	9.13
Apr 16 - Apr 30	13.22	12.86	12.54	12.27	12.03	11.81	11.62	11.46	11.31	11.17	11.05	10.83
May 1 - May 15	16.58	16.23	15.92	15.65	15.41	15.20	15.02	14.85	14.70	14.57	14.45	14.23
May 16 - May 31	20.64	20.31	20.01	19.76	19.53	19.33	19.15	19.00	18.85	18.73	18.61	18.41
Jun 1 - Jun 15	20.41	20.25	20.11	19.98	19.86	19.76	19.66	19.58	19.51	19.44	19.38	19.27
Jun 16 - Jun 30	21.80	21.54	21.31	21.11	20.93	20.78	20.64	20.52	20.41	20.31	20.22	20.07
Jul 1 - Jul 15	24.41	24.00	23.63	23.31	23.03	22.79	22.57	22.38	22.21	22.06	21.92	21.68
Jul 16 - Jul 31	24.06	23.76	23.50	23.27	23.08	22.90	22.75	22.62	22.50	22.39	22.30	22.13
Aug 1 - Aug 15	25.00	24.70	24.44	24.21	24.01	23.83	23.67	23.53	23.41	23.30	23.20	23.03
Aug 16 - Aug 31	24.19	23.98	23.80	23.65	23.51	23.39	23.29	23.19	23.11	23.04	22.97	22.85
Sep 1 - Sep 15	22.17	22.06	21.97	21.89	21.82	21.76	21.70	21.65	21.61	21.57	21.53	21.47
Sep 16 - Sep 30	20.13	20.06	19.99	19.94	19.89	19.85	19.81	19.78	19.75	19.72	19.70	19.66
Oct 1 - Oct 15	17.81	17.79	17.76	17.74	17.72	17.70	17.69	17.67	17.66	17.65	17.64	17.62
Oct 16 - Oct 31	13.86	13.91	13.95	13.98	14.01	14.03	14.05	14.07	14.08	14.10	14.11	14.13
Nov 1 - Nov 15	10.68	10.72	10.74	10.76	10.78	10.79	10.80	10.81	10.82	10.83	10.83	10.84
Nov 16 - Nov 30	7.26	7.33	7.40	7.45	7.50	7.54	7.58	7.61	7.64	7.66	7.68	7.72
Dec 1 - Dec 15	4.69	4.73	4.76	4.79	4.81	4.83	4.85	4.86	4.88	4.89	4.90	4.92
Dec 16 - Dec 31	3.71	3.63	3.57	3.51	3.46	3.41	3.37	3.33	3.30	3.27	3.24	3.19

Table 3-1 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 136 - Mid-point between Scott River and Seiad Valley												
Jan 1 - Jan 15	4.21	4.18	4.15	4.13	4.11	4.09	4.07	4.06	4.04	4.03	4.02	3.99
Jan 16 - Jan 31	3.74	3.68	3.62	3.57	3.52	3.48	3.44	3.40	3.37	3.34	3.31	3.26
Feb 1 - Feb 15	4.32	4.18	4.05	3.94	3.84	3.74	3.66	3.59	3.52	3.46	3.40	3.30
Feb 16 - Feb 28	6.32	6.10	5.90	5.71	5.54	5.39	5.25	5.12	5.00	4.89	4.79	4.61
Mar 1 - Mar 15	7.97	7.69	7.44	7.22	7.01	6.82	6.65	6.49	6.35	6.22	6.10	5.88
Mar 16 - Mar 31	12.49	12.19	11.91	11.65	11.41	11.19	10.98	10.79	10.61	10.44	10.28	10.00
Apr 1 - Apr 15	11.04	10.90	10.77	10.65	10.55	10.45	10.36	10.27	10.19	10.12	10.05	9.93
Apr 16 - Apr 30	14.69	14.41	14.15	13.91	13.68	13.47	13.27	13.09	12.91	12.75	12.60	12.33
May 1 - May 15	17.89	17.67	17.46	17.24	17.04	16.85	16.68	16.51	16.35	16.20	16.06	15.80
May 16 - May31	20.76	20.62	20.47	20.33	20.19	20.06	19.93	19.81	19.69	19.59	19.48	19.29
Jun 1 - Jun 15	20.98	20.87	20.76	20.65	20.55	20.46	20.37	20.28	20.20	20.13	20.06	19.93
Jun 16 - Jun 30	22.85	22.64	22.43	22.24	22.06	21.89	21.74	21.60	21.47	21.35	21.24	21.04
Jul 1 - Jul 15	26.13	25.77	25.43	25.12	24.83	24.56	24.32	24.09	23.88	23.69	23.51	23.19
Jul 16 - Jul 31	25.35	25.08	24.82	24.59	24.37	24.17	24.00	23.83	23.68	23.55	23.42	23.20
Aug 1 - Aug 15	26.06	25.82	25.58	25.37	25.16	24.98	24.81	24.66	24.52	24.39	24.26	24.04
Aug 16 - Aug 31	24.80	24.66	24.52	24.38	24.25	24.14	24.03	23.93	23.84	23.76	23.68	23.53
Sep 1 - Sep 15	22.90	22.77	22.66	22.56	22.47	22.39	22.31	22.25	22.19	22.13	22.08	21.99
Sep 16 - Sep 30	20.86	20.76	20.66	20.58	20.50	20.43	20.37	20.32	20.27	20.23	20.19	20.11
Oct 1 - Oct 15	18.40	18.34	18.28	18.23	18.18	18.15	18.11	18.08	18.05	18.02	18.00	17.96
Oct 16 - Oct 31	14.05	14.07	14.10	14.12	14.14	14.16	14.17	14.18	14.19	14.20	14.21	14.23
Nov 1 - Nov 15	10.88	10.89	10.91	10.92	10.93	10.93	10.94	10.95	10.95	10.95	10.96	10.96
Nov 16 - Nov 30	7.28	7.33	7.38	7.42	7.46	7.49	7.52	7.55	7.58	7.60	7.63	7.67
Dec 1 - Dec 15	4.97	4.98	4.99	5.00	5.01	5.02	5.02	5.03	5.04	5.05	5.05	5.06
Dec 16 - Dec 31	4.57	4.50	4.42	4.36	4.30	4.24	4.18	4.13	4.08	4.04	4.00	3.92

Table 3-1 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 97 - Mid-point between Seiad Valley and Salmon River												
Jan 1 - Jan 15	4.45	4.42	4.39	4.37	4.34	4.32	4.30	4.28	4.26	4.25	4.23	4.20
Jan 16 - Jan 31	4.20	4.13	4.08	4.02	3.97	3.92	3.88	3.84	3.80	3.76	3.73	3.66
Feb 1 - Feb 15	4.97	4.85	4.74	4.64	4.54	4.45	4.36	4.28	4.21	4.14	4.07	3.95
Feb 16 - Feb 28	6.88	6.73	6.57	6.43	6.29	6.16	6.03	5.91	5.80	5.69	5.59	5.41
Mar 1 - Mar 15	8.27	8.11	7.95	7.79	7.64	7.50	7.37	7.24	7.12	7.00	6.89	6.69
Mar 16 - Mar 31	12.17	12.00	11.83	11.66	11.50	11.34	11.19	11.04	10.91	10.78	10.65	10.42
Apr 1 - Apr 15	10.68	10.63	10.57	10.52	10.47	10.42	10.37	10.32	10.27	10.22	10.18	10.08
Apr 16 - Apr 30	13.67	13.58	13.48	13.38	13.27	13.17	13.06	12.96	12.86	12.76	12.67	12.49
May 1 - May 15	15.25	15.28	15.29	15.28	15.27	15.25	15.23	15.20	15.17	15.13	15.10	15.02
May 16 - May 31	17.90	17.97	18.03	18.07	18.10	18.12	18.14	18.15	18.15	18.15	18.15	18.13
Jun 1 - Jun 15	19.50	19.58	19.64	19.68	19.71	19.72	19.73	19.73	19.73	19.72	19.71	19.68
Jun 16 - Jun 30	23.28	23.20	23.11	23.00	22.88	22.76	22.65	22.54	22.43	22.32	22.22	22.02
Jul 1 - Jul 15	26.76	26.66	26.51	26.34	26.16	25.97	25.79	25.61	25.43	25.26	25.09	24.77
Jul 16 - Jul 31	25.70	25.64	25.55	25.44	25.31	25.18	25.05	24.92	24.79	24.67	24.55	24.33
Aug 1 - Aug 15	26.28	26.23	26.15	26.04	25.93	25.80	25.68	25.56	25.44	25.33	25.22	25.01
Aug 16 - Aug 31	24.52	24.55	24.55	24.52	24.47	24.42	24.37	24.31	24.25	24.19	24.14	24.03
Sep 1 - Sep 15	23.14	23.12	23.09	23.04	22.98	22.92	22.86	22.80	22.75	22.69	22.64	22.54
Sep 16 - Sep 30	21.30	21.26	21.21	21.15	21.08	21.02	20.97	20.91	20.86	20.81	20.76	20.67
Oct 1 - Oct 15	18.73	18.70	18.67	18.63	18.59	18.55	18.52	18.48	18.45	18.42	18.39	18.34
Oct 16 - Oct 31	13.39	13.47	13.54	13.60	13.65	13.70	13.74	13.78	13.81	13.85	13.88	13.93
Nov 1 - Nov 15	9.57	9.67	9.75	9.82	9.89	9.95	10.00	10.05	10.10	10.14	10.18	10.25
Nov 16 - Nov 30	6.60	6.65	6.70	6.74	6.78	6.82	6.86	6.90	6.93	6.96	6.99	7.05
Dec 1 - Dec 15	4.84	4.85	4.86	4.87	4.88	4.89	4.90	4.90	4.91	4.92	4.93	4.94
Dec 16 - Dec 31	4.90	4.88	4.85	4.83	4.80	4.78	4.75	4.73	4.70	4.68	4.65	4.60

Table 3-1 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 55 - Mid-point between Salmon River and Trinity River												
Jan 1 - Jan 15	4.74	4.72	4.69	4.67	4.65	4.62	4.60	4.58	4.56	4.55	4.53	4.49
Jan 16 - Jan 31	4.55	4.50	4.45	4.41	4.37	4.32	4.28	4.25	4.21	4.17	4.14	4.07
Feb 1 - Feb 15	5.41	5.33	5.25	5.17	5.10	5.02	4.95	4.89	4.82	4.76	4.70	4.58
Feb 16 - Feb 28	7.14	7.04	6.94	6.84	6.74	6.65	6.56	6.46	6.38	6.29	6.21	6.05
Mar 1 - Mar 15	8.40	8.31	8.21	8.11	8.02	7.93	7.83	7.74	7.66	7.57	7.49	7.33
Mar 16 - Mar 31	11.84	11.75	11.66	11.56	11.47	11.37	11.28	11.19	11.11	11.02	10.94	10.78
Apr 1 - Apr 15	10.64	10.62	10.60	10.57	10.54	10.52	10.49	10.46	10.43	10.40	10.37	10.30
Apr 16 - Apr 30	13.36	13.33	13.29	13.24	13.19	13.14	13.09	13.03	12.98	12.92	12.87	12.76
May 1 - May 15	14.86	14.87	14.88	14.89	14.89	14.89	14.89	14.88	14.88	14.87	14.86	14.83
May 16 - May 31	17.45	17.48	17.50	17.52	17.54	17.56	17.57	17.59	17.60	17.60	17.61	17.62
Jun 1 - Jun 15	18.80	18.86	18.91	18.96	19.00	19.03	19.06	19.09	19.11	19.13	19.15	19.18
Jun 16 - Jun 30	22.16	22.21	22.25	22.26	22.26	22.25	22.24	22.21	22.18	22.14	22.11	22.02
Jul 1 - Jul 15	25.80	25.85	25.88	25.88	25.85	25.81	25.76	25.69	25.62	25.54	25.45	25.28
Jul 16 - Jul 31	25.02	25.09	25.12	25.14	25.14	25.11	25.08	25.04	24.98	24.93	24.87	24.74
Aug 1 - Aug 15	25.56	25.64	25.69	25.71	25.71	25.69	25.66	25.62	25.57	25.51	25.46	25.34
Aug 16 - Aug 31	23.80	23.89	23.97	24.02	24.05	24.07	24.08	24.08	24.07	24.06	24.05	24.01
Sep 1 - Sep 15	22.59	22.67	22.72	22.75	22.77	22.77	22.77	22.76	22.75	22.73	22.71	22.66
Sep 16 - Sep 30	20.81	20.88	20.92	20.94	20.95	20.95	20.94	20.92	20.90	20.88	20.86	20.81
Oct 1 - Oct 15	18.05	18.12	18.17	18.21	18.23	18.25	18.26	18.27	18.27	18.27	18.27	18.26
Oct 16 - Oct 31	13.29	13.34	13.39	13.44	13.48	13.52	13.56	13.60	13.63	13.66	13.69	13.75
Nov 1 - Nov 15	10.04	10.04	10.05	10.06	10.08	10.10	10.11	10.13	10.15	10.17	10.19	10.23
Nov 16 - Nov 30	7.23	7.24	7.24	7.25	7.26	7.27	7.28	7.30	7.31	7.32	7.33	7.35
Dec 1 - Dec 15	5.45	5.45	5.45	5.45	5.45	5.45	5.44	5.44	5.44	5.44	5.44	5.44
Dec 16 - Dec 31	5.52	5.50	5.48	5.46	5.45	5.43	5.41	5.40	5.38	5.36	5.34	5.31

Table 3-1 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 24 - Mid-point between Trinity River and Pacific Ocean												
Jan 1 - Jan 15	5.39	5.36	5.34	5.32	5.30	5.27	5.25	5.23	5.21	5.19	5.17	5.13
Jan 16 - Jan 31	5.19	5.16	5.12	5.09	5.06	5.02	4.99	4.96	4.93	4.90	4.87	4.81
Feb 1 - Feb 15	5.91	5.87	5.82	5.78	5.73	5.69	5.64	5.60	5.55	5.51	5.47	5.39
Feb 16 - Feb 28	7.26	7.22	7.18	7.13	7.09	7.04	7.00	6.96	6.91	6.87	6.83	6.75
Mar 1 - Mar 15	8.23	8.20	8.16	8.13	8.09	8.05	8.02	7.98	7.94	7.91	7.87	7.80
Mar 16 - Mar 31	11.39	11.35	11.31	11.27	11.23	11.19	11.15	11.11	11.07	11.03	10.99	10.91
Apr 1 - Apr 15	10.45	10.44	10.43	10.42	10.40	10.39	10.37	10.36	10.35	10.33	10.32	10.29
Apr 16 - Apr 30	12.93	12.92	12.91	12.89	12.87	12.85	12.83	12.81	12.79	12.76	12.74	12.68
May 1 - May 15	14.46	14.47	14.48	14.48	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.48
May 16 - May 31	16.83	16.85	16.86	16.87	16.88	16.89	16.90	16.91	16.91	16.92	16.93	16.94
Jun 1 - Jun 15	18.01	18.03	18.06	18.08	18.11	18.13	18.16	18.18	18.20	18.22	18.24	18.27
Jun 16 - Jun 30	20.91	20.95	20.99	21.02	21.05	21.07	21.08	21.10	21.11	21.11	21.11	21.11
Jul 1 - Jul 15	24.65	24.69	24.72	24.75	24.76	24.77	24.77	24.77	24.76	24.74	24.72	24.66
Jul 16 - Jul 31	24.12	24.17	24.20	24.23	24.26	24.27	24.28	24.29	24.28	24.28	24.27	24.24
Aug 1 - Aug 15	24.69	24.74	24.78	24.81	24.83	24.85	24.86	24.87	24.87	24.86	24.85	24.82
Aug 16 - Aug 31	22.78	22.84	22.89	22.94	22.98	23.02	23.05	23.08	23.10	23.13	23.14	23.17
Sep 1 - Sep 15	21.68	21.74	21.79	21.83	21.86	21.90	21.92	21.95	21.96	21.98	21.99	22.01
Sep 16 - Sep 30	19.90	19.96	20.01	20.05	20.09	20.12	20.15	20.17	20.18	20.20	20.21	20.22
Oct 1 - Oct 15	17.22	17.27	17.32	17.36	17.40	17.43	17.46	17.49	17.51	17.54	17.56	17.59
Oct 16 - Oct 31	13.34	13.36	13.38	13.40	13.42	13.45	13.47	13.49	13.51	13.53	13.55	13.59
Nov 1 - Nov 15	10.90	10.88	10.87	10.85	10.84	10.83	10.82	10.81	10.81	10.81	10.81	10.80
Nov 16 - Nov 30	8.25	8.24	8.23	8.23	8.23	8.22	8.22	8.22	8.21	8.21	8.21	8.20
Dec 1 - Dec 15	6.60	6.60	6.59	6.58	6.58	6.57	6.57	6.56	6.56	6.55	6.54	6.53
Dec 16 - Dec 31	6.83	6.82	6.81	6.80	6.78	6.77	6.76	6.75	6.74	6.72	6.71	6.69

Table 3-1 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 191 - Immediately downstream of Iron Gate Dam											
Jan 1 - Jan 15	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69
Jan 16 - Jan 31	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63
Feb 1 - Feb 15	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
Feb 16 - Feb 28	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31
Mar 1 - Mar 15	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
Mar 16 - Mar 31	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82
Apr 1 - Apr 15	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14
Apr 16 - Apr 30	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63
May 1 - May 15	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07
May 16 - May 31	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36
Jun 1 - Jun 15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15
Jun 16 - Jun 30	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47
Jul 1 - Jul 15	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30
Jul 16 - Jul 31	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50
Aug 1 - Aug 15	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30
Aug 16 - Aug 31	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68
Sep 1 - Sep 15	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80
Sep 16 - Sep 30	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19
Oct 1 - Oct 15	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39
Oct 16 - Oct 31	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19
Nov 1 - Nov 15	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85
Nov 16 - Nov 30	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06
Dec 1 - Dec 15	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04
Dec 16 - Dec 31	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59

Table 3-1 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 184 - Mid-point between Iron Gate Dam and Shasta River											
Jan 1 - Jan 15	3.73	3.73	3.73	3.73	3.72	3.72	3.72	3.72	3.72	3.72	3.72
Jan 16 - Jan 31	2.71	2.70	2.69	2.69	2.69	2.68	2.68	2.68	2.67	2.67	2.67
Feb 1 - Feb 15	2.22	2.21	2.20	2.19	2.18	2.18	2.17	2.17	2.16	2.16	2.16
Feb 16 - Feb 28	2.64	2.61	2.59	2.57	2.55	2.54	2.52	2.51	2.50	2.49	2.48
Mar 1 - Mar 15	3.54	3.51	3.48	3.46	3.44	3.42	3.41	3.40	3.38	3.37	3.36
Mar 16 - Mar 31	6.38	6.33	6.29	6.25	6.22	6.20	6.17	6.15	6.13	6.12	6.10
Apr 1 - Apr 15	8.43	8.40	8.38	8.37	8.35	8.34	8.33	8.32	8.31	8.30	8.29
Apr 16 - Apr 30	9.25	9.19	9.15	9.11	9.07	9.04	9.02	8.99	8.97	8.96	8.94
May 1 - May 15	12.76	12.70	12.65	12.60	12.57	12.54	12.51	12.48	12.46	12.44	12.42
May 16 - May 31	17.02	16.96	16.91	16.87	16.83	16.80	16.78	16.75	16.73	16.71	16.69
Jun 1 - Jun 15	18.49	18.46	18.43	18.41	18.40	18.38	18.37	18.35	18.34	18.33	18.32
Jun 16 - Jun 30	18.92	18.88	18.85	18.82	18.80	18.78	18.76	18.74	18.73	18.72	18.70
Jul 1 - Jul 15	19.94	19.88	19.84	19.80	19.76	19.73	19.71	19.68	19.66	19.64	19.63
Jul 16 - Jul 31	20.94	20.90	20.87	20.84	20.82	20.80	20.78	20.76	20.75	20.74	20.73
Aug 1 - Aug 15	21.76	21.72	21.69	21.66	21.64	21.62	21.60	21.58	21.57	21.55	21.54
Aug 16 - Aug 31	22.00	21.97	21.95	21.93	21.91	21.90	21.89	21.87	21.86	21.86	21.85
Sep 1 - Sep 15	20.99	20.98	20.96	20.95	20.94	20.94	20.93	20.92	20.92	20.91	20.91
Sep 16 - Sep 30	19.34	19.32	19.31	19.31	19.30	19.29	19.29	19.28	19.28	19.27	19.27
Oct 1 - Oct 15	17.50	17.49	17.48	17.48	17.47	17.47	17.46	17.46	17.46	17.45	17.45
Oct 16 - Oct 31	14.23	14.23	14.23	14.22	14.22	14.22	14.22	14.22	14.22	14.22	14.22
Nov 1 - Nov 15	10.89	10.89	10.89	10.89	10.89	10.88	10.88	10.88	10.88	10.88	10.88
Nov 16 - Nov 30	7.98	7.99	8.00	8.01	8.01	8.02	8.02	8.02	8.03	8.03	8.03
Dec 1 - Dec 15	4.99	5.00	5.00	5.01	5.01	5.01	5.02	5.02	5.02	5.02	5.02
Dec 16 - Dec 31	2.74	2.73	2.72	2.71	2.70	2.70	2.69	2.69	2.68	2.68	2.67

Table 3-1 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 160 - Mid-point between Shasta River and Scott River											
Jan 1 - Jan 15	3.83	3.83	3.82	3.81	3.81	3.80	3.80	3.80	3.79	3.79	3.79
Jan 16 - Jan 31	2.96	2.94	2.92	2.90	2.89	2.87	2.86	2.85	2.84	2.83	2.82
Feb 1 - Feb 15	2.71	2.67	2.63	2.59	2.56	2.53	2.51	2.49	2.47	2.45	2.44
Feb 16 - Feb 28	3.62	3.52	3.44	3.37	3.30	3.25	3.20	3.15	3.11	3.08	3.04
Mar 1 - Mar 15	4.63	4.52	4.42	4.34	4.27	4.21	4.15	4.10	4.05	4.01	3.97
Mar 16 - Mar 31	7.95	7.78	7.65	7.52	7.42	7.32	7.24	7.17	7.10	7.04	6.98
Apr 1 - Apr 15	9.05	8.99	8.93	8.89	8.84	8.81	8.77	8.74	8.72	8.69	8.67
Apr 16 - Apr 30	10.65	10.50	10.36	10.25	10.14	10.05	9.97	9.90	9.84	9.78	9.72
May 1 - May 15	14.06	13.91	13.77	13.66	13.56	13.47	13.40	13.33	13.26	13.21	13.15
May 16 - May 31	18.24	18.10	17.97	17.87	17.77	17.69	17.61	17.55	17.49	17.43	17.38
Jun 1 - Jun 15	19.18	19.10	19.04	18.98	18.93	18.89	18.85	18.81	18.78	18.75	18.72
Jun 16 - Jun 30	19.94	19.83	19.73	19.65	19.58	19.52	19.46	19.41	19.36	19.32	19.29
Jul 1 - Jul 15	21.48	21.31	21.17	21.05	20.94	20.84	20.75	20.68	20.61	20.55	20.49
Jul 16 - Jul 31	22.00	21.88	21.78	21.70	21.62	21.56	21.50	21.45	21.40	21.36	21.32
Aug 1 - Aug 15	22.88	22.76	22.66	22.57	22.49	22.42	22.36	22.30	22.25	22.21	22.17
Aug 16 - Aug 31	22.76	22.68	22.61	22.55	22.50	22.45	22.41	22.37	22.34	22.31	22.28
Sep 1 - Sep 15	21.42	21.38	21.34	21.31	21.28	21.25	21.23	21.21	21.19	21.17	21.16
Sep 16 - Sep 30	19.62	19.59	19.57	19.55	19.53	19.51	19.49	19.48	19.47	19.46	19.45
Oct 1 - Oct 15	17.61	17.59	17.58	17.57	17.56	17.56	17.55	17.54	17.54	17.53	17.53
Oct 16 - Oct 31	14.14	14.15	14.16	14.17	14.18	14.19	14.19	14.20	14.20	14.20	14.21
Nov 1 - Nov 15	10.85	10.86	10.86	10.86	10.87	10.87	10.87	10.88	10.88	10.88	10.88
Nov 16 - Nov 30	7.76	7.79	7.81	7.83	7.85	7.86	7.88	7.89	7.90	7.91	7.92
Dec 1 - Dec 15	4.93	4.95	4.96	4.97	4.98	4.98	4.99	5.00	5.00	5.00	5.01
Dec 16 - Dec 31	3.15	3.12	3.08	3.06	3.03	3.01	2.99	2.97	2.96	2.94	2.93

Table 3-1 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 136 - Mid-point between Scott River and Seiad Valley											
Jan 1 - Jan 15	3.97	3.96	3.94	3.93	3.92	3.91	3.90	3.89	3.88	3.88	3.87
Jan 16 - Jan 31	3.22	3.18	3.15	3.12	3.10	3.08	3.06	3.04	3.02	3.00	2.99
Feb 1 - Feb 15	3.21	3.14	3.07	3.02	2.97	2.92	2.88	2.84	2.81	2.78	2.75
Feb 16 - Feb 28	4.45	4.31	4.19	4.08	3.99	3.90	3.82	3.75	3.69	3.63	3.58
Mar 1 - Mar 15	5.69	5.53	5.38	5.26	5.14	5.04	4.95	4.86	4.79	4.72	4.65
Mar 16 - Mar 31	9.74	9.52	9.32	9.14	8.98	8.83	8.69	8.57	8.46	8.35	8.25
Apr 1 - Apr 15	9.82	9.72	9.63	9.56	9.49	9.42	9.36	9.31	9.26	9.22	9.18
Apr 16 - Apr 30	12.10	11.88	11.70	11.53	11.38	11.24	11.11	11.00	10.90	10.80	10.71
May 1 - May 15	15.57	15.37	15.19	15.02	14.87	14.74	14.61	14.50	14.40	14.30	14.21
May 16 - May 31	19.12	18.96	18.82	18.69	18.58	18.47	18.37	18.28	18.20	18.13	18.06
Jun 1 - Jun 15	19.82	19.71	19.62	19.54	19.47	19.40	19.34	19.29	19.24	19.19	19.15
Jun 16 - Jun 30	20.87	20.72	20.58	20.46	20.35	20.25	20.17	20.09	20.01	19.95	19.89
Jul 1 - Jul 15	22.92	22.67	22.46	22.27	22.10	21.95	21.81	21.69	21.58	21.48	21.38
Jul 16 - Jul 31	23.01	22.84	22.69	22.56	22.44	22.34	22.25	22.16	22.08	22.01	21.95
Aug 1 - Aug 15	23.85	23.69	23.54	23.41	23.29	23.18	23.09	23.00	22.92	22.85	22.78
Aug 16 - Aug 31	23.41	23.30	23.20	23.12	23.04	22.97	22.91	22.85	22.80	22.75	22.71
Sep 1 - Sep 15	21.91	21.84	21.78	21.73	21.68	21.64	21.60	21.56	21.53	21.50	21.47
Sep 16 - Sep 30	20.05	20.00	19.95	19.91	19.87	19.84	19.81	19.78	19.76	19.74	19.72
Oct 1 - Oct 15	17.92	17.89	17.87	17.84	17.82	17.80	17.79	17.77	17.76	17.74	17.73
Oct 16 - Oct 31	14.24	14.25	14.26	14.27	14.27	14.28	14.28	14.28	14.29	14.29	14.29
Nov 1 - Nov 15	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97
Nov 16 - Nov 30	7.70	7.73	7.76	7.78	7.81	7.82	7.84	7.86	7.87	7.88	7.90
Dec 1 - Dec 15	5.07	5.08	5.08	5.09	5.09	5.10	5.10	5.10	5.11	5.11	5.11
Dec 16 - Dec 31	3.85	3.79	3.73	3.68	3.63	3.59	3.55	3.52	3.48	3.45	3.42

Table 3-1 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 97 - Mid-point between Seiad Valley and Salmon River											
Jan 1 - Jan 15	4.17	4.15	4.13	4.11	4.09	4.07	4.06	4.05	4.04	4.02	4.01
Jan 16 - Jan 31	3.60	3.55	3.51	3.47	3.43	3.40	3.37	3.34	3.31	3.29	3.26
Feb 1 - Feb 15	3.85	3.75	3.67	3.59	3.52	3.46	3.40	3.35	3.30	3.25	3.21
Feb 16 - Feb 28	5.24	5.09	4.96	4.83	4.72	4.62	4.52	4.43	4.35	4.28	4.21
Mar 1 - Mar 15	6.50	6.34	6.18	6.05	5.92	5.80	5.69	5.59	5.50	5.42	5.34
Mar 16 - Mar 31	10.20	10.01	9.83	9.66	9.51	9.37	9.24	9.11	9.00	8.89	8.79
Apr 1 - Apr 15	10.00	9.92	9.85	9.78	9.72	9.66	9.61	9.56	9.52	9.47	9.43
Apr 16 - Apr 30	12.32	12.16	12.01	11.88	11.75	11.63	11.52	11.41	11.32	11.23	11.14
May 1 - May 15	14.94	14.86	14.78	14.70	14.63	14.55	14.48	14.41	14.34	14.28	14.21
May 16 - May 31	18.10	18.06	18.02	17.98	17.94	17.90	17.86	17.82	17.79	17.75	17.72
Jun 1 - Jun 15	19.64	19.60	19.56	19.52	19.47	19.43	19.39	19.35	19.32	19.28	19.25
Jun 16 - Jun 30	21.84	21.67	21.52	21.38	21.25	21.12	21.01	20.91	20.82	20.73	20.65
Jul 1 - Jul 15	24.48	24.21	23.96	23.73	23.52	23.32	23.15	22.98	22.83	22.70	22.57
Jul 16 - Jul 31	24.12	23.93	23.76	23.60	23.45	23.31	23.19	23.08	22.97	22.87	22.78
Aug 1 - Aug 15	24.81	24.63	24.46	24.31	24.17	24.04	23.92	23.81	23.70	23.61	23.52
Aug 16 - Aug 31	23.92	23.82	23.73	23.64	23.55	23.48	23.40	23.34	23.28	23.22	23.17
Sep 1 - Sep 15	22.45	22.37	22.30	22.23	22.16	22.11	22.05	22.00	21.96	21.92	21.88
Sep 16 - Sep 30	20.59	20.52	20.46	20.40	20.34	20.29	20.25	20.20	20.17	20.13	20.10
Oct 1 - Oct 15	18.29	18.25	18.21	18.18	18.14	18.11	18.09	18.06	18.04	18.02	18.00
Oct 16 - Oct 31	13.97	14.01	14.04	14.07	14.09	14.11	14.13	14.15	14.16	14.17	14.19
Nov 1 - Nov 15	10.31	10.36	10.41	10.45	10.48	10.51	10.54	10.56	10.58	10.61	10.62
Nov 16 - Nov 30	7.11	7.15	7.20	7.24	7.28	7.31	7.35	7.38	7.40	7.43	7.45
Dec 1 - Dec 15	4.95	4.96	4.98	4.99	4.99	5.00	5.01	5.02	5.02	5.03	5.04
Dec 16 - Dec 31	4.56	4.51	4.47	4.43	4.39	4.35	4.32	4.28	4.25	4.22	4.18

Table 3-1 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 55 - Mid-point between Salmon River and Trinity River											
Jan 1 - Jan 15	4.46	4.43	4.41	4.38	4.36	4.34	4.32	4.30	4.28	4.27	4.25
Jan 16 - Jan 31	4.02	3.96	3.91	3.86	3.82	3.78	3.74	3.71	3.68	3.65	3.62
Feb 1 - Feb 15	4.48	4.38	4.29	4.21	4.13	4.06	3.99	3.93	3.87	3.82	3.77
Feb 16 - Feb 28	5.91	5.77	5.65	5.53	5.42	5.32	5.22	5.13	5.05	4.97	4.89
Mar 1 - Mar 15	7.18	7.04	6.91	6.78	6.67	6.56	6.45	6.35	6.26	6.17	6.09
Mar 16 - Mar 31	10.64	10.49	10.36	10.23	10.11	10.00	9.89	9.78	9.68	9.59	9.50
Apr 1 - Apr 15	10.24	10.19	10.13	10.08	10.03	9.99	9.94	9.90	9.86	9.82	9.78
Apr 16 - Apr 30	12.65	12.55	12.45	12.35	12.26	12.17	12.08	11.99	11.91	11.84	11.76
May 1 - May 15	14.80	14.77	14.73	14.69	14.65	14.61	14.57	14.53	14.49	14.45	14.41
May 16 - May 31	17.62	17.61	17.61	17.60	17.59	17.58	17.56	17.55	17.54	17.52	17.51
Jun 1 - Jun 15	19.19	19.20	19.20	19.20	19.20	19.19	19.18	19.17	19.16	19.14	19.13
Jun 16 - Jun 30	21.93	21.83	21.74	21.64	21.55	21.46	21.37	21.29	21.21	21.14	21.07
Jul 1 - Jul 15	25.10	24.91	24.72	24.54	24.37	24.20	24.04	23.89	23.75	23.62	23.49
Jul 16 - Jul 31	24.61	24.48	24.35	24.21	24.09	23.96	23.85	23.74	23.64	23.54	23.45
Aug 1 - Aug 15	25.21	25.08	24.95	24.83	24.71	24.59	24.48	24.38	24.28	24.19	24.10
Aug 16 - Aug 31	23.96	23.91	23.86	23.80	23.74	23.68	23.62	23.57	23.52	23.47	23.42
Sep 1 - Sep 15	22.62	22.56	22.51	22.46	22.40	22.35	22.31	22.26	22.22	22.18	22.14
Sep 16 - Sep 30	20.76	20.71	20.66	20.61	20.57	20.53	20.48	20.45	20.41	20.38	20.34
Oct 1 - Oct 15	18.25	18.24	18.22	18.20	18.18	18.17	18.15	18.13	18.12	18.10	18.09
Oct 16 - Oct 31	13.80	13.84	13.88	13.92	13.95	13.98	14.00	14.03	14.05	14.06	14.08
Nov 1 - Nov 15	10.27	10.30	10.34	10.37	10.40	10.43	10.45	10.48	10.50	10.52	10.54
Nov 16 - Nov 30	7.38	7.40	7.42	7.44	7.46	7.48	7.50	7.51	7.53	7.55	7.56
Dec 1 - Dec 15	5.44	5.43	5.43	5.43	5.43	5.43	5.43	5.42	5.42	5.42	5.42
Dec 16 - Dec 31	5.28	5.24	5.21	5.18	5.14	5.11	5.08	5.05	5.02	4.99	4.96

Table 3-1 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 24 - Mid-point between Trinity River and Pacific Ocean											
Jan 1 - Jan 15	5.10	5.06	5.03	5.00	4.97	4.94	4.91	4.89	4.86	4.84	4.82
Jan 16 - Jan 31	4.76	4.70	4.65	4.60	4.56	4.51	4.47	4.43	4.39	4.35	4.32
Feb 1 - Feb 15	5.31	5.23	5.16	5.09	5.02	4.96	4.90	4.84	4.78	4.72	4.67
Feb 16 - Feb 28	6.66	6.58	6.51	6.43	6.36	6.29	6.22	6.16	6.09	6.03	5.97
Mar 1 - Mar 15	7.72	7.65	7.58	7.51	7.45	7.38	7.32	7.26	7.20	7.14	7.09
Mar 16 - Mar 31	10.83	10.75	10.67	10.60	10.53	10.46	10.40	10.33	10.27	10.21	10.15
Apr 1 - Apr 15	10.26	10.23	10.20	10.17	10.14	10.11	10.09	10.06	10.03	10.00	9.98
Apr 16 - Apr 30	12.63	12.57	12.52	12.47	12.41	12.36	12.31	12.26	12.20	12.15	12.11
May 1 - May 15	14.47	14.46	14.45	14.44	14.42	14.41	14.39	14.38	14.36	14.34	14.32
May 16 - May 31	16.95	16.96	16.97	16.97	16.98	16.98	16.98	16.98	16.98	16.98	16.98
Jun 1 - Jun 15	18.30	18.32	18.35	18.37	18.39	18.40	18.42	18.43	18.44	18.45	18.46
Jun 16 - Jun 30	21.10	21.08	21.05	21.03	20.99	20.96	20.93	20.89	20.86	20.82	20.78
Jul 1 - Jul 15	24.59	24.51	24.43	24.34	24.25	24.16	24.07	23.98	23.89	23.80	23.71
Jul 16 - Jul 31	24.19	24.14	24.08	24.02	23.95	23.89	23.82	23.76	23.69	23.63	23.56
Aug 1 - Aug 15	24.78	24.73	24.67	24.61	24.55	24.49	24.43	24.36	24.30	24.24	24.18
Aug 16 - Aug 31	23.19	23.19	23.19	23.18	23.18	23.17	23.15	23.14	23.12	23.11	23.09
Sep 1 - Sep 15	22.02	22.02	22.02	22.01	22.00	21.99	21.98	21.96	21.95	21.93	21.92
Sep 16 - Sep 30	20.23	20.23	20.22	20.21	20.20	20.19	20.18	20.16	20.15	20.14	20.13
Oct 1 - Oct 15	17.62	17.64	17.66	17.67	17.69	17.70	17.70	17.71	17.72	17.72	17.73
Oct 16 - Oct 31	13.63	13.67	13.70	13.73	13.76	13.79	13.82	13.84	13.86	13.89	13.91
Nov 1 - Nov 15	10.80	10.80	10.81	10.81	10.81	10.82	10.82	10.83	10.84	10.84	10.85
Nov 16 - Nov 30	8.20	8.20	8.20	8.19	8.19	8.19	8.19	8.19	8.19	8.19	8.19
Dec 1 - Dec 15	6.52	6.51	6.50	6.49	6.48	6.48	6.47	6.46	6.45	6.44	6.43
Dec 16 - Dec 31	6.66	6.64	6.61	6.59	6.56	6.54	6.51	6.49	6.46	6.44	6.42

Table 3-2. Daily Average Water Temperature Output Table for 2004 Meteorological and Tributary Conditions

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 191 - Immediately downstream of Iron Gate Dam												
Jan 1 - Jan 15	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
Jan 16 - Jan 31	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
Feb 1 - Feb 15	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23
Feb 16 - Feb 28	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76
Mar 1 - Mar 15	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99
Mar 16 - Mar 31	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11
Apr 1 - Apr 15	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60
Apr 16 - Apr 30	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49
May 1 - May 15	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48
May 16 - May 31	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84
Jun 1 - Jun 15	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08
Jun 16 - Jun 30	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38
Jul 1 - Jul 15	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36
Jul 16 - Jul 31	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71
Aug 1 - Aug 15	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79
Aug 16 - Aug 31	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60
Sep 1 - Sep 15	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70
Sep 16 - Sep 30	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83
Oct 1 - Oct 15	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53
Oct 16 - Oct 31	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63
Nov 1 - Nov 15	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12
Nov 16 - Nov 30	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63
Dec 1 - Dec 15	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06
Dec 16 - Dec 31	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57

Table 3-2 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 184 - Mid-point between Iron Gate Dam and Shasta River												
Jan 1 - Jan 15	3.76	3.72	3.68	3.65	3.63	3.60	3.59	3.57	3.56	3.55	3.54	3.52
Jan 16 - Jan 31	3.26	3.18	3.11	3.06	3.01	2.97	2.94	2.92	2.89	2.87	2.85	2.82
Feb 1 - Feb 15	3.12	3.02	2.93	2.86	2.81	2.76	2.72	2.69	2.66	2.63	2.61	2.57
Feb 16 - Feb 28	3.93	3.80	3.70	3.62	3.55	3.49	3.44	3.40	3.36	3.33	3.29	3.24
Mar 1 - Mar 15	6.21	5.97	5.78	5.61	5.48	5.37	5.27	5.18	5.11	5.04	4.99	4.89
Mar 16 - Mar 31	9.16	8.94	8.76	8.61	8.49	8.38	8.29	8.22	8.15	8.09	8.03	7.94
Apr 1 - Apr 15	11.36	11.16	11.01	10.88	10.78	10.69	10.61	10.54	10.48	10.43	10.39	10.31
Apr 16 - Apr 30	12.25	12.06	11.91	11.78	11.67	11.58	11.50	11.44	11.38	11.33	11.28	11.20
May 1 - May 15	15.04	14.87	14.73	14.61	14.52	14.44	14.37	14.31	14.26	14.21	14.17	14.10
May 16 - May 31	16.27	16.11	15.98	15.88	15.79	15.72	15.65	15.60	15.55	15.51	15.47	15.41
Jun 1 - Jun 15	17.57	17.40	17.26	17.15	17.06	16.98	16.91	16.86	16.81	16.76	16.73	16.66
Jun 16 - Jun 30	19.20	18.98	18.81	18.67	18.56	18.46	18.38	18.31	18.25	18.20	18.15	18.07
Jul 1 - Jul 15	20.60	20.45	20.34	20.24	20.16	20.10	20.04	19.99	19.95	19.92	19.88	19.83
Jul 16 - Jul 31	21.91	21.77	21.66	21.56	21.49	21.43	21.37	21.33	21.29	21.25	21.22	21.17
Aug 1 - Aug 15	21.72	21.61	21.52	21.45	21.40	21.35	21.31	21.27	21.24	21.21	21.19	21.15
Aug 16 - Aug 31	21.28	21.20	21.14	21.08	21.04	21.01	20.98	20.95	20.93	20.91	20.89	20.86
Sep 1 - Sep 15	19.99	19.96	19.94	19.91	19.90	19.88	19.87	19.86	19.85	19.84	19.83	19.82
Sep 16 - Sep 30	18.07	18.05	18.03	18.01	17.99	17.98	17.97	17.96	17.96	17.95	17.94	17.93
Oct 1 - Oct 15	16.94	16.89	16.85	16.82	16.80	16.78	16.76	16.74	16.73	16.72	16.71	16.69
Oct 16 - Oct 31	13.30	13.35	13.39	13.42	13.44	13.46	13.48	13.49	13.50	13.51	13.52	13.54
Nov 1 - Nov 15	10.05	10.06	10.07	10.08	10.09	10.09	10.10	10.10	10.11	10.11	10.11	10.11
Nov 16 - Nov 30	7.48	7.50	7.52	7.53	7.54	7.55	7.56	7.57	7.57	7.58	7.58	7.59
Dec 1 - Dec 15	5.28	5.26	5.24	5.23	5.22	5.21	5.20	5.19	5.18	5.18	5.17	5.16
Dec 16 - Dec 31	3.65	3.65	3.64	3.63	3.63	3.62	3.62	3.62	3.62	3.61	3.61	3.61

Table 3-2 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 160 - Mid-point between Shasta River and Scott River												
Jan 1 - Jan 15	4.11	4.06	4.02	3.98	3.95	3.92	3.89	3.87	3.85	3.83	3.81	3.78
Jan 16 - Jan 31	3.98	3.87	3.78	3.70	3.63	3.57	3.51	3.47	3.42	3.38	3.34	3.28
Feb 1 - Feb 15	4.41	4.24	4.10	3.98	3.87	3.78	3.69	3.62	3.55	3.48	3.43	3.33
Feb 16 - Feb 28	5.49	5.34	5.20	5.08	4.97	4.87	4.77	4.69	4.62	4.55	4.48	4.36
Mar 1 - Mar 15	7.90	7.66	7.44	7.25	7.08	6.92	6.78	6.66	6.54	6.44	6.34	6.17
Mar 16 - Mar 31	10.73	10.49	10.29	10.11	9.94	9.80	9.67	9.55	9.44	9.34	9.25	9.08
Apr 1 - Apr 15	12.24	12.05	11.89	11.75	11.63	11.51	11.41	11.33	11.24	11.17	11.10	10.98
Apr 16 - Apr 30	13.50	13.30	13.12	12.96	12.82	12.69	12.58	12.48	12.39	12.31	12.23	12.09
May 1 - May 15	16.26	16.06	15.89	15.74	15.61	15.49	15.38	15.28	15.20	15.12	15.05	14.92
May 16 - May 31	17.79	17.59	17.41	17.25	17.12	16.99	16.88	16.78	16.69	16.61	16.53	16.40
Jun 1 - Jun 15	19.14	18.92	18.73	18.55	18.40	18.27	18.15	18.04	17.95	17.86	17.78	17.64
Jun 16 - Jun 30	21.48	21.17	20.89	20.65	20.44	20.25	20.08	19.94	19.80	19.68	19.57	19.38
Jul 1 - Jul 15	22.48	22.23	22.02	21.83	21.67	21.52	21.39	21.27	21.17	21.08	20.99	20.85
Jul 16 - Jul 31	23.81	23.56	23.35	23.16	22.99	22.85	22.72	22.61	22.51	22.41	22.33	22.19
Aug 1 - Aug 15	23.32	23.12	22.94	22.78	22.65	22.53	22.42	22.33	22.25	22.17	22.10	21.99
Aug 16 - Aug 31	22.47	22.32	22.19	22.08	21.98	21.89	21.82	21.75	21.69	21.63	21.58	21.50
Sep 1 - Sep 15	20.46	20.41	20.36	20.31	20.27	20.24	20.21	20.18	20.16	20.13	20.12	20.08
Sep 16 - Sep 30	18.35	18.32	18.29	18.26	18.24	18.22	18.20	18.18	18.17	18.15	18.14	18.12
Oct 1 - Oct 15	17.27	17.22	17.17	17.13	17.09	17.06	17.03	17.00	16.98	16.96	16.94	16.91
Oct 16 - Oct 31	12.45	12.56	12.66	12.74	12.81	12.87	12.92	12.97	13.01	13.05	13.08	13.14
Nov 1 - Nov 15	9.64	9.69	9.74	9.78	9.81	9.84	9.86	9.88	9.90	9.92	9.93	9.95
Nov 16 - Nov 30	6.98	7.05	7.10	7.15	7.19	7.22	7.25	7.28	7.30	7.32	7.34	7.37
Dec 1 - Dec 15	5.35	5.35	5.35	5.34	5.34	5.33	5.33	5.32	5.32	5.31	5.31	5.30
Dec 16 - Dec 31	3.84	3.82	3.80	3.79	3.78	3.77	3.76	3.75	3.74	3.73	3.73	3.72

Table 3-2 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 136 - Mid-point between Scott River and Seiad Valley												
Jan 1 - Jan 15	4.89	4.83	4.78	4.73	4.68	4.64	4.60	4.56	4.53	4.50	4.46	4.41
Jan 16 - Jan 31	4.98	4.88	4.79	4.71	4.63	4.56	4.49	4.42	4.36	4.31	4.25	4.16
Feb 1 - Feb 15	5.67	5.52	5.39	5.27	5.15	5.04	4.94	4.85	4.76	4.68	4.60	4.46
Feb 16 - Feb 28	6.94	6.83	6.73	6.64	6.55	6.46	6.38	6.30	6.23	6.16	6.10	5.98
Mar 1 - Mar 15	9.02	8.88	8.74	8.61	8.49	8.37	8.26	8.16	8.06	7.96	7.87	7.70
Mar 16 - Mar 31	10.87	10.77	10.68	10.59	10.51	10.43	10.35	10.28	10.21	10.14	10.07	9.95
Apr 1 - Apr 15	11.71	11.66	11.61	11.56	11.51	11.46	11.42	11.37	11.33	11.29	11.25	11.18
Apr 16 - Apr 30	12.65	12.60	12.56	12.51	12.46	12.41	12.37	12.33	12.29	12.25	12.21	12.13
May 1 - May 15	14.50	14.48	14.46	14.45	14.43	14.41	14.39	14.38	14.36	14.34	14.32	14.29
May 16 - May 31	16.15	16.14	16.13	16.11	16.09	16.07	16.05	16.03	16.00	15.98	15.96	15.92
Jun 1 - Jun 15	18.14	18.11	18.06	18.02	17.98	17.94	17.89	17.85	17.81	17.77	17.73	17.66
Jun 16 - Jun 30	21.54	21.41	21.28	21.15	21.02	20.90	20.78	20.67	20.57	20.47	20.38	20.20
Jul 1 - Jul 15	22.91	22.76	22.62	22.49	22.36	22.25	22.14	22.04	21.94	21.85	21.77	21.61
Jul 16 - Jul 31	24.64	24.46	24.28	24.12	23.96	23.82	23.69	23.57	23.46	23.36	23.26	23.09
Aug 1 - Aug 15	24.05	23.90	23.75	23.60	23.47	23.35	23.24	23.14	23.05	22.96	22.88	22.73
Aug 16 - Aug 31	23.22	23.08	22.95	22.83	22.72	22.62	22.53	22.45	22.38	22.31	22.24	22.13
Sep 1 - Sep 15	20.74	20.69	20.64	20.60	20.56	20.52	20.49	20.46	20.43	20.41	20.39	20.35
Sep 16 - Sep 30	18.64	18.61	18.57	18.54	18.52	18.49	18.47	18.45	18.43	18.41	18.39	18.36
Oct 1 - Oct 15	17.73	17.66	17.60	17.54	17.49	17.45	17.40	17.37	17.34	17.31	17.28	17.23
Oct 16 - Oct 31	12.50	12.58	12.65	12.71	12.76	12.82	12.86	12.91	12.95	12.98	13.02	13.08
Nov 1 - Nov 15	9.73	9.76	9.79	9.82	9.85	9.87	9.89	9.91	9.93	9.95	9.96	9.99
Nov 16 - Nov 30	7.10	7.14	7.17	7.20	7.23	7.25	7.28	7.30	7.32	7.34	7.35	7.38
Dec 1 - Dec 15	5.60	5.61	5.62	5.62	5.62	5.62	5.62	5.62	5.62	5.61	5.61	5.60
Dec 16 - Dec 31	4.45	4.41	4.37	4.33	4.30	4.27	4.25	4.22	4.20	4.18	4.16	4.12

Table 3-2 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 97 - Mid-point between Seiad Valley and Salmon River												
Jan 1 - Jan 15	5.44	5.42	5.39	5.37	5.34	5.32	5.30	5.28	5.25	5.23	5.21	5.17
Jan 16 - Jan 31	5.85	5.81	5.78	5.74	5.70	5.67	5.63	5.60	5.56	5.53	5.49	5.43
Feb 1 - Feb 15	6.36	6.30	6.23	6.17	6.11	6.05	5.99	5.93	5.87	5.81	5.76	5.65
Feb 16 - Feb 28	6.94	6.88	6.81	6.75	6.69	6.63	6.58	6.53	6.48	6.43	6.38	6.29
Mar 1 - Mar 15	8.59	8.53	8.47	8.42	8.36	8.31	8.25	8.20	8.15	8.10	8.06	7.96
Mar 16 - Mar 31	9.64	9.61	9.59	9.56	9.53	9.51	9.48	9.46	9.43	9.41	9.38	9.33
Apr 1 - Apr 15	10.45	10.45	10.44	10.44	10.43	10.43	10.42	10.41	10.41	10.40	10.39	10.38
Apr 16 - Apr 30	11.59	11.59	11.58	11.58	11.57	11.56	11.55	11.55	11.54	11.53	11.52	11.50
May 1 - May 15	13.65	13.65	13.66	13.67	13.67	13.67	13.67	13.67	13.67	13.67	13.67	13.67
May 16 - May 31	15.48	15.50	15.50	15.51	15.52	15.52	15.52	15.52	15.52	15.51	15.51	15.50
Jun 1 - Jun 15	17.61	17.62	17.62	17.62	17.61	17.60	17.59	17.58	17.57	17.55	17.54	17.51
Jun 16 - Jun 30	20.92	20.90	20.87	20.84	20.81	20.77	20.73	20.68	20.63	20.59	20.53	20.43
Jul 1 - Jul 15	22.24	22.24	22.23	22.21	22.18	22.15	22.11	22.08	22.04	22.00	21.95	21.86
Jul 16 - Jul 31	24.05	24.06	24.05	24.02	23.98	23.93	23.88	23.83	23.77	23.72	23.66	23.55
Aug 1 - Aug 15	23.47	23.50	23.51	23.49	23.47	23.43	23.39	23.35	23.31	23.26	23.22	23.13
Aug 16 - Aug 31	22.74	22.77	22.77	22.76	22.74	22.71	22.68	22.64	22.61	22.57	22.54	22.47
Sep 1 - Sep 15	20.10	20.16	20.21	20.23	20.25	20.26	20.27	20.28	20.28	20.29	20.29	20.28
Sep 16 - Sep 30	17.90	17.96	18.01	18.04	18.07	18.09	18.11	18.13	18.14	18.15	18.16	18.18
Oct 1 - Oct 15	17.03	17.07	17.09	17.11	17.12	17.13	17.13	17.13	17.13	17.12	17.12	17.11
Oct 16 - Oct 31	12.13	12.21	12.28	12.35	12.41	12.47	12.52	12.57	12.62	12.66	12.70	12.78
Nov 1 - Nov 15	9.50	9.54	9.58	9.62	9.65	9.68	9.71	9.74	9.76	9.79	9.81	9.85
Nov 16 - Nov 30	7.17	7.18	7.20	7.22	7.23	7.25	7.26	7.27	7.29	7.30	7.31	7.34
Dec 1 - Dec 15	5.87	5.86	5.84	5.83	5.82	5.81	5.80	5.80	5.79	5.78	5.78	5.77
Dec 16 - Dec 31	4.70	4.68	4.65	4.63	4.61	4.59	4.57	4.55	4.53	4.51	4.49	4.46

Table 3-2 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 55 - Mid-point between Salmon River and Trinity River												
Jan 1 - Jan 15	5.58	5.56	5.55	5.54	5.53	5.51	5.50	5.49	5.48	5.46	5.45	5.43
Jan 16 - Jan 31	6.11	6.09	6.08	6.06	6.04	6.02	6.00	5.98	5.96	5.94	5.92	5.88
Feb 1 - Feb 15	6.67	6.64	6.60	6.57	6.53	6.50	6.46	6.43	6.39	6.36	6.33	6.26
Feb 16 - Feb 28	7.00	6.96	6.92	6.88	6.84	6.81	6.77	6.74	6.70	6.67	6.64	6.58
Mar 1 - Mar 15	8.18	8.15	8.12	8.09	8.06	8.04	8.01	7.98	7.96	7.93	7.91	7.86
Mar 16 - Mar 31	8.89	8.88	8.87	8.86	8.85	8.84	8.83	8.82	8.82	8.81	8.80	8.78
Apr 1 - Apr 15	9.74	9.74	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.76	9.76
Apr 16 - Apr 30	10.97	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.99	10.99	10.98	10.98
May 1 - May 15	12.85	12.86	12.87	12.88	12.89	12.89	12.90	12.91	12.92	12.92	12.93	12.94
May 16 - May 31	14.56	14.58	14.59	14.61	14.62	14.63	14.64	14.65	14.66	14.67	14.67	14.69
Jun 1 - Jun 15	16.73	16.75	16.77	16.78	16.79	16.80	16.81	16.81	16.82	16.82	16.82	16.83
Jun 16 - Jun 30	20.21	20.22	20.23	20.23	20.23	20.23	20.22	20.21	20.20	20.19	20.17	20.14
Jul 1 - Jul 15	21.91	21.92	21.93	21.94	21.94	21.93	21.93	21.92	21.91	21.90	21.88	21.84
Jul 16 - Jul 31	23.90	23.91	23.91	23.91	23.90	23.89	23.87	23.85	23.83	23.81	23.78	23.72
Aug 1 - Aug 15	23.41	23.43	23.44	23.45	23.45	23.44	23.43	23.41	23.40	23.38	23.36	23.31
Aug 16 - Aug 31	22.76	22.77	22.77	22.77	22.77	22.76	22.74	22.73	22.71	22.69	22.67	22.63
Sep 1 - Sep 15	20.18	20.21	20.24	20.26	20.27	20.28	20.29	20.29	20.30	20.30	20.31	20.31
Sep 16 - Sep 30	17.82	17.86	17.88	17.91	17.93	17.95	17.97	17.99	18.01	18.02	18.04	18.06
Oct 1 - Oct 15	16.96	16.99	17.01	17.02	17.03	17.04	17.05	17.06	17.06	17.07	17.07	17.07
Oct 16 - Oct 31	11.98	12.03	12.09	12.14	12.18	12.23	12.27	12.31	12.35	12.39	12.42	12.49
Nov 1 - Nov 15	9.19	9.22	9.26	9.30	9.33	9.36	9.40	9.43	9.46	9.48	9.51	9.56
Nov 16 - Nov 30	7.21	7.22	7.23	7.24	7.25	7.26	7.27	7.29	7.30	7.31	7.32	7.34
Dec 1 - Dec 15	6.11	6.10	6.08	6.07	6.06	6.05	6.04	6.03	6.03	6.02	6.02	6.01
Dec 16 - Dec 31	5.10	5.09	5.07	5.05	5.03	5.02	5.00	4.98	4.97	4.95	4.93	4.90

Table 3-2 Continued

Flow at IGD, cfs	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800
River Mile 24 - Mid-point between Trinity River and Pacific Ocean												
Jan 1 - Jan 15	6.33	6.32	6.31	6.30	6.29	6.28	6.26	6.25	6.24	6.23	6.22	6.20
Jan 16 - Jan 31	6.94	6.93	6.92	6.90	6.89	6.88	6.87	6.86	6.85	6.84	6.82	6.80
Feb 1 - Feb 15	7.21	7.19	7.18	7.16	7.14	7.13	7.11	7.10	7.08	7.06	7.04	7.01
Feb 16 - Feb 28	7.62	7.59	7.57	7.54	7.52	7.50	7.47	7.45	7.43	7.41	7.39	7.35
Mar 1 - Mar 15	8.89	8.87	8.86	8.84	8.83	8.81	8.80	8.79	8.77	8.76	8.74	8.72
Mar 16 - Mar 31	9.65	9.64	9.63	9.63	9.62	9.61	9.60	9.59	9.59	9.58	9.57	9.55
Apr 1 - Apr 15	10.59	10.58	10.58	10.58	10.57	10.57	10.57	10.56	10.56	10.55	10.55	10.54
Apr 16 - Apr 30	11.61	11.61	11.60	11.60	11.60	11.59	11.59	11.59	11.58	11.58	11.58	11.57
May 1 - May 15	13.48	13.49	13.49	13.49	13.49	13.49	13.49	13.49	13.49	13.49	13.49	13.49
May 16 - May 31	14.32	14.33	14.34	14.35	14.36	14.37	14.38	14.38	14.39	14.40	14.40	14.42
Jun 1 - Jun 15	16.48	16.49	16.49	16.50	16.51	16.52	16.52	16.53	16.54	16.54	16.55	16.55
Jun 16 - Jun 30	19.75	19.76	19.77	19.78	19.78	19.78	19.78	19.78	19.78	19.78	19.77	19.77
Jul 1 - Jul 15	21.17	21.19	21.21	21.22	21.24	21.25	21.26	21.26	21.27	21.27	21.27	21.26
Jul 16 - Jul 31	23.94	23.94	23.94	23.94	23.94	23.93	23.92	23.91	23.90	23.89	23.87	23.83
Aug 1 - Aug 15	23.59	23.59	23.59	23.59	23.59	23.58	23.58	23.57	23.56	23.55	23.54	23.50
Aug 16 - Aug 31	22.60	22.61	22.62	22.62	22.62	22.62	22.62	22.62	22.61	22.60	22.60	22.58
Sep 1 - Sep 15	19.74	19.77	19.79	19.82	19.84	19.86	19.88	19.89	19.91	19.92	19.94	19.96
Sep 16 - Sep 30	17.99	18.00	18.01	18.02	18.03	18.04	18.05	18.05	18.06	18.07	18.08	18.09
Oct 1 - Oct 15	17.20	17.20	17.21	17.21	17.21	17.21	17.21	17.21	17.21	17.21	17.21	17.21
Oct 16 - Oct 31	12.35	12.38	12.40	12.43	12.46	12.48	12.50	12.53	12.56	12.58	12.60	12.65
Nov 1 - Nov 15	9.82	9.83	9.84	9.85	9.86	9.87	9.88	9.89	9.89	9.90	9.91	9.93
Nov 16 - Nov 30	8.06	8.05	8.04	8.03	8.02	8.01	8.00	7.99	7.99	7.98	7.97	7.96
Dec 1 - Dec 15	6.61	6.60	6.58	6.57	6.55	6.54	6.53	6.52	6.50	6.49	6.48	6.46
Dec 16 - Dec 31	5.88	5.86	5.84	5.82	5.81	5.79	5.77	5.75	5.74	5.72	5.70	5.67

Table 3-2 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 191 - Immediately downstream of Iron Gate Dam											
Jan 1 - Jan 15	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
Jan 16 - Jan 31	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
Feb 1 - Feb 15	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23
Feb 16 - Feb 28	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76
Mar 1 - Mar 15	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99
Mar 16 - Mar 31	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11
Apr 1 - Apr 15	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60
Apr 16 - Apr 30	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49
May 1 - May 15	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48
May 16 - May 31	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84
Jun 1 - Jun 15	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08
Jun 16 - Jun 30	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38
Jul 1 - Jul 15	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36
Jul 16 - Jul 31	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71
Aug 1 - Aug 15	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79
Aug 16 - Aug 31	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60
Sep 1 - Sep 15	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70
Sep 16 - Sep 30	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83
Oct 1 - Oct 15	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53
Oct 16 - Oct 31	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63
Nov 1 - Nov 15	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12
Nov 16 - Nov 30	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63
Dec 1 - Dec 15	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06
Dec 16 - Dec 31	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57

Table 3-2 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 184 - Mid-point between Iron Gate Dam and Shasta River											
Jan 1 - Jan 15	3.50	3.49	3.48	3.47	3.46	3.46	3.45	3.45	3.44	3.44	3.43
Jan 16 - Jan 31	2.79	2.77	2.76	2.74	2.73	2.72	2.71	2.70	2.69	2.68	2.67
Feb 1 - Feb 15	2.54	2.51	2.49	2.47	2.45	2.44	2.43	2.41	2.40	2.40	2.39
Feb 16 - Feb 28	3.20	3.16	3.13	3.11	3.09	3.07	3.05	3.03	3.02	3.01	3.00
Mar 1 - Mar 15	4.81	4.74	4.68	4.63	4.59	4.55	4.52	4.49	4.46	4.44	4.42
Mar 16 - Mar 31	7.86	7.80	7.75	7.70	7.66	7.63	7.60	7.57	7.54	7.52	7.50
Apr 1 - Apr 15	10.24	10.19	10.14	10.11	10.07	10.04	10.02	9.99	9.97	9.95	9.94
Apr 16 - Apr 30	11.14	11.08	11.04	11.00	10.97	10.94	10.91	10.89	10.87	10.85	10.83
May 1 - May 15	14.04	14.00	13.96	13.92	13.89	13.87	13.84	13.82	13.80	13.79	13.77
May 16 - May 31	15.36	15.31	15.28	15.24	15.22	15.19	15.17	15.15	15.14	15.12	15.11
Jun 1 - Jun 15	16.61	16.56	16.53	16.49	16.47	16.44	16.42	16.40	16.38	16.37	16.35
Jun 16 - Jun 30	18.00	17.95	17.90	17.86	17.83	17.80	17.78	17.75	17.73	17.71	17.70
Jul 1 - Jul 15	19.79	19.75	19.72	19.69	19.67	19.65	19.63	19.62	19.60	19.59	19.58
Jul 16 - Jul 31	21.13	21.09	21.06	21.04	21.02	21.00	20.98	20.96	20.95	20.94	20.93
Aug 1 - Aug 15	21.12	21.09	21.07	21.05	21.03	21.01	21.00	20.99	20.98	20.97	20.96
Aug 16 - Aug 31	20.84	20.82	20.80	20.78	20.77	20.76	20.75	20.74	20.74	20.73	20.72
Sep 1 - Sep 15	19.81	19.80	19.79	19.79	19.78	19.77	19.77	19.77	19.76	19.76	19.76
Sep 16 - Sep 30	17.92	17.92	17.91	17.91	17.90	17.90	17.89	17.89	17.89	17.89	17.88
Oct 1 - Oct 15	16.68	16.66	16.65	16.65	16.64	16.63	16.63	16.62	16.62	16.61	16.61
Oct 16 - Oct 31	13.55	13.56	13.57	13.57	13.58	13.58	13.59	13.59	13.59	13.60	13.60
Nov 1 - Nov 15	10.12	10.12	10.12	10.12	10.12	10.12	10.13	10.13	10.13	10.13	10.13
Nov 16 - Nov 30	7.59	7.60	7.60	7.60	7.61	7.61	7.61	7.61	7.61	7.61	7.61
Dec 1 - Dec 15	5.15	5.15	5.14	5.14	5.13	5.13	5.12	5.12	5.12	5.12	5.11
Dec 16 - Dec 31	3.61	3.60	3.60	3.60	3.60	3.60	3.60	3.59	3.59	3.59	3.59

Table 3-2 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 160 - Mid-point between Shasta River and Scott River											
Jan 1 - Jan 15	3.75	3.72	3.70	3.68	3.67	3.65	3.64	3.63	3.61	3.60	3.60
Jan 16 - Jan 31	3.22	3.18	3.14	3.10	3.07	3.04	3.02	2.99	2.97	2.96	2.94
Feb 1 - Feb 15	3.25	3.17	3.11	3.06	3.01	2.97	2.93	2.89	2.86	2.83	2.81
Feb 16 - Feb 28	4.26	4.17	4.10	4.03	3.96	3.91	3.85	3.81	3.76	3.72	3.69
Mar 1 - Mar 15	6.02	5.89	5.77	5.67	5.58	5.50	5.42	5.36	5.30	5.24	5.19
Mar 16 - Mar 31	8.94	8.82	8.72	8.62	8.54	8.46	8.40	8.34	8.28	8.23	8.18
Apr 1 - Apr 15	10.88	10.79	10.72	10.65	10.59	10.54	10.49	10.44	10.41	10.37	10.34
Apr 16 - Apr 30	11.98	11.88	11.79	11.72	11.65	11.59	11.53	11.48	11.44	11.40	11.36
May 1 - May 15	14.81	14.72	14.63	14.56	14.50	14.44	14.39	14.35	14.31	14.27	14.23
May 16 - May 31	16.28	16.19	16.10	16.02	15.96	15.90	15.84	15.80	15.75	15.71	15.68
Jun 1 - Jun 15	17.52	17.42	17.33	17.25	17.18	17.12	17.07	17.02	16.97	16.93	16.90
Jun 16 - Jun 30	19.22	19.09	18.97	18.87	18.78	18.70	18.62	18.56	18.50	18.45	18.40
Jul 1 - Jul 15	20.73	20.62	20.53	20.45	20.39	20.33	20.27	20.22	20.18	20.14	20.10
Jul 16 - Jul 31	22.07	21.97	21.88	21.81	21.74	21.69	21.63	21.59	21.55	21.51	21.47
Aug 1 - Aug 15	21.89	21.81	21.74	21.68	21.62	21.58	21.53	21.50	21.46	21.43	21.40
Aug 16 - Aug 31	21.43	21.36	21.31	21.27	21.23	21.19	21.16	21.13	21.11	21.09	21.06
Sep 1 - Sep 15	20.05	20.03	20.01	19.99	19.97	19.96	19.95	19.94	19.92	19.92	19.91
Sep 16 - Sep 30	18.10	18.09	18.07	18.06	18.05	18.04	18.03	18.03	18.02	18.01	18.01
Oct 1 - Oct 15	16.88	16.86	16.84	16.82	16.80	16.79	16.78	16.77	16.76	16.75	16.74
Oct 16 - Oct 31	13.19	13.23	13.26	13.29	13.32	13.34	13.36	13.38	13.40	13.41	13.43
Nov 1 - Nov 15	9.98	9.99	10.01	10.02	10.03	10.04	10.05	10.06	10.06	10.07	10.07
Nov 16 - Nov 30	7.40	7.42	7.44	7.46	7.47	7.48	7.49	7.50	7.51	7.52	7.53
Dec 1 - Dec 15	5.29	5.28	5.27	5.27	5.26	5.25	5.25	5.24	5.24	5.23	5.23
Dec 16 - Dec 31	3.71	3.70	3.69	3.69	3.68	3.68	3.67	3.67	3.66	3.66	3.66

Table 3-2 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 136 - Mid-point between Scott River and Seiad Valley											
Jan 1 - Jan 15	4.35	4.31	4.27	4.23	4.19	4.16	4.13	4.10	4.08	4.05	4.03
Jan 16 - Jan 31	4.07	3.99	3.92	3.86	3.80	3.75	3.70	3.65	3.61	3.57	3.54
Feb 1 - Feb 15	4.33	4.22	4.12	4.02	3.94	3.87	3.80	3.73	3.67	3.62	3.57
Feb 16 - Feb 28	5.86	5.76	5.66	5.57	5.49	5.41	5.34	5.27	5.20	5.14	5.08
Mar 1 - Mar 15	7.55	7.40	7.27	7.15	7.04	6.93	6.83	6.74	6.66	6.58	6.50
Mar 16 - Mar 31	9.84	9.74	9.64	9.55	9.47	9.39	9.32	9.25	9.18	9.12	9.06
Apr 1 - Apr 15	11.11	11.05	11.00	10.94	10.89	10.85	10.80	10.76	10.73	10.69	10.66
Apr 16 - Apr 30	12.07	12.00	11.95	11.89	11.84	11.79	11.75	11.71	11.67	11.63	11.60
May 1 - May 15	14.26	14.23	14.20	14.17	14.14	14.12	14.10	14.08	14.06	14.04	14.02
May 16 - May 31	15.88	15.84	15.80	15.76	15.73	15.70	15.67	15.64	15.62	15.59	15.57
Jun 1 - Jun 15	17.59	17.52	17.46	17.40	17.35	17.30	17.25	17.21	17.17	17.13	17.09
Jun 16 - Jun 30	20.04	19.89	19.76	19.64	19.53	19.43	19.34	19.25	19.18	19.10	19.04
Jul 1 - Jul 15	21.47	21.35	21.23	21.13	21.04	20.95	20.87	20.80	20.74	20.68	20.63
Jul 16 - Jul 31	22.93	22.80	22.68	22.57	22.47	22.39	22.31	22.23	22.17	22.11	22.05
Aug 1 - Aug 15	22.60	22.49	22.39	22.30	22.22	22.14	22.08	22.01	21.96	21.91	21.86
Aug 16 - Aug 31	22.03	21.94	21.87	21.80	21.73	21.68	21.63	21.58	21.54	21.50	21.46
Sep 1 - Sep 15	20.31	20.28	20.24	20.22	20.19	20.17	20.15	20.13	20.11	20.10	20.08
Sep 16 - Sep 30	18.34	18.31	18.29	18.27	18.25	18.24	18.22	18.21	18.19	18.18	18.17
Oct 1 - Oct 15	17.18	17.15	17.11	17.08	17.06	17.03	17.01	16.99	16.97	16.95	16.94
Oct 16 - Oct 31	13.13	13.17	13.21	13.24	13.27	13.30	13.33	13.35	13.37	13.38	13.40
Nov 1 - Nov 15	10.01	10.02	10.04	10.05	10.06	10.07	10.08	10.09	10.10	10.10	10.11
Nov 16 - Nov 30	7.41	7.43	7.45	7.46	7.48	7.49	7.50	7.51	7.52	7.53	7.54
Dec 1 - Dec 15	5.59	5.58	5.57	5.56	5.55	5.54	5.53	5.53	5.52	5.51	5.50
Dec 16 - Dec 31	4.09	4.06	4.04	4.01	3.99	3.97	3.96	3.94	3.93	3.92	3.90

Table 3-2 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 97 - Mid-point between Seiad Valley and Salmon River											
Jan 1 - Jan 15	5.13	5.09	5.05	5.02	4.98	4.95	4.92	4.89	4.86	4.83	4.81
Jan 16 - Jan 31	5.36	5.30	5.24	5.18	5.13	5.07	5.02	4.97	4.93	4.88	4.84
Feb 1 - Feb 15	5.55	5.45	5.36	5.28	5.20	5.12	5.04	4.97	4.91	4.84	4.78
Feb 16 - Feb 28	6.21	6.13	6.05	5.98	5.91	5.84	5.78	5.72	5.66	5.61	5.55
Mar 1 - Mar 15	7.87	7.79	7.71	7.63	7.55	7.48	7.41	7.35	7.28	7.22	7.16
Mar 16 - Mar 31	9.29	9.24	9.20	9.16	9.12	9.08	9.04	9.00	8.97	8.94	8.90
Apr 1 - Apr 15	10.36	10.35	10.34	10.32	10.31	10.30	10.28	10.27	10.26	10.25	10.23
Apr 16 - Apr 30	11.48	11.46	11.44	11.43	11.41	11.39	11.37	11.36	11.34	11.33	11.31
May 1 - May 15	13.67	13.67	13.67	13.66	13.66	13.66	13.65	13.65	13.65	13.65	13.64
May 16 - May 31	15.49	15.48	15.47	15.46	15.45	15.44	15.43	15.42	15.41	15.40	15.39
Jun 1 - Jun 15	17.47	17.44	17.40	17.37	17.34	17.30	17.27	17.24	17.22	17.19	17.16
Jun 16 - Jun 30	20.33	20.23	20.13	20.04	19.95	19.87	19.79	19.71	19.64	19.58	19.51
Jul 1 - Jul 15	21.77	21.68	21.59	21.51	21.43	21.35	21.28	21.21	21.15	21.09	21.04
Jul 16 - Jul 31	23.44	23.33	23.22	23.12	23.03	22.94	22.86	22.79	22.71	22.65	22.58
Aug 1 - Aug 15	23.03	22.94	22.86	22.77	22.69	22.62	22.55	22.49	22.43	22.37	22.32
Aug 16 - Aug 31	22.39	22.32	22.26	22.19	22.13	22.07	22.02	21.97	21.92	21.88	21.84
Sep 1 - Sep 15	20.27	20.26	20.25	20.23	20.21	20.20	20.18	20.17	20.16	20.14	20.13
Sep 16 - Sep 30	18.18	18.19	18.19	18.19	18.18	18.18	18.18	18.17	18.17	18.16	18.16
Oct 1 - Oct 15	17.10	17.08	17.07	17.05	17.04	17.02	17.01	16.99	16.98	16.97	16.96
Oct 16 - Oct 31	12.84	12.90	12.95	13.00	13.04	13.08	13.12	13.15	13.18	13.20	13.23
Nov 1 - Nov 15	9.88	9.91	9.93	9.95	9.97	9.99	10.01	10.02	10.03	10.05	10.06
Nov 16 - Nov 30	7.36	7.38	7.40	7.41	7.43	7.44	7.45	7.47	7.48	7.49	7.50
Dec 1 - Dec 15	5.76	5.75	5.74	5.73	5.72	5.71	5.70	5.70	5.69	5.68	5.67
Dec 16 - Dec 31	4.43	4.40	4.37	4.35	4.32	4.30	4.28	4.26	4.24	4.22	4.21

Table 3-2 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 55 - Mid-point between Salmon River and Trinity River											
Jan 1 - Jan 15	5.40	5.38	5.36	5.33	5.31	5.29	5.27	5.24	5.22	5.20	5.18
Jan 16 - Jan 31	5.84	5.81	5.77	5.73	5.69	5.66	5.62	5.59	5.55	5.52	5.48
Feb 1 - Feb 15	6.19	6.13	6.06	6.00	5.94	5.88	5.82	5.77	5.71	5.66	5.61
Feb 16 - Feb 28	6.52	6.46	6.41	6.36	6.31	6.26	6.21	6.17	6.13	6.08	6.04
Mar 1 - Mar 15	7.81	7.76	7.71	7.66	7.62	7.58	7.53	7.49	7.45	7.41	7.37
Mar 16 - Mar 31	8.76	8.75	8.73	8.71	8.70	8.68	8.66	8.64	8.63	8.61	8.59
Apr 1 - Apr 15	9.76	9.76	9.76	9.76	9.76	9.76	9.76	9.75	9.75	9.75	9.75
Apr 16 - Apr 30	10.98	10.98	10.98	10.98	10.97	10.97	10.97	10.97	10.96	10.96	10.96
May 1 - May 15	12.95	12.97	12.98	12.99	13.00	13.00	13.01	13.02	13.03	13.03	13.04
May 16 - May 31	14.70	14.71	14.73	14.74	14.74	14.75	14.76	14.77	14.77	14.78	14.78
Jun 1 - Jun 15	16.83	16.83	16.83	16.83	16.83	16.82	16.82	16.81	16.81	16.80	16.80
Jun 16 - Jun 30	20.10	20.05	20.01	19.96	19.92	19.87	19.83	19.78	19.74	19.70	19.66
Jul 1 - Jul 15	21.80	21.75	21.70	21.65	21.60	21.55	21.50	21.45	21.40	21.36	21.32
Jul 16 - Jul 31	23.66	23.59	23.52	23.45	23.38	23.31	23.24	23.18	23.12	23.06	23.00
Aug 1 - Aug 15	23.26	23.20	23.14	23.08	23.02	22.96	22.90	22.85	22.79	22.74	22.70
Aug 16 - Aug 31	22.58	22.53	22.48	22.43	22.39	22.34	22.29	22.25	22.21	22.17	22.13
Sep 1 - Sep 15	20.31	20.31	20.30	20.29	20.28	20.27	20.25	20.24	20.23	20.22	20.21
Sep 16 - Sep 30	18.08	18.09	18.10	18.11	18.12	18.12	18.13	18.13	18.13	18.13	18.14
Oct 1 - Oct 15	17.07	17.06	17.06	17.05	17.04	17.04	17.03	17.02	17.01	17.01	17.00
Oct 16 - Oct 31	12.56	12.62	12.67	12.72	12.77	12.81	12.85	12.89	12.92	12.95	12.98
Nov 1 - Nov 15	9.60	9.64	9.68	9.71	9.74	9.76	9.79	9.81	9.83	9.85	9.87
Nov 16 - Nov 30	7.35	7.37	7.39	7.40	7.41	7.43	7.44	7.45	7.46	7.47	7.48
Dec 1 - Dec 15	6.00	5.99	5.98	5.97	5.97	5.96	5.95	5.94	5.94	5.93	5.92
Dec 16 - Dec 31	4.87	4.84	4.82	4.79	4.76	4.74	4.72	4.69	4.67	4.65	4.63

Table 3-2 Continued

Flow at IGD, cfs	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
River Mile 24 - Mid-point between Trinity River and Pacific Ocean											
Jan 1 - Jan 15	6.18	6.16	6.14	6.12	6.10	6.08	6.06	6.04	6.02	6.00	5.98
Jan 16 - Jan 31	6.78	6.75	6.73	6.70	6.68	6.66	6.63	6.61	6.59	6.56	6.54
Feb 1 - Feb 15	6.98	6.94	6.91	6.88	6.84	6.81	6.78	6.74	6.71	6.68	6.65
Feb 16 - Feb 28	7.32	7.28	7.24	7.21	7.18	7.14	7.11	7.08	7.05	7.02	7.00
Mar 1 - Mar 15	8.69	8.66	8.64	8.61	8.58	8.56	8.53	8.51	8.48	8.46	8.43
Mar 16 - Mar 31	9.54	9.52	9.51	9.49	9.47	9.46	9.44	9.43	9.41	9.40	9.38
Apr 1 - Apr 15	10.53	10.53	10.52	10.51	10.50	10.49	10.49	10.48	10.47	10.46	10.45
Apr 16 - Apr 30	11.56	11.55	11.54	11.54	11.53	11.52	11.51	11.50	11.49	11.49	11.48
May 1 - May 15	13.49	13.49	13.49	13.49	13.48	13.48	13.48	13.48	13.48	13.48	13.48
May 16 - May 31	14.43	14.44	14.45	14.46	14.46	14.47	14.48	14.49	14.49	14.50	14.51
Jun 1 - Jun 15	16.56	16.57	16.57	16.57	16.57	16.58	16.58	16.58	16.58	16.57	16.57
Jun 16 - Jun 30	19.75	19.74	19.72	19.70	19.68	19.66	19.64	19.61	19.59	19.56	19.54
Jul 1 - Jul 15	21.26	21.25	21.23	21.22	21.20	21.18	21.16	21.14	21.12	21.09	21.07
Jul 16 - Jul 31	23.79	23.75	23.70	23.66	23.61	23.57	23.52	23.47	23.43	23.38	23.34
Aug 1 - Aug 15	23.47	23.43	23.38	23.34	23.30	23.26	23.22	23.17	23.13	23.09	23.05
Aug 16 - Aug 31	22.55	22.52	22.50	22.47	22.44	22.41	22.38	22.35	22.32	22.29	22.26
Sep 1 - Sep 15	19.97	19.98	19.99	20.00	20.01	20.01	20.02	20.02	20.02	20.02	20.02
Sep 16 - Sep 30	18.10	18.11	18.12	18.13	18.13	18.14	18.15	18.15	18.15	18.16	18.16
Oct 1 - Oct 15	17.20	17.19	17.19	17.18	17.17	17.16	17.15	17.15	17.14	17.13	17.12
Oct 16 - Oct 31	12.69	12.73	12.77	12.80	12.84	12.87	12.90	12.93	12.96	12.99	13.01
Nov 1 - Nov 15	9.94	9.96	9.98	9.99	10.01	10.02	10.03	10.04	10.05	10.06	10.07
Nov 16 - Nov 30	7.95	7.94	7.93	7.93	7.92	7.91	7.91	7.90	7.90	7.90	7.89
Dec 1 - Dec 15	6.44	6.43	6.41	6.40	6.38	6.37	6.36	6.34	6.33	6.32	6.31
Dec 16 - Dec 31	5.64	5.61	5.57	5.54	5.51	5.48	5.46	5.43	5.40	5.37	5.35

Appendix 3-C

Memorandum dated September 10, 2007 - Klamath River Flow and Water Temperature Applications – Flow: Temperature Tables

and

Preliminary Results of the Temperature Modeling Conducted for the Coho Life-Cycle Model to Assess the Effects of Klamath River Flows on Temperature Downstream of Iron Gate Dam

Watercourse Engineering Inc.

Memorandum

Date: 9/10/07

To: Steve Cramer, Cramer Fish Sciences
Jon Hicks, U.S. Bureau of Reclamation

Copies: Casey Justice, Cramer Fish Sciences
Cindy Williams, U.S. Bureau of Reclamation

From: Leon Basdekas, Watercourse Engineering, Inc.
Mike Deas, Watercourse Engineering, Inc.

RE: Klamath River Flow and Water Temperature Applications – Flow:Temperature Tables

General

The Klamath River flow and temperature modeling work for this project task employed the model described in TM-7, wherein the calendar year 2003 was used as a calibration year while calendar years 2001, 2002 and 2004 were used as validation. Details of the model development, calibration and validation can be found in TM-7.

Based on discussions with Cramer Fish Sciences (CFS) and the Bureau of Reclamation, Klamath Falls (Reclamation), Watercourse Engineering, Inc performed flow and water temperature modeling simulations to support the CFS Coho life cycle model as well as requests from Reclamation for their biological assessment. The methods described herein are an approach to a more exhaustive water temperature and flow study as compared to examining specific flow schedules for alternative comparisons. These simulations consisted of using two sets of lower Klamath River tributary hydrology and associated meteorological conditions. 2001 represented a dry year and 2004 represented an average year. For the purposes of this document when the years 2001 and 2004 are referenced this will refer to the lower Klamath River tributary hydrology and associated meteorology for the respective years. For both 2001 and 2004, 23 constant flow simulations were performed where the flow from Iron Gate Dam was held constant for the entire year. The flow values ranged from 600 cfs to 1,600 cfs in 100 cfs increments and from 1,600 cfs to 4,000 cfs in 200 cfs increments. Based on examination of past Iron Gate flow data the use of the tables for the months of July, August and September the maximum flow schedule used should be 2,600 cfs. All other months may utilize the full range of values in the tables.

Summary tables prepared for CFS and Reclamation were similar to the format shown in Table 1, where time is represented in rows and Iron Gate Dam release is represented in columns. Four tables per simulation/flow were prepared, including: daily average flow, daily average water temperature, daily maximum flow, and daily maximum water temperature. These daily tables report flow in cubic meters per second and water temperature in degrees Celsius.

Table 1. Example of summary table format for average daily water temperatures

	FLOW SCHEDULE						
		Iron Gate Flow					
Date	Julian Day	600	700	800	900	1000	Continued
1/1	1	3.811	3.816	3.820	3.824	3.828	
1/2	2	3.024	3.072	3.109	3.139	3.166	
1/3	3	2.676	2.772	2.851	2.916	2.970	
1/4	4	2.793	2.876	2.948	3.010	3.065	
1/5	5	3.011	3.070	3.118	3.159	3.192	
1/6	6	3.081	3.118	3.153	3.187	3.218	
1/7	7	3.823	3.828	3.834	3.841	3.847	
1/8	8	4.764	4.714	4.663	4.612	4.561	
1/9	9	5.205	5.068	4.945	4.836	4.738	
1/10	10	4.758	4.630	4.517	4.418	4.331	
continued							

CFS requested the tabular data for the nodes corresponding to the mid point of the habitat reaches used in their Coho life cycle model. Reclamation requested additional tabular data corresponding to nodes above and below the Shasta, Scott, Salmon and Trinity Rivers. Additionally, Reclamation requested their tables be further summarized on a semi-monthly basis. Figure 1 is an example chart which illustrates how the water temperature may change with different Iron Gate release schedules. Similar graphs can be constructed for any flow schedule and node.

Examining the effects of a particular release schedule at Iron Gat dam can be made using the tables for a specific model node. For example, the 2002 Biological Opinion flows for the Dry year type could be represented by taking resulting temperatures by finding the time period by row then going across the rows until the corresponding Iron Gate flow release column is reached. This will give an approximation of the water temperature expected for that time for a specified flow release from Iron Gate. Temperatures for an Iron Gate flow value that is not represented in the table e.g. 1,450 cfs may be found by linear interpolation between the values of 1,400 cfs and 1,500 cfs. While it is recognized that there is some error introduced due to interpolation it is expected to be less than significant for the purposes of these tables.

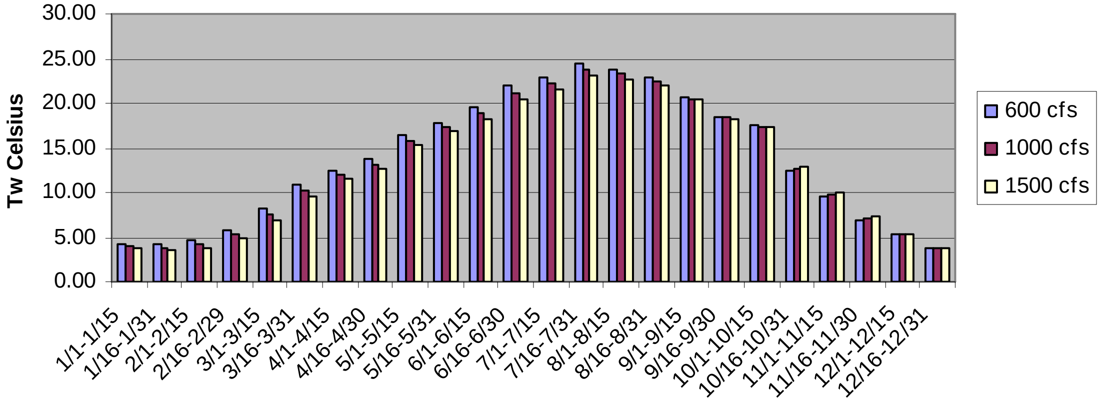


Figure 1 Semi-monthly Average Water Temperature Above the Scott River for three Iron Gate Dam Release Schedules

The Excel files contain tabular data summarizing various steady flow simulations. Results for each node/river mile are contained in separate workbooks. The daily mean and daily maximums flow (cms) and water temperature (Celsius) are given for the requested node/river mile. Additionally, all the daily values have been summarized on a semi-monthly basis and the flow values for the summaries were converted to cfs. Semi-monthly ranges are for the 1st through the 15th of each month then the 16th to the through the remainder of the month. Summary tabular data can be found starting on row 372.

Limitations

While these tables of output provide a powerful way to view the Klamath River under different flow regimes, there are some limitations that need to be noted.

<u>Travel Times</u>
A natural hydrograph travels down the channel resulting in a continuum of changing flow and thermal responses. Using the tables does not consider this. Travel time for a flow change and corresponding temperature change will not be captured using the tables. Travel time from Iron Gate Dam to the mouth varies by flow rate but is on the order of days. Intermediate points on the river may have travel times from hours to days.

<u>High Summer Flow Rates</u>
One assumption made in this analysis is that Iron Gate Dam water temperature does not vary with varying release rates from the dam. Deas and Orlob (1999) explored the impact of variable flow regimes on Iron Gate Reservoir thermal structure and subsequent release temperatures. Specifically, several simulations were completed assessing variable flows from Iron Gate Dam. Within these simulations were alternatives that compared higher summer flow releases from Iron Gate Dam with historic conditions, including flows of 2,500 cfs from June through October (High-1) and 1,700 cfs from June through October (High-2). Release temperatures were slightly cooler (0.1°C to 0.2°C) in early June. However, release temperatures were higher in July and August for High-1 (0.2°C

to 0.4°C and High-2 (0.1°C to 0.3 °C). The higher flow alternatives produced a slightly deeper thermocline in Iron Gate Reservoir during the summer as compared to historic conditions, which resulted in increased water temperatures at the penstock intake. In the early fall conditions were slightly cooler (0.2°C) than historic conditions. Thus, previous analyses suggest that release temperatures may vary slightly under different flow regimes.

The current version of the temperature model has been calibrated for flows of over 2,000 cfs in June and flows generally under 2,000 cfs for July through September. Although flows up to 4,000 cfs were assessed in this analysis, summer period flows of this magnitude have not been experienced historically and the model has not been tested at the upper flow ranges. Because the model is physically based (versus empirical), some level of extrapolation is acceptable. Based on past model performance and model formulation, temperature results are limited to flows equal to or less 2,600 cfs for the months of July, August and September.

Low Flow Rates

During the preparation of INSE (1999), the University of California, Davis, prepared a suite of simulations for Dr. Thom Hardy. These simulations were similar in nature to the current work completed by Watercourse to support the Cramer Fish Sciences fish population model activities. Steady flow releases ranged from 300 to 3,000 cfs and thermal conditions were simulated from Iron Gate Dam to Seiad Valley for metrological conditions typical of mid-August. This analysis yielded insight into model limitations associated with simulation of very low flow releases from Iron Gate Dam. Namely, at low flow rates water temperature results are compromised due to physical representation of river geometry. Modeled flows are excessively shallow due to trapezoidal cross section approximation in the flow and temperature model. Specifically, maximum and minimum daily temperatures are probably too high and minimums too low for flows less than 500 cfs, while mean temperatures are probably representative. The current version of the RMA-11 model is based on similar geometry and assumptions. As such, simulations below 600 cfs were not included in this analysis.

Conclusions

Use of these tables for constructing a flow schedule for Iron Gate releases can be an effective way to explore many scenarios. It may be prudent to perform a complete RMA simulation once a few alternatives have been identified to check for sensitivities to such things travel time.

References

Deas, M.L., and G.T. Orlob. Klamath River Modeling Project. Sponsored by the United States Fish and Wildlife Service Klamath Basin Fisheries Task Force. Project #96-HP-01. Center for Environmental and Water Resources Engineering, Department of Civil and Environmental Engineering, Water Resources Modeling Group, University of California, Davis. Report No. 99-04. December.

Institute for Natural Systems Engineering (INSE). 1999 . Evaluation of Interim Instream Flow Needs in the Klamath River: Phase I. Final report. Prepared for the Department of the Interior. August 1999. 53 pp . +appendices.

Preliminary Results of the Temperature Modeling Conducted for the Coho Life-Cycle Model to Assess the Effects of Klamath River Flows on Temperature Downstream of Iron Gate Dam

As part of the Cramer Fish Sciences coho life-cycle model, Watercourse Engineering conducted model runs to assess the effects of flow on water temperature downstream of Iron Gate Dam. Watercourse modeled several steady state flow regimes ranging from 600 to 4000 cfs with both, 2001 (dry year) and 2004 (average year) meteorological and tributary inflow conditions, to estimate daily average water temperature at several locations downstream of Iron Gate Dam.

This modeling effort yielded results consistent with previous Klamath River temperature modeling efforts, where greater flows downstream of Iron Gate Dam provide modest thermal benefits (cooler water temperatures) that diminish with increased distance from the dam (Watercourse 2007). The modeling effort showed that increased flows from Iron Gate Dam provide cooler water temperatures throughout a larger portion of the Klamath River in a dry year than during an average water year. This is due to less cooling of the main-stem Klamath River from tributary inflows during dry year conditions. However, when assessing the effect of flow on water temperature you must rely on the 2004 model run, due to the fact that 2001 was a dry water year and water would not be available to sustain the increased flows downstream of Iron Gate Dam that were used for the 2001 model run. Although greater flows from Iron Gate Dam can provide decreased water temperature in the upper and middle reaches of the Klamath River throughout the year, May and June are the only months when daily average temperature stressful to salmon occur and Reclamation's proposed action may deviate from the 2002 NMFS biological opinion. Therefore, the thermal benefits from increased flows can only be attained during the months of May and June.

Table 3-C-1 and Table 3-C-2 are the average daily water temperature output tables from the flow and temperature modeling effort conducted by Watercourse Engineering. Figures 3-C-1 through 3-C-16 were developed with the data from output Table 3-C-1 and Table 3-C-2. The figures show the estimated effects of flow on water temperature for the months of March through June when Reclamation proposes floor flows that diverge from the NMFS 2002 biological opinion recommended flows for below average, average, above average, and wet water year types. However, Reclamation doesn't propose to operate at the floors during all years, rather only during dry years when water supply is limited. During below average, average, above average, and wet water years (years when water is available to provide flows above the floors) the Interactive Management team will provide recommendations as to how to utilize the conservation water supply for suckers and salmon.

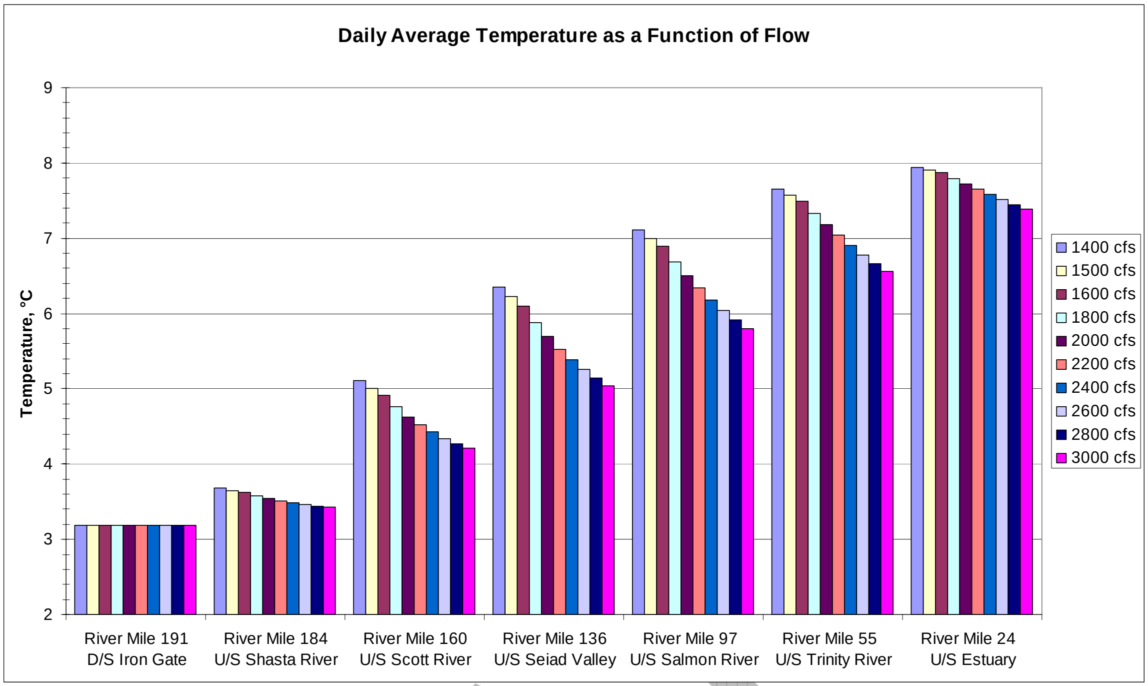


Figure 3-C-1. March 1 – March 15 for the 2001 Model Run.

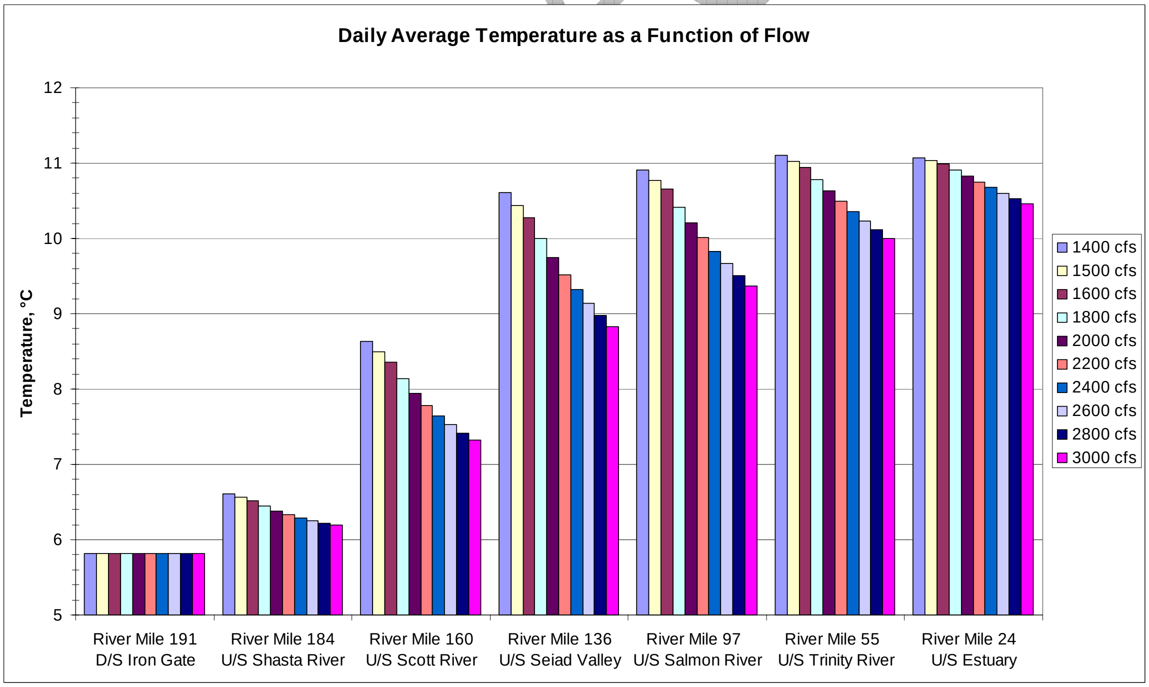


Figure 3-C-2. March 15 – March 31 for the 2001 Model Run.

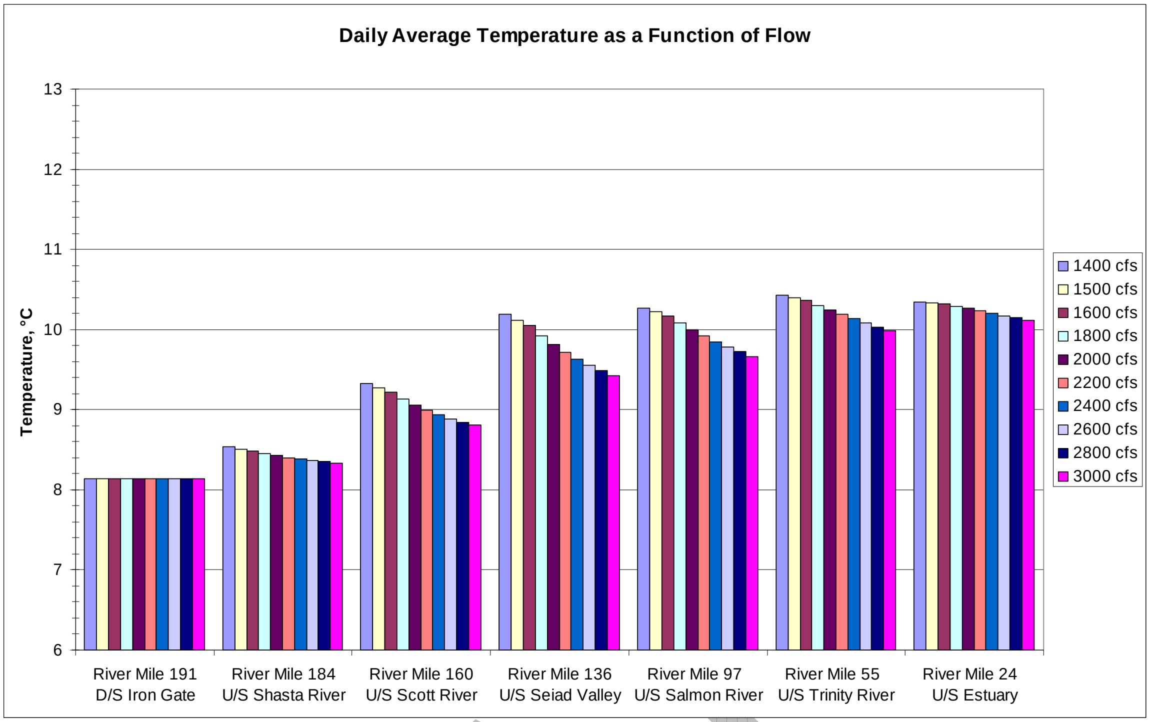


Figure 3-C-3. April 1 – April 15 for the 2001 Model Run.

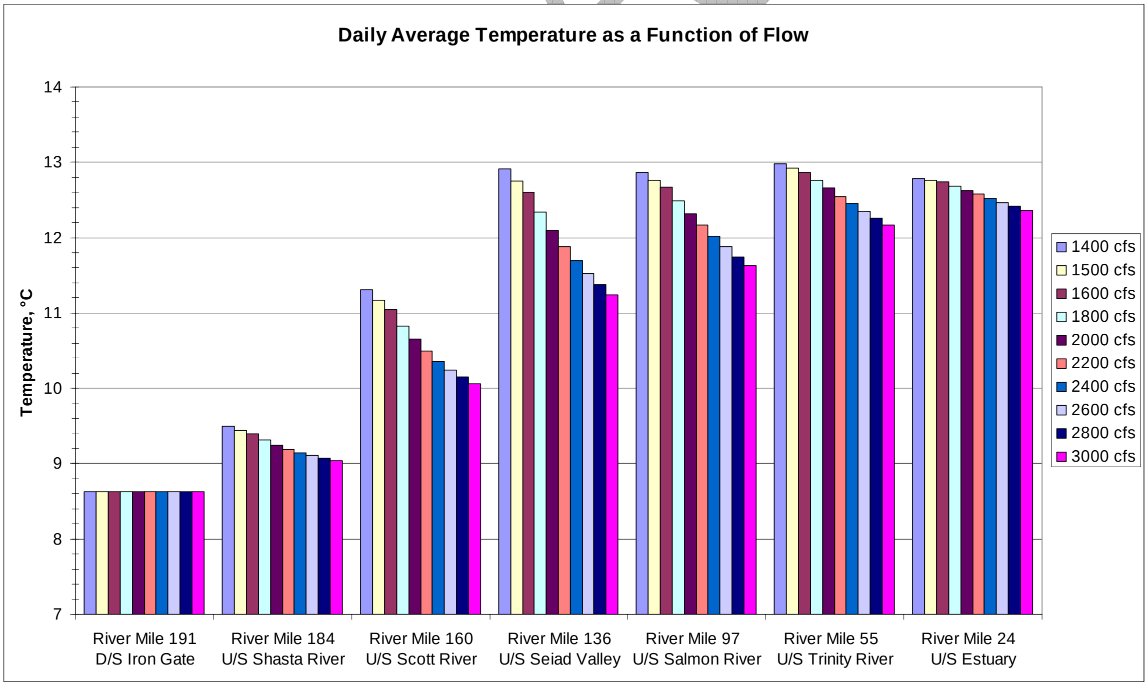


Figure 3-C-4. April 16 – April 30 for the 2001 Model Run.

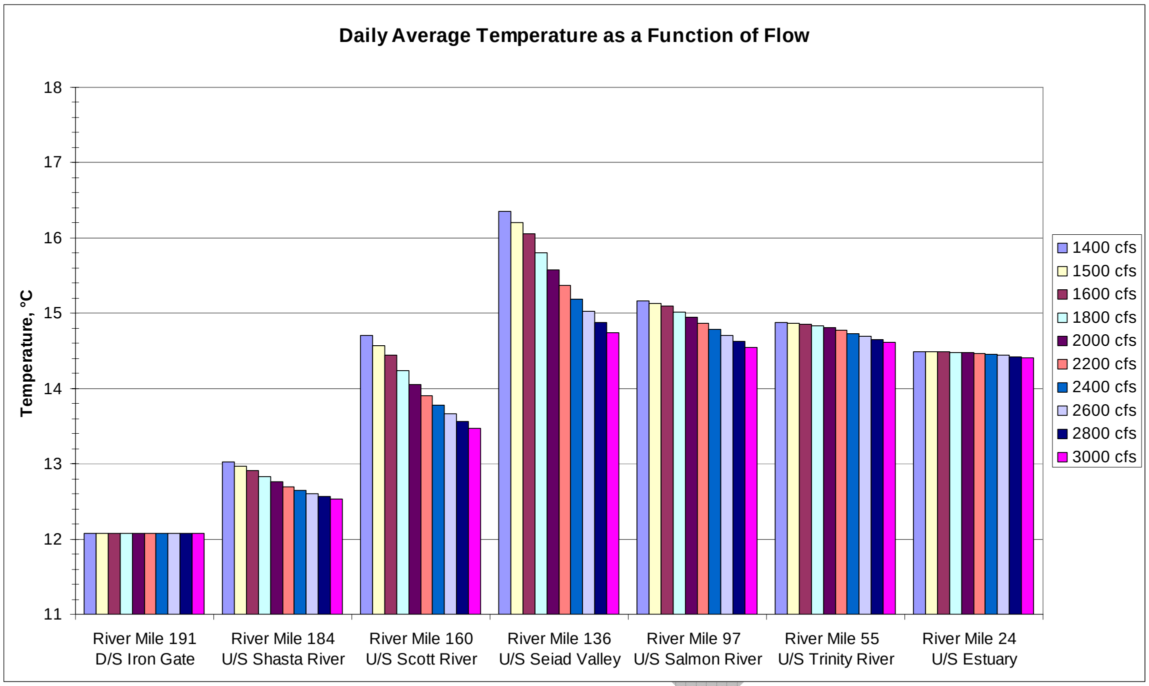


Figure 3-C-5. May 1 – May 15 for the 2001 Model Run.

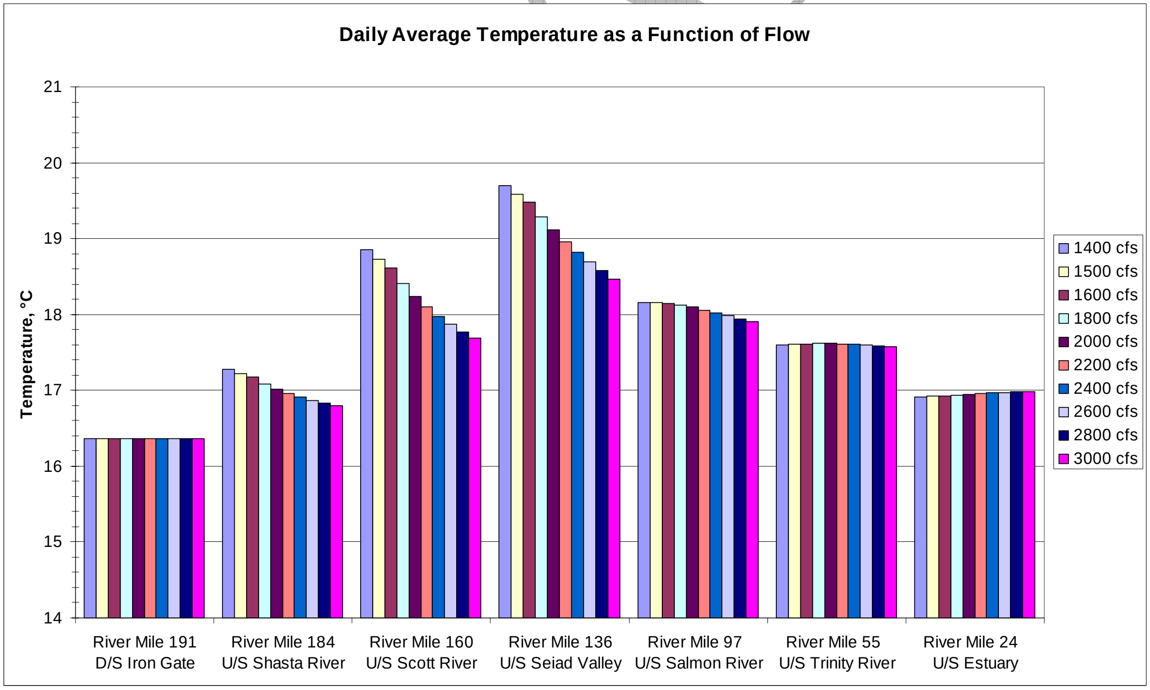


Figure 3-C-6. May 16 – May 31 for the 2001 Model Run.

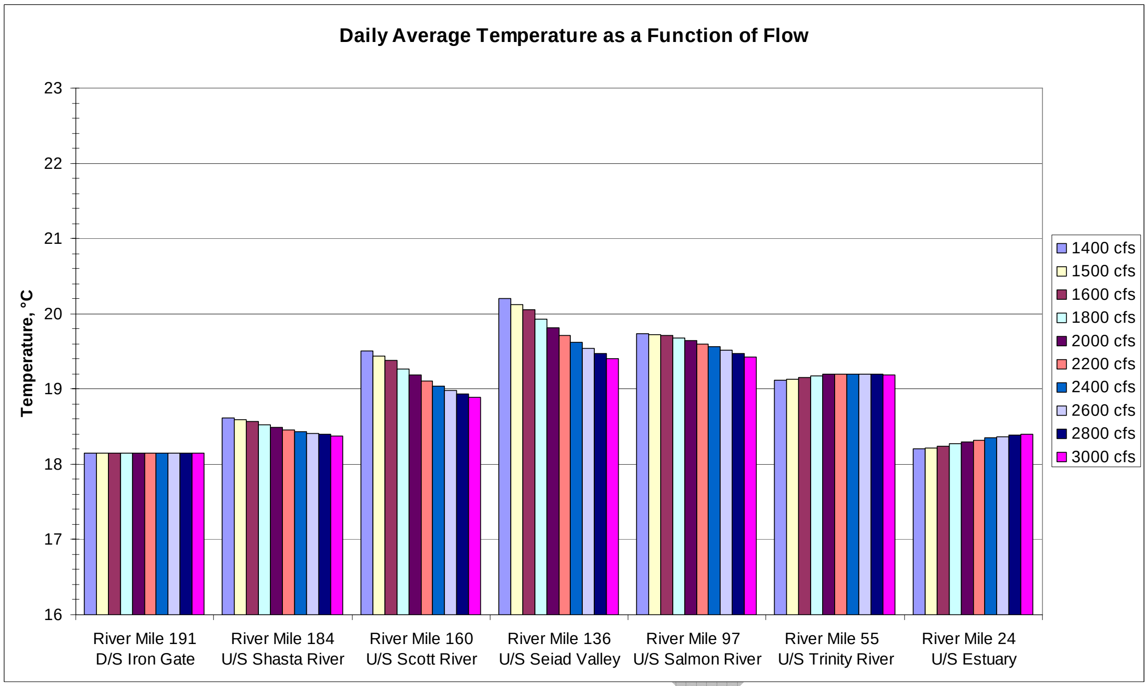


Figure 3-C-7. June 1 – June 15 for the 2001 Model Run.

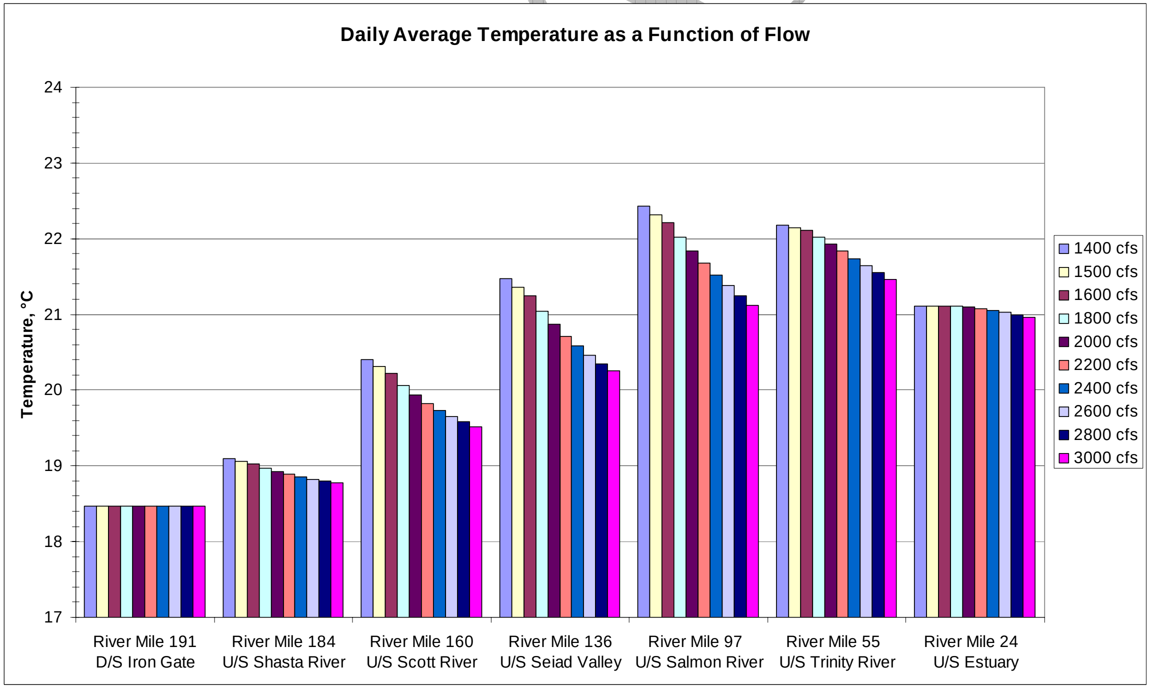


Figure 3-C-8. June 16 – June 30 for the 2001 Model Run.

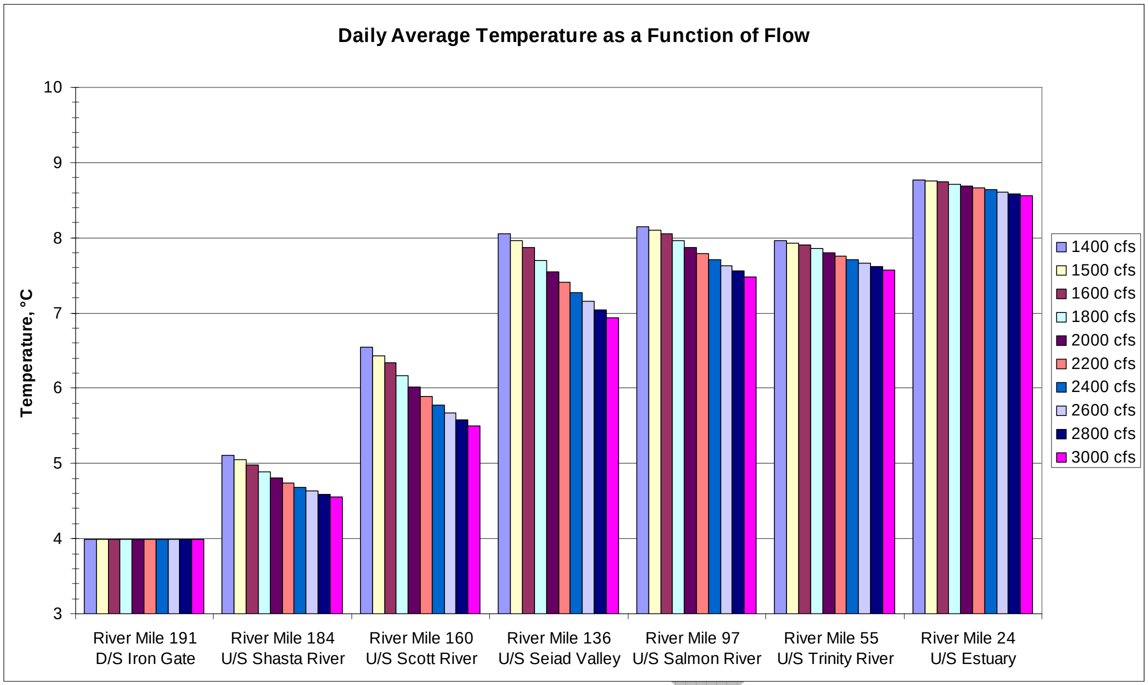


Figure 3-C-9. March 1 – March 16 for the 2004 Model Run.

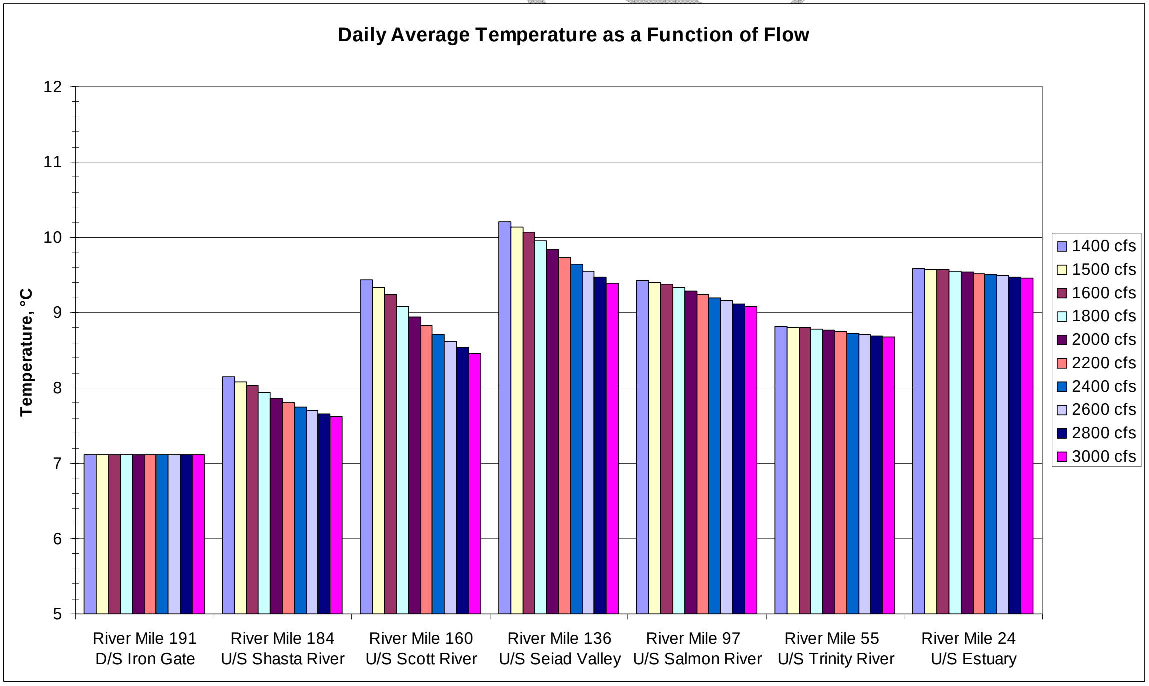


Figure 3-C-10. March 16 – March 31 for the 2004 Model Run.

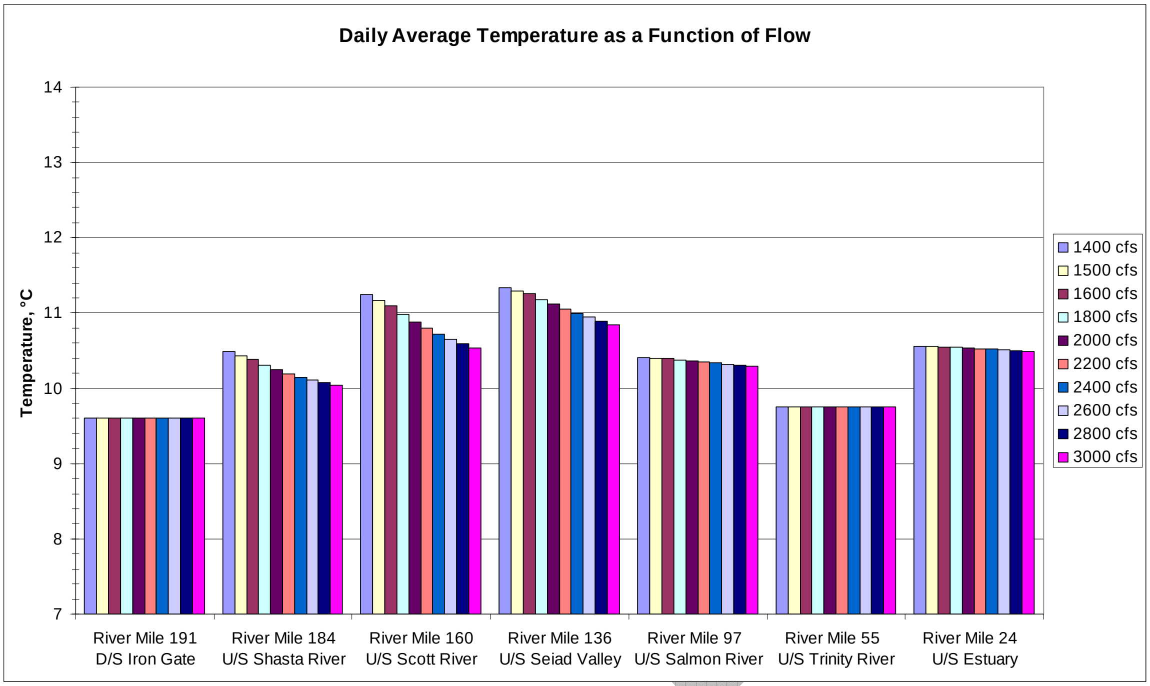


Figure 3-C-11. April 1 – April 15 for the 2004 Model Run.

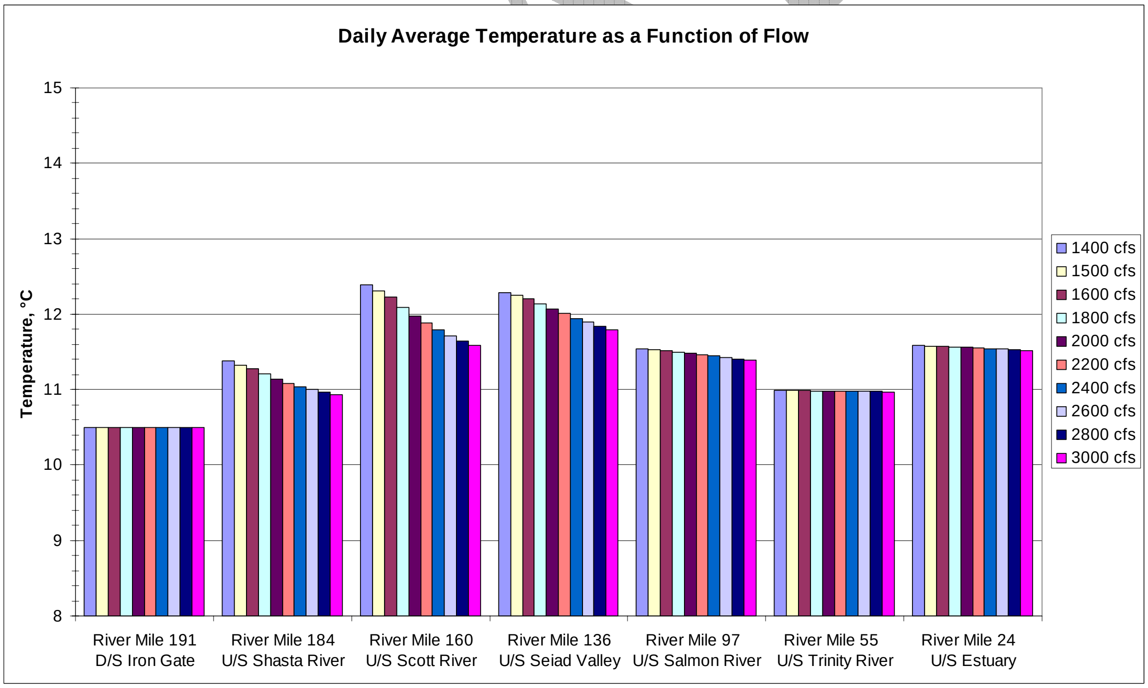


Figure 3-C-12. April 16 – April 30 for the 2004 Model Run.

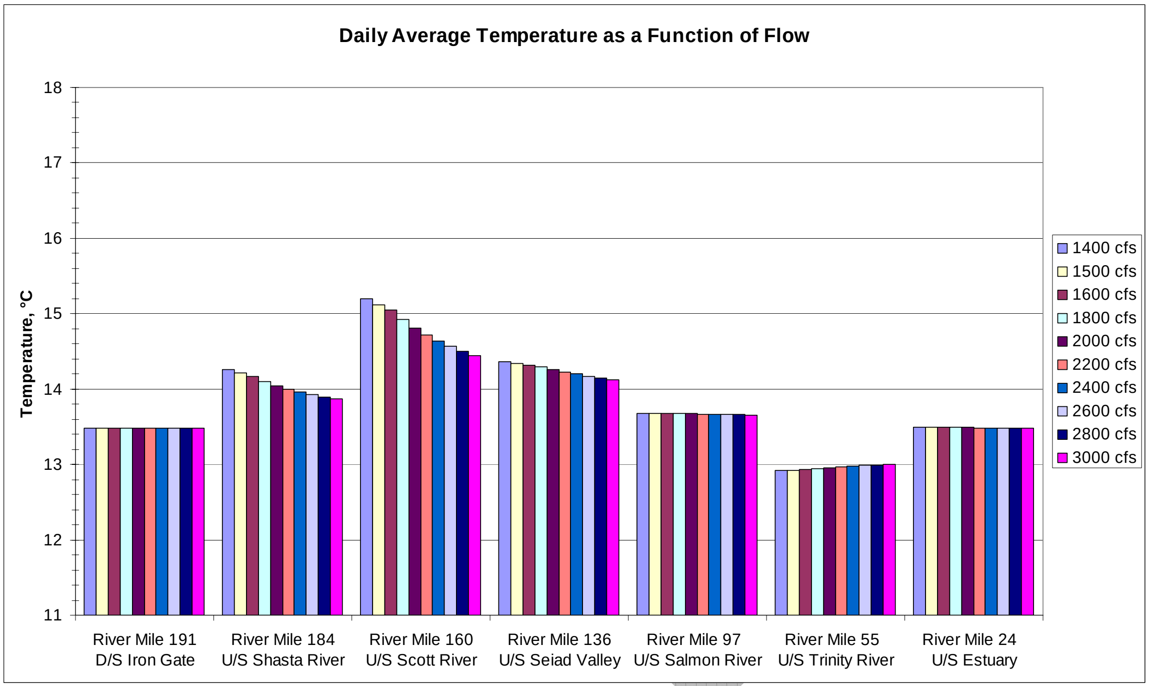


Figure 3-C-13. May 1 – May 15 for the 2004 Model Run.

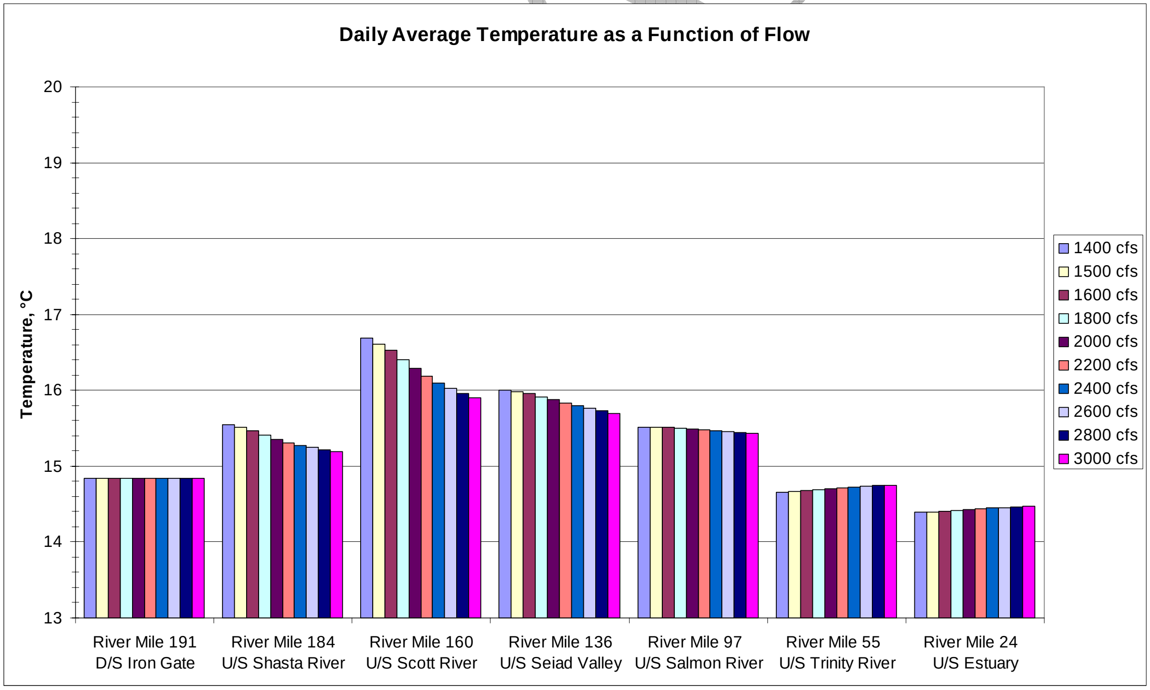


Figure 3-C-14. May 16 – May 31 for the 2004 Model Run.

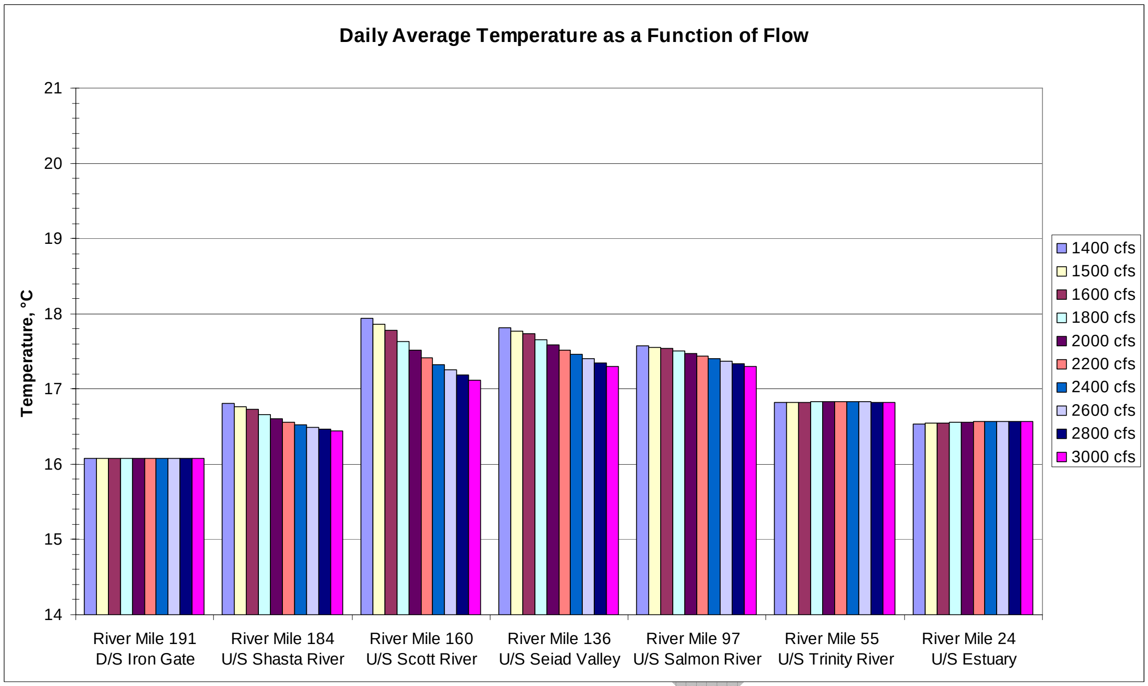


Figure 3-C-15. June 1 – June 15 for the 2004 Model Run.

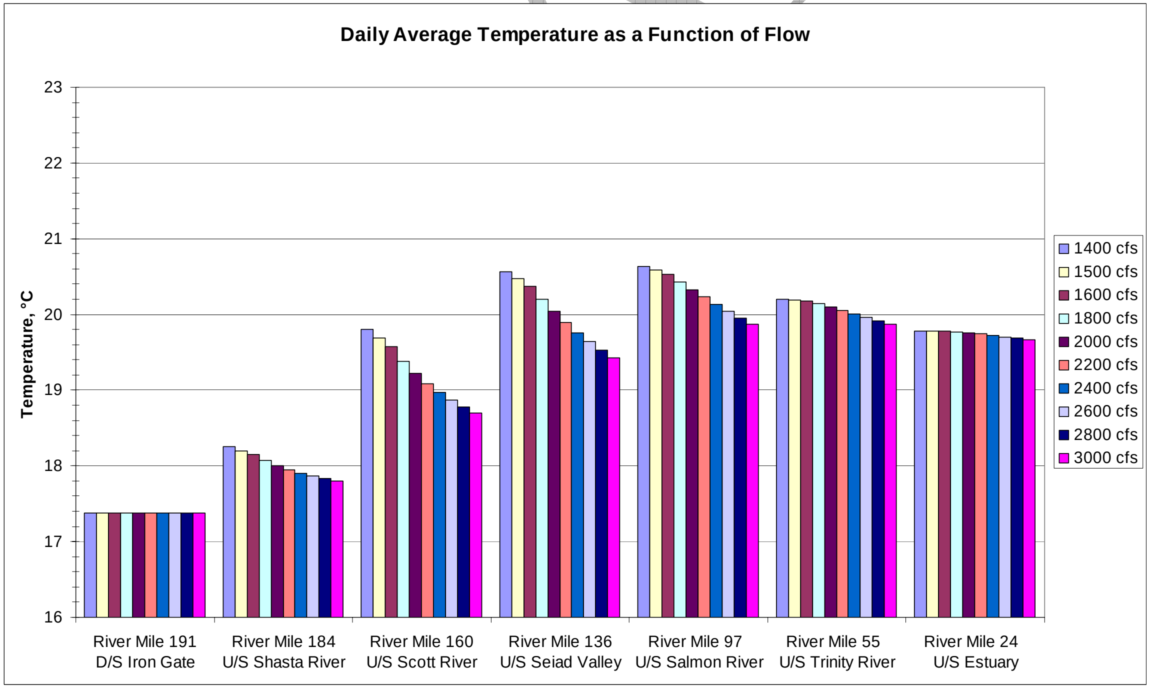


Figure 3-C-16. June 15 – June 30 for the 2004 Model Run.

Table 3-C-1. Daily Average Water Temperature Output Table for 2001 Meteorological and Tributary Conditions

	Flow, cfs											
	600	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**	**1800**
River Mile 191 - Immediately downstream of Iron Gate Dam												
Jan 1 - Jan 15	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69
Jan 16 - Jan 31	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63
Feb 1 - Feb 15	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
Feb 16 - Feb 28	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31
Mar 1 - Mar 15	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
Mar 16 - Mar 31	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82
Apr 1 - Apr 15	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14
Apr 16 - Apr 30	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63
May 1 - May 15	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07
May 16 - May 31	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36
Jun 1 - Jun 15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15
Jun 16 - Jun 30	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47
Jul 1 - Jul 15	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30
Jul 16 - Jul 31	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50
Aug 1 - Aug 15	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30
Aug 16 - Aug 31	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68
Sep 1 - Sep 15	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80
Sep 16 - Sep 30	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19
Oct 1 - Oct 15	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39
Oct 16 - Oct 31	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19
Nov 1 - Nov 15	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85
Nov 16 - Nov 30	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06
Dec 1 - Dec 15	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04
Dec 16 - Dec 31	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59

River Mile 184 - Mid-point between Iron Gate Dam and Shasta River

Jan 1 - Jan 15	3.80	3.78	3.78	3.77	3.76	3.76	3.75	3.75	3.75	3.74	3.74	3.74
Jan 16 - Jan 31	2.85	2.82	2.80	2.78	2.77	2.76	2.75	2.74	2.73	2.73	2.72	2.71
Feb 1 - Feb 15	2.47	2.43	2.39	2.36	2.33	2.31	2.30	2.28	2.27	2.26	2.25	2.23
Feb 16 - Feb 28	3.30	3.17	3.08	3.00	2.94	2.89	2.84	2.80	2.77	2.74	2.72	2.68
Mar 1 - Mar 15	4.27	4.13	4.02	3.93	3.86	3.81	3.76	3.72	3.68	3.65	3.62	3.57
Mar 16 - Mar 31	7.54	7.33	7.16	7.02	6.91	6.82	6.74	6.67	6.61	6.56	6.52	6.44
Apr 1 - Apr 15	8.95	8.85	8.78	8.72	8.67	8.63	8.59	8.56	8.53	8.51	8.49	8.45
Apr 16 - Apr 30	10.48	10.25	10.07	9.93	9.81	9.71	9.63	9.56	9.50	9.44	9.39	9.31
May 1 - May 15	14.07	13.83	13.64	13.49	13.37	13.26	13.17	13.09	13.03	12.97	12.92	12.83
May 16 - May 31	18.31	18.07	17.89	17.74	17.61	17.51	17.42	17.34	17.28	17.22	17.17	17.08
Jun 1 - Jun 15	19.12	19.01	18.92	18.85	18.78	18.73	18.69	18.65	18.62	18.59	18.57	18.52
Jun 16 - Jun 30	19.78	19.62	19.50	19.40	19.32	19.25	19.19	19.14	19.10	19.06	19.03	18.97
Jul 1 - Jul 15	21.20	20.96	20.78	20.64	20.52	20.42	20.33	20.26	20.19	20.14	20.09	20.01
Jul 16 - Jul 31	21.77	21.62	21.50	21.40	21.32	21.25	21.20	21.15	21.11	21.07	21.04	20.98
Aug 1 - Aug 15	22.64	22.48	22.36	22.26	22.17	22.10	22.04	21.99	21.95	21.91	21.87	21.81
Aug 16 - Aug 31	22.58	22.48	22.39	22.33	22.27	22.22	22.18	22.15	22.12	22.09	22.07	22.03
Sep 1 - Sep 15	21.32	21.26	21.21	21.18	21.15	21.12	21.10	21.08	21.06	21.05	21.03	21.01
Sep 16 - Sep 30	19.58	19.54	19.50	19.47	19.45	19.43	19.41	19.40	19.39	19.38	19.37	19.35
Oct 1 - Oct 15	17.66	17.63	17.61	17.59	17.57	17.56	17.55	17.54	17.53	17.52	17.52	17.51
Oct 16 - Oct 31	14.23	14.23	14.23	14.23	14.23	14.23	14.23	14.23	14.23	14.23	14.23	14.23
Nov 1 - Nov 15	10.93	10.92	10.92	10.92	10.91	10.91	10.91	10.90	10.90	10.90	10.90	10.90
Nov 16 - Nov 30	7.78	7.82	7.85	7.87	7.89	7.91	7.92	7.93	7.94	7.95	7.96	7.97
Dec 1 - Dec 15	4.87	4.89	4.91	4.93	4.94	4.95	4.96	4.96	4.97	4.98	4.98	4.99
Dec 16 - Dec 31	3.01	2.96	2.92	2.89	2.87	2.85	2.83	2.81	2.80	2.79	2.78	2.76

River Mile 160 - Mid-point between Shasta River and Scott River

Jan 1 - Jan 15	3.97	3.95	3.93	3.92	3.91	3.89	3.88	3.88	3.87	3.86	3.85	3.84
Jan 16 - Jan 31	3.35	3.30	3.25	3.21	3.17	3.14	3.11	3.08	3.06	3.04	3.02	2.99
Feb 1 - Feb 15	3.54	3.41	3.31	3.22	3.14	3.07	3.01	2.96	2.91	2.87	2.83	2.77
Feb 16 - Feb 28	5.24	5.01	4.81	4.63	4.48	4.35	4.23	4.12	4.03	3.94	3.87	3.73
Mar 1 - Mar 15	6.58	6.29	6.04	5.83	5.64	5.48	5.34	5.22	5.11	5.01	4.92	4.76
Mar 16 - Mar 31	10.72	10.31	9.97	9.67	9.40	9.18	8.98	8.80	8.64	8.49	8.36	8.14
Apr 1 - Apr 15	10.16	10.00	9.87	9.75	9.64	9.55	9.47	9.40	9.33	9.27	9.22	9.13
Apr 16 - Apr 30	13.22	12.86	12.54	12.27	12.03	11.81	11.62	11.46	11.31	11.17	11.05	10.83
May 1 - May 15	16.58	16.23	15.92	15.65	15.41	15.20	15.02	14.85	14.70	14.57	14.45	14.23
May 16 - May 31	20.64	20.31	20.01	19.76	19.53	19.33	19.15	19.00	18.85	18.73	18.61	18.41
Jun 1 - Jun 15	20.41	20.25	20.11	19.98	19.86	19.76	19.66	19.58	19.51	19.44	19.38	19.27
Jun 16 - Jun 30	21.80	21.54	21.31	21.11	20.93	20.78	20.64	20.52	20.41	20.31	20.22	20.07
Jul 1 - Jul 15	24.41	24.00	23.63	23.31	23.03	22.79	22.57	22.38	22.21	22.06	21.92	21.68
Jul 16 - Jul 31	24.06	23.76	23.50	23.27	23.08	22.90	22.75	22.62	22.50	22.39	22.30	22.13
Aug 1 - Aug 15	25.00	24.70	24.44	24.21	24.01	23.83	23.67	23.53	23.41	23.30	23.20	23.03
Aug 16 - Aug 31	24.19	23.98	23.80	23.65	23.51	23.39	23.29	23.19	23.11	23.04	22.97	22.85
Sep 1 - Sep 15	22.17	22.06	21.97	21.89	21.82	21.76	21.70	21.65	21.61	21.57	21.53	21.47
Sep 16 - Sep 30	20.13	20.06	19.99	19.94	19.89	19.85	19.81	19.78	19.75	19.72	19.70	19.66
Oct 1 - Oct 15	17.81	17.79	17.76	17.74	17.72	17.70	17.69	17.67	17.66	17.65	17.64	17.62
Oct 16 - Oct 31	13.86	13.91	13.95	13.98	14.01	14.03	14.05	14.07	14.08	14.10	14.11	14.13
Nov 1 - Nov 15	10.68	10.72	10.74	10.76	10.78	10.79	10.80	10.81	10.82	10.83	10.83	10.84
Nov 16 - Nov 30	7.26	7.33	7.40	7.45	7.50	7.54	7.58	7.61	7.64	7.66	7.68	7.72
Dec 1 - Dec 15	4.69	4.73	4.76	4.79	4.81	4.83	4.85	4.86	4.88	4.89	4.90	4.92
Dec 16 - Dec 31	3.71	3.63	3.57	3.51	3.46	3.41	3.37	3.33	3.30	3.27	3.24	3.19

River Mile 136 - Mid-point between Scott River and Seiad Valley

Jan 1 - Jan 15	4.21	4.18	4.15	4.13	4.11	4.09	4.07	4.06	4.04	4.03	4.02	3.99
Jan 16 - Jan 31	3.74	3.68	3.62	3.57	3.52	3.48	3.44	3.40	3.37	3.34	3.31	3.26
Feb 1 - Feb 15	4.32	4.18	4.05	3.94	3.84	3.74	3.66	3.59	3.52	3.46	3.40	3.30
Feb 16 - Feb 28	6.32	6.10	5.90	5.71	5.54	5.39	5.25	5.12	5.00	4.89	4.79	4.61
Mar 1 - Mar 15	7.97	7.69	7.44	7.22	7.01	6.82	6.65	6.49	6.35	6.22	6.10	5.88
Mar 16 - Mar 31	12.49	12.19	11.91	11.65	11.41	11.19	10.98	10.79	10.61	10.44	10.28	10.00
Apr 1 - Apr 15	11.04	10.90	10.77	10.65	10.55	10.45	10.36	10.27	10.19	10.12	10.05	9.93
Apr 16 - Apr 30	14.69	14.41	14.15	13.91	13.68	13.47	13.27	13.09	12.91	12.75	12.60	12.33
May 1 - May 15	17.89	17.67	17.46	17.24	17.04	16.85	16.68	16.51	16.35	16.20	16.06	15.80
May 16 - May 31	20.76	20.62	20.47	20.33	20.19	20.06	19.93	19.81	19.69	19.59	19.48	19.29
Jun 1 - Jun 15	20.98	20.87	20.76	20.65	20.55	20.46	20.37	20.28	20.20	20.13	20.06	19.93
Jun 16 - Jun 30	22.85	22.64	22.43	22.24	22.06	21.89	21.74	21.60	21.47	21.35	21.24	21.04
Jul 1 - Jul 15	26.13	25.77	25.43	25.12	24.83	24.56	24.32	24.09	23.88	23.69	23.51	23.19
Jul 16 - Jul 31	25.35	25.08	24.82	24.59	24.37	24.17	24.00	23.83	23.68	23.55	23.42	23.20
Aug 1 - Aug 15	26.06	25.82	25.58	25.37	25.16	24.98	24.81	24.66	24.52	24.39	24.26	24.04
Aug 16 - Aug 31	24.80	24.66	24.52	24.38	24.25	24.14	24.03	23.93	23.84	23.76	23.68	23.53
Sep 1 - Sep 15	22.90	22.77	22.66	22.56	22.47	22.39	22.31	22.25	22.19	22.13	22.08	21.99
Sep 16 - Sep 30	20.86	20.76	20.66	20.58	20.50	20.43	20.37	20.32	20.27	20.23	20.19	20.11
Oct 1 - Oct 15	18.40	18.34	18.28	18.23	18.18	18.15	18.11	18.08	18.05	18.02	18.00	17.96
Oct 16 - Oct 31	14.05	14.07	14.10	14.12	14.14	14.16	14.17	14.18	14.19	14.20	14.21	14.23
Nov 1 - Nov 15	10.88	10.89	10.91	10.92	10.93	10.93	10.94	10.95	10.95	10.95	10.96	10.96
Nov 16 - Nov 30	7.28	7.33	7.38	7.42	7.46	7.49	7.52	7.55	7.58	7.60	7.63	7.67
Dec 1 - Dec 15	4.97	4.98	4.99	5.00	5.01	5.02	5.02	5.03	5.04	5.05	5.05	5.06
Dec 16 - Dec 31	4.57	4.50	4.42	4.36	4.30	4.24	4.18	4.13	4.08	4.04	4.00	3.92

River Mile 97 - Mid-point between Seiad Valley and Salmon River

Jan 1 - Jan 15	4.45	4.42	4.39	4.37	4.34	4.32	4.30	4.28	4.26	4.25	4.23	4.20
Jan 16 - Jan 31	4.20	4.13	4.08	4.02	3.97	3.92	3.88	3.84	3.80	3.76	3.73	3.66

Feb 1 - Feb 15	4.97	4.85	4.74	4.64	4.54	4.45	4.36	4.28	4.21	4.14	4.07	3.95
Feb 16 - Feb 28	6.88	6.73	6.57	6.43	6.29	6.16	6.03	5.91	5.80	5.69	5.59	5.41
Mar 1 - Mar 15	8.27	8.11	7.95	7.79	7.64	7.50	7.37	7.24	7.12	7.00	6.89	6.69
Mar 16 - Mar 31	12.17	12.00	11.83	11.66	11.50	11.34	11.19	11.04	10.91	10.78	10.65	10.42
Apr 1 - Apr 15	10.68	10.63	10.57	10.52	10.47	10.42	10.37	10.32	10.27	10.22	10.18	10.08
Apr 16 - Apr 30	13.67	13.58	13.48	13.38	13.27	13.17	13.06	12.96	12.86	12.76	12.67	12.49
May 1 - May 15	15.25	15.28	15.29	15.28	15.27	15.25	15.23	15.20	15.17	15.13	15.10	15.02
May 16 - May 31	17.90	17.97	18.03	18.07	18.10	18.12	18.14	18.15	18.15	18.15	18.15	18.13
Jun 1 - Jun 15	19.50	19.58	19.64	19.68	19.71	19.72	19.73	19.73	19.73	19.72	19.71	19.68
Jun 16 - Jun 30	23.28	23.20	23.11	23.00	22.88	22.76	22.65	22.54	22.43	22.32	22.22	22.02
Jul 1 - Jul 15	26.76	26.66	26.51	26.34	26.16	25.97	25.79	25.61	25.43	25.26	25.09	24.77
Jul 16 - Jul 31	25.70	25.64	25.55	25.44	25.31	25.18	25.05	24.92	24.79	24.67	24.55	24.33
Aug 1 - Aug 15	26.28	26.23	26.15	26.04	25.93	25.80	25.68	25.56	25.44	25.33	25.22	25.01
Aug 16 - Aug 31	24.52	24.55	24.55	24.52	24.47	24.42	24.37	24.31	24.25	24.19	24.14	24.03
Sep 1 - Sep 15	23.14	23.12	23.09	23.04	22.98	22.92	22.86	22.80	22.75	22.69	22.64	22.54
Sep 16 - Sep 30	21.30	21.26	21.21	21.15	21.08	21.02	20.97	20.91	20.86	20.81	20.76	20.67
Oct 1 - Oct 15	18.73	18.70	18.67	18.63	18.59	18.55	18.52	18.48	18.45	18.42	18.39	18.34
Oct 16 - Oct 31	13.39	13.47	13.54	13.60	13.65	13.70	13.74	13.78	13.81	13.85	13.88	13.93
Nov 1 - Nov 15	9.57	9.67	9.75	9.82	9.89	9.95	10.00	10.05	10.10	10.14	10.18	10.25
Nov 16 - Nov 30	6.60	6.65	6.70	6.74	6.78	6.82	6.86	6.90	6.93	6.96	6.99	7.05
Dec 1 - Dec 15	4.84	4.85	4.86	4.87	4.88	4.89	4.90	4.90	4.91	4.92	4.93	4.94
Dec 16 - Dec 31	4.90	4.88	4.85	4.83	4.80	4.78	4.75	4.73	4.70	4.68	4.65	4.60

River Mile 55 - Mid-point between Salmon River and Trinity River

Jan 1 - Jan 15	4.74	4.72	4.69	4.67	4.65	4.62	4.60	4.58	4.56	4.55	4.53	4.49
Jan 16 - Jan 31	4.55	4.50	4.45	4.41	4.37	4.32	4.28	4.25	4.21	4.17	4.14	4.07
Feb 1 - Feb 15	5.41	5.33	5.25	5.17	5.10	5.02	4.95	4.89	4.82	4.76	4.70	4.58
Feb 16 - Feb 28	7.14	7.04	6.94	6.84	6.74	6.65	6.56	6.46	6.38	6.29	6.21	6.05
Mar 1 - Mar 15	8.40	8.31	8.21	8.11	8.02	7.93	7.83	7.74	7.66	7.57	7.49	7.33
Mar 16 - Mar 31	11.84	11.75	11.66	11.56	11.47	11.37	11.28	11.19	11.11	11.02	10.94	10.78
Apr 1 - Apr 15	10.64	10.62	10.60	10.57	10.54	10.52	10.49	10.46	10.43	10.40	10.37	10.30
Apr 16 - Apr 30	13.36	13.33	13.29	13.24	13.19	13.14	13.09	13.03	12.98	12.92	12.87	12.76
May 1 - May 15	14.86	14.87	14.88	14.89	14.89	14.89	14.89	14.88	14.88	14.87	14.86	14.83
May 16 - May 31	17.45	17.48	17.50	17.52	17.54	17.56	17.57	17.59	17.60	17.60	17.61	17.62
Jun 1 - Jun 15	18.80	18.86	18.91	18.96	19.00	19.03	19.06	19.09	19.11	19.13	19.15	19.18
Jun 16 - Jun 30	22.16	22.21	22.25	22.26	22.26	22.25	22.24	22.21	22.18	22.14	22.11	22.02
Jul 1 - Jul 15	25.80	25.85	25.88	25.88	25.85	25.81	25.76	25.69	25.62	25.54	25.45	25.28
Jul 16 - Jul 31	25.02	25.09	25.12	25.14	25.14	25.11	25.08	25.04	24.98	24.93	24.87	24.74
Aug 1 - Aug 15	25.56	25.64	25.69	25.71	25.71	25.69	25.66	25.62	25.57	25.51	25.46	25.34
Aug 16 - Aug 31	23.80	23.89	23.97	24.02	24.05	24.07	24.08	24.08	24.07	24.06	24.05	24.01
Sep 1 - Sep 15	22.59	22.67	22.72	22.75	22.77	22.77	22.77	22.76	22.75	22.73	22.71	22.66
Sep 16 - Sep 30	20.81	20.88	20.92	20.94	20.95	20.95	20.94	20.92	20.90	20.88	20.86	20.81
Oct 1 - Oct 15	18.05	18.12	18.17	18.21	18.23	18.25	18.26	18.27	18.27	18.27	18.27	18.26
Oct 16 - Oct 31	13.29	13.34	13.39	13.44	13.48	13.52	13.56	13.60	13.63	13.66	13.69	13.75
Nov 1 - Nov 15	10.04	10.04	10.05	10.06	10.08	10.10	10.11	10.13	10.15	10.17	10.19	10.23
Nov 16 - Nov 30	7.23	7.24	7.24	7.25	7.26	7.27	7.28	7.30	7.31	7.32	7.33	7.35
Dec 1 - Dec 15	5.45	5.45	5.45	5.45	5.45	5.45	5.44	5.44	5.44	5.44	5.44	5.44
Dec 16 - Dec 31	5.52	5.50	5.48	5.46	5.45	5.43	5.41	5.40	5.38	5.36	5.34	5.31

River Mile 24 - Mid-point between Trinity River and Pacific Ocean

Jan 1 - Jan 15	5.39	5.36	5.34	5.32	5.30	5.27	5.25	5.23	5.21	5.19	5.17	5.13
Jan 16 - Jan 31	5.19	5.16	5.12	5.09	5.06	5.02	4.99	4.96	4.93	4.90	4.87	4.81
Feb 1 - Feb 15	5.91	5.87	5.82	5.78	5.73	5.69	5.64	5.60	5.55	5.51	5.47	5.39
Feb 16 - Feb 28	7.26	7.22	7.18	7.13	7.09	7.04	7.00	6.96	6.91	6.87	6.83	6.75
Mar 1 - Mar 15	8.23	8.20	8.16	8.13	8.09	8.05	8.02	7.98	7.94	7.91	7.87	7.80
Mar 16 - Mar 31	11.39	11.35	11.31	11.27	11.23	11.19	11.15	11.11	11.07	11.03	10.99	10.91
Apr 1 - Apr 15	10.45	10.44	10.43	10.42	10.40	10.39	10.37	10.36	10.35	10.33	10.32	10.29
Apr 16 - Apr 30	12.93	12.92	12.91	12.89	12.87	12.85	12.83	12.81	12.79	12.76	12.74	12.68
May 1 - May 15	14.46	14.47	14.48	14.48	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.48
May 16 - May 31	16.83	16.85	16.86	16.87	16.88	16.89	16.90	16.91	16.91	16.92	16.93	16.94
Jun 1 - Jun 15	18.01	18.03	18.06	18.08	18.11	18.13	18.16	18.18	18.20	18.22	18.24	18.27
Jun 16 - Jun 30	20.91	20.95	20.99	21.02	21.05	21.07	21.08	21.10	21.11	21.11	21.11	21.11
Jul 1 - Jul 15	24.65	24.69	24.72	24.75	24.76	24.77	24.77	24.77	24.76	24.74	24.72	24.66
Jul 16 - Jul 31	24.12	24.17	24.20	24.23	24.26	24.27	24.28	24.29	24.28	24.28	24.27	24.24
Aug 1 - Aug 15	24.69	24.74	24.78	24.81	24.83	24.85	24.86	24.87	24.87	24.86	24.85	24.82
Aug 16 - Aug 31	22.78	22.84	22.89	22.94	22.98	23.02	23.05	23.08	23.10	23.13	23.14	23.17
Sep 1 - Sep 15	21.68	21.74	21.79	21.83	21.86	21.90	21.92	21.95	21.96	21.98	21.99	22.01
Sep 16 - Sep 30	19.90	19.96	20.01	20.05	20.09	20.12	20.15	20.17	20.18	20.20	20.21	20.22
Oct 1 - Oct 15	17.22	17.27	17.32	17.36	17.40	17.43	17.46	17.49	17.51	17.54	17.56	17.59
Oct 16 - Oct 31	13.34	13.36	13.38	13.40	13.42	13.45	13.47	13.49	13.51	13.53	13.55	13.59
Nov 1 - Nov 15	10.90	10.88	10.87	10.85	10.84	10.83	10.82	10.81	10.81	10.81	10.81	10.80
Nov 16 - Nov 30	8.25	8.24	8.23	8.23	8.23	8.22	8.22	8.22	8.21	8.21	8.21	8.20
Dec 1 - Dec 15	6.60	6.60	6.59	6.58	6.58	6.57	6.57	6.56	6.56	6.55	6.54	6.53
Dec 16 - Dec 31	6.83	6.82	6.81	6.80	6.78	6.77	6.76	6.75	6.74	6.72	6.71	6.69

Flow, cfs

2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000

River Mile 191 - Immediately downstream of Iron Gate Dam

Jan 1 - Jan 15	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69
Jan 16 - Jan 31	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63
Feb 1 - Feb 15	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
Feb 16 - Feb 28	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31	2.31
Mar 1 - Mar 15	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
Mar 16 - Mar 31	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82
Apr 1 - Apr 15	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14	8.14
Apr 16 - Apr 30	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63
May 1 - May 15	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07	12.07
May 16 - May 31	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36	16.36
Jun 1 - Jun 15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15	18.15
Jun 16 - Jun 30	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47	18.47
Jul 1 - Jul 15	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30
Jul 16 - Jul 31	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50
Aug 1 - Aug 15	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30	21.30
Aug 16 - Aug 31	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68	21.68
Sep 1 - Sep 15	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80	20.80
Sep 16 - Sep 30	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19	19.19
Oct 1 - Oct 15	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39	17.39
Oct 16 - Oct 31	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19	14.19
Nov 1 - Nov 15	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85
Nov 16 - Nov 30	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06
Dec 1 - Dec 15	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04
Dec 16 - Dec 31	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59

River Mile 184 - Mid-point between Iron Gate Dam and Shasta River

Jan 1 - Jan 15	3.73	3.73	3.73	3.73	3.72	3.72	3.72	3.72	3.72	3.72	3.72
Jan 16 - Jan 31	2.71	2.70	2.69	2.69	2.69	2.68	2.68	2.68	2.67	2.67	2.67
Feb 1 - Feb 15	2.22	2.21	2.20	2.19	2.18	2.18	2.17	2.17	2.16	2.16	2.16
Feb 16 - Feb 28	2.64	2.61	2.59	2.57	2.55	2.54	2.52	2.51	2.50	2.49	2.48
Mar 1 - Mar 15	3.54	3.51	3.48	3.46	3.44	3.42	3.41	3.40	3.38	3.37	3.36
Mar 16 - Mar 31	6.38	6.33	6.29	6.25	6.22	6.20	6.17	6.15	6.13	6.12	6.10

Apr 1 - Apr 15	8.43	8.40	8.38	8.37	8.35	8.34	8.33	8.32	8.31	8.30	8.29
Apr 16 - Apr 30	9.25	9.19	9.15	9.11	9.07	9.04	9.02	8.99	8.97	8.96	8.94
May 1 - May 15	12.76	12.70	12.65	12.60	12.57	12.54	12.51	12.48	12.46	12.44	12.42
May 16 - May 31	17.02	16.96	16.91	16.87	16.83	16.80	16.78	16.75	16.73	16.71	16.69
Jun 1 - Jun 15	18.49	18.46	18.43	18.41	18.40	18.38	18.37	18.35	18.34	18.33	18.32
Jun 16 - Jun 30	18.92	18.88	18.85	18.82	18.80	18.78	18.76	18.74	18.73	18.72	18.70
Jul 1 - Jul 15	19.94	19.88	19.84	19.80	19.76	19.73	19.71	19.68	19.66	19.64	19.63
Jul 16 - Jul 31	20.94	20.90	20.87	20.84	20.82	20.80	20.78	20.76	20.75	20.74	20.73
Aug 1 - Aug 15	21.76	21.72	21.69	21.66	21.64	21.62	21.60	21.58	21.57	21.55	21.54
Aug 16 - Aug 31	22.00	21.97	21.95	21.93	21.91	21.90	21.89	21.87	21.86	21.86	21.85
Sep 1 - Sep 15	20.99	20.98	20.96	20.95	20.94	20.94	20.93	20.92	20.92	20.91	20.91
Sep 16 - Sep 30	19.34	19.32	19.31	19.31	19.30	19.29	19.29	19.28	19.28	19.27	19.27
Oct 1 - Oct 15	17.50	17.49	17.48	17.48	17.47	17.47	17.46	17.46	17.46	17.45	17.45
Oct 16 - Oct 31	14.23	14.23	14.23	14.22	14.22	14.22	14.22	14.22	14.22	14.22	14.22
Nov 1 - Nov 15	10.89	10.89	10.89	10.89	10.89	10.88	10.88	10.88	10.88	10.88	10.88
Nov 16 - Nov 30	7.98	7.99	8.00	8.01	8.01	8.02	8.02	8.02	8.03	8.03	8.03
Dec 1 - Dec 15	4.99	5.00	5.00	5.01	5.01	5.01	5.02	5.02	5.02	5.02	5.02
Dec 16 - Dec 31	2.74	2.73	2.72	2.71	2.70	2.70	2.69	2.69	2.68	2.68	2.67

River Mile 160 - Mid-point between Shasta River and Scott River

Jan 1 - Jan 15	3.83	3.83	3.82	3.81	3.81	3.80	3.80	3.80	3.79	3.79	3.79
Jan 16 - Jan 31	2.96	2.94	2.92	2.90	2.89	2.87	2.86	2.85	2.84	2.83	2.82
Feb 1 - Feb 15	2.71	2.67	2.63	2.59	2.56	2.53	2.51	2.49	2.47	2.45	2.44
Feb 16 - Feb 28	3.62	3.52	3.44	3.37	3.30	3.25	3.20	3.15	3.11	3.08	3.04
Mar 1 - Mar 15	4.63	4.52	4.42	4.34	4.27	4.21	4.15	4.10	4.05	4.01	3.97
Mar 16 - Mar 31	7.95	7.78	7.65	7.52	7.42	7.32	7.24	7.17	7.10	7.04	6.98
Apr 1 - Apr 15	9.05	8.99	8.93	8.89	8.84	8.81	8.77	8.74	8.72	8.69	8.67
Apr 16 - Apr 30	10.65	10.50	10.36	10.25	10.14	10.05	9.97	9.90	9.84	9.78	9.72
May 1 - May 15	14.06	13.91	13.77	13.66	13.56	13.47	13.40	13.33	13.26	13.21	13.15
May 16 - May 31	18.24	18.10	17.97	17.87	17.77	17.69	17.61	17.55	17.49	17.43	17.38
Jun 1 - Jun 15	19.18	19.10	19.04	18.98	18.93	18.89	18.85	18.81	18.78	18.75	18.72
Jun 16 - Jun 30	19.94	19.83	19.73	19.65	19.58	19.52	19.46	19.41	19.36	19.32	19.29
Jul 1 - Jul 15	21.48	21.31	21.17	21.05	20.94	20.84	20.75	20.68	20.61	20.55	20.49
Jul 16 - Jul 31	22.00	21.88	21.78	21.70	21.62	21.56	21.50	21.45	21.40	21.36	21.32

Aug 1 - Aug 15	22.88	22.76	22.66	22.57	22.49	22.42	22.36	22.30	22.25	22.21	22.17
Aug 16 - Aug 31	22.76	22.68	22.61	22.55	22.50	22.45	22.41	22.37	22.34	22.31	22.28
Sep 1 - Sep 15	21.42	21.38	21.34	21.31	21.28	21.25	21.23	21.21	21.19	21.17	21.16
Sep 16 - Sep 30	19.62	19.59	19.57	19.55	19.53	19.51	19.49	19.48	19.47	19.46	19.45
Oct 1 - Oct 15	17.61	17.59	17.58	17.57	17.56	17.56	17.55	17.54	17.54	17.53	17.53
Oct 16 - Oct 31	14.14	14.15	14.16	14.17	14.18	14.19	14.19	14.20	14.20	14.20	14.21
Nov 1 - Nov 15	10.85	10.86	10.86	10.86	10.87	10.87	10.87	10.88	10.88	10.88	10.88
Nov 16 - Nov 30	7.76	7.79	7.81	7.83	7.85	7.86	7.88	7.89	7.90	7.91	7.92
Dec 1 - Dec 15	4.93	4.95	4.96	4.97	4.98	4.98	4.99	5.00	5.00	5.00	5.01
Dec 16 - Dec 31	3.15	3.12	3.08	3.06	3.03	3.01	2.99	2.97	2.96	2.94	2.93

River Mile 136 - Mid-point between Scott River and Seiad Valley

Jan 1 - Jan 15	3.97	3.96	3.94	3.93	3.92	3.91	3.90	3.89	3.88	3.88	3.87
Jan 16 - Jan 31	3.22	3.18	3.15	3.12	3.10	3.08	3.06	3.04	3.02	3.00	2.99
Feb 1 - Feb 15	3.21	3.14	3.07	3.02	2.97	2.92	2.88	2.84	2.81	2.78	2.75
Feb 16 - Feb 28	4.45	4.31	4.19	4.08	3.99	3.90	3.82	3.75	3.69	3.63	3.58
Mar 1 - Mar 15	5.69	5.53	5.38	5.26	5.14	5.04	4.95	4.86	4.79	4.72	4.65
Mar 16 - Mar 31	9.74	9.52	9.32	9.14	8.98	8.83	8.69	8.57	8.46	8.35	8.25
Apr 1 - Apr 15	9.82	9.72	9.63	9.56	9.49	9.42	9.36	9.31	9.26	9.22	9.18
Apr 16 - Apr 30	12.10	11.88	11.70	11.53	11.38	11.24	11.11	11.00	10.90	10.80	10.71
May 1 - May 15	15.57	15.37	15.19	15.02	14.87	14.74	14.61	14.50	14.40	14.30	14.21
May 16 - May 31	19.12	18.96	18.82	18.69	18.58	18.47	18.37	18.28	18.20	18.13	18.06
Jun 1 - Jun 15	19.82	19.71	19.62	19.54	19.47	19.40	19.34	19.29	19.24	19.19	19.15
Jun 16 - Jun 30	20.87	20.72	20.58	20.46	20.35	20.25	20.17	20.09	20.01	19.95	19.89
Jul 1 - Jul 15	22.92	22.67	22.46	22.27	22.10	21.95	21.81	21.69	21.58	21.48	21.38
Jul 16 - Jul 31	23.01	22.84	22.69	22.56	22.44	22.34	22.25	22.16	22.08	22.01	21.95
Aug 1 - Aug 15	23.85	23.69	23.54	23.41	23.29	23.18	23.09	23.00	22.92	22.85	22.78
Aug 16 - Aug 31	23.41	23.30	23.20	23.12	23.04	22.97	22.91	22.85	22.80	22.75	22.71
Sep 1 - Sep 15	21.91	21.84	21.78	21.73	21.68	21.64	21.60	21.56	21.53	21.50	21.47
Sep 16 - Sep 30	20.05	20.00	19.95	19.91	19.87	19.84	19.81	19.78	19.76	19.74	19.72
Oct 1 - Oct 15	17.92	17.89	17.87	17.84	17.82	17.80	17.79	17.77	17.76	17.74	17.73
Oct 16 - Oct 31	14.24	14.25	14.26	14.27	14.27	14.28	14.28	14.28	14.29	14.29	14.29
Nov 1 - Nov 15	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97	10.97
Nov 16 - Nov 30	7.70	7.73	7.76	7.78	7.81	7.82	7.84	7.86	7.87	7.88	7.90

Dec 1 - Dec 15	5.07	5.08	5.08	5.09	5.09	5.10	5.10	5.10	5.11	5.11	5.11
Dec 16 - Dec 31	3.85	3.79	3.73	3.68	3.63	3.59	3.55	3.52	3.48	3.45	3.42

River Mile 97 - Mid-point between Seiad Valley and Salmon River

Jan 1 - Jan 15	4.17	4.15	4.13	4.11	4.09	4.07	4.06	4.05	4.04	4.02	4.01
Jan 16 - Jan 31	3.60	3.55	3.51	3.47	3.43	3.40	3.37	3.34	3.31	3.29	3.26
Feb 1 - Feb 15	3.85	3.75	3.67	3.59	3.52	3.46	3.40	3.35	3.30	3.25	3.21
Feb 16 - Feb 28	5.24	5.09	4.96	4.83	4.72	4.62	4.52	4.43	4.35	4.28	4.21
Mar 1 - Mar 15	6.50	6.34	6.18	6.05	5.92	5.80	5.69	5.59	5.50	5.42	5.34
Mar 16 - Mar 31	10.20	10.01	9.83	9.66	9.51	9.37	9.24	9.11	9.00	8.89	8.79
Apr 1 - Apr 15	10.00	9.92	9.85	9.78	9.72	9.66	9.61	9.56	9.52	9.47	9.43
Apr 16 - Apr 30	12.32	12.16	12.01	11.88	11.75	11.63	11.52	11.41	11.32	11.23	11.14
May 1 - May 15	14.94	14.86	14.78	14.70	14.63	14.55	14.48	14.41	14.34	14.28	14.21
May 16 - May 31	18.10	18.06	18.02	17.98	17.94	17.90	17.86	17.82	17.79	17.75	17.72
Jun 1 - Jun 15	19.64	19.60	19.56	19.52	19.47	19.43	19.39	19.35	19.32	19.28	19.25
Jun 16 - Jun 30	21.84	21.67	21.52	21.38	21.25	21.12	21.01	20.91	20.82	20.73	20.65
Jul 1 - Jul 15	24.48	24.21	23.96	23.73	23.52	23.32	23.15	22.98	22.83	22.70	22.57
Jul 16 - Jul 31	24.12	23.93	23.76	23.60	23.45	23.31	23.19	23.08	22.97	22.87	22.78
Aug 1 - Aug 15	24.81	24.63	24.46	24.31	24.17	24.04	23.92	23.81	23.70	23.61	23.52
Aug 16 - Aug 31	23.92	23.82	23.73	23.64	23.55	23.48	23.40	23.34	23.28	23.22	23.17
Sep 1 - Sep 15	22.45	22.37	22.30	22.23	22.16	22.11	22.05	22.00	21.96	21.92	21.88
Sep 16 - Sep 30	20.59	20.52	20.46	20.40	20.34	20.29	20.25	20.20	20.17	20.13	20.10
Oct 1 - Oct 15	18.29	18.25	18.21	18.18	18.14	18.11	18.09	18.06	18.04	18.02	18.00
Oct 16 - Oct 31	13.97	14.01	14.04	14.07	14.09	14.11	14.13	14.15	14.16	14.17	14.19
Nov 1 - Nov 15	10.31	10.36	10.41	10.45	10.48	10.51	10.54	10.56	10.58	10.61	10.62
Nov 16 - Nov 30	7.11	7.15	7.20	7.24	7.28	7.31	7.35	7.38	7.40	7.43	7.45
Dec 1 - Dec 15	4.95	4.96	4.98	4.99	4.99	5.00	5.01	5.02	5.02	5.03	5.04
Dec 16 - Dec 31	4.56	4.51	4.47	4.43	4.39	4.35	4.32	4.28	4.25	4.22	4.18

River Mile 55 - Mid-point between Salmon River and Trinity River

Jan 1 - Jan 15	4.46	4.43	4.41	4.38	4.36	4.34	4.32	4.30	4.28	4.27	4.25
Jan 16 - Jan 31	4.02	3.96	3.91	3.86	3.82	3.78	3.74	3.71	3.68	3.65	3.62
Feb 1 - Feb 15	4.48	4.38	4.29	4.21	4.13	4.06	3.99	3.93	3.87	3.82	3.77
Feb 16 - Feb 28	5.91	5.77	5.65	5.53	5.42	5.32	5.22	5.13	5.05	4.97	4.89

Mar 1 - Mar 15	7.18	7.04	6.91	6.78	6.67	6.56	6.45	6.35	6.26	6.17	6.09
Mar 16 - Mar 31	10.64	10.49	10.36	10.23	10.11	10.00	9.89	9.78	9.68	9.59	9.50
Apr 1 - Apr 15	10.24	10.19	10.13	10.08	10.03	9.99	9.94	9.90	9.86	9.82	9.78
Apr 16 - Apr 30	12.65	12.55	12.45	12.35	12.26	12.17	12.08	11.99	11.91	11.84	11.76
May 1 - May 15	14.80	14.77	14.73	14.69	14.65	14.61	14.57	14.53	14.49	14.45	14.41
May 16 - May 31	17.62	17.61	17.61	17.60	17.59	17.58	17.56	17.55	17.54	17.52	17.51
Jun 1 - Jun 15	19.19	19.20	19.20	19.20	19.20	19.19	19.18	19.17	19.16	19.14	19.13
Jun 16 - Jun 30	21.93	21.83	21.74	21.64	21.55	21.46	21.37	21.29	21.21	21.14	21.07
Jul 1 - Jul 15	25.10	24.91	24.72	24.54	24.37	24.20	24.04	23.89	23.75	23.62	23.49
Jul 16 - Jul 31	24.61	24.48	24.35	24.21	24.09	23.96	23.85	23.74	23.64	23.54	23.45
Aug 1 - Aug 15	25.21	25.08	24.95	24.83	24.71	24.59	24.48	24.38	24.28	24.19	24.10
Aug 16 - Aug 31	23.96	23.91	23.86	23.80	23.74	23.68	23.62	23.57	23.52	23.47	23.42
Sep 1 - Sep 15	22.62	22.56	22.51	22.46	22.40	22.35	22.31	22.26	22.22	22.18	22.14
Sep 16 - Sep 30	20.76	20.71	20.66	20.61	20.57	20.53	20.48	20.45	20.41	20.38	20.34
Oct 1 - Oct 15	18.25	18.24	18.22	18.20	18.18	18.17	18.15	18.13	18.12	18.10	18.09
Oct 16 - Oct 31	13.80	13.84	13.88	13.92	13.95	13.98	14.00	14.03	14.05	14.06	14.08
Nov 1 - Nov 15	10.27	10.30	10.34	10.37	10.40	10.43	10.45	10.48	10.50	10.52	10.54
Nov 16 - Nov 30	7.38	7.40	7.42	7.44	7.46	7.48	7.50	7.51	7.53	7.55	7.56
Dec 1 - Dec 15	5.44	5.43	5.43	5.43	5.43	5.43	5.43	5.42	5.42	5.42	5.42
Dec 16 - Dec 31	5.28	5.24	5.21	5.18	5.14	5.11	5.08	5.05	5.02	4.99	4.96

River Mile 24 - Mid-point between Trinity River and Pacific Ocean

Jan 1 - Jan 15	5.10	5.06	5.03	5.00	4.97	4.94	4.91	4.89	4.86	4.84	4.82
Jan 16 - Jan 31	4.76	4.70	4.65	4.60	4.56	4.51	4.47	4.43	4.39	4.35	4.32
Feb 1 - Feb 15	5.31	5.23	5.16	5.09	5.02	4.96	4.90	4.84	4.78	4.72	4.67
Feb 16 - Feb 28	6.66	6.58	6.51	6.43	6.36	6.29	6.22	6.16	6.09	6.03	5.97
Mar 1 - Mar 15	7.72	7.65	7.58	7.51	7.45	7.38	7.32	7.26	7.20	7.14	7.09
Mar 16 - Mar 31	10.83	10.75	10.67	10.60	10.53	10.46	10.40	10.33	10.27	10.21	10.15
Apr 1 - Apr 15	10.26	10.23	10.20	10.17	10.14	10.11	10.09	10.06	10.03	10.00	9.98
Apr 16 - Apr 30	12.63	12.57	12.52	12.47	12.41	12.36	12.31	12.26	12.20	12.15	12.11
May 1 - May 15	14.47	14.46	14.45	14.44	14.42	14.41	14.39	14.38	14.36	14.34	14.32
May 16 - May 31	16.95	16.96	16.97	16.97	16.98	16.98	16.98	16.98	16.98	16.98	16.98
Jun 1 - Jun 15	18.30	18.32	18.35	18.37	18.39	18.40	18.42	18.43	18.44	18.45	18.46
Jun 16 - Jun 30	21.10	21.08	21.05	21.03	20.99	20.96	20.93	20.89	20.86	20.82	20.78

Jul 1 - Jul 15	24.59	24.51	24.43	24.34	24.25	24.16	24.07	23.98	23.89	23.80	23.71
Jul 16 - Jul 31	24.19	24.14	24.08	24.02	23.95	23.89	23.82	23.76	23.69	23.63	23.56
Aug 1 - Aug 15	24.78	24.73	24.67	24.61	24.55	24.49	24.43	24.36	24.30	24.24	24.18
Aug 16 - Aug 31	23.19	23.19	23.19	23.18	23.18	23.17	23.15	23.14	23.12	23.11	23.09
Sep 1 - Sep 15	22.02	22.02	22.02	22.01	22.00	21.99	21.98	21.96	21.95	21.93	21.92
Sep 16 - Sep 30	20.23	20.23	20.22	20.21	20.20	20.19	20.18	20.16	20.15	20.14	20.13
Oct 1 - Oct 15	17.62	17.64	17.66	17.67	17.69	17.70	17.70	17.71	17.72	17.72	17.73
Oct 16 - Oct 31	13.63	13.67	13.70	13.73	13.76	13.79	13.82	13.84	13.86	13.89	13.91
Nov 1 - Nov 15	10.80	10.80	10.81	10.81	10.81	10.82	10.82	10.83	10.84	10.84	10.85
Nov 16 - Nov 30	8.20	8.20	8.20	8.19	8.19	8.19	8.19	8.19	8.19	8.19	8.19
Dec 1 - Dec 15	6.52	6.51	6.50	6.49	6.48	6.48	6.47	6.46	6.45	6.44	6.43
Dec 16 - Dec 31	6.66	6.64	6.61	6.59	6.56	6.54	6.51	6.49	6.46	6.44	6.42

Table 3-C-2. Daily Average Water Temperature Output Table for 2004 Meteorological and Tributary Conditions

	Flow, cfs											
	600	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**	**1800**
River Mile 191 - Immediately downstream of Iron Gate Dam												
Jan 1 - Jan 15	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
Jan 16 - Jan 31	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
Feb 1 - Feb 15	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23
Feb 16 - Feb 28	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76
Mar 1 - Mar 15	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99
Mar 16 - Mar 31	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11
Apr 1 - Apr 15	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60
Apr 16 - Apr 30	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49
May 1 - May 15	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48
May 16 - May 31	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84
Jun 1 - Jun 15	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08
Jun 16 - Jun 30	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38
Jul 1 - Jul 15	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36
Jul 16 - Jul 31	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71
Aug 1 - Aug 15	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79
Aug 16 - Aug 31	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60
Sep 1 - Sep 15	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70
Sep 16 - Sep 30	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83
Oct 1 - Oct 15	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53
Oct 16 - Oct 31	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63
Nov 1 - Nov 15	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12
Nov 16 - Nov 30	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63
Dec 1 - Dec 15	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06
Dec 16 - Dec 31	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57
River Mile 184 - Mid-point between Iron Gate Dam and Shasta River												
Jan 1 - Jan 15	3.76	3.72	3.68	3.65	3.63	3.60	3.59	3.57	3.56	3.55	3.54	3.52

Jan 16 - Jan 31	3.26	3.18	3.11	3.06	3.01	2.97	2.94	2.92	2.89	2.87	2.85	2.82
Feb 1 - Feb 15	3.12	3.02	2.93	2.86	2.81	2.76	2.72	2.69	2.66	2.63	2.61	2.57
Feb 16 - Feb 28	3.93	3.80	3.70	3.62	3.55	3.49	3.44	3.40	3.36	3.33	3.29	3.24
Mar 1 - Mar 15	6.21	5.97	5.78	5.61	5.48	5.37	5.27	5.18	5.11	5.04	4.99	4.89
Mar 16 - Mar 31	9.16	8.94	8.76	8.61	8.49	8.38	8.29	8.22	8.15	8.09	8.03	7.94
Apr 1 - Apr 15	11.36	11.16	11.01	10.88	10.78	10.69	10.61	10.54	10.48	10.43	10.39	10.31
Apr 16 - Apr 30	12.25	12.06	11.91	11.78	11.67	11.58	11.50	11.44	11.38	11.33	11.28	11.20
May 1 - May 15	15.04	14.87	14.73	14.61	14.52	14.44	14.37	14.31	14.26	14.21	14.17	14.10
May 16 - May 31	16.27	16.11	15.98	15.88	15.79	15.72	15.65	15.60	15.55	15.51	15.47	15.41
Jun 1 - Jun 15	17.57	17.40	17.26	17.15	17.06	16.98	16.91	16.86	16.81	16.76	16.73	16.66
Jun 16 - Jun 30	19.20	18.98	18.81	18.67	18.56	18.46	18.38	18.31	18.25	18.20	18.15	18.07
Jul 1 - Jul 15	20.60	20.45	20.34	20.24	20.16	20.10	20.04	19.99	19.95	19.92	19.88	19.83
Jul 16 - Jul 31	21.91	21.77	21.66	21.56	21.49	21.43	21.37	21.33	21.29	21.25	21.22	21.17
Aug 1 - Aug 15	21.72	21.61	21.52	21.45	21.40	21.35	21.31	21.27	21.24	21.21	21.19	21.15
Aug 16 - Aug 31	21.28	21.20	21.14	21.08	21.04	21.01	20.98	20.95	20.93	20.91	20.89	20.86
Sep 1 - Sep 15	19.99	19.96	19.94	19.91	19.90	19.88	19.87	19.86	19.85	19.84	19.83	19.82
Sep 16 - Sep 30	18.07	18.05	18.03	18.01	17.99	17.98	17.97	17.96	17.96	17.95	17.94	17.93
Oct 1 - Oct 15	16.94	16.89	16.85	16.82	16.80	16.78	16.76	16.74	16.73	16.72	16.71	16.69
Oct 16 - Oct 31	13.30	13.35	13.39	13.42	13.44	13.46	13.48	13.49	13.50	13.51	13.52	13.54
Nov 1 - Nov 15	10.05	10.06	10.07	10.08	10.09	10.09	10.10	10.10	10.11	10.11	10.11	10.11
Nov 16 - Nov 30	7.48	7.50	7.52	7.53	7.54	7.55	7.56	7.57	7.57	7.58	7.58	7.59
Dec 1 - Dec 15	5.28	5.26	5.24	5.23	5.22	5.21	5.20	5.19	5.18	5.18	5.17	5.16
Dec 16 - Dec 31	3.65	3.65	3.64	3.63	3.63	3.62	3.62	3.62	3.62	3.61	3.61	3.61

River Mile 160 - Mid-point between Shasta River and Scott River

Jan 1 - Jan 15	4.11	4.06	4.02	3.98	3.95	3.92	3.89	3.87	3.85	3.83	3.81	3.78
Jan 16 - Jan 31	3.98	3.87	3.78	3.70	3.63	3.57	3.51	3.47	3.42	3.38	3.34	3.28
Feb 1 - Feb 15	4.41	4.24	4.10	3.98	3.87	3.78	3.69	3.62	3.55	3.48	3.43	3.33
Feb 16 - Feb 28	5.49	5.34	5.20	5.08	4.97	4.87	4.77	4.69	4.62	4.55	4.48	4.36
Mar 1 - Mar 15	7.90	7.66	7.44	7.25	7.08	6.92	6.78	6.66	6.54	6.44	6.34	6.17
Mar 16 - Mar 31	10.73	10.49	10.29	10.11	9.94	9.80	9.67	9.55	9.44	9.34	9.25	9.08
Apr 1 - Apr 15	12.24	12.05	11.89	11.75	11.63	11.51	11.41	11.33	11.24	11.17	11.10	10.98
Apr 16 - Apr 30	13.50	13.30	13.12	12.96	12.82	12.69	12.58	12.48	12.39	12.31	12.23	12.09

May 1 - May 15	16.26	16.06	15.89	15.74	15.61	15.49	15.38	15.28	15.20	15.12	15.05	14.92
May 16 - May 31	17.79	17.59	17.41	17.25	17.12	16.99	16.88	16.78	16.69	16.61	16.53	16.40
Jun 1 - Jun 15	19.14	18.92	18.73	18.55	18.40	18.27	18.15	18.04	17.95	17.86	17.78	17.64
Jun 16 - Jun 30	21.48	21.17	20.89	20.65	20.44	20.25	20.08	19.94	19.80	19.68	19.57	19.38
Jul 1 - Jul 15	22.48	22.23	22.02	21.83	21.67	21.52	21.39	21.27	21.17	21.08	20.99	20.85
Jul 16 - Jul 31	23.81	23.56	23.35	23.16	22.99	22.85	22.72	22.61	22.51	22.41	22.33	22.19
Aug 1 - Aug 15	23.32	23.12	22.94	22.78	22.65	22.53	22.42	22.33	22.25	22.17	22.10	21.99
Aug 16 - Aug 31	22.47	22.32	22.19	22.08	21.98	21.89	21.82	21.75	21.69	21.63	21.58	21.50
Sep 1 - Sep 15	20.46	20.41	20.36	20.31	20.27	20.24	20.21	20.18	20.16	20.13	20.12	20.08
Sep 16 - Sep 30	18.35	18.32	18.29	18.26	18.24	18.22	18.20	18.18	18.17	18.15	18.14	18.12
Oct 1 - Oct 15	17.27	17.22	17.17	17.13	17.09	17.06	17.03	17.00	16.98	16.96	16.94	16.91
Oct 16 - Oct 31	12.45	12.56	12.66	12.74	12.81	12.87	12.92	12.97	13.01	13.05	13.08	13.14
Nov 1 - Nov 15	9.64	9.69	9.74	9.78	9.81	9.84	9.86	9.88	9.90	9.92	9.93	9.95
Nov 16 - Nov 30	6.98	7.05	7.10	7.15	7.19	7.22	7.25	7.28	7.30	7.32	7.34	7.37
Dec 1 - Dec 15	5.35	5.35	5.35	5.34	5.34	5.33	5.33	5.32	5.32	5.31	5.31	5.30
Dec 16 - Dec 31	3.84	3.82	3.80	3.79	3.78	3.77	3.76	3.75	3.74	3.73	3.73	3.72

River Mile 136 - Mid-point between Scott River and Seiad Valley

Jan 1 - Jan 15	4.89	4.83	4.78	4.73	4.68	4.64	4.60	4.56	4.53	4.50	4.46	4.41
Jan 16 - Jan 31	4.98	4.88	4.79	4.71	4.63	4.56	4.49	4.42	4.36	4.31	4.25	4.16
Feb 1 - Feb 15	5.67	5.52	5.39	5.27	5.15	5.04	4.94	4.85	4.76	4.68	4.60	4.46
Feb 16 - Feb 28	6.94	6.83	6.73	6.64	6.55	6.46	6.38	6.30	6.23	6.16	6.10	5.98
Mar 1 - Mar 15	9.02	8.88	8.74	8.61	8.49	8.37	8.26	8.16	8.06	7.96	7.87	7.70
Mar 16 - Mar 31	10.87	10.77	10.68	10.59	10.51	10.43	10.35	10.28	10.21	10.14	10.07	9.95
Apr 1 - Apr 15	11.71	11.66	11.61	11.56	11.51	11.46	11.42	11.37	11.33	11.29	11.25	11.18
Apr 16 - Apr 30	12.65	12.60	12.56	12.51	12.46	12.41	12.37	12.33	12.29	12.25	12.21	12.13
May 1 - May 15	14.50	14.48	14.46	14.45	14.43	14.41	14.39	14.38	14.36	14.34	14.32	14.29
May 16 - May 31	16.15	16.14	16.13	16.11	16.09	16.07	16.05	16.03	16.00	15.98	15.96	15.92
Jun 1 - Jun 15	18.14	18.11	18.06	18.02	17.98	17.94	17.89	17.85	17.81	17.77	17.73	17.66
Jun 16 - Jun 30	21.54	21.41	21.28	21.15	21.02	20.90	20.78	20.67	20.57	20.47	20.38	20.20
Jul 1 - Jul 15	22.91	22.76	22.62	22.49	22.36	22.25	22.14	22.04	21.94	21.85	21.77	21.61
Jul 16 - Jul 31	24.64	24.46	24.28	24.12	23.96	23.82	23.69	23.57	23.46	23.36	23.26	23.09
Aug 1 - Aug 15	24.05	23.90	23.75	23.60	23.47	23.35	23.24	23.14	23.05	22.96	22.88	22.73

Aug 16 - Aug 31	23.22	23.08	22.95	22.83	22.72	22.62	22.53	22.45	22.38	22.31	22.24	22.13
Sep 1 - Sep 15	20.74	20.69	20.64	20.60	20.56	20.52	20.49	20.46	20.43	20.41	20.39	20.35
Sep 16 - Sep 30	18.64	18.61	18.57	18.54	18.52	18.49	18.47	18.45	18.43	18.41	18.39	18.36
Oct 1 - Oct 15	17.73	17.66	17.60	17.54	17.49	17.45	17.40	17.37	17.34	17.31	17.28	17.23
Oct 16 - Oct 31	12.50	12.58	12.65	12.71	12.76	12.82	12.86	12.91	12.95	12.98	13.02	13.08
Nov 1 - Nov 15	9.73	9.76	9.79	9.82	9.85	9.87	9.89	9.91	9.93	9.95	9.96	9.99
Nov 16 - Nov 30	7.10	7.14	7.17	7.20	7.23	7.25	7.28	7.30	7.32	7.34	7.35	7.38
Dec 1 - Dec 15	5.60	5.61	5.62	5.62	5.62	5.62	5.62	5.62	5.62	5.61	5.61	5.60
Dec 16 - Dec 31	4.45	4.41	4.37	4.33	4.30	4.27	4.25	4.22	4.20	4.18	4.16	4.12

River Mile 97 - Mid-point between Seiad Valley and Salmon River

Jan 1 - Jan 15	5.44	5.42	5.39	5.37	5.34	5.32	5.30	5.28	5.25	5.23	5.21	5.17
Jan 16 - Jan 31	5.85	5.81	5.78	5.74	5.70	5.67	5.63	5.60	5.56	5.53	5.49	5.43
Feb 1 - Feb 15	6.36	6.30	6.23	6.17	6.11	6.05	5.99	5.93	5.87	5.81	5.76	5.65
Feb 16 - Feb 28	6.94	6.88	6.81	6.75	6.69	6.63	6.58	6.53	6.48	6.43	6.38	6.29
Mar 1 - Mar 15	8.59	8.53	8.47	8.42	8.36	8.31	8.25	8.20	8.15	8.10	8.06	7.96
Mar 16 - Mar 31	9.64	9.61	9.59	9.56	9.53	9.51	9.48	9.46	9.43	9.41	9.38	9.33
Apr 1 - Apr 15	10.45	10.45	10.44	10.44	10.43	10.43	10.42	10.41	10.41	10.40	10.39	10.38
Apr 16 - Apr 30	11.59	11.59	11.58	11.58	11.57	11.56	11.55	11.55	11.54	11.53	11.52	11.50
May 1 - May 15	13.65	13.65	13.66	13.67	13.67	13.67	13.67	13.67	13.67	13.67	13.67	13.67
May 16 - May 31	15.48	15.50	15.50	15.51	15.52	15.52	15.52	15.52	15.52	15.51	15.51	15.50
Jun 1 - Jun 15	17.61	17.62	17.62	17.62	17.61	17.60	17.59	17.58	17.57	17.55	17.54	17.51
Jun 16 - Jun 30	20.92	20.90	20.87	20.84	20.81	20.77	20.73	20.68	20.63	20.59	20.53	20.43
Jul 1 - Jul 15	22.24	22.24	22.23	22.21	22.18	22.15	22.11	22.08	22.04	22.00	21.95	21.86
Jul 16 - Jul 31	24.05	24.06	24.05	24.02	23.98	23.93	23.88	23.83	23.77	23.72	23.66	23.55
Aug 1 - Aug 15	23.47	23.50	23.51	23.49	23.47	23.43	23.39	23.35	23.31	23.26	23.22	23.13
Aug 16 - Aug 31	22.74	22.77	22.77	22.76	22.74	22.71	22.68	22.64	22.61	22.57	22.54	22.47
Sep 1 - Sep 15	20.10	20.16	20.21	20.23	20.25	20.26	20.27	20.28	20.28	20.29	20.29	20.28
Sep 16 - Sep 30	17.90	17.96	18.01	18.04	18.07	18.09	18.11	18.13	18.14	18.15	18.16	18.18
Oct 1 - Oct 15	17.03	17.07	17.09	17.11	17.12	17.13	17.13	17.13	17.13	17.12	17.12	17.11
Oct 16 - Oct 31	12.13	12.21	12.28	12.35	12.41	12.47	12.52	12.57	12.62	12.66	12.70	12.78
Nov 1 - Nov 15	9.50	9.54	9.58	9.62	9.65	9.68	9.71	9.74	9.76	9.79	9.81	9.85
Nov 16 - Nov 30	7.17	7.18	7.20	7.22	7.23	7.25	7.26	7.27	7.29	7.30	7.31	7.34

Dec 1 - Dec 15	5.87	5.86	5.84	5.83	5.82	5.81	5.80	5.80	5.79	5.78	5.78	5.77
Dec 16 - Dec 31	4.70	4.68	4.65	4.63	4.61	4.59	4.57	4.55	4.53	4.51	4.49	4.46

River Mile 55 - Mid-point between Salmon River and Trinity River

Jan 1 - Jan 15	5.58	5.56	5.55	5.54	5.53	5.51	5.50	5.49	5.48	5.46	5.45	5.43
Jan 16 - Jan 31	6.11	6.09	6.08	6.06	6.04	6.02	6.00	5.98	5.96	5.94	5.92	5.88
Feb 1 - Feb 15	6.67	6.64	6.60	6.57	6.53	6.50	6.46	6.43	6.39	6.36	6.33	6.26
Feb 16 - Feb 28	7.00	6.96	6.92	6.88	6.84	6.81	6.77	6.74	6.70	6.67	6.64	6.58
Mar 1 - Mar 15	8.18	8.15	8.12	8.09	8.06	8.04	8.01	7.98	7.96	7.93	7.91	7.86
Mar 16 - Mar 31	8.89	8.88	8.87	8.86	8.85	8.84	8.83	8.82	8.82	8.81	8.80	8.78
Apr 1 - Apr 15	9.74	9.74	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.76	9.76
Apr 16 - Apr 30	10.97	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.99	10.99	10.98	10.98
May 1 - May 15	12.85	12.86	12.87	12.88	12.89	12.89	12.90	12.91	12.92	12.92	12.93	12.94
May 16 - May 31	14.56	14.58	14.59	14.61	14.62	14.63	14.64	14.65	14.66	14.67	14.67	14.69
Jun 1 - Jun 15	16.73	16.75	16.77	16.78	16.79	16.80	16.81	16.81	16.82	16.82	16.82	16.83
Jun 16 - Jun 30	20.21	20.22	20.23	20.23	20.23	20.23	20.22	20.21	20.20	20.19	20.17	20.14
Jul 1 - Jul 15	21.91	21.92	21.93	21.94	21.94	21.93	21.93	21.92	21.91	21.90	21.88	21.84
Jul 16 - Jul 31	23.90	23.91	23.91	23.91	23.90	23.89	23.87	23.85	23.83	23.81	23.78	23.72
Aug 1 - Aug 15	23.41	23.43	23.44	23.45	23.45	23.44	23.43	23.41	23.40	23.38	23.36	23.31
Aug 16 - Aug 31	22.76	22.77	22.77	22.77	22.77	22.76	22.74	22.73	22.71	22.69	22.67	22.63
Sep 1 - Sep 15	20.18	20.21	20.24	20.26	20.27	20.28	20.29	20.29	20.30	20.30	20.31	20.31
Sep 16 - Sep 30	17.82	17.86	17.88	17.91	17.93	17.95	17.97	17.99	18.01	18.02	18.04	18.06
Oct 1 - Oct 15	16.96	16.99	17.01	17.02	17.03	17.04	17.05	17.06	17.06	17.07	17.07	17.07
Oct 16 - Oct 31	11.98	12.03	12.09	12.14	12.18	12.23	12.27	12.31	12.35	12.39	12.42	12.49
Nov 1 - Nov 15	9.19	9.22	9.26	9.30	9.33	9.36	9.40	9.43	9.46	9.48	9.51	9.56
Nov 16 - Nov 30	7.21	7.22	7.23	7.24	7.25	7.26	7.27	7.29	7.30	7.31	7.32	7.34
Dec 1 - Dec 15	6.11	6.10	6.08	6.07	6.06	6.05	6.04	6.03	6.03	6.02	6.02	6.01
Dec 16 - Dec 31	5.10	5.09	5.07	5.05	5.03	5.02	5.00	4.98	4.97	4.95	4.93	4.90

River Mile 24 - Mid-point between Trinity River and Pacific Ocean

Jan 1 - Jan 15	6.33	6.32	6.31	6.30	6.29	6.28	6.26	6.25	6.24	6.23	6.22	6.20
Jan 16 - Jan 31	6.94	6.93	6.92	6.90	6.89	6.88	6.87	6.86	6.85	6.84	6.82	6.80
Feb 1 - Feb 15	7.21	7.19	7.18	7.16	7.14	7.13	7.11	7.10	7.08	7.06	7.04	7.01

Feb 16 - Feb 28	7.62	7.59	7.57	7.54	7.52	7.50	7.47	7.45	7.43	7.41	7.39	7.35
Mar 1 - Mar 15	8.89	8.87	8.86	8.84	8.83	8.81	8.80	8.79	8.77	8.76	8.74	8.72
Mar 16 - Mar 31	9.65	9.64	9.63	9.63	9.62	9.61	9.60	9.59	9.59	9.58	9.57	9.55
Apr 1 - Apr 15	10.59	10.58	10.58	10.58	10.57	10.57	10.57	10.56	10.56	10.55	10.55	10.54
Apr 16 - Apr 30	11.61	11.61	11.60	11.60	11.60	11.59	11.59	11.59	11.58	11.58	11.58	11.57
May 1 - May 15	13.48	13.49	13.49	13.49	13.49	13.49	13.49	13.49	13.49	13.49	13.49	13.49
May 16 - May 31	14.32	14.33	14.34	14.35	14.36	14.37	14.38	14.38	14.39	14.40	14.40	14.42
Jun 1 - Jun 15	16.48	16.49	16.49	16.50	16.51	16.52	16.52	16.53	16.54	16.54	16.55	16.55
Jun 16 - Jun 30	19.75	19.76	19.77	19.78	19.78	19.78	19.78	19.78	19.78	19.78	19.77	19.77
Jul 1 - Jul 15	21.17	21.19	21.21	21.22	21.24	21.25	21.26	21.26	21.27	21.27	21.27	21.26
Jul 16 - Jul 31	23.94	23.94	23.94	23.94	23.94	23.93	23.92	23.91	23.90	23.89	23.87	23.83
Aug 1 - Aug 15	23.59	23.59	23.59	23.59	23.59	23.58	23.58	23.57	23.56	23.55	23.54	23.50
Aug 16 - Aug 31	22.60	22.61	22.62	22.62	22.62	22.62	22.62	22.62	22.61	22.60	22.60	22.58
Sep 1 - Sep 15	19.74	19.77	19.79	19.82	19.84	19.86	19.88	19.89	19.91	19.92	19.94	19.96
Sep 16 - Sep 30	17.99	18.00	18.01	18.02	18.03	18.04	18.05	18.05	18.06	18.07	18.08	18.09
Oct 1 - Oct 15	17.20	17.20	17.21	17.21	17.21	17.21	17.21	17.21	17.21	17.21	17.21	17.21
Oct 16 - Oct 31	12.35	12.38	12.40	12.43	12.46	12.48	12.50	12.53	12.56	12.58	12.60	12.65
Nov 1 - Nov 15	9.82	9.83	9.84	9.85	9.86	9.87	9.88	9.89	9.89	9.90	9.91	9.93
Nov 16 - Nov 30	8.06	8.05	8.04	8.03	8.02	8.01	8.00	7.99	7.99	7.98	7.97	7.96
Dec 1 - Dec 15	6.61	6.60	6.58	6.57	6.55	6.54	6.53	6.52	6.50	6.49	6.48	6.46
Dec 16 - Dec 31	5.88	5.86	5.84	5.82	5.81	5.79	5.77	5.75	5.74	5.72	5.70	5.67

	Flow, cfs										
	2000	**2200**	**2400**	**2600**	**2800**	**3000**	**3200**	**3400**	**3600**	**3800**	**4000**
River Mile 191 - Immediately downstream of Iron Gate Dam											
Jan 1 - Jan 15	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
Jan 16 - Jan 31	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
Feb 1 - Feb 15	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23
Feb 16 - Feb 28	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76
Mar 1 - Mar 15	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99
Mar 16 - Mar 31	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11
Apr 1 - Apr 15	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60

Apr 16 - Apr 30	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49	10.49
May 1 - May 15	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48	13.48
May 16 - May 31	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84	14.84
Jun 1 - Jun 15	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08
Jun 16 - Jun 30	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38	17.38
Jul 1 - Jul 15	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36
Jul 16 - Jul 31	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71	20.71
Aug 1 - Aug 15	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79	20.79
Aug 16 - Aug 31	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60	20.60
Sep 1 - Sep 15	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70
Sep 16 - Sep 30	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83	17.83
Oct 1 - Oct 15	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53	16.53
Oct 16 - Oct 31	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63
Nov 1 - Nov 15	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12
Nov 16 - Nov 30	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63
Dec 1 - Dec 15	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06
Dec 16 - Dec 31	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57	3.57

River Mile 184 - Mid-point between Iron Gate Dam and Shasta River

Jan 1 - Jan 15	3.50	3.49	3.48	3.47	3.46	3.46	3.45	3.45	3.44	3.44	3.43
Jan 16 - Jan 31	2.79	2.77	2.76	2.74	2.73	2.72	2.71	2.70	2.69	2.68	2.67
Feb 1 - Feb 15	2.54	2.51	2.49	2.47	2.45	2.44	2.43	2.41	2.40	2.40	2.39
Feb 16 - Feb 28	3.20	3.16	3.13	3.11	3.09	3.07	3.05	3.03	3.02	3.01	3.00
Mar 1 - Mar 15	4.81	4.74	4.68	4.63	4.59	4.55	4.52	4.49	4.46	4.44	4.42
Mar 16 - Mar 31	7.86	7.80	7.75	7.70	7.66	7.63	7.60	7.57	7.54	7.52	7.50
Apr 1 - Apr 15	10.24	10.19	10.14	10.11	10.07	10.04	10.02	9.99	9.97	9.95	9.94
Apr 16 - Apr 30	11.14	11.08	11.04	11.00	10.97	10.94	10.91	10.89	10.87	10.85	10.83
May 1 - May 15	14.04	14.00	13.96	13.92	13.89	13.87	13.84	13.82	13.80	13.79	13.77
May 16 - May 31	15.36	15.31	15.28	15.24	15.22	15.19	15.17	15.15	15.14	15.12	15.11
Jun 1 - Jun 15	16.61	16.56	16.53	16.49	16.47	16.44	16.42	16.40	16.38	16.37	16.35
Jun 16 - Jun 30	18.00	17.95	17.90	17.86	17.83	17.80	17.78	17.75	17.73	17.71	17.70
Jul 1 - Jul 15	19.79	19.75	19.72	19.69	19.67	19.65	19.63	19.62	19.60	19.59	19.58
Jul 16 - Jul 31	21.13	21.09	21.06	21.04	21.02	21.00	20.98	20.96	20.95	20.94	20.93

Aug 1 - Aug 15	21.12	21.09	21.07	21.05	21.03	21.01	21.00	20.99	20.98	20.97	20.96
Aug 16 - Aug 31	20.84	20.82	20.80	20.78	20.77	20.76	20.75	20.74	20.74	20.73	20.72
Sep 1 - Sep 15	19.81	19.80	19.79	19.79	19.78	19.77	19.77	19.77	19.76	19.76	19.76
Sep 16 - Sep 30	17.92	17.92	17.91	17.91	17.90	17.90	17.89	17.89	17.89	17.89	17.88
Oct 1 - Oct 15	16.68	16.66	16.65	16.65	16.64	16.63	16.63	16.62	16.62	16.61	16.61
Oct 16 - Oct 31	13.55	13.56	13.57	13.57	13.58	13.58	13.59	13.59	13.59	13.60	13.60
Nov 1 - Nov 15	10.12	10.12	10.12	10.12	10.12	10.12	10.13	10.13	10.13	10.13	10.13
Nov 16 - Nov 30	7.59	7.60	7.60	7.60	7.61	7.61	7.61	7.61	7.61	7.61	7.61
Dec 1 - Dec 15	5.15	5.15	5.14	5.14	5.13	5.13	5.12	5.12	5.12	5.12	5.11
Dec 16 - Dec 31	3.61	3.60	3.60	3.60	3.60	3.60	3.60	3.59	3.59	3.59	3.59

River Mile 160 - Mid-point between Shasta River and Scott River

Jan 1 - Jan 15	3.75	3.72	3.70	3.68	3.67	3.65	3.64	3.63	3.61	3.60	3.60
Jan 16 - Jan 31	3.22	3.18	3.14	3.10	3.07	3.04	3.02	2.99	2.97	2.96	2.94
Feb 1 - Feb 15	3.25	3.17	3.11	3.06	3.01	2.97	2.93	2.89	2.86	2.83	2.81
Feb 16 - Feb 28	4.26	4.17	4.10	4.03	3.96	3.91	3.85	3.81	3.76	3.72	3.69
Mar 1 - Mar 15	6.02	5.89	5.77	5.67	5.58	5.50	5.42	5.36	5.30	5.24	5.19
Mar 16 - Mar 31	8.94	8.82	8.72	8.62	8.54	8.46	8.40	8.34	8.28	8.23	8.18
Apr 1 - Apr 15	10.88	10.79	10.72	10.65	10.59	10.54	10.49	10.44	10.41	10.37	10.34
Apr 16 - Apr 30	11.98	11.88	11.79	11.72	11.65	11.59	11.53	11.48	11.44	11.40	11.36
May 1 - May 15	14.81	14.72	14.63	14.56	14.50	14.44	14.39	14.35	14.31	14.27	14.23
May 16 - May 31	16.28	16.19	16.10	16.02	15.96	15.90	15.84	15.80	15.75	15.71	15.68
Jun 1 - Jun 15	17.52	17.42	17.33	17.25	17.18	17.12	17.07	17.02	16.97	16.93	16.90
Jun 16 - Jun 30	19.22	19.09	18.97	18.87	18.78	18.70	18.62	18.56	18.50	18.45	18.40
Jul 1 - Jul 15	20.73	20.62	20.53	20.45	20.39	20.33	20.27	20.22	20.18	20.14	20.10
Jul 16 - Jul 31	22.07	21.97	21.88	21.81	21.74	21.69	21.63	21.59	21.55	21.51	21.47
Aug 1 - Aug 15	21.89	21.81	21.74	21.68	21.62	21.58	21.53	21.50	21.46	21.43	21.40
Aug 16 - Aug 31	21.43	21.36	21.31	21.27	21.23	21.19	21.16	21.13	21.11	21.09	21.06
Sep 1 - Sep 15	20.05	20.03	20.01	19.99	19.97	19.96	19.95	19.94	19.92	19.92	19.91
Sep 16 - Sep 30	18.10	18.09	18.07	18.06	18.05	18.04	18.03	18.03	18.02	18.01	18.01
Oct 1 - Oct 15	16.88	16.86	16.84	16.82	16.80	16.79	16.78	16.77	16.76	16.75	16.74
Oct 16 - Oct 31	13.19	13.23	13.26	13.29	13.32	13.34	13.36	13.38	13.40	13.41	13.43
Nov 1 - Nov 15	9.98	9.99	10.01	10.02	10.03	10.04	10.05	10.06	10.06	10.07	10.07

Nov 16 - Nov 30	7.40	7.42	7.44	7.46	7.47	7.48	7.49	7.50	7.51	7.52	7.53
Dec 1 - Dec 15	5.29	5.28	5.27	5.27	5.26	5.25	5.25	5.24	5.24	5.23	5.23
Dec 16 - Dec 31	3.71	3.70	3.69	3.69	3.68	3.68	3.67	3.67	3.66	3.66	3.66

River Mile 136 - Mid-point between Scott River and Seiad Valley

Jan 1 - Jan 15	4.35	4.31	4.27	4.23	4.19	4.16	4.13	4.10	4.08	4.05	4.03
Jan 16 - Jan 31	4.07	3.99	3.92	3.86	3.80	3.75	3.70	3.65	3.61	3.57	3.54
Feb 1 - Feb 15	4.33	4.22	4.12	4.02	3.94	3.87	3.80	3.73	3.67	3.62	3.57
Feb 16 - Feb 28	5.86	5.76	5.66	5.57	5.49	5.41	5.34	5.27	5.20	5.14	5.08
Mar 1 - Mar 15	7.55	7.40	7.27	7.15	7.04	6.93	6.83	6.74	6.66	6.58	6.50
Mar 16 - Mar 31	9.84	9.74	9.64	9.55	9.47	9.39	9.32	9.25	9.18	9.12	9.06
Apr 1 - Apr 15	11.11	11.05	11.00	10.94	10.89	10.85	10.80	10.76	10.73	10.69	10.66
Apr 16 - Apr 30	12.07	12.00	11.95	11.89	11.84	11.79	11.75	11.71	11.67	11.63	11.60
May 1 - May 15	14.26	14.23	14.20	14.17	14.14	14.12	14.10	14.08	14.06	14.04	14.02
May 16 - May 31	15.88	15.84	15.80	15.76	15.73	15.70	15.67	15.64	15.62	15.59	15.57
Jun 1 - Jun 15	17.59	17.52	17.46	17.40	17.35	17.30	17.25	17.21	17.17	17.13	17.09
Jun 16 - Jun 30	20.04	19.89	19.76	19.64	19.53	19.43	19.34	19.25	19.18	19.10	19.04
Jul 1 - Jul 15	21.47	21.35	21.23	21.13	21.04	20.95	20.87	20.80	20.74	20.68	20.63
Jul 16 - Jul 31	22.93	22.80	22.68	22.57	22.47	22.39	22.31	22.23	22.17	22.11	22.05
Aug 1 - Aug 15	22.60	22.49	22.39	22.30	22.22	22.14	22.08	22.01	21.96	21.91	21.86
Aug 16 - Aug 31	22.03	21.94	21.87	21.80	21.73	21.68	21.63	21.58	21.54	21.50	21.46
Sep 1 - Sep 15	20.31	20.28	20.24	20.22	20.19	20.17	20.15	20.13	20.11	20.10	20.08
Sep 16 - Sep 30	18.34	18.31	18.29	18.27	18.25	18.24	18.22	18.21	18.19	18.18	18.17
Oct 1 - Oct 15	17.18	17.15	17.11	17.08	17.06	17.03	17.01	16.99	16.97	16.95	16.94
Oct 16 - Oct 31	13.13	13.17	13.21	13.24	13.27	13.30	13.33	13.35	13.37	13.38	13.40
Nov 1 - Nov 15	10.01	10.02	10.04	10.05	10.06	10.07	10.08	10.09	10.10	10.10	10.11
Nov 16 - Nov 30	7.41	7.43	7.45	7.46	7.48	7.49	7.50	7.51	7.52	7.53	7.54
Dec 1 - Dec 15	5.59	5.58	5.57	5.56	5.55	5.54	5.53	5.53	5.52	5.51	5.50
Dec 16 - Dec 31	4.09	4.06	4.04	4.01	3.99	3.97	3.96	3.94	3.93	3.92	3.90

River Mile 97 - Mid-point between Seiad Valley and Salmon River

Jan 1 - Jan 15	5.13	5.09	5.05	5.02	4.98	4.95	4.92	4.89	4.86	4.83	4.81
Jan 16 - Jan 31	5.36	5.30	5.24	5.18	5.13	5.07	5.02	4.97	4.93	4.88	4.84

Feb 1 - Feb 15	5.55	5.45	5.36	5.28	5.20	5.12	5.04	4.97	4.91	4.84	4.78
Feb 16 - Feb 28	6.21	6.13	6.05	5.98	5.91	5.84	5.78	5.72	5.66	5.61	5.55
Mar 1 - Mar 15	7.87	7.79	7.71	7.63	7.55	7.48	7.41	7.35	7.28	7.22	7.16
Mar 16 - Mar 31	9.29	9.24	9.20	9.16	9.12	9.08	9.04	9.00	8.97	8.94	8.90
Apr 1 - Apr 15	10.36	10.35	10.34	10.32	10.31	10.30	10.28	10.27	10.26	10.25	10.23
Apr 16 - Apr 30	11.48	11.46	11.44	11.43	11.41	11.39	11.37	11.36	11.34	11.33	11.31
May 1 - May 15	13.67	13.67	13.67	13.66	13.66	13.66	13.65	13.65	13.65	13.65	13.64
May 16 - May 31	15.49	15.48	15.47	15.46	15.45	15.44	15.43	15.42	15.41	15.40	15.39
Jun 1 - Jun 15	17.47	17.44	17.40	17.37	17.34	17.30	17.27	17.24	17.22	17.19	17.16
Jun 16 - Jun 30	20.33	20.23	20.13	20.04	19.95	19.87	19.79	19.71	19.64	19.58	19.51
Jul 1 - Jul 15	21.77	21.68	21.59	21.51	21.43	21.35	21.28	21.21	21.15	21.09	21.04
Jul 16 - Jul 31	23.44	23.33	23.22	23.12	23.03	22.94	22.86	22.79	22.71	22.65	22.58
Aug 1 - Aug 15	23.03	22.94	22.86	22.77	22.69	22.62	22.55	22.49	22.43	22.37	22.32
Aug 16 - Aug 31	22.39	22.32	22.26	22.19	22.13	22.07	22.02	21.97	21.92	21.88	21.84
Sep 1 - Sep 15	20.27	20.26	20.25	20.23	20.21	20.20	20.18	20.17	20.16	20.14	20.13
Sep 16 - Sep 30	18.18	18.19	18.19	18.19	18.18	18.18	18.18	18.17	18.17	18.16	18.16
Oct 1 - Oct 15	17.10	17.08	17.07	17.05	17.04	17.02	17.01	16.99	16.98	16.97	16.96
Oct 16 - Oct 31	12.84	12.90	12.95	13.00	13.04	13.08	13.12	13.15	13.18	13.20	13.23
Nov 1 - Nov 15	9.88	9.91	9.93	9.95	9.97	9.99	10.01	10.02	10.03	10.05	10.06
Nov 16 - Nov 30	7.36	7.38	7.40	7.41	7.43	7.44	7.45	7.47	7.48	7.49	7.50
Dec 1 - Dec 15	5.76	5.75	5.74	5.73	5.72	5.71	5.70	5.70	5.69	5.68	5.67
Dec 16 - Dec 31	4.43	4.40	4.37	4.35	4.32	4.30	4.28	4.26	4.24	4.22	4.21

River Mile 55 - Mid-point between Salmon River and Trinity River

Jan 1 - Jan 15	5.40	5.38	5.36	5.33	5.31	5.29	5.27	5.24	5.22	5.20	5.18
Jan 16 - Jan 31	5.84	5.81	5.77	5.73	5.69	5.66	5.62	5.59	5.55	5.52	5.48
Feb 1 - Feb 15	6.19	6.13	6.06	6.00	5.94	5.88	5.82	5.77	5.71	5.66	5.61
Feb 16 - Feb 28	6.52	6.46	6.41	6.36	6.31	6.26	6.21	6.17	6.13	6.08	6.04
Mar 1 - Mar 15	7.81	7.76	7.71	7.66	7.62	7.58	7.53	7.49	7.45	7.41	7.37
Mar 16 - Mar 31	8.76	8.75	8.73	8.71	8.70	8.68	8.66	8.64	8.63	8.61	8.59
Apr 1 - Apr 15	9.76	9.76	9.76	9.76	9.76	9.76	9.76	9.75	9.75	9.75	9.75
Apr 16 - Apr 30	10.98	10.98	10.98	10.98	10.97	10.97	10.97	10.97	10.96	10.96	10.96
May 1 - May 15	12.95	12.97	12.98	12.99	13.00	13.00	13.01	13.02	13.03	13.03	13.04

May 16 - May 31	14.70	14.71	14.73	14.74	14.74	14.75	14.76	14.77	14.77	14.78	14.78
Jun 1 - Jun 15	16.83	16.83	16.83	16.83	16.83	16.82	16.82	16.81	16.81	16.80	16.80
Jun 16 - Jun 30	20.10	20.05	20.01	19.96	19.92	19.87	19.83	19.78	19.74	19.70	19.66
Jul 1 - Jul 15	21.80	21.75	21.70	21.65	21.60	21.55	21.50	21.45	21.40	21.36	21.32
Jul 16 - Jul 31	23.66	23.59	23.52	23.45	23.38	23.31	23.24	23.18	23.12	23.06	23.00
Aug 1 - Aug 15	23.26	23.20	23.14	23.08	23.02	22.96	22.90	22.85	22.79	22.74	22.70
Aug 16 - Aug 31	22.58	22.53	22.48	22.43	22.39	22.34	22.29	22.25	22.21	22.17	22.13
Sep 1 - Sep 15	20.31	20.31	20.30	20.29	20.28	20.27	20.25	20.24	20.23	20.22	20.21
Sep 16 - Sep 30	18.08	18.09	18.10	18.11	18.12	18.12	18.13	18.13	18.13	18.13	18.14
Oct 1 - Oct 15	17.07	17.06	17.06	17.05	17.04	17.04	17.03	17.02	17.01	17.01	17.00
Oct 16 - Oct 31	12.56	12.62	12.67	12.72	12.77	12.81	12.85	12.89	12.92	12.95	12.98
Nov 1 - Nov 15	9.60	9.64	9.68	9.71	9.74	9.76	9.79	9.81	9.83	9.85	9.87
Nov 16 - Nov 30	7.35	7.37	7.39	7.40	7.41	7.43	7.44	7.45	7.46	7.47	7.48
Dec 1 - Dec 15	6.00	5.99	5.98	5.97	5.97	5.96	5.95	5.94	5.94	5.93	5.92
Dec 16 - Dec 31	4.87	4.84	4.82	4.79	4.76	4.74	4.72	4.69	4.67	4.65	4.63

River Mile 24 - Mid-point between Trinity River and Pacific Ocean

Jan 1 - Jan 15	6.18	6.16	6.14	6.12	6.10	6.08	6.06	6.04	6.02	6.00	5.98
Jan 16 - Jan 31	6.78	6.75	6.73	6.70	6.68	6.66	6.63	6.61	6.59	6.56	6.54
Feb 1 - Feb 15	6.98	6.94	6.91	6.88	6.84	6.81	6.78	6.74	6.71	6.68	6.65
Feb 16 - Feb 28	7.32	7.28	7.24	7.21	7.18	7.14	7.11	7.08	7.05	7.02	7.00
Mar 1 - Mar 15	8.69	8.66	8.64	8.61	8.58	8.56	8.53	8.51	8.48	8.46	8.43
Mar 16 - Mar 31	9.54	9.52	9.51	9.49	9.47	9.46	9.44	9.43	9.41	9.40	9.38
Apr 1 - Apr 15	10.53	10.53	10.52	10.51	10.50	10.49	10.49	10.48	10.47	10.46	10.45
Apr 16 - Apr 30	11.56	11.55	11.54	11.54	11.53	11.52	11.51	11.50	11.49	11.49	11.48
May 1 - May 15	13.49	13.49	13.49	13.49	13.48	13.48	13.48	13.48	13.48	13.48	13.48
May 16 - May 31	14.43	14.44	14.45	14.46	14.46	14.47	14.48	14.49	14.49	14.50	14.51
Jun 1 - Jun 15	16.56	16.57	16.57	16.57	16.57	16.58	16.58	16.58	16.58	16.57	16.57
Jun 16 - Jun 30	19.75	19.74	19.72	19.70	19.68	19.66	19.64	19.61	19.59	19.56	19.54
Jul 1 - Jul 15	21.26	21.25	21.23	21.22	21.20	21.18	21.16	21.14	21.12	21.09	21.07
Jul 16 - Jul 31	23.79	23.75	23.70	23.66	23.61	23.57	23.52	23.47	23.43	23.38	23.34
Aug 1 - Aug 15	23.47	23.43	23.38	23.34	23.30	23.26	23.22	23.17	23.13	23.09	23.05
Aug 16 - Aug 31	22.55	22.52	22.50	22.47	22.44	22.41	22.38	22.35	22.32	22.29	22.26

Sep 1 - Sep 15	19.97	19.98	19.99	20.00	20.01	20.01	20.02	20.02	20.02	20.02	20.02
Sep 16 - Sep 30	18.10	18.11	18.12	18.13	18.13	18.14	18.15	18.15	18.15	18.16	18.16
Oct 1 - Oct 15	17.20	17.19	17.19	17.18	17.17	17.16	17.15	17.15	17.14	17.13	17.12
Oct 16 - Oct 31	12.69	12.73	12.77	12.80	12.84	12.87	12.90	12.93	12.96	12.99	13.01
Nov 1 - Nov 15	9.94	9.96	9.98	9.99	10.01	10.02	10.03	10.04	10.05	10.06	10.07
Nov 16 - Nov 30	7.95	7.94	7.93	7.93	7.92	7.91	7.91	7.90	7.90	7.90	7.89
Dec 1 - Dec 15	6.44	6.43	6.41	6.40	6.38	6.37	6.36	6.34	6.33	6.32	6.31
Dec 16 - Dec 31	5.64	5.61	5.57	5.54	5.51	5.48	5.46	5.43	5.40	5.37	5.35

Appendix 3-D

Appendix Tables

Appendix 3-D-1. Baseline Monthly average IGD Discharge, 1961 to 2006.

	October	November	December	January	February	March	April	May	June	July	August	September
1961	1,461	1,716	2,524	1,773	1,906	2,005	1,756	1,575	1,387	983	1,094	1,382
1962	1,907	2,253	1,985	1,907	1,769	1,676	2,634	1,386	929	766	968	1,308
1963	2,511	2,852	3,661	2,103	2,189	2,548	3,841	2,937	857	743	1,058	1,574
1964	1,761	2,425	2,908	2,936	1,885	1,631	2,780	1,061	1,005	857	1,073	1,369
1965	1,774	1,876	6,653	9,489	9,150	6,306	2,232	1,828	866	738	1,208	2,052
1966	2,798	4,188	3,040	2,554	1,545	1,776	2,482	1,035	712	729	1,052	1,313
1967	1,574	1,796	3,069	3,099	3,212	2,044	2,458	4,230	1,545	727	1,016	1,311
1968	1,654	1,805	2,725	1,870	1,928	2,459	1,306	1,018	708	734	747	1,048
1969	1,382	1,356	1,498	2,287	3,204	2,640	5,412	3,009	1,121	734	1,023	1,332
1970	1,744	2,773	2,615	5,326	5,656	4,328	1,412	1,459	868	714	1,019	1,310
1971	1,379	2,953	4,122	4,016	3,447	4,872	6,922	4,973	2,125	778	1,014	1,540
1972	2,753	3,152	3,777	4,100	3,640	10,780	3,641	2,447	787	719	1,029	1,640
1973	1,791	2,827	3,389	3,292	2,659	2,394	1,418	1,034	746	706	701	725
1974	1,333	2,221	4,076	6,177	4,064	5,672	6,874	3,037	886	737	1,030	1,327
1975	1,688	2,708	3,002	3,085	3,361	4,651	4,293	3,890	1,313	778	1,098	1,612
1976	2,432	3,156	3,805	3,132	2,785	2,567	1,812	1,138	733	718	1,054	1,428
1977	1,827	2,985	1,894	1,656	1,336	724	761	1,015	742	719	718	1,014
1978	1,322	1,390	3,903	4,348	3,435	3,567	3,575	2,130	772	732	1,041	1,326
1979	1,329	1,623	1,824	2,027	1,644	2,596	1,391	1,575	731	733	1,022	1,303
1980	1,308	1,337	1,435	3,395	3,618	3,225	1,723	1,626	748	746	1,051	1,348
1981	1,342	1,343	1,465	1,364	1,540	1,817	1,545	1,033	751	736	1,033	916
1982	852	1,306	3,836	3,810	6,777	6,923	5,971	2,445	804	1,429	1,039	1,345
1983	1,874	3,021	4,062	3,075	5,123	7,681	5,353	4,168	2,591	903	1,014	1,567
1984	2,746	4,167	6,735	4,013	3,885	5,774	5,192	3,770	1,973	761	1,030	1,674
1985	3,353	5,254	3,976	2,142	1,764	2,609	4,445	1,366	1,095	722	1,011	1,645
1986	1,675	2,129	2,859	2,365	6,332	7,497	2,985	1,666	751	728	1,015	1,405

Appendix Table 3-D-1. Continued.

	October	November	December	January	February	March	April	May	June	July	August	September
1987	1,801	1,844	2,143	1,827	2,579	2,646	1,453	1,013	740	802	935	1,332
1988	1,341	1,331	1,517	1,681	2,217	1,926	1,165	973	829	633	974	1,038
1989	1,037	1,166	1,324	1,605	2,125	5,692	4,676	2,467	921	740	1,035	1,337
1990	1,382	1,400	1,540	1,812	1,806	2,038	1,545	1,033	852	729	979	1,168
1991	1,345	1,324	1,621	1,334	747	923	778	874	677	544	647	749
1992	879	873	889	888	525	511	740	512	506	428	398	538
1993	904	915	914	1,011	910	5,054	5,191	2,677	2,408	692	1,039	1,359
1994	1,375	1,414	1,387	1,127	730	640	572	727	704	574	636	906
1995	937	909	944	1,191	1,105	4,212	3,217	3,251	1,073	745	1,040	1,350
1996	1,345	1,337	1,681	3,885	9,031	5,223	3,375	3,279	1,532	1,043	1,065	1,316
1997	1,346	1,461	3,494	9,553	5,545	2,985	2,327	2,104	1,243	820	1,058	1,035
1998	1,482	1,703	1,797	3,618	4,558	4,715	4,662	5,558	3,289	1,125	1,119	1,395
1999	1,398	2,171	3,207	3,474	4,163	7,312	5,784	3,103	1,933	1,336	1,149	1,341
2000	1,429	1,822	1,822	2,792	3,684	3,705	2,567	2,282	1,334	1,052	1,067	1,266
2001	1,326	1,318	1,291	1,292	1,297	1,288	1,598	1,726	1,897	1,012	1,023	1,026
2002	1,308	1,312	1,320	1,794	1,855	2,360	1,748	1,520	993	837	666	813
2003	1,047	887	1,064	1,457	1,042	1,592	2,746	2,356	1,303	827	996	1,254
2004	1,366	1,364	1,523	1,375	1,920	2,169	1,813	1,288	942	668	762	913
2005	927	964	1,164	1,058	909	871	1,363	3,562	1,222	925	999	1,218
2006	1,357	1,388	2,638	6,529	5,266	3,732	6,439	4,036	3,102	1,385	1,033	1,078

Source: J. Hicks, Reclamation, July 3, 2007 email to K. Schultz, Reclamation.

Appendix 3-D-2. IGD Discharge exceedences, in cfs, 1961 to 2006.

% Exceed	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
2%	876	886	912	999	710	627	723	706	660	532	612	706
5%	910	911	974	1,076	787	761	765	899	705	589	652	765
10%	987	1,065	1,227	1,242	976	1,106	1,236	1,014	722	680	710	910
20%	1,322	1,324	1,435	1,457	1,540	1,776	1,418	1,034	746	719	968	1,035
30%	1,342	1,350	1,532	1,784	1,788	2,041	1,661	1,327	780	729	1,005	1,193
40%	1,357	1,400	1,822	1,907	1,920	2,459	1,813	1,575	857	734	1,016	1,308
50%	1,382	1,710	2,334	2,326	2,398	2,625	2,525	1,777	925	739	1,026	1,321
60%	1,482	1,844	2,859	3,075	3,212	3,567	2,985	2,356	1,073	761	1,033	1,337
70%	1,716	2,237	3,138	3,344	3,629	4,490	3,741	2,807	1,273	811	1,041	1,355
80%	1,801	2,827	3,777	3,885	4,163	5,223	4,676	3,251	1,532	903	1,058	1,405
90%	2,472	3,087	4,019	4,837	5,601	6,615	5,598	3,963	2,049	1,048	1,084	1,593

Appendix Table 3-D-3. Total quantity of water available at Iron Gate Dam if all net inflows into UKL are passed through Keno Dam and all accretions from Keno Dam to Iron Gate are added to those flows. This reflects no Klamath Project or National Wildlife Refuge diversions, no refilling of Upper Klamath Lake, and no attempt to meet ESA requirements for listed suckers in Upper Klamath Lake.

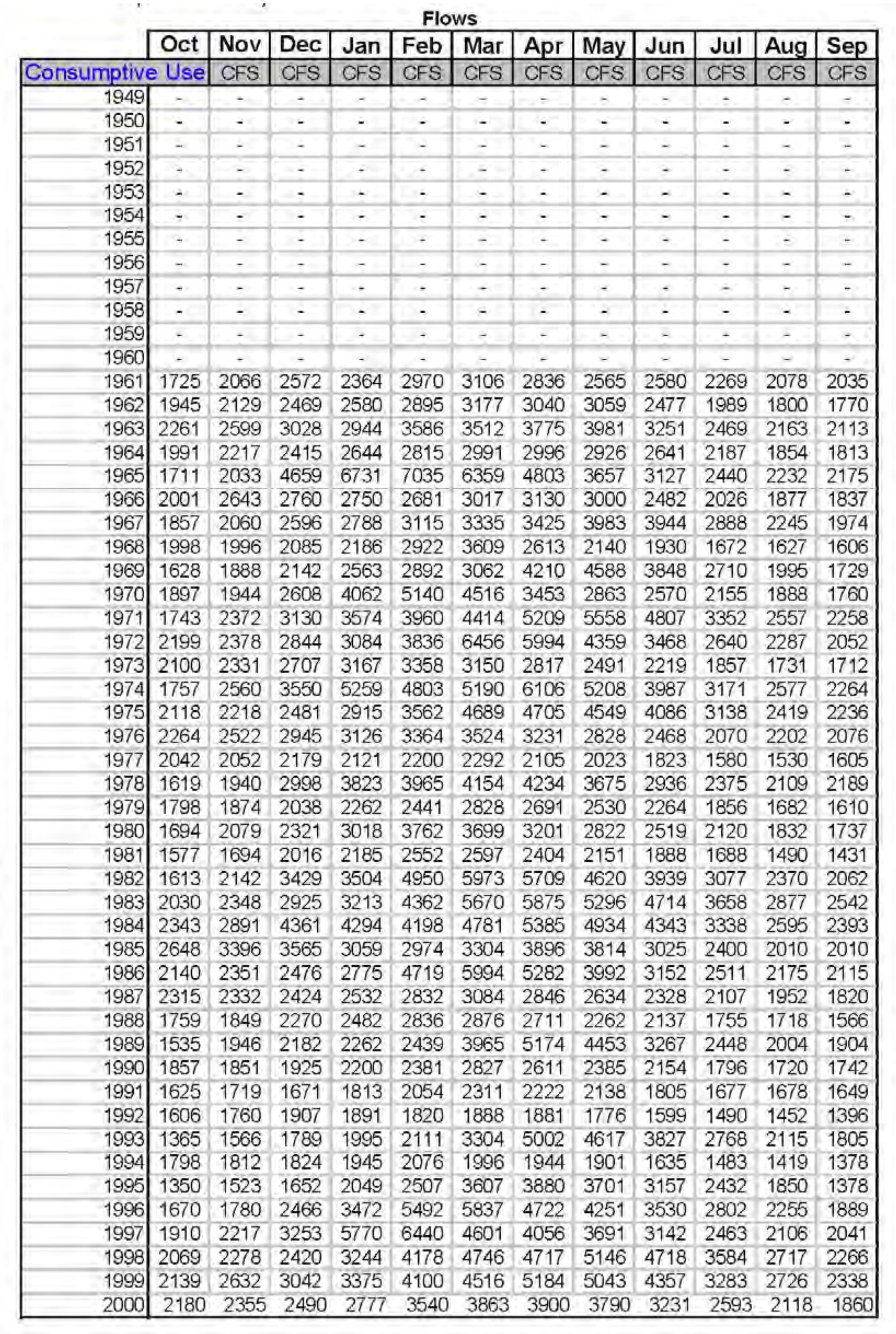
Year	October	November	December	January	Feburary	March	April	May	June	July	August	September
1961	1,538	2,372	2,610	1,985	3,040	2,963	2,330	2,077	1,794	913	1,132	1,330
1962	1,860	2,035	2,223	1,964	2,921	2,621	3,674	2,359	1,169	774	1,045	1,151
1963	3,072	2,695	3,657	2,211	3,977	2,720	3,986	3,315	1,529	1,053	1,044	1,348
1964	1,802	2,451	2,409	2,958	2,489	2,390	3,860	2,155	1,920	1,089	1,098	1,206
1965	1,587	2,232	9,724	8,248	7,479	4,242	3,462	3,125	1,757	1,253	1,390	1,509
1966	2,179	2,746	2,686	2,716	2,343	3,261	3,946	2,058	1,328	911	821	1,413
1967	1,388	2,390	3,033	3,047	3,110	3,140	3,436	4,544	2,775	868	910	986
1968	1,658	1,780	2,252	2,354	3,680	3,066	1,672	1,503	871	677	1,033	1,182
1969	1,491	2,063	2,170	3,147	2,734	2,997	5,933	3,827	2,066	769	817	1,070
1970	1,587	1,970	3,121	6,309	4,516	3,949	2,321	2,136	1,469	790	651	1,201
1971	1,659	3,208	3,338	4,539	3,866	5,049	5,929	5,485	3,205	1,498	899	1,478
1972	1,892	2,856	3,114	3,037	5,336	9,390	4,305	3,463	2,030	1,012	1,155	1,368
1973	1,973	2,502	3,385	3,311	2,907	3,021	2,420	2,003	965	907	733	1,141
1974	1,986	3,900	4,176	6,154	3,959	5,519	6,732	4,243	2,471	1,513	1,239	1,426
1975	1,746	2,157	2,905	2,954	3,504	4,756	4,622	4,982	3,045	1,373	1,230	1,545
1976	2,145	2,765	3,230	3,061	3,167	3,220	3,078	2,468	1,528	1,195	1,613	1,353
1977	1,589	2,186	1,955	1,811	2,090	2,056	1,455	1,662	1,138	568	773	1,411
1978	1,524	2,388	4,092	4,281	3,655	3,945	3,773	2,721	1,434	1,085	914	1,627
1979	1,425	1,694	1,943	2,372	2,458	2,874	2,146	2,382	790	634	759	1,226
1980	1,722	2,230	2,283	4,185	3,760	3,076	2,587	2,335	1,333	746	559	1,208
1981	1,277	1,848	2,339	2,075	2,638	2,069	2,060	1,567	822	502	597	1,013
1982	1,466	2,795	5,164	3,154	7,240	5,689	5,275	3,964	2,356	1,385	1,020	1,474
1983	1,959	2,647	3,628	3,180	4,860	6,432	5,384	4,784	3,526	1,696	1,393	1,485
1984	1,966	3,187	5,145	3,243	3,697	5,793	5,102	4,464	2,950	1,308	1,258	1,553
1985	2,186	3,859	2,801	2,375	2,635	3,266	4,935	2,344	1,556	831	647	1,914

Appendix Table 3-D-3. Continued.

Year	October	November	December	January	Feburary	March	April	May	June	July	August	September
1986	1,873	2,290	2,269	3,217	6,660	6,267	3,519	2,552	1,522	832	753	1,769
1987	1,844	2,131	2,212	2,430	2,853	3,172	2,496	1,496	1,197	1,066	761	1,122
1988	1,394	1,741	2,640	2,514	2,664	2,473	1,844	1,550	1,447	421	596	943
1989	1,320	2,455	1,908	2,055	2,049	5,784	4,956	3,188	1,332	513	930	1,424
1990	1,613	1,777	1,899	2,454	2,194	2,715	2,221	1,598	1,007	638	989	1,083
1991	1,338	1,519	1,555	2,017	1,813	2,189	1,753	1,599	950	679	491	858
1992	1,126	1,659	1,606	1,614	1,466	1,446	1,399	754	360	646	398	755
1993	1,145	1,654	1,860	2,019	1,976	5,881	5,116	3,637	2,530	738	784	1,092
1994	1,558	1,468	1,896	1,749	1,583	1,665	1,337	1,134	601	260	503	759
1995	1,026	1,652	1,607	2,792	3,221	4,136	3,538	3,266	1,943	991	600	1,283
1996	1,775	1,740	3,505	3,926	7,913	4,588	3,851	3,841	1,651	816	889	1,344
1997	1,738	2,523	5,009	8,294	4,717	3,488	3,415	2,815	1,504	936	1,174	1,444
1998	1,746	2,181	1,816	3,775	3,726	4,290	3,788	4,702	3,067	1,180	783	1,284
1999	1,771	2,911	2,979	3,307	3,411	4,663	5,383	4,507	2,685	1,269	1,411	1,481
2000	1,817	2,119	2,303	3,362	3,697	3,451	3,694	2,816	1,525	847	732	1,543
2001	1,617	1,934	1,914	1,773	1,787	2,235	1,788	1,160	629	597	684	943
2002	1,935	2,032	2,348	2,803	2,205	2,622	2,667	1,970	922	549	548	880
2003	1,286	1,683	2,181	2,801	2,128	2,322	2,853	2,348	864	402	558	1,089
2004	1,261	1,550	2,193	2,312	3,024	3,232	2,301	1,671	931	565	670	1,006
Median	1,659	2,184	2,378	2,879	3,075	3,226	3,490	2,425	1,513	839	819	1,284
Maximum	3,072	3,900	9,724	8,294	7,913	9,390	6,732	5,485	3,526	1,696	1,613	1,914
Minimum	1,026	1,468	1,555	1,614	1,466	1,446	1,337	754	360	260	398	755

Source: J. Hicks, Reclamation, August 31, 2007 email to K. Schultz, Reclamation.

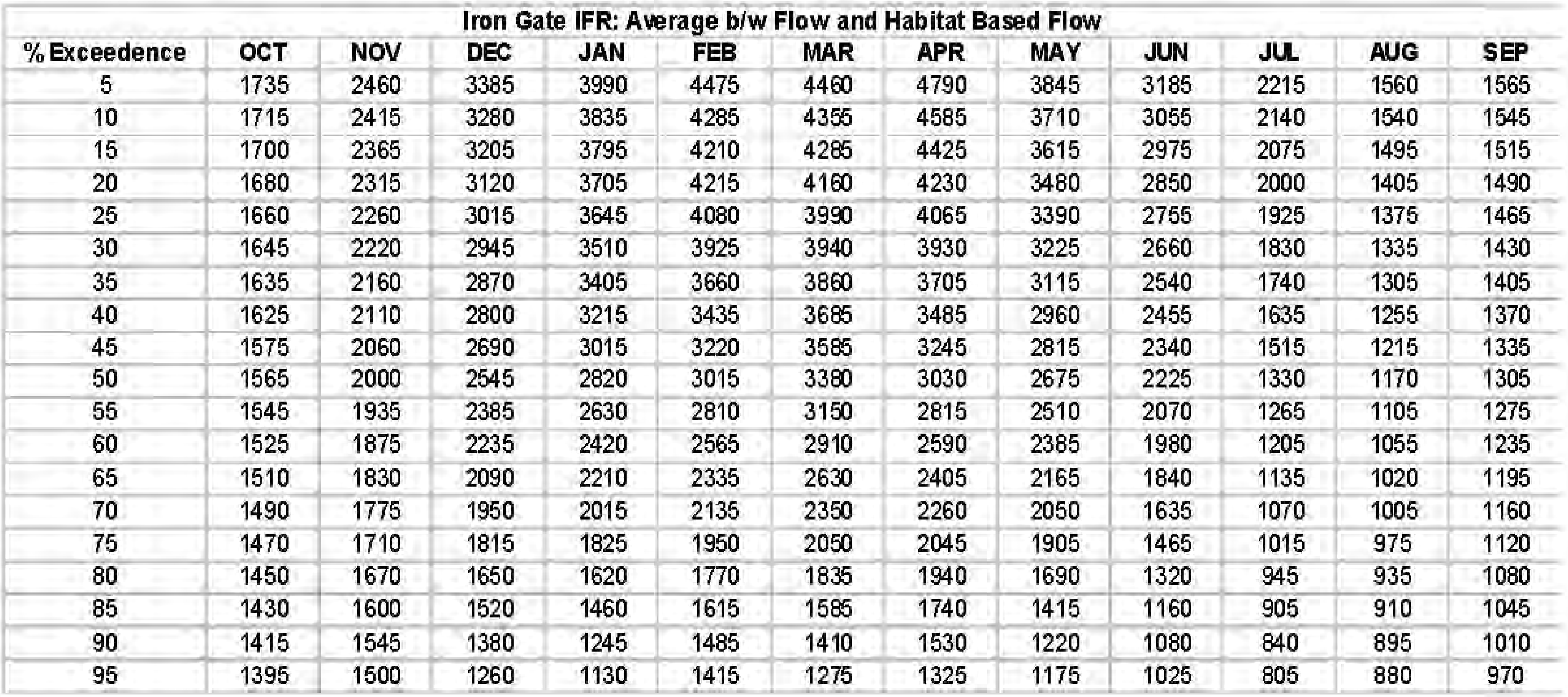
Table 3-D-4. Estimated mean monthly unimpaired flows at IGD, as derived from the level pool consumptive use study. This modeling relied upon the elimination of all potential diversion from the entire Upper Klamath River basin, not just diversions to the Klamath Reclamation Project.



Flows

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Consumptive Use	CFS	CFS	CFS	CFS	CFS	CFS	CFS	CFS	CFS	CFS	CFS	CFS
1949	-	-	-	-	-	-	-	-	-	-	-	-
1950	-	-	-	-	-	-	-	-	-	-	-	-
1951	-	-	-	-	-	-	-	-	-	-	-	-
1952	-	-	-	-	-	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	-	-	-	-	-	-
1954	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	-	-	-	-	-	-	-	-
1958	-	-	-	-	-	-	-	-	-	-	-	-
1959	-	-	-	-	-	-	-	-	-	-	-	-
1960	-	-	-	-	-	-	-	-	-	-	-	-
1961	1725	2066	2572	2364	2970	3106	2836	2565	2580	2269	2078	2035
1962	1945	2129	2469	2580	2895	3177	3040	3059	2477	1989	1800	1770
1963	2261	2599	3028	2944	3586	3512	3775	3981	3251	2469	2163	2113
1964	1991	2217	2415	2644	2815	2991	2996	2926	2641	2187	1854	1813
1965	1711	2033	4659	6731	7035	6359	4803	3657	3127	2440	2232	2175
1966	2001	2643	2760	2750	2681	3017	3130	3000	2482	2026	1877	1837
1967	1857	2060	2596	2788	3115	3335	3425	3983	3944	2888	2245	1974
1968	1998	1996	2085	2186	2922	3609	2613	2140	1930	1672	1627	1606
1969	1628	1888	2142	2563	2892	3062	4210	4588	3848	2710	1995	1729
1970	1897	1944	2608	4062	5140	4516	3453	2863	2570	2155	1888	1760
1971	1743	2372	3130	3574	3960	4414	5209	5558	4807	3352	2557	2258
1972	2199	2378	2844	3084	3836	6456	5994	4359	3468	2640	2287	2052
1973	2100	2331	2707	3167	3358	3150	2817	2491	2219	1857	1731	1712
1974	1757	2560	3550	5259	4803	5190	6106	5208	3987	3171	2577	2264
1975	2118	2218	2481	2915	3562	4689	4705	4549	4086	3138	2419	2236
1976	2264	2522	2945	3126	3364	3524	3231	2828	2468	2070	2202	2076
1977	2042	2052	2179	2121	2200	2292	2105	2023	1823	1580	1530	1605
1978	1619	1940	2998	3823	3965	4154	4234	3675	2936	2375	2109	2189
1979	1798	1874	2038	2262	2441	2828	2691	2530	2264	1856	1682	1610
1980	1694	2079	2321	3018	3762	3699	3201	2822	2519	2120	1832	1737
1981	1577	1694	2016	2185	2552	2597	2404	2151	1888	1688	1490	1431
1982	1613	2142	3429	3504	4950	5973	5709	4620	3939	3077	2370	2062
1983	2030	2348	2925	3213	4362	5670	5875	5296	4714	3658	2877	2542
1984	2343	2891	4361	4294	4198	4781	5385	4934	4343	3338	2595	2393
1985	2648	3396	3565	3059	2974	3304	3896	3814	3025	2400	2010	2010
1986	2140	2351	2476	2775	4719	5994	5282	3992	3152	2511	2175	2115
1987	2315	2332	2424	2532	2832	3084	2846	2634	2328	2107	1952	1820
1988	1759	1849	2270	2482	2836	2876	2711	2262	2137	1755	1718	1566
1989	1535	1946	2182	2262	2439	3965	5174	4453	3267	2448	2004	1904
1990	1857	1851	1925	2200	2381	2827	2611	2385	2154	1796	1720	1742
1991	1625	1719	1671	1813	2054	2311	2222	2138	1805	1677	1678	1649
1992	1606	1760	1907	1891	1820	1888	1881	1776	1599	1490	1452	1396
1993	1365	1566	1789	1995	2111	3304	5002	4617	3827	2768	2115	1805
1994	1798	1812	1824	1945	2076	1996	1944	1901	1635	1483	1419	1378
1995	1350	1523	1652	2049	2507	3607	3880	3701	3157	2432	1850	1378
1996	1670	1780	2466	3472	5492	5837	4722	4251	3530	2802	2255	1889
1997	1910	2217	3253	5770	6440	4601	4056	3691	3142	2463	2106	2041
1998	2069	2278	2420	3244	4178	4746	4717	5146	4718	3584	2717	2266
1999	2139	2632	3042	3375	4100	4516	5184	5043	4357	3283	2726	2338
2000	2180	2355	2490	2777	3540	3863	3900	3790	3231	2593	2118	1860

Appendix Table 3-D-5. Hardy and Addleys' 2006 in-stream flow recommendations for IGD by annual exceedence levels for Hardy and Addleys' estimated unimpaired flows.



Iron Gate IFR: Average b/w Flow and Habitat Based Flow												
% Exceedence	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**
5	1735	2460	3385	3990	4475	4460	4790	3845	3185	2215	1560	1565
10	1715	2415	3280	3835	4285	4355	4585	3710	3055	2140	1540	1545
15	1700	2365	3205	3795	4210	4285	4425	3615	2975	2075	1495	1515
20	1680	2315	3120	3705	4215	4160	4230	3480	2850	2000	1405	1490
25	1660	2260	3015	3645	4080	3990	4065	3390	2755	1925	1375	1465
30	1645	2220	2945	3510	3925	3940	3930	3225	2660	1830	1335	1430
35	1635	2160	2870	3405	3660	3860	3705	3115	2540	1740	1305	1405
40	1625	2110	2800	3215	3435	3685	3485	2960	2455	1635	1255	1370
45	1575	2060	2690	3015	3220	3585	3245	2815	2340	1515	1215	1335
50	1565	2000	2545	2820	3015	3380	3030	2675	2225	1330	1170	1305
55	1545	1935	2385	2630	2810	3150	2815	2510	2070	1265	1105	1275
60	1525	1875	2235	2420	2565	2910	2590	2385	1980	1205	1055	1235
65	1510	1830	2090	2210	2335	2630	2405	2165	1840	1135	1020	1195
70	1490	1775	1950	2015	2135	2350	2260	2050	1635	1070	1005	1160
75	1470	1710	1815	1825	1950	2050	2045	1905	1465	1015	975	1120
80	1450	1670	1650	1620	1770	1835	1940	1690	1320	945	935	1080
85	1430	1600	1520	1460	1615	1585	1740	1415	1160	905	910	1045
90	1415	1545	1380	1245	1485	1410	1530	1220	1080	840	895	1010
95	1395	1500	1260	1130	1415	1275	1325	1175	1025	805	880	970

Source: Table 27, page 182 of Hardy and Addley 2006.

Appendix Table 3-D-6. Modeled Iron Gate Dam flow exceedences (2008 to 2018) under the Proposed Action in cubic feet per second (cfs) at 5 percent increments.

Percentile	Exceedence	Oct	Nov	Dec	Jan	Feb	Mar I	Mar II	Apr I	Apr II	May I	May II	Jun I	Jun II	Jul I	Jul II	Aug	Sep
0.05	**95%**	1,300	1,337	1,329	1,330	1,300	1,450	1,450	1,500	1,500	1,500	1,500	1,400	1,400	1,000	1,000	1,000	1,000
0.10	**90%**	1,300	1,342	1,333	1,335	1,300	1,450	1,450	1,500	1,500	1,505	1,505	1,407	1,407	1,000	1,001	1,000	1,000
0.15	**85%**	1,300	1,348	1,342	1,345	1,300	1,450	1,450	1,500	1,500	1,524	1,522	1,432	1,432	1,007	1,007	1,004	1,006
0.20	**80%**	1,300	1,354	1,348	1,354	1,300	1,717	1,815	1,500	1,500	1,532	1,529	1,442	1,442	1,016	1,015	1,005	1,010
0.25	**75%**	1,304	1,366	1,353	1,362	1,300	2,115	2,172	1,500	1,500	1,542	1,539	1,455	1,455	1,021	1,020	1,007	1,014
0.30	**70%**	1,310	1,375	1,360	1,369	1,315	2,285	2,445	1,500	1,500	1,572	1,567	1,496	1,496	1,036	1,034	1,012	1,024
0.35	**65%**	1,314	1,395	1,366	1,385	1,459	2,439	2,489	1,500	1,677	1,589	1,583	1,518	1,518	1,044	1,042	1,014	1,030
0.40	**60%**	1,326	1,408	1,407	1,401	1,821	2,571	2,559	1,624	2,189	1,605	1,599	1,545	1,563	1,062	1,059	1,020	1,041
0.45	**55%**	1,331	1,416	1,436	1,679	2,406	2,675	2,739	2,035	2,711	1,641	1,632	1,587	1,587	1,073	1,068	1,023	1,048
0.50	**50%**	1,335	1,426	1,648	1,795	2,526	2,850	2,780	2,434	2,931	1,727	1,712	1,658	1,658	1,095	1,087	1,030	1,062
0.55	**45%**	1,338	1,435	1,814	2,046	2,637	2,892	2,862	2,645	3,115	1,909	1,909	1,689	1,696	1,107	1,097	1,032	1,070
0.60	**40%**	1,340	1,455	1,903	2,265	2,991	2,971	3,055	2,747	3,217	2,067	2,067	1,706	1,731	1,122	1,114	1,038	1,082
0.65	**35%**	1,341	1,527	2,031	2,569	3,452	3,244	3,147	2,977	3,447	2,485	2,486	1,736	1,744	1,135	1,129	1,044	1,086
0.70	**30%**	1,343	1,639	2,414	2,600	3,517	3,670	3,771	3,478	3,948	2,775	2,775	1,745	1,769	1,142	1,146	1,051	1,092
0.75	**25%**	1,357	1,755	2,930	2,655	3,771	4,371	4,671	3,901	4,371	2,919	2,919	1,786	1,814	1,168	1,159	1,056	1,113
0.80	**20%**	1,358	1,978	2,996	2,989	3,909	4,868	4,972	4,286	4,757	3,111	3,111	1,942	1,943	1,196	1,190	1,066	1,145
0.85	**15%**	1,362	2,180	3,168	3,484	4,709	5,370	5,488	5,004	5,474	3,592	3,591	2,426	2,322	1,301	1,283	1,095	1,183
0.90	**10%**	1,377	2,898	3,341	3,962	5,612	6,006	5,960	5,309	5,779	3,884	3,885	2,576	2,549	1,395	1,365	1,120	1,239
0.95	**5%**	1,384	3,267	4,798	6,280	7,119	6,681	6,573	5,704	6,174	4,247	4,247	2,748	2,653	1,438	1,420	1,142	1,267

Appendix Table 3-D-7. Estimate available habitat for juvenile and fry coho salmon within the main stem of the Klamath River at R Ranch, a site within the main stem of the Klamath River between the confluence of the Shasta River (river mile 177) to IGD (river mile 190). Estimate available habitat for juvenile and fry coho salmon are depicted for the (2008 to 2018) modeled flows under the Proposed Action at 25 percent, 50 percent, and 75 percent exceedence levels.

				Anticipated Flows								
Month	Minimum Flow	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat	
		Juvenile	Fry	25%	Juvenile	Fry	50%	Juvenile	Fry	75%	Juvenile	Fry
Oct	1300	57 - 64	69 - 78	1300	57 - 64	69 - 78	1300	57 - 64	69 - 78	1300	57 - 64	69 - 78
	1300	57 - 64	69 - 78	1300	57 - 64	69 - 78	1300	57 - 64	69 - 78	1300	57 - 64	69 - 78
Nov	1300	57 - 64	69 - 78	2325	72 - 75	94 - 99	1300	57 - 64	69 - 78	1300	57 - 64	69 - 78
	1300	57 - 64	69 - 78	2325	72 - 75	94 - 99	1300	57 - 64	69 - 78	1300	57 - 64	69 - 78
Dec	1300	57 - 64	69 - 78	3360	81 - 85	97 - 93	2170	69 - 72	90 - 94	1300	57 - 64	69 - 78
	1300	57 - 64	69 - 78	3360	81 - 85	97 - 93	2170	69 - 72	90 - 94	1300	57 - 64	69 - 78
Jan	1300	57 - 64	69 - 78	3042	78 - 81	***100 - 97***	2057	69 - 72	90 - 94	1300	57 - 64	69 - 78
	1300	57 - 64	69 - 78	3042	78 - 81	***100 - 97***	2057	69 - 72	90 - 94	1300	57 - 64	69 - 78
Feb	1300	57 - 64	69 - 78	3325	81 - 85	***97 - 93***	2158	69 - 72	90 - 94	1300	57 - 64	69 - 78
	1300	57 - 64	69 - 78	3325	81 - 85	***97 - 93***	2158	69 - 72	90 - 94	1300	57 - 64	69 - 78
Mar	1450	64 - 66	78 - 84	4216	91 - 96	***89 - 83***	2713	75 - 78	99 - 100	2078	69 - 72	90 - 94
	1450	64 - 66	78 - 84	4671	91 - 96	***89 - 83***	2780	78 - 81	***100 - 97***	2172	69 - 72	90 - 94
Apr	1500	64 - 66	78 - 84	4996	96 - 100	***83 - 77***	3650	85 - 91	***93 - 89***	2232	72 - 75	94 - 99
	1500	64 - 66	78 - 84	4032	85 - 91	***93 - 89***	2493	75 - 78	99 - 100	1500	64 - 66	78 - 84
May	1500	64 - 66	78 - 84	2420	72 - 75	94 - 99	1500	64 - 66	78 - 84	1500	64 - 66	78 - 84
	1500	64 - 66	78 - 84	2420	72 - 75	94 - 99	1500	64 - 66	78 - 84	1500	64 - 66	78 - 84
Jun	1400	64 - 66	78 - 84	1400	64 - 66	78 - 84	1400	64 - 66	78 - 84	1400	64 - 66	78 - 84
	1400	64 - 66	78 - 84	1400	64 - 66	78 - 84	1400	64 - 66	78 - 84	1400	64 - 66	78 - 84
Jul	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69
	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69
Aug	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69
	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69
Sep	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69
	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69	1000	54 - 57	63 - 69

Appendix Table 3-D-7. Continued.

Source of maximum available habitat values: Table I-1 of Hardy and Addley 2006. Table I-1 of Hardy and Addley 2006 presented the maximum available habitat for a given discharge. The discharge values were given in cfs intervals. The presented range of percent of maximum available habitat reflects the interval range that the modeled discharge fell within.

Note: Percent maximum available habitat values in bold and italics indicate flows above maximum available habitat flow.

Appendix Table 3-D-8. Estimate available habitat for juvenile and fry coho salmon within the main stem of the Klamath River at Trees of Heaven, a study site within the main stem of the Klamath River just below the confluence of the Shasta River. Estimate available habitat for juvenile and fry coho salmon are depicted under the (2008 to 2018) modeled flows at IGD of the Proposed Action at 25 percent, 50 percent, and 75 percent exceedence levels.

				Anticipated Flows								
Month	Minimum Flow	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat	
		Juvenile	Fry	25%	Juvenile	Fry	50%	Juvenile	Fry	75%	Juvenile	Fry
Oct	1300	56 - 57	***100 - 90***	1300	56 - 57	***100 - 90***	1300	56 - 57	***100 - 90***	1300	56 - 57	***100 - 90***
	1300	56 - 57	***100 - 90***	1300	56 - 57	***100 - 90***	1300	56 - 57	***100 - 90***	1300	56 - 57	***100 - 90***
Nov	1300	56 - 57	***100 - 90***	2325	55 - 54	***83 - 84***	1300	56 - 57	***100 - 90***	1300	56 - 57	***100 - 90***
	1300	56 - 57	***100 - 90***	2325	55 - 54	***83 - 84***	1300	56 - 57	***100 - 90***	1300	56 - 57	***100 - 90***
Dec	1300	56 - 57	***100 - 90***	3360	57 - 68	***76 - 63***	2170	55 - 54	***83 - 84***	1300	56 - 57	***100 - 90***
	1300	56 - 57	***100 - 90***	3360	57 - 68	***76 - 63***	2170	55 - 54	***83 - 84***	1300	56 - 57	***100 - 90***
Jan	1300	56 - 57	***100 - 90***	3042	54 - 57	***84 - 76***	2057	55 - 54	***83 - 84***	1300	56 - 57	***100 - 90***
	1300	56 - 57	***100 - 90***	3042	54 - 57	***84 - 76***	2057	55 - 54	***83 - 84***	1300	56 - 57	***100 - 90***
Feb	1300	56 - 57	***100 - 90***	3325	57 - 68	***76 - 63***	2158	55 - 54	***83 - 84***	1300	56 - 57	***100 - 90***
	1300	56 - 57	***100 - 90***	3325	57 - 68	***76 - 63***	2158	55 - 54	***83 - 84***	1300	56 - 57	***100 - 90***
Mar	1450	56 - 57	***100 - 90***	4216	68 - 78	***63 - 51***	2713	54 - 57	***84 - 76***	2078	55 - 54	***83 - 84***
	1450	56 - 57	***100 - 90***	4671	78 - 85	***51 - 42***	2780	54 - 57	***84 - 76***	2172	55 - 54	***83 - 84***
Apr	1500	56 - 57	***100 - 90***	4996	78 - 85	***51 - 42***	3650	57 - 68	***76 - 63***	2232	55 - 54	***83 - 84***
	1500	56 - 57	***100 - 90***	4032	68 - 78	***63 - 51***	2493	55 - 54	***83 - 84***	1500	56 - 57	***100 - 90***
May	1500	56 - 57	***100 - 90***	2420	55 - 54	***83 - 84***	1500	56 - 57	***100 - 90***	1500	56 - 57	***100 - 90***
	1500	56 - 57	***100 - 90***	2420	55 - 54	***83 - 84***	1500	56 - 57	***100 - 90***	1500	56 - 57	***100 - 90***
Jun	1400	56 - 57	***100 - 90***	1400	56 - 57	***100 - 90***	1400	56 - 57	***100 - 90***	1400	56 - 57	***100 - 90***
	1400	56 - 57	***100 - 90***	1400	56 - 57	***100 - 90***	1400	56 - 57	***100 - 90***	1400	56 - 57	***100 - 90***
Jul	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100
	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100
Aug	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100
	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100
Sep	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100
	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100	1000	45 - 56	92 - 100

Appendix Table 3-D-8. Continued.

Source of maximum available habitat values: Table I-2 of Hardy and Addley 2006. Table I-2 of Hardy and Addley 2006 presented the maximum available habitat for a given discharge. The discharge values were given in cfs intervals. The presented range of percent of maximum available habitat reflects the interval range that the modeled discharge fell within.

Note: Percent maximum available habitat values in bold and italics indicate flows above maximum available habitat flow.

Appendix Table 3-D-9. Estimate available habitat for juvenile and fry coho salmon within the main stem of the Klamath River at Brown Bear, a study site within the main stem of the Klamath River just upstream of the confluence of the Scott River. Estimate available habitat for juvenile and fry coho salmon are depicted under the (2008 to 2018) modeled flows at IGD of the Proposed Action at 25 percent, 50 percent, and 75 percent exceedence levels.

				Anticipated Flows								
Month	Minimum Flow	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat	
		Juvenile	Fry	25%	Juvenile	Fry	50%	Juvenile	Fry	75%	Juvenile	Fry
Oct	1300	***63 - 52***	34 - 36	1300	***63 - 52***	34 - 36	1300	***63 - 52***	34 - 36	1300	***63 - 52***	34 - 36
	1300	***63 - 52***	34 - 36	1300	***63 - 52***	34 - 36	1300	***63 - 52***	34 - 36	1300	***63 - 52***	34 - 36
Nov	1300	***63 - 52***	34 - 36	2325	***48 - 40***	41 - 50	1300	***63 - 52***	34 - 36	1300	***63 - 52***	34 - 36
	1300	***63 - 52***	34 - 36	2325	***48 - 40***	41 - 50	1300	***63 - 52***	34 - 36	1300	***63 - 52***	34 - 36
Dec	1300	***63 - 52***	34 - 36	3360	***40 - 33***	50 - 52	2170	***48 - 40***	41 - 50	1300	***63 - 52***	34 - 36
	1300	***63 - 52***	34 - 36	3360	***40 - 33***	50 - 52	2170	***48 - 40***	41 - 50	1300	***63 - 52***	34 - 36
Jan	1300	***63 - 52***	34 - 36	3042	***40 - 33***	50 - 52	2057	***48 - 40***	41 - 50	1300	***63 - 52***	34 - 36
	1300	***63 - 52***	34 - 36	3042	***40 - 33***	50 - 52	2057	***48 - 40***	41 - 50	1300	***63 - 52***	34 - 36
Feb	1300	***63 - 52***	34 - 36	3325	***40 - 33***	50 - 52	2158	***48 - 40***	41 - 50	1300	***63 - 52***	34 - 36
	1300	***63 - 52***	34 - 36	3325	***40 - 33***	50 - 52	2158	***48 - 40***	41 - 50	1300	***63 - 52***	34 - 36
Mar	1450	***63 - 52***	34 - 36	4216	***26 - 18***	52 - 48	2713	***48 - 40***	41 - 50	2078	***48 - 40***	41 - 50
	1450	***63 - 52***	34 - 36	4671	***26 - 18***	52 - 48	2780	***40 - 33***	50 - 52	2172	***48 - 40***	41 - 50
Apr	1500	***63 - 52***	34 - 36	4996	***18 - 16***	48 - 47	3650	***33 - 26***	52 - 52	2232	***48 - 40***	41 - 50
	1500	***63 - 52***	34 - 36	4032	***33 - 26***	52 - 52	2493	***48 - 40***	41 - 50	1500	***63 - 52***	34 - 36
May	1500	***63 - 52***	34 - 36	2420	***48 - 40***	41 - 50	1500	***63 - 52***	34 - 36	1500	***63 - 52***	34 - 36
	1500	***63 - 52***	34 - 36	2420	***48 - 40***	41 - 50	1500	***63 - 52***	34 - 36	1500	***63 - 52***	34 - 36
Jun	1400	***63 - 52***	34 - 36	1400	***63 - 52***	34 - 36	1400	***63 - 52***	34 - 36	1400	***63 - 52***	34 - 36
	1400	***63 - 52***	34 - 36	1400	***63 - 52***	34 - 36	1400	***63 - 52***	34 - 36	1400	***63 - 52***	34 - 36
Jul	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34
	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34
Aug	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34
	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34
Sep	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34
	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34	1000	***83 - 63***	36 - 34

Appendix Table 3-D-9. Continued.

Source of maximum available habitat values: Table I-3 of Hardy and Addley 2006. Table I-3 of Hardy and Addley 2006 presented the maximum available habitat for a given discharge. The discharge values were given in cfs intervals. The presented range of percent of maximum available habitat reflects the interval range that the modeled discharge fell within.

Note: Percent maximum available habitat values in bold and italics indicate flows above maximum available habitat flow.

Appendix Table 3-D-10. Estimate available habitat for juvenile and fry coho salmon within the main stem of the Klamath River at Seiad, a study site within the main stem of the Klamath River downstream of the confluence of the Scott River. Estimate available habitat for juvenile and fry coho salmon are depicted under the (2008 to 2018) modeled flows at IGD of the Proposed Action at 25 percent, 50 percent, and 75 percent exceedence levels.

Month	Minimum Flow	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat		Projected Exceedence	Percent [1] Maximum Habitat	
		Juvenile	Fry	25%	Juvenile	Fry	50%	Juvenile	Fry	75%	Juvenile	Fry
Oct	1300	43 - 44	96 - 93	1300	43 - 44	96 - 93	1300	43 - 44	96 - 93	1300	43 - 44	96 - 93
	1300	43 - 44	96 - 93	1300	43 - 44	96 - 93	1300	43 - 44	96 - 93	1300	43 - 44	96 - 93
Nov	1300	43 - 44	96 - 93	2325	39 - 54	89 - 92	1300	43 - 44	96 - 93	1300	43 - 44	96 - 93
	1300	43 - 44	96 - 93	2325	39 - 54	89 - 92	1300	43 - 44	96 - 93	1300	43 - 44	96 - 93
Dec	1300	43 - 44	96 - 93	3360	53 - 47	98 - 100	2170	39 - 54	89 - 92	1300	43 - 44	96 - 93
	1300	43 - 44	96 - 93	3360	53 - 47	98 - 100	2170	39 - 54	89 - 92	1300	43 - 44	96 - 93
Jan	1300	43 - 44	96 - 93	3042	54 - 53	92 - 98	2057	44 - 39	91 - 89	1300	43 - 44	96 - 93
	1300	43 - 44	96 - 93	3042	54 - 53	92 - 98	2057	44 - 39	91 - 89	1300	43 - 44	96 - 93
Feb	1300	43 - 44	96 - 93	3325	53 - 47	98 - 100	2158	39 - 54	89 - 92	1300	43 - 44	96 - 93
	1300	43 - 44	96 - 93	3325	53 - 47	98 - 100	2158	39 - 54	89 - 92	1300	43 - 44	96 - 93
Mar	1450	45 - 44	93 - 91	4216	47 - 44	***100 - 97***	2713	54 - 53	92 - 98	2078	44 - 39	91 - 89
	1450	45 - 44	93 - 91	4671	44 - 52	***97 - 86***	2780	54 - 53	92 - 98	2172	39 - 54	89 - 92
Apr	1500	44 - 39	91 - 89	4996	44 - 52	***97 - 86***	3650	53 - 47	98 - 100	2232	39 - 54	89 - 92
	1500	44 - 39	91 - 89	4032	47 - 44	***100 - 97***	2493	39 - 54	89 - 92	1500	44 - 39	91 - 89
May	1500	44 - 39	91 - 89	2420	39 - 54	89 - 92	1500	44 - 39	91 - 89	1500	44 - 39	91 - 89
	1500	44 - 39	91 - 89	2420	39 - 54	89 - 92	1500	44 - 39	91 - 89	1500	44 - 39	91 - 89
Jun	1400	45 - 44	93 - 91	1400	45 - 44	93 - 91	1400	45 - 44	93 - 91	1400	45 - 44	93 - 91
	1400	45 - 44	93 - 91	1400	45 - 44	93 - 91	1400	45 - 44	93 - 91	1400	45 - 44	93 - 91
Jul	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96
	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96
Aug	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96
	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96
Sep	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96
	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96	1000	44 - 43	99 - 96

Appendix Table 3-D-10. Continued.

Source of maximum available habitat values: Table I-4 of Hardy and Addley 2006. Table I-4 of Hardy and Addley 2006 presented the maximum available habitat for a given discharge. The discharge values were given in cfs intervals. The presented range of percent of maximum available habitat reflects the interval range that the modeled discharge fell within.

Note: Percent maximum available habitat values in bold and italics indicate flows above maximum available habitat flow.

Biological Assessment

The Effects of the Proposed Action to Operate the Klamath Project from April 1, 2008 to March 31, 2018 On Federally-Listed Threatened and Endangered Species

Appendix 4-A - Glossary

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Klamath Basin Area Office
Mid Pacific Region

Action means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States or upon the high seas. Examples include, but are not limited to:

(a) actions intended to conserve listed species or their habitat;
(b) the promulgation of regulations;
(c) the granting of licenses, contracts, leases, easements, rights-of-way, permits, or grants-in-aid; or
(d) actions directly or indirectly causing modifications to the land, water, or air.

Action area means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action.

Biological assessment refers to the information prepared by or under the direction of the Federal agency concerning listed and proposed species and designated and proposed critical habitat that may be present in the action area and the evaluation potential effects of the action on such species and habitat.

Biological opinion is the document that states the opinion of the Service as to whether or not the Federal action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat.

Conservation recommendations are suggestions of the Service regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information.

Critical habitat refers to an area designated as critical habitat listed in 50 CFR parts 17 or 226.

Cumulative effects are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation.

Destruction or adverse modification is currently undefined due to court cases vacating the Services statutory definition. Until a new definition is promulgated, the Services are relying on the statutory definition of “conserve” and “critical Habitat” to interpret the meaning of destruction or adverse modification of critical habitat (USFWS, Advanced Interagency Consultation Training Study Guide for Response Analysis, nd <http://training.fws.gov/EC/Resources/Advanced_Sec_7/June_2005/Study_Guides/Response.pdf> Accessed September 6, 2007

Effects of the action refers to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline.

Endangered species are “any species which is in danger of extinction throughout all or a significant portion of its range.”

Environmental Baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

Evolutionarily Significant Unit (ESU) is a population or group of populations of salmon that are substantially reproductively isolated from other populations and contribute substantially to the evolutionary legacy of the biological species.

Interactive Management (IM) water is water available in the system after meeting proposed flows and lake levels and addressing Project obligations. IM water will enhance minimum levels to bring river flows and lake elevations closer to desired targets beyond the jeopardy standard, to contribute toward tribal trust obligations, and to help conserve and enhance fish and wildlife habitat.

Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration.

Formal consultation is a process between the Service and the Federal agency that commences with the Federal agency's written request for consultation under section 7(a)(2) of the Act and concludes with the Service's issuance of the biological opinion under section 7(b)(3) of the Act.

Incidental take refers to takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant.

Informal consultation is an optional process that includes all discussions, correspondence, etc., between the Service and the Federal agency or the designated non-Federal representative prior to formal consultation, if required.

Jeopardize the continued existence of means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.

Listed species means any species of fish, wildlife, or plant which has been determined to be endangered or threatened under section 4 of the Act. Listed species are found in 50 CFR 17.11-17.12.

Major construction activity is a construction project (or other undertaking having similar physical impacts) which is a major Federal action significantly affecting the quality of the human environment as referred to in the National Environmental Policy Act [NEPA, 42 U.S.C. 4332(2)(C)].

Proposed critical habitat means habitat proposed in the Federal Register to be designated or revised as critical habitat under section 4 of the Act for any listed or proposed species.

Proposed species means any species of fish, wildlife, or plant that is proposed in the Federal Register to be listed under section 4 of the Act.

Reasonable and prudent alternatives refer to alternative actions identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, that is economically and technologically feasible, and that the Director believes would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat.

Reasonable and prudent measures refer to those actions the Director believes necessary or appropriate to minimize the impacts, i.e., amount or extent, of incidental take.

Recovery means improvement in the status of listed species to the point at which listing is no longer appropriate under the criteria set out in section 4(a)(1) of the Act.

Service means the U.S. Fish and Wildlife Service or the National Marine Fisheries Service, as appropriate.

Threatened species are “those animals and plants likely to become endangered within the foreseeable future throughout all or a significant portion of their ranges."