US Army Corps of Engineers
Walla Walla District

Lower Granite Reservoir In-Water Disposal Test: Proposed Monitoring Program

ESSA Environmental and Social Systems Analysts Ltd.

December, 1987

Lower Granite Reservoir In-Water Disposal Test: Proposed Monitoring Program

by

Tim M. Webb
Nicholas C. Sonntag
Lorne A. Greig
Michael L. Jones

ESSA Environmental and Social Systems Analysts Ltd.
Box 12155 - 808 Nelson Street
Vancouver, B.C.
V6Z 2H2

for

U.S. Army Corps of Engineers
Walla Walla, Washington 99362

December, 1987

ACKNOWLEDGEMENTS

This report represents the completion of a consensus building process facilitated to develop a monitoring strategy for the test of in-water disposal of dredged materials in the Lower Granite Reservoir. The content of this report is a result of the scholarship of over 30 participants who attended two workshops held in July and August, 1987. We would like to acknowledge their contribution to this report and make it clear to the reader that although four authors are indicated, the knowledge, information, and ideas contained in these pages were very much a group effort.

A special note of thanks to Teri Barila of the U.S. Army Corps of Engineers in Walla Walla, Washington, and John Lunz of the U.S. Army Corps of Engineers Waterways Experimental Station in Vicksburg, Mississippi. Their intellectual leadership and faith in the process were instrumental in ensuring development of the monitoring plan was accomplished quickly, and in an environment of cooperation and enthusiasm.

Finally, we would like to thank Pille Bunnell for her continuing care to produce the report figures, and Gwen Eisler for her editing and report production.

EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers is currently evaluating alternative solutions to reestablishing the original flood freeboard design for the Lewiston-Clarkston levee system established as part of the Lower Granite Lock and Dam project (completed in 1975), located on the Snake River. Among the alternatives being considered are dredging and in-water dredged material disposal activities. An in-water disposal test is proposed by the Corps for 1988 and 1989 (December-March of the respective years, beginning in December, 1987). This test must address two needs. First, it must adequately evaluate the environmental impacts of the proposed test activities on the aquatic resources (primarily salmonids) Second, it must develop a technically defensible dredging and disposal monitoring plan, while complying with the philosophy of the Federal Standard. To meet these requirements the Corps decided to use a formalized procedure best known by the name Adaptive Environmental Assessment and Management (AEAM).

In July, 1987, ESSA Environmental and Social Systems Analysts Ltd. was contracted by the Corps to facilitate implementation of the AEAM process and develop the ecological monitoring program for the in-water disposal test. To accomplish these requirements, two interagency workshops were held in Portland, Oregon (July 22-23 and August 17-19, 1987), followed by two technical meetings.

CONCEPTUAL MODEL AND HYPOTHESES

The first workshop focused on developing a conceptual model of the biophysical system in the Lower Granite Reservoir. This conceptual model formed the basis for synthesizing current system understanding and identifying the potential for positive and negative effects on key system indicators, also called Valued Ecosystem Components (VEC).

Following development of the conceptual model a set of four hypotheses was developed. Each hypothesis is structured as a series of steps defining the linkages between disposal and/or dredging activities and one or more of the VECs. The four hypotheses cover the effects of dredging and in-water disposal on: salmonid predator habitat, salmonid habitat, resident game fish, and recreational fishing effort.

At the second workshop the hypotheses were clarified and a disposal design, monitoring program and priorities were developed. These were further refined at two technical meeting held after the second workshop.

DISPOSAL SITE DESIGN

Three disposal site types are recommended: two sites currently between the 20 ft. and 60 ft. depth contours (mid water sites), and one site currently at a depth greater than 60 ft. (deep water site). The recommended design of the mid water sites is:

1) an island parallel to the shore and approximately 1000 feet long; and

2) a submerged plateau, within 15 feet of the surface at high pool, between 500 and 1000 feet long and extending to the edge of the shelf.

The rationale for constructing an island is that it is the design most likely to produce opportunities for generating measurable responses from the fish and other indicator organisms.

The large volume of material required to construct these sites reduces the likelihood that all three sites can be constructed in a single year. A number of different options are discussed based on the availability of dredge material in each year. A scenario is described in which two mid sites and three deep sites are constructed over a three year period using approximately 800,000 cubic yards per year. If more dredge material becomes available the submerged mid water site and the deep sites should be constructed with the highest priority and the island mid water site be constructed subsequently as fast as possible.

RECOMMENDED MONITORING

The monitoring procedures recommended for the proposed disposal sites fit into four categories:

1) fish abundance relative to reference sites;

2) benthos abundance, composition and recovery relative to reference sites;

3) various habitat variables to aid in the interpretation of the fish and benthos results; and

4) synoptic and long term sampling and monitoring.

Fish - Fish groups to be monitored at the disposal and reference sites consist of salmonid juveniles, predators of salmonids, and resident fish of interest to anglers. The monitoring recommended is intended to determine if there are significant direct effects attributable to the disposal activity. Levels of natural variability and limitations on sampling effort will mean that, at least in the first year, only fairly large differences will be detectable.

Benthos - From a monitoring standpoint the benthos represents a portion of the biological system of direct interest which is relatively tractable to monitor. It is recommended that the biomass and species composition of benthos be monitored at both the disposal and reference sites. This will allow important inferences to be made on some of the likely effects on the abundance and distribution of various fish species.

Habitat - It is recommended that a number of habitat characteristics be monitored, largely to provide information to aid in the interpretation of the fish and benthos results. These habitat characteristics are: bathymetry, substrate composition, sedimentation rates, and macrophyte development.

Synoptic Survey - there are significant gaps in understanding of the habitat requirements of fish. It is therefore recommended that a synoptic survey of habitat and fish abundance be carried out throughout the reservoir to define fish-habitat associations. While this synoptic monitoring is not directly tied to the disposal test program it does represent an approach to filling an important information gap related to in-water disposal.

CONCLUSIONS

Based on the workshops, the technical meetings, and further analysis the following are proposed as being critical to continued success in the development and implementation of this monitoring program:

1) the process of interagency consultation and consensus building must continue. This is needed to further refine the rationale for monitoring criteria and to develop an agreed upon structure for the interpretation of results;

2) following the first year of data collection a significant effort must be applied to data analysis and subsequent design work to refine the monitoring program design;

3) work to define preliminary criteria for habitat variables should be initiated immediately. Results of the first years program will significantly aid this process; and

4) prior to the second year (and subsequent years) of the study, the plan for construction of the mid and deep water test sites should be re-evaluated based on the previous years data and the potential availability of dredge material.

TABLE OF CONTENTS

Page

1.0 INTRODUCTION. 1

2.0 OBJECTIVES. 4

3.0 PROCESS 5
3.1 Overall Approach: AEAM 5
3.2 Application. 7

4.0 CONCEPTUAL MODEL. 11
4.1 Introduction 11
4.2 Bounding 12
4.2.1 Actions 12
4.2.2 Valued Ecosystem Components 14
4.2.3 Space and Time. 15
4.2.4 Definition of Subsystems. 17
4.3 Subsystem Descriptions 17
4.4 Conceptual Model 19

5.0 HYPOTHESES. 22
5.1 Hypothesis No. 1 27
5.1.1 Linkages. 27
5.1.2 Conclusion. 38
5.1.3 Monitoring. 39
5.2 Hypothesis No. 2 44
5.2.1 Linkages. 44
5.2.2 Conclusion. 53
5.2.3 Monitoring. 53
5.3 Hypotheses No. 3 59
5.3.1 Linkages. 59
5.3.2 Conclusion. 61
5.3.3 Monitoring. 62
5.4 Hypothesis No. 4 66
5.4.1 Linkages. 66
5.4.2 Conclusion. 69
5.4.3 Monitoring. 69
5.5 Summary. 70

6.0 DESIGN CONSIDERATIONS 72
6.1 Configuration of Disposal Site 73
6.2 Disposal Site Observations 80
6.2.1 Bathymetry. 82
6.2.2 Substrate Composition 85
6.2.3 Accumulation of New Sediment. 87
6.2.4 Benthos 89
6.2.5 Macrophytes 92
6.2.6 Zooplankton 94
6.2.7 Fish Utilization. 95
6.2.8 Fish Feeding. 105
6.2.9 Wildlife. 106

TABLE OF CONTENTS (cont'd)

	Page
6.3 Reservoir Wide Observations.	107
6.3.1 Bathymetry Survey	108
6.3.2 Synoptic Survey of Fish Use	110
6.3.3 Long Term Predator Abundance Monitoring . .	112
7.0 OVERVIEW AND INTERPRETATION	114
7.1 Summary of Monitoring Program.	114
7.2 Relative Priorities.	114
7.3 Evaluation of Results.	119
7.3.1 Biological Significance	119
7.3.2 Analysis and Criteria	120
7.4 Design Issues.	123
7.5 Conclusions.	123
8.0 REFERENCES.	125
APPENDIX 1: Issues Raised at First Workshop.	A1
APPENDIX 2: First Workshop Subgroup Reports.	A5

LIST OF TABLES

Table		Page
1	List of participants at July 22-23 and August 17-19, 1987 workshops	9
2	Interaction matrix showing the linkages identified by the participants at the workshop	18
3	Matrix of resident fish species' responses to changes in habitat.	21
4	Summary of monitoring recommended actions developed at second workshop.	71
5	Pair-wise value ranking of research priorities for habitat observations	118
A1	Relative meausres of suspended sediment and turbidity at dredging site.	A7
A2	Substrate composition at dredging and sisposal sites . .	A12
A3	List of fish species discussed by the resident fish subgroup	A19
A4	List of life history processes discussed by the resident fish subgroup.	A20
A5	Physical, chemical, and habitat changes potentially resulting from dredging and disposal operations whose impacts were considered by the resident fish subgroup. .	A20
A6	Summary of the physical/habitat changes that influence squawfish.	A22
A7	Summary of the physical/habitat changes that influence sturgeon	A23
A8	Summary of the physical/habitat changes that influence other cyprinids.	A24
A9	Summary of the physical/habitat changes that influence centrarchids and percids	A25
A10	Summary of the physical/habitat changes that influence catfish.	A26
A11	Summary of the physical/habitat changes that influence carp	A27

LIST OF FIGURES

Figure		Page
1	Location of proposed dredging sites for 1988 test period	13
2	Conceptual model developed out of workshop discussions .	20
3	Hypothesis 1	24
4	Hypothesis 2	41
5	Typical response of benthic productivity to non-toxic disturbance.	49
6	Typical gradient of benthic productivity	51
7	Hypothesis 3	56
8	Hypothesis 4	64
9	One of the proposed schedules for construction of mid and deep water disposal sites.	77
10	Fish types vulnerable to the different gear types proposed for the monitoring program.	97
11	Detailed annual schedule for sampling fish utilization .	99
12	Summary of schedule of monitoring proposed for the 5 year program	115
A1	Location of proposed dredging sites for test period. . .	A8
A2	Possible topographic characteristics of the disposal field at the proposed mid-water disposal site.	A14

1.0 INTRODUCTION

The Lower Granite Lock and Dam project, located on the Snake River, was completed in 1975 and provides slack-water navigation to the cities of Lewiston, Idaho and Clarkston, Washington. The project includes a levee system to protect large areas of industrial, commercial, and residential properties in the Lewiston area from inundation by waters impounded behind Lower Granite Dam. The design levee freeboard of 5' has been reduced to about 2' due to sediment deposition.

Approximately 2 million cubic yards (mcy) of sediment enter the reservoir annually. About 800,000 cy of this material are deposited in critical flow areas between Lewiston and Silcott Island (River Mile 131). Of the 38 mcy of sediment estimated to have been deposited in the reservoir since 1975, about 10 mcy would have to be dredged to regain the design water surface elevation at the confluence of the Clearwater and Snake Rivers. To maintain the required freeboard at the levee system, about 800,000 cy must be dredged annually. The U.S. Army Corps of Engineers is evaluating alternative solutions to reestablish the original flood freeboard design for the Lewiston-Clarkston levee system. A feasibility study and environmental impact statement are being prepared to address project actions, economics, and the probable environmental effects of all sedimentation control alternatives.

Among the alternatives being considered (e.g., levee raise, upland disposal, in-river structures, lowering spillway crest, lowering reservoir level at spring freshet; Corps, 1986) are dredging and in-water dredged material disposal activities. An in-water disposal test is proposed by the Corps for 1988 and 1989 (December-March of the respective years, beginning in December, 1987). For this test, material dredged at the confluence of the Clearwater and Snake would be transported to RM 120 and deposited in mid-depth (20'-60') and deep (> 60') water sites. The test will be designed to document the physical and chemical alterations to the disposal site environment and the biological responses, particularly the fish responses, to those physical and chemical environmental alterations.

The reservoir is utilized by a variety of anadromous salmonid fish having commercial and sports fishery value, and by resident game fish. Information is limited on the response of salmonid and resident fish species to habitat alterations affected by dredged material disposal in freshwater reservoir systems. In addition, resource management agency's response to proposed in-water disposal focuses on the "unknown risk" associated with the activity. Not enough is known about the ecology of salmonids in reservoirs to determine what constitutes desirable habitat, whether it can be created, or whether it is even wise to attempt to create it. For example, shallow water habitat has been shown to be extensively utilized by salmonids. However, creating additional shallow water habitat in present mid-depth or deep areas as a way to achieve fishery management objectives may not be recommended because it could actually increase the losses of juvenile salmon to predatory fish. The Corps believes and intends to test the concept that in-water disposal of dredged material can be managed to meet operational objectives while achieving no net loss of, and with possible benefit to, aquatic resources.

During initial discussions of the in-water disposal test, two basic requirements emerged. The first requirement that emerged was the need to adequately evaluate the environmental impacts of the proposed test activities on the aquatic resources (primarily salmon and steelhead trout) utilizing the in-water disposal locations. The second requirement was to develop a technically defensible disposal and disposal monitoring plan, while complying with the philosophy of the Federal Standard. To meet these requirements the Corps decided to use a formalized procedure best known by the name Adaptive Environmental Assessment and Management (AEAM), initially developed by C.S. Holling and his associates (Holling, 1978; ESSA, 1982).

In July, 1987, ESSA Environmental and Social Systems Analysts Ltd. was contracted by the Corps to facilitate implementation of the AEAM process and develop the ecological monitoring program for the in-water disposal test. To accomplish these requirements, two workshops were held in Portland, Oregon (July 22-23 and August 17-19, 1987), followed by two technical meetings. It should be noted that although the workshops only focused on in-water disposal, other alternatives are also under study by the Corps.

This report summarizes the discussions held at the workshops and subsequent technical meetings and details the monitoring recommendations for the in-water disposal test. Chapter 2.0 describes the objectives of the project while Chapter 3.0 lays out the adaptation of the AEAM process used to facilitate the development of the monitoring programs. Chapter 4.0 and describes the conceptual model developed at the first workshop, and in Chapter 5.0, the specific hypotheses extracted from the conceptual model are described. Chapter 6.0 provides a detailed description of the overall monitoring strategy. Chapter 7.0 provides an overview of the recommended monitoring program and some discussion on evaluation of program results.

2.0 OBJECTIVES

The overall objective of this study is to:

- o design a monitoring program to evaluate the effects of dredging and in-water disposal activities, conducted during the December to March period, on the aquatic resources in the Lower Granite Reservoir.

Given the above overall objective, the objective of the first workshop was to:

- o develop a conceptual model describing the potential biophysical impacts of dredging and in-water disposal, conducted during the December to March period, in the Lower Granite Reservoir.

The objectives of the second workshop were to:

- o evaluate the evidence supporting the four hypotheses extracted from the conceptual model;
- o develop a set of monitoring recommendations to address the uncertainties identified in the evaluation of the hypotheses; and
- o synthesize the hypothesis oriented monitoring recommendations into an overall monitoring strategy.

3.0 PROCESS

3.1 Overall Approach: AEAM

During the past two decades, an increase in the level of public concern regarding the environmental effects of resource development has increased the role of environmental assessments in resource planning and management. Although most of these assessments have been multidisciplinary, there have been few attempts at implementing a coordinated, interdisciplinary approach to the assessment analysis. An interdisciplinary approach involves bringing together disciplinary specialists, resource development planners, government regulators, and other interested parties to determine collectively what is or is not a potential environmental issue. As a result, specific studies are firmly focused on the task to be achieved; that is, their integration into an impact assessment leading to post-approval environmental management.

The development of the Lower Granite Reservoir in-water disposal test monitoring program was designed using an interdisciplinary approach. The approach chosen was Adaptive Environmental Assessment and Management (AEAM), documented in Holling (1978), ESSA (1982), and Walters (1986). Its history of providing input into regulatory decision making for a variety of projects in the U.S. and Canada makes AEAM a good approach to achieving the objectives indicated in Chapter 2.

The central focus of the AEAM approach, as conceived for the Lower Granite reservoir test, was the development of a conceptual model of the biophysical processes in the reservoir. Development of this model was accomplished in a workshop setting, involving the necessary scientific, technical, and policy expertise available from the key agencies, universities, and other interests in the region. The workshop approach is designed to ensure all parties participate in the model design and are given ample opportunity to evolve a common framework around which the monitoring program can be formulated. Following development of the conceptual model, four impact hypotheses were extracted from the conceptual model to provide a focus for discussions at the second workshop. At the second workshop the hypotheses were evaluated, refined, and where appropriate, monitoring recommendations to address the impacts suggested in the hypotheses developed

The impact hypothesis is an important concept in the AEAM approach to development of a research and monitoring program (Everitt et al, 1985). Simply stated, an impact hypothesis is a statement (written or visual) describing a set of interacting processes which link the proposed activities with their potential environmental effects. Every impact hypothesis has three primary parts that must be characterized:

1) the action (e.g., dredging, disposal) - the potential cause of effect;

2) the valued ecosystem component (VEC) or indicator (e.g., the number of chinook salmon) - the component of the ecosystem potentially affected by the action (directly or indirectly), and to which society has attributed some value; and

3) the linkages - the sequence of biophysical processes that link the action to the VEC.

Monitoring, in the context of this approach, is a scientific process designed to test specific hypotheses on the causes of environmental impacts. Monitoring, therefore, becomes the repetitive measurement of variables likely to change due to direct or indirect effects of identified actions. This kind of monitoring, therefore, is not intended to serve a surveillance function, nor is it part of the regulatory process used to ensure a proponent meets the environmental terms and conditions of its operating permits. Notwithstanding the necessity for such regulatory monitoring, the monitoring recommendations emerging out of this approach are intended to measure environmental impacts and increase understanding of cause-effect relationships.

3.2 Application

To implement the application of the AEAM approach to the development of the Lower Granite Reservoir in-water disposal test monitoring program, a number of distinct tasks were identified:

1) First Workshop - a two day workshop to design the conceptual model and initiate a cooperative environment for development of the monitoring plan. This workshop was held in Portland, Oregon on July 22-23, 1987 in Portland, Oregon;

2) Hypothesis Generation - finalization of the conceptual model and development of the impact hypotheses. This occurred after the workshop and was documented in an interim report distributed prior to the second workshop;

3) Second Workshop - a three day workshop at which the hypotheses were evaluated and appropriate research and monitoring recommendations developed. This workshop was held August 17-19, 1987 in Portland, Oregon; and

4) Monitoring Plan Refinement - detailed design of the monitoring plan, including sampling strategy and recommended analysis of the collected data. This task included two technical meetings at which some of the details of the monitoring plan were discussed and refined. This report is the monitoring plan.

The attendees at the two workshops represented a variety of scientific and technical expertise identified as knowledgeable about the biophysical system potentially impacted by dredging and in-water disposal of dredge material in the Lower Granite Reservoir. Their names and affiliations are shown in Table 1.

Table 1: List of participants at July 22-23 and August 17-19, 1987 workshops.

NAME	AFFILIATION	TELEPHONE	July 22-27	August 17-19
Barila, Teri	Corps of Engineers, Walla District	(509)522-6630	*	*
Bennett, David	University of Idaho, Moscow	(208)885-6337	*	*
Carrubba, Sheryl	Corps of Engineers, Portland District	(503)221-6085		*
Case, Nancy	Corps of Engineers, Portland District	(503)221-3153	*	
Cunningham, Lester	Corps of Engineers, Walla District	(509)522-6615		*
Dauble, Dennis	Battelle, Pacific Northwest Laboratory	(509)376-3631	*	*
Deusen, Millard S.	Washington Department of Fisheries	(206)753-2082	*	
Ebel, Wes	National Marine Fisheries Service (NMFS)	(206)442-4445	*	
Falter, Mike	University of Idaho, Moscow	(208)885-7123	*	*
Greig, Lorne	ESSA Ltd., Toronto	(416)967-7330	*	*
Heberger, Roy	Fish & Wildlife Service, Boise	(208)334-1931		*
Hilborn, Ray	University of Washington	(206)679-2322	*	
Homziak, Jurij	WES	(601)634-3891		*
Hopman, Bob	Corps of Engineers, North Pacific Division	(503)221-3778	*	
Iadanza, Nicholas	National Marine Fisheries Service (NMFS)	(503)230-5428	*	*
Jones, Michael	ESSA Ltd., Toronto	(416)967-7330	*	*
Li, Hiram W.	OSU Coop. Fish. Res. Unit	(503)754-4531	*	
Lunz, John D.	Corps of Engineers (WES)	(601)634-3303		*
Myers, Ralph	U.S. Fish & Wildlife Service, Boise Field Office	(208)334-1931	*	
Nelson, Bill	U.S. Fish & Wildlife Service	(509)538-2299	*	*
Patterson, Ken	Corps of Engineers, Portland District	(503)221-3153	*	*

Peterson, Phil	Washington Department of Fisheries	(509)575-2743		*
Redlinger, Jake	Corps of Engineers, North Pacific Division	(503)221-3779	*	
Reese, Jim	Corps of Engineers, North Pacific Division	(503)221-3832	*	*
Rickel, Bob	Corps of Engineers, Walla District	(509)522-6598		
Rieman, Bruce	Oregon Department of Fish & Wildlife	(503)657-2036	*	*
Rondorf, Dennis	U.S. Fish & Wildlife Service	(509)538-2299	*	
Sather-Blair, Signe	U.S. Fish & Wildlife Service, Boise Field Office	(208)334-1931	*	
Sonntag, Nicholas	ESSA Ltd., Vancouver	(604)689-2912	*	*
Swan, George	National Marine Fisheries Service (NMFS)	(509)547-7515	*	*
Theriot, Edwin	Waterways Experiment Station, COE	(601)634-2678	*	
Turner, Rudd	COE, Portland District	(503)221-6401	*	*
Wasserman, Larry	Yakima Indian Nation	(509)865-5121	*	*
Webb, Tim	ESSA Ltd., Vancouver	(604)689-2912	*	*
Williams, David T.	Waterways Experiment Station, COE	(601)634-2623	*	

4.0 CONCEPTUAL MODEL

4.1 Introduction

The first workshop was directed towards the development of a conceptual model of the biophysical system in the Lower Granite Reservoir. The major steps in developing this model included:

1) characterization of the dredging and disposal activities proposed for the in-water disposal test;

2) identification of the VECs to be incorporated in the conceptual model;

3) discussion of the temporal and spatial considerations;

4) division of the system into interacting subsystems; and

5) development of a conceptual description of each subsystem for eventual integration into the overall conceptual model.

After the workshop, two more steps were completed, based on the workshop discussions:

6) development of the overall conceptual model; and

7) extraction of a set of hypotheses to serve as the basis for development of the research and monitoring program.

The first four steps are commonly referred to as bounding the system of interest. The fifth is priorization of the critical processes within each subsystem prior to their synthesis into an integrated framework (i.e., model). The sixth and seventh steps are the initiation of the monitoring program design -- identification of the key questions, posed as hypotheses, we wish the monitoring program to address.

The following sections describe the outcome of these steps.

4.2 Bounding

4.2.1 Actions

The dredging project calls for flood-control dredging at the confluence of the Snake and Clearwater Rivers and in-water disposal of the excavated material in two, down-river disposal areas below River Mile 120. The selected time period for dredging and disposal is between December 15 to March 31. Although the selection of this window was outside the mandate of this project it was selected to minimize the potential for negative impacts on the salmonid and resident fish populations. More detail on the dredging and disposal sites and materials can be found in a variety of documents (Corps 1986, 1987). It should be noted that the disposal window restriction noted here does not preclude the possibility of considering future dredging activities taking place outside the December-March window.

For the purposes of the bounding activity, the following features of the dredging and disposal activities were highlighted:

- Dredging - Removal of 800,000 cubic yards from two sites during the December-March window (Figure 1.). Dredge technology used can be hydraulic or mechanical, notwithstanding the need to consider the variability of removal rates and costs associated with different technologies; and

- Disposal - All dredge material will be disposed of in-water below River Mile 120. Two possible sites have been selected: a mid-depth site (20'-60') and a deep site (>60'). The decision on the disposal pattern in these sites, and their actual shape was

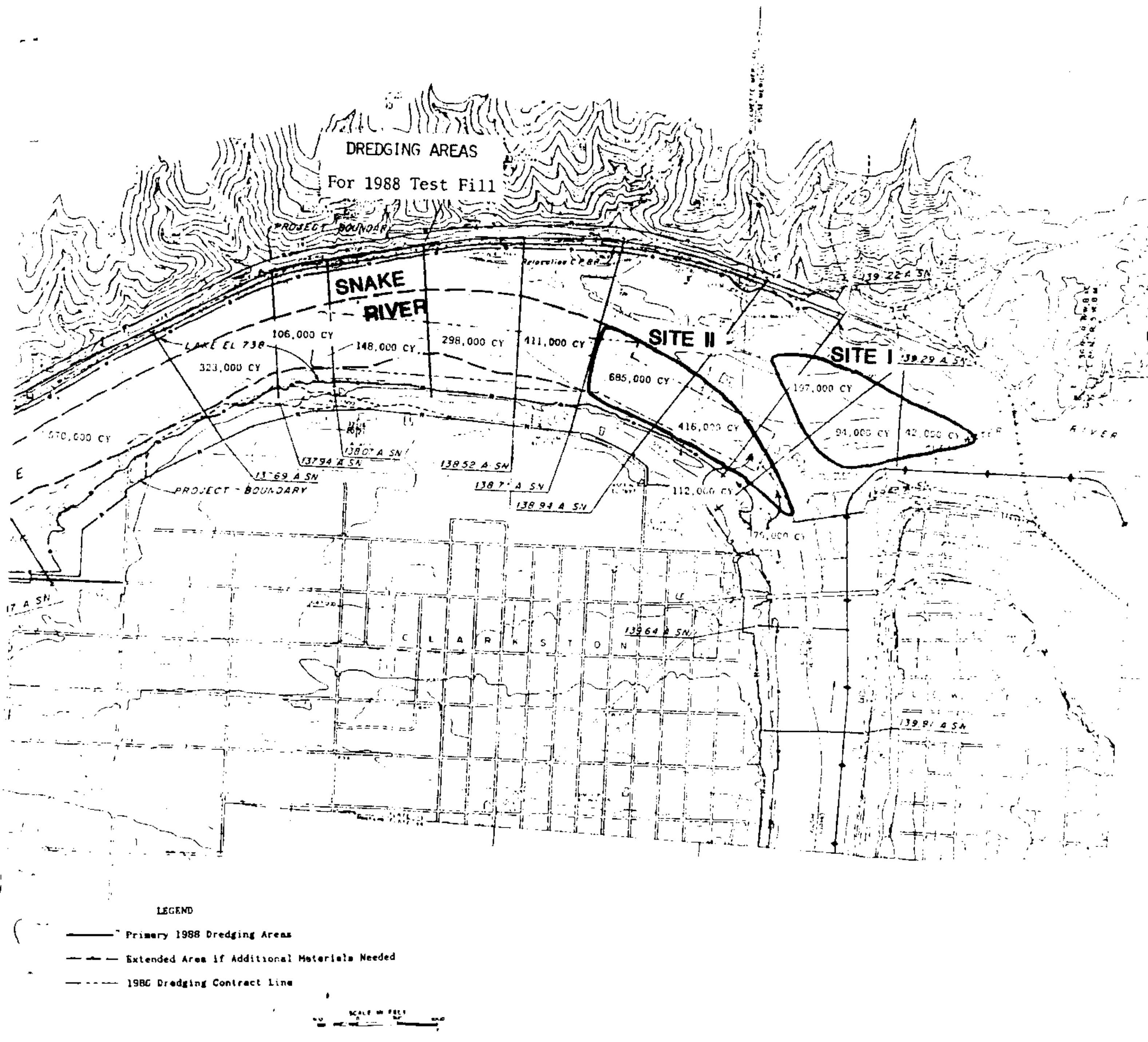

Figure 1 : Location of proposed dredging sites for 1988 test period. Adapted from: Environmental Assessment. Position Paper, July 2, 1987. Clearwater/Snake River Confluence Dredging, Winter 1987/88 Dredging Window.

not established prior to the workshops and could be adjusted to suit the needs of the in-water disposal test. Ultimately, the major consideration at the site is the practicality of the design, given available funds, and the requirement that all the 800,000 cubic yards be removed and disposed of in the selected window. The disposal technology will be a "bottom dump" scow or hopper.

In summary, there are two actions: dredging and disposal (including transport to the disposal site).

4.2.2 Valued Ecosystem Components

Beanlands and Duinker (1983) define VECs as:

> "...attributes of components of the environment for which there is public or professional concern, or both, and to which the assessment should be primarily directed... These may be determined on the basis of perceived public concerns related to social, cultural, economic, and aesthetic values. They may also reflect the scientific concerns of the professional community..."

To assist in the development of the VECs, the workshop participants were asked to identify what they felt were the key biophysical issues related to the in-water disposal test, and in-water disposal in the longer term. These are repeated in Appendix 1.

The final list of VECs was:

- o chinook salmon
  - spring/summer
  - fall
- o steelhead trout

- o resident game fish
  - white sturgeon
  - smallmouth bass
  - channel catfish
  - crappies
- o sport fish catch, especially of steelhead
- o wildlife (e.g., ducks, geese)

There was some discussion of other possible VECs related to the economic function served by the reservoir in the region, and the potential costs associated with a possible flood if dredging were not to proceed immediately. Notwithstanding the importance of these concerns, and the need for all agencies to address the associated tradeoffs that will likely have to be made, it was decided to restrict this exercise to the in-water disposal test and its associated impacts on fish and their habitat. However, as noted earlier, other disposal alternatives are being considered by the Corps.

4.2.3 Space and Time

In considering the spatial context of the conceptual model, two aspects must be addressed: extent and resolution. The extent of the model is the Lower Granite Reservoir. The effects of dredging and disposal on the VECs must be determined recognizing that the selective VECs use large areas within the reservoir and, therefore, "integrate" across the variety of conditions encountered. As for resolution, it was agreed that the necessary resolution of the model would be a function of the habitat considerations for the VECs and this would evolve from the workshop discussions.

Time also has two aspects that must be considered: horizon and resolution. The time horizon for the workshop discussions was not restricted to the 2 year in-water disposal test. Since many of the possible impacts may not become evident for 20-30 years, it was necessary to maintain both a short and long term perspective on the evaluation of possible impacts. For example, changes in the population of salmonids may take four or five generations before they are detectable. Even then, it will likely be impossible to differentiate impacts due to dredging from all the other factors affecting the salmonids outside the Lower Granite system (e.g., other reservoirs, harvesting). Therefore, the time horizon was set at 100 years, the approximate time period over which dredge material can be deposited in the Lower Granite Reservoir below Mile 120.

The temporal resolution selected was seasonal. It was felt this would capture the principle concerns and allow for differentiation between effects on adult and juvenile salmonids.

As indicated earlier, the proposed duration of the in-water disposal test is two years. Although this may change, it is clear that many of the possible impacts at the fish population level will not be evident in such a short time period. Therefore, the test must direct itself toward using the data collected to improve understanding of aspects of the conceptual model that are reasonable surrogates for the possible longer term effects (e.g., habitat utilization). Further, for this analysis, we are only interested in the changes brought about by dredging and disposal during the December - March window, and the possible effects of those changes on the fish at any time of the year they are in the Lower Granite Reservoir. Since the salmonids are generally not resident in the reservoir during the identified dredging window (note: there is evidence to indicate some salmonids overwinter in the reservoir), most impacts will likely be indirect. Therefore it is important that a monitoring program be designed to address specific questions (i.e., hypotheses) with clear stopping rules associated with each monitoring component. In this context stopping rules consist of a statement of how long an activity should be carried out and under what conditions it should be stopped. This approach should help to ensure that the monitoring program is useful and relevant.

4.2.4 Definition of Subsystems

The final procedure in the bounding exercise was the establishment of a meaningful division of the biophysical system into three or four subsystems. This division satisfies two needs. First, it allows the participants to contribute their knowledge to a focused discussion on the key processes underlying a particular aspect (i.e., subsystem) of the overall system. Second, it allows the workshop participants to be divided into smaller working groups thereby facilitating coverage of greater amounts of material in a relatively short period of time.

The subsystems identified were:

- Physical and Chemical Changes
- Fish Habitat
- Salmonid Fish Dynamics
- Resident Fish Dynamics

Before the subgroups could address each subsystem the interactions between the subsystems were identified. This was done to ensure all subgroup discussions were operating at the same level of process aggregation, and to ensure all possible pathways from action to VEC were discussed and clarified. The matrix developed is shown in Table 2.

4.3 Subsystem Descriptions

Although the interaction matrix developed at the workshop had four subsystems, it was decided that the subgroup sessions would be more fruitful if the physical/chemical and habitat discussions were held in the same subgroup. This seemed reasonable since much of the

Table 2: Interaction matrix showing the linkages identified by the participants at the workshop. Each row represents the linkages FROM the indicated subsystem to all the other subsystems. Each column represents all the linkages TO the indicated subsystem from all the other subsystems.

FROM \ TO	PHYSICAL/CHEMICAL ALTERATIONS	HABITAT	SALMONIDS	RESIDENT FISH
PHYSICAL/ CHEMICAL ALTERATIONS		· grain size (clay, silt, sand, organic) → composition, rate of change · amount of new habitat by depth, location, composition · topography - bathymetric relief · slope, proximity to other habitats · timing of disposal · ΔT, ΔDO_2 · duration, extent of plume · amount lost from high flow events · chemical characteristics - substrate	· dredging equipment type (flow, entrainment) · timing · # barge trips/day · characteristics of plume (turbidity, chemical)	· dredging equipment type (flow, entrainment) · timing · # barge trips/day · characteristics of plume (turbidity, chemical)
HABITAT	· change in water velocity		· amount of cover · area of substrate by depth, size class - topography · benthos abundance by species · location of substrate a) above/below river rapids → velocity b) north/south → shade of reservoir	· location relative to access points · depth of macrophyte beds (5-12' below max. pond ht.) · location - proximity to other habitats · density/composition of macrophyte beds · benthos · crayfish
SALMONIDS	———	———	(fishery)	· density, size by species
RESIDENT FISH	———	· macrophyte consumption by carp	· prey consumption rate of salmon by species	(fishery)

discussion dealing with physical changes would likely be oriented around how to engineer the disposal activity to create "good" fish habitat.

Each subgroup met for about six hours. The results of those discussions are presented in Appendix 2.

4.4 Conceptual Model

Following the workshop, the proceedings of the workshop were reviewed and the material was synthesized into an integrated conceptual model (Figure 2). This model captures the major pathways, described by the participants, that lead from the activities (i.e., dredging and disposal) to the identified VECs. To simplify the diagram, the interactions between habitat alterations brought about by dredging, and the resident fish populations, are described in more detail in an accompanying table (Table 3).

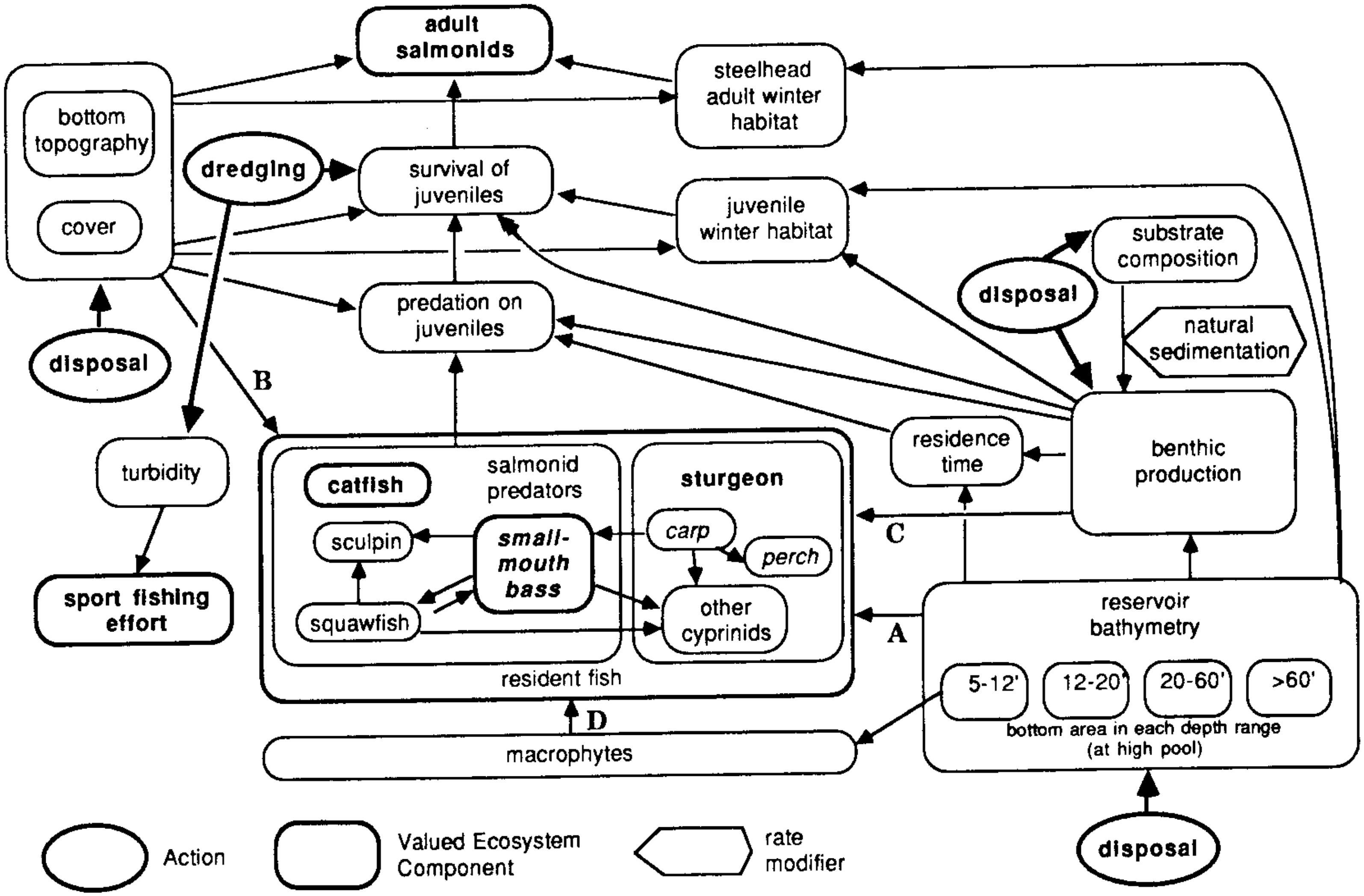

Figure 2: Conceptual model developed out of workshop discussions. Table 3 provides more detail on the significance of the four linkages (A,B,C,D) into the resident fish block.

Table 3: Matrix of resident fish species' responses to changes in habitat.

	A Increased Shallow	B Increased Cover	C Increased Benthos	D Increased Macrophytes
Squawfish				
rearing	+	-	+	+
imm/adult		-	+	
predation		-	-	-
Sturgeon				
rearing			+	
imm/adult	-		+	
Other Cyprinids				
rearing	+	-	+	+
imm/adult			+	+
Centrarchids & Percids				
rearing	+		+	+
imm/adult	+	+	+	+
predation		+	-	+
Catfish				
rearing	?	?	?	?
imm/adult	-	+	+	
predation		+	-	+
Carp				
rearing	+	-	+	
imm/adult	+		+	+

5.0 HYPOTHESES

Following development of the conceptual model, four hypotheses were extracted to describe the major issues for discussion at the second workshop. The specific tasks completed in those discussions were:

1) Clarification of the Hypothesis - This involved developing an agreement on the structure of the hypothesis and, if necessary, restatement of the hypothesis and the linkages. At this stage some linkages could have been discarded and if the linkages dropped were crucial to demonstrating a causal chain from activity to VEC then the hypothesis would have been dropped from further consideration. This, however, did not occur in this exercise.

2) Documentation of Existing Knowledge - For all linkages making up the hypothesis, the following information was discussed and documented: a) evidence for and against; b) uncertainties; and c) other information potentially useful.

3) Conclusion - For each hypothesis it was necessary to conclude whether the hypothesis: a) is extremely unlikely and not worth testing; b) is possible, but too difficult to detect; c) requires more information before a monitoring plan can be designed; or d) can be tested with a detailed monitoring plan.

4) Monitoring and Research - If the conclusion at step three was (c) or (d), detailed discussion was facilitated focusing on the linkages in the hypothesis. This discussion

addressed the following questions that need to be answered in designing a test of an impact hypothesis: What should be monitored? What do we want to know? What do we actually measure? What information do we get from these measurements? How does this information help us achieve what we want to know?

5) Documentation - In the subgroup session, recorders were assigned specific responsibilities to document the deliberations of the hypothesis discussions. These were drafted during the workshop.

The following sections in this chapter describe the outcome of the discussion on each hypothesis. Each section deals with a specific hypothesis and traces the discussion through to the set of monitoring recommendations developed at the workshop.

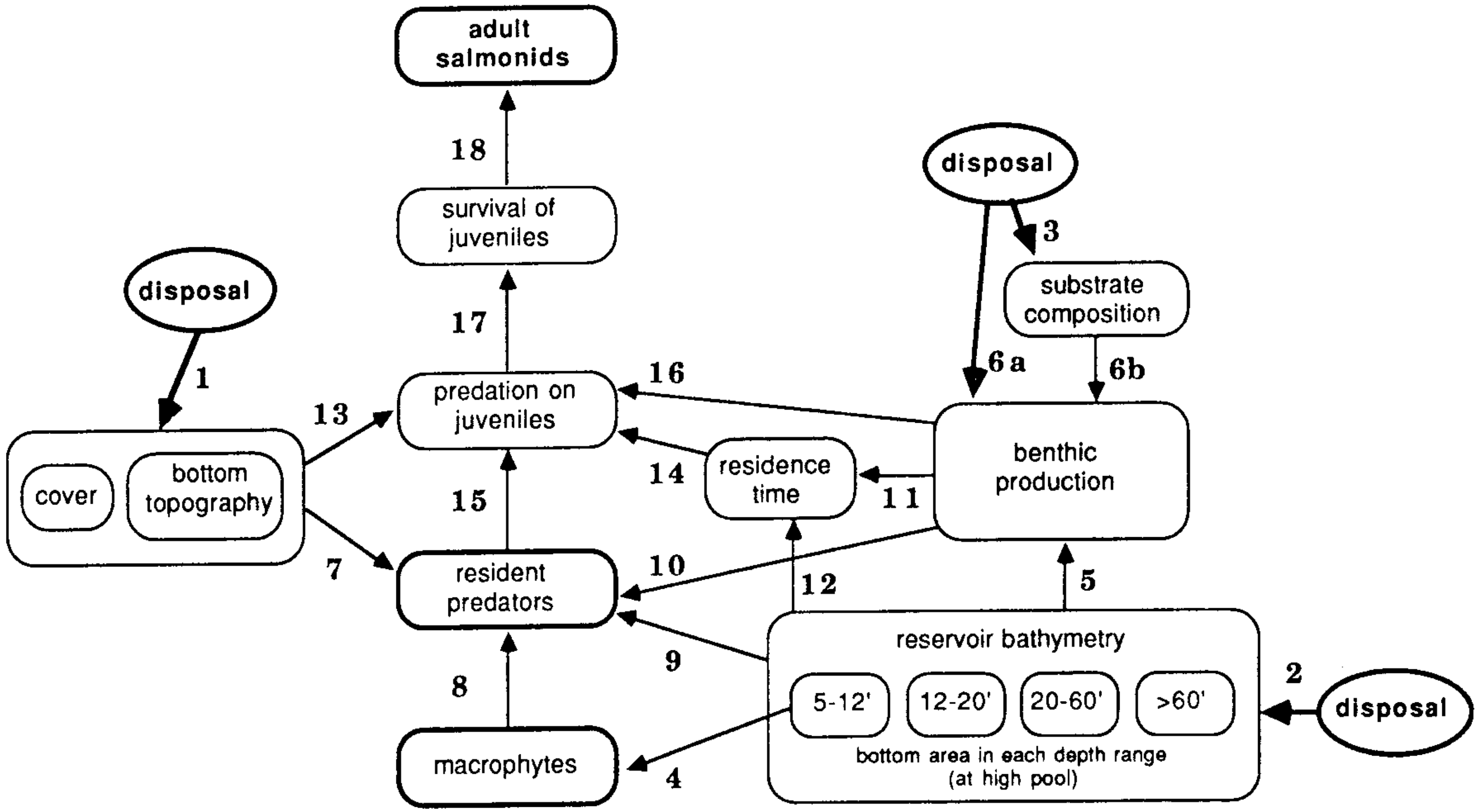

Figure 3:

Hypothesis 1: In-water disposal of dredge materials into the Lower Granite Reservoir will lead to changes in predation on juvenile salmonids (steelhead and chinook) and to long term changes in the numbers of adult salmonids.

HYPOTHESIS NO. 1

In-water disposal of dredge materials into the Lower Granite Reservoir will lead to changes in predation on juvenile salmonids (steelhead and chinook) and to long term changes in the numbers of adult salmonids.

Link 1: In-water disposal of dredge materials in the lower reservoir will cause changes in the bottom topography (local patterns of relief) and cover for salmon and their predators.

Link 2: In-water disposal of dredge materials in the lower reservoir will change the bathymetry of the reservoir. This will result in changes in the relative amount of substrates in the very shallow (5 - 12 ft.), shallow (12 - 20 ft.), mid-depth (20 - 60 ft.) and deep water (> 60 ft.) zones within the reservoir.

Link 3: In-water disposal of dredge materials will cause a short-term increase in the grain size of the substrate at the disposal site.

Link 4: A change in the reservoir morphometry, which increases the amount of substrate in the very shallow water zone (5 - 12 ft.), will lead to an increase in the area of macrophyte beds within the reservoir. A change in the reservoir morphometry, which does not change the area of the very shallow water zone, will not lead to changes in the total area of macrophytes.

Link 5: A change in the reservoir bathymetry, which results in a reduction in the mean depth of the reservoir, will lead to an increase in the production and standing crop of benthos. The increase in benthos will be greatest in areas of new substrate in the shallow water zone (12 - 20 ft.).

Link 6: A) In-water disposal of dredge material will bury the benthic community and, in the short term, will eliminate production at the disposal site. B) A short-term increase in the grain size of the substrate will reduce the benthic productivity and rate of recolonization of the disposal site. Long term benthic productivity will depend upon the substrate composition, the natural sedimentation rate and longer term disposal activities.

Link 7: Changes in topographic relief and amounts of cover will affect growth and survival of bass and catfish, but not squawfish.

rehandling of dredged materials. Since a total operating depth of approximately 20 feet is required, only the lower limits of shallow habitats are likely to be affected. In the absence of rehandling of the disposed material, the change in reservoir bathymetry will be limited to mid-depth and deep areas.

Link 3: In-water disposal of dredge materials will cause a short term change in the grain size of the substrate at the disposal site.

The validity of this link depends upon two critical assumptions. First, the existing gradation of the substrate varies from mostly sand, near the Clearwater confluence, to mostly silt and clay sizes, downstream of river mile 120. Second, the substrate change will be transitory due to a substantial influx of sediment into the disposal area during future spring runoff periods.

There are four major uncertainties central to the question of the long term character of the sediment (i.e., grain size, distribution) and rate of change of the post-disposal substrate:

1) the erosion potential during extreme flood events (50 year flood) and rates of erosion, if any, during "average" years;

2) whether some areas in the disposal site presently have coarse exposed substrates (e.g. talus slopes, gravel patches);

3) the present spatial variation in sedimentation rates within the lower reservoir; and

4) the future pattern (grain size) and rate of natural deposition after disturbance of the area by deposition of dredged materials.

5.1 HYPOTHESIS NO. 1

5.1.1 Linkages

Link 1: In-water disposal of dredge materials in the lower reservoir will cause changes in the bottom topography (local patterns of relief) and cover.

Dredging in the upper end of the reservoir will increase water depths by up to 10 feet at the dredging sites. The resulting excavations would, for a period of at least a few weeks, create deeper habitats with increased cover in the upper end of the reservoir.

At the disposal sites, local topography and cover is not likely to be altered substantially by in-water disposal of dredged materials. Deeper parts of the reservoir are gradually silting in by "natural" processes that have already deposited substantial amounts of sediment. It is likely that this has covered most bottom features that would provide cover. Considering the gradual slopes (10-15% angles of repose) of disposed sediments, and the logistics of the dumping operation, it is unlikely that significant topographic relief, and hence cover, will be created.

Link 2: In-water disposal of dredge materials in the lower reservoir will change the bathymetry of the reservoir. This will result in changes in the relative amount of substrates in the very shallow (5-12 ft.), shallow (12-20 ft.), mid-depth (20-60 ft.), and deep water (>60 ft.) zones within the reservoir.

Within the limitations established on the placement of disposed material this link is true. Certainly, average depths in the lower half of the reservoir will be reduced over time by disposal operations. However, due to the typical draft of barges (approximately 12 feet) and the additional depth required for operation of bottom doors, significant changes in very shallow habitats are unlikely without increased near the deep water side of the site. This would likely result in a slight increase in the rate of sediment deposition in the near shore areas and a slight reduction toward the center of the channel. Erosion, if any, would take place during the rising limb of the hydrograph with higher than normal deposition occurring during the falling limb.

Link 4: **A change in reservoir bathymetry that changes the amount of substrate in the very shallow water zone (5 - 12 ft.) will lead to changes in the area of macrophyte beds within the reservoir.**

Macrophytes in the lower reservoir are usually limited to areas between 5 and 12 ft. below maximum pond elevation. Consequently, in the short term, no additional areas of macrophytes are predicted if the in-water disposal does not raise the substrate to within 12 ft. of maximum pond elevation. However, if the disposal design includes rehandling of the material, then the creation and/or destruction of macrophyte areas becomes more likely.

In the long term, the total area of macrophyte habitat should increase as the natural accrual of sediments in the lower basin raises substrate elevations into this zone. A relatively rapid rate of sedimentation has been observed within the Lower Granite Reservoir and over the life of the reservoir has averaged at least 2 in./yr.

It is expected that increases in the distribution of macrophytes could occur regardless of the in-water disposal program. By reducing the mean depth in the lower reservoir, in-water disposal will, however, accelerate the rate at which this will occur. Some control of the long term rate of development of macrophytes should be feasible through limitation of the maximum elevation of newly created habitat. This will vary between sites due to variations in the local rate of sediment accrual.

Evidence from the Lower Granite Reservoir which supports the likelihood of the postulated change includes:

- o Bed material sampling in 1982, 1984, and 1985, dredging in 1986, and site characterization studies and dredging in 1987 indicated the existing substrate at the confluence was predominantly fine sand with a relatively uniform transition to silts and clays in the proposed disposal area (downstream of river mile 120).

- o Sediment range surveys (conducted almost yearly) document progressive build-up of sediment (2" to 4" per year) in the disposal reach.

- o Suspended sediment sampling (1972-1979) indicates that most of the sediment enters the reservoir during the late spring and early summer runoff period (April-July).

- o Physical modeling using HEC-2 backwater computation indicates average changes in velocity will be relatively small (15-20%). Consequently, changes in the pattern and rate of deposition is also expected to be small.

Conversely evidence which suggests there may be no significant change in substrate includes:

- o Core samples in proposed dredge areas do not indicate the sediments are uniform throughout the area. Although sediments near the confluence of the Snake and Clearwater rivers are primarily sandy, those further downstream tend to increase in their relative silt/clay content. Their similarity to the sediments at the disposal sites imply their relocation would result in only small changes in substrate following disposal.

- o A change in substrate at the dredge sites from exposure of original river gravels would be transitory since sedimentation rates in the proposed dredging zones are very high. Hence gravels exposed during winter dredging would be covered within a few months, primarily during the period of high flow.

From a hydraulic perspective, it is likely that the velocities at the disposal site will be slightly reduced near shore and over the disposal mound and slightly ences in species composition may have been observed (documentation needed).

In addition to long term effects of bathymetry changes, there may be a short term increase in production immediately after disposal. This would occur from recolonization via dispersal and then growth in the next growing season. Finally, increases in macrophytes in the reservoir, resulting from decreased mean depth may stimulate benthos, especially crayfish.

In summary, there are several theoretical reasons for expecting increased benthos production to result from the creation of new shallow water habitat. The existing evidence supporting this conclusion, however, is limited and further investigation of this link is warranted.

Link 6: **A) In-water disposal of dredge material will bury the benthic community and, in the short term, will eliminate production at the disposal site. B) A short-term increase in the grain size of the substrate will reduce the benthic productivity and rate of recolonization of the disposal site. Long term benthic productivity will depend upon the substrate composition, the natural sedimentation rate and longer term disposal activities.**

Bennett's work shows benthic recolonization of newly deposited materials occurs within 6-9 months (Bennett pers. comm). These rapid recolonization rates and the fact that the area impacted annually by disposal will be small ensure the overall impacts of disposal on the benthos will not be significant. This should be especially true in areas consisting of fine material.

If the disposal area is also an area experiencing high deposition rates, there will probably be few impacts. Additional deposition will take place after disposal and this newly deposited material should be similar in composition to the existing substrata. If the area is presently devoid of depositional material then deposition will likely impact those

Link 5: A change in the reservoir bathymetry, which results in a reduction in the mean depth of the reservoir, will lead to an increase in the production and standing crop of benthos. The increase in benthos will be greatest in areas of new substrate in the shallow water zone (12 - 20 ft.).

Reduction of mean reservoir depth by increasing the amount of substrate in the shallow water zone will likely increase the amount of reservoir bottom within the euphotic zone. The transport of sediment from one portion of the reservoir to another results in no net change in the reservoir volume, and consequently, no change in the average reservoir retention time or flow velocities. Over the life of the reservoir, there will be a gradual decrease in the average reservoir retention time and flow velocity due to sediment accumulation with or without an in-water dredging and disposal program. The effects of dredging are local, tending to reduce the velocities in the dredging zone and increase velocities in the disposal zone. Local changes in velocity (estimated at 15-20% over the life of the reservoir) are expected to be ecologically insignificant. Nutrient loading will not be directly affected by the proposed action. However, as a result of diminished average depth in the lower reservoir, detritus will spend less time in the water column prior to reaching the bottom. Hence more organic material will be delivered to the substrate at new shallow areas constructed by disposal. These two factors - increased substrate in the euphotic zone and increased detrital supply to the substrate - should theoretically lead to increased benthos production.

Results from studies in the Lower Granite reservoir (Bennett and Shrier (1986)) do not support this expectation. No significant difference in production or standing crop was observed between deep and shallow water habitats. In the Lower Granite, the benthic community is extremely simple (dominated by two taxa - dipterans and oligochaetes). In other systems with greater diversity, qualitative differtality on larval and juvenile cyprinids and may be a dominant factor influencing year class success. Year class strength of squawfish in a lower Columbia Reservoir has been negatively correlated with size of the same year class of walleye and a predation mechanism has been proposed as the likely explanation (Rieman and Beamesberfer in prep).

Increased macrophytes may also increase net production of invertebrates and juvenile fish. They, in turn, may serve as additional prey for squawfish, thereby affecting their growth and survival.

There is uncertainty about this linkage, but the strongest evidence suggests predation may be important in the development of squawfish year classes. Increases in macrophytes will very likely increase at least holding cover for if not total numbers of potential predators.

Link 9: **Changes in the area of shallow water habitat will alter growth and survival of squawfish and bass, but not catfish.**

Link 10: **Changes in the abundance of benthos will affect growth and survival of squawfish, bass, and catfish.**

Increased shallow water habitat (12 - 20 feet) may lead to increases of very shallow (< 5 feet) habitat through normal deposition or alteration of flow characteristics in the long term. This "marginal" habitat in the upper littoral zone has been considered critical to the early life history of squawfish in a Columbia River reservoir (LaBolle 1984; Shephard and Cushing 1980). Any increase in a limiting habitat in Lower Granite could result in a large increase in the squawfish population. At this time, the population of squawfish appears to be small (Bennett, pers. comm.) and marginal habitat is rare.

Increased shallow water habitat can result in a net increase in benthic production which would benefit squawfish since they utilize benthic invertebrates (Bennett and Shrier organisms currently using the habitat (e.g. crayfish).

Link 7: Changes in topographic relief and amounts of cover will affect growth and survival of bass and catfish, but not squawfish.

Changes in relief and cover are not expected to be dramatic. After disposal a relief of several meters may occur over a horizonal distance of 100 m but not enough to provide cover for individual fish or groups of fish.

Squawfish appear to be highly mobile (Beamesberfer et al. 1987) and likely are not associated with structure or cover in a localized area unless it protects them from high velocities (Faler et al. 1985).

If existing structure (i.e., rocky bottom or other dramatic relief) is eliminated by disposal, the vulnerability of prey to squawfish may be increased through elimination of cover or complexity. Cover/predation interactions are documented in the bass literature but suggest strata with high levels of cover, structure, and complexity. Because squawfish may forage in open water (simple environment) any increase in complexity may benefit prey.

Unless disposal results in dramatic reductions in complexity of existing habitat it is unlikely that this link is important for squawfish. If monitoring were to be carried out in relation to this link then several years of research on the foraging behavior of squawfish would be required to provide relevant information.

Link 8: Changes in the area of macrophytes will affect growth and survival of squawfish and bass, but not catfish.

Increased areal extent of macrophytes will undoubtedly provide additional cover for bass, perch, and perhaps catfish. Additional cover may correspondingly increase the abundance of these fish. In turn, each of these may prey on larval and juvenile squawfish. Percids can cause severe morreservoir could benefit from the increased standing crop of benthos through increased growth rates but increased residence time seems unlikely; unfortunately the food requirements of these stocks are unknown.

In conclusion, it appears that the magnitude of change in standing crop of benthos will not be sufficient to cause a change in the residence times of migrating steelhead and spring/summer chinook. Fall chinook may be affected but the magnitude of the effect is expected to be very small.

Link 12: **Changes in reservoir bathymetry will affect the flow rate over the long term resulting in a change in the residence times of juvenile salmonids.**

Dredging with in-water disposal will not remove material from the reservoir it will simply rearrange the existing material causing little or no change in the overall reservoir volume or retention time. Naturally occurring rates of change in transit time will be increased in the disposal area and decreased in the dredging area with no overall effect.

The transport of sediment from one portion of the reservoir to another results in no net change in the reservoir volume, and consequently, no change in the average reservoir retention time or flow velocities. Over the life of the reservoir, there will be a gradual decrease in the average reservoir retention time and flow velocity due to sediment accumulation with or without an in-water dredging and disposal program. The effects of dredging are local, tending to reduce the velocities in the dredging zone and increase velocities in the disposal zone. Local changes in velocity (estimated at 15-20% over the life of the reservoir) are expected to be ecologically insignificant.

Link 13: **Changes in topographic relief and cover will tend to affect predation by squawfish, bass and catfish on juvenile salmonids.**

1986). Intraspecific and interspecific competition have been supported with other cyprinids. Food could limit growth and survival of squawfish.

Reservoirs along the lower Columbia may provide important lessons in relation to the Lower Granite. In lower Columbia reservoirs, growth of squawfish is among the highest rates recorded (Rieman and Beamesberfer in prep). Apparently, growth in the first year is not strongly correlated with year class strength since compensation in growth is not obvious, and competition for food is not apparent (Rieman and Beamesberfer in prep).

Squawfish reproduction and early rearing occurs predominantly in the upper reaches of lower Columbia reservoirs; probably in the most riverine habitat (Li et al. 1981). Upper littoral zone ("marginal") habitats in the tailrace of John Day reservoir are believed to be critical to larval squawfish (Li et al. 1981). If the habitat and squawfish population in Lower Granite is similar to the John Day Reservoir it is unlikely that any habitat changes in the lower reservoir will have an important influence on survival of squawfish during a critical period. Lower reservoir habitat limitation for squawfish seems unlikely.

Link 11: Changes in benthic production will affect the residence time of juvenile salmonids.

Work by Bennett and Shrier (1987) and Faler et al. (in press) indicate that the standing crop of benthos increases with decreasing depth. Since spring and summer chinook are primarily actively migrating through the area and also utilize other food sources (i.e., terrestrial insects, zooplankton, etc.) it appears highly unlikely that increased benthos would increase their residence time. Fall chinook, however, spend some time rearing in the reservoir and it is possible that additional food could cause them to spend more time or increase growth rates while in the reservoir. Spring and summer chinook and steelhead which overwinter in the and are unlikely to switch to benthic organisms no matter how abundant. However, increasing benthic production may result in higher predator survival and could allow them to grow to a larger (piscivorous) size more quickly.

Link 17: **Changes in the rate of predation on juvenile salmonids in the lower reservoir will affect their overall juvenile survival rate.**

Link 18: **Changes in the juvenile survival rate will result in changes in the number of adult salmonids returning to spawn.**

With no evidence to the contrary, both of these links seem to be highly likely. It is possible that density dependent factors within and outside of the reservoir will limit the effects of these links but there is not enough information available to test this possibility.

5.1.2 Conclusion

The overall conclusion concerning this hypothesis is that it is possible and appropriate monitoring should be instituted.

According to this hypothesis, there are two potential routes for disposal activities to result in impacts on salmonids:

1) changes in benthic production affecting residence time and cover, and thus predation; and

2) effects on predator populations and aggregations of predators, and thus predation.

The group in general felt that the effects due to increases in benthic production would be small if there was no photic zone alteration. Creating photic zone habitat would increase benthos significantly in a localized area and could have a small effect on fall chinook rearing and migration.

The importance of this link depends on the abundance and type of habitat being covered by the disposal. Small mouth bass (SMB) and channel catfish are known to be associated with complex habitat. If SMB are an important salmonid predator, then changing from complex to simple habitat could reduce SMB population and reduce predation. Squawfish, on the other hand, are ubiquitous and may be an important salmonid predator. If complex habitat is reduced there is a potential for reduction in the cover available for juvenile salmonids which could make them more susceptible to squawfish predation.

To resolve some of this uncertainty, it is necessary to know how much complex habitat currently exists in mid depth areas. If complex habitat is rare it is recommended that it should not be covered by disposal because of the danger of improving the effectiveness of predation on salmonids.

Link 14: **Changes in juvenile salmonid residence time in the reservoir will affect the impact of squawfish, bass, and catfish predation on salmonids.**

According to 'conventional wisdom' shorter residence times result in a decreased susceptibility to predation. However, dredging and disposal are not expected to have a significant effect on overall transit time through the reservoir.

Link 15: **Changes in the abundance of squawfish, bass, or catfish will affect predation on juvenile salmonids.**

Predators tend to eat salmonids when they are present. Increasing numbers of predators will increase predation if all predators consume salmonids equally.

Link 16: **Changes in the abundance of benthos will tend to affect the impact of predation by squawfish, bass, and catfish on juvenile salmonids.**

Predators will feed on salmonids when they are present expected levels of abundance.

3) SYNOPTIC SURVEYS - of habitat and predator utilization in the whole Lower Granite reservoir and long term abundance monitoring of predators.

While not specifically a part of the monitoring program linked to this hypothesis, synoptic research/baseline monitoring would be useful in increasing the current level of understanding of the relationship between physical habitat parameters and predator utilization. This research would consist of a detailed bathymetric survey coordinated with a synoptic survey of fish distribution. The survey of fish distribution would focus on squawfish and could be carried out using either hydroacoustic methods or nets and traps.

Similarly long term abundance monitoring of predators would not provide information directly relevant to this hypothesis in the short term but in the long term such information could be extremely useful in interpreting other variables.

Effects through predator population and aggregation responses were felt to be the most likely source of adverse impacts.

5.1.3 Monitoring

The monitoring recommendations are:

1) PREDATOR ABUNDANCE - monitor the abundance of predators in the disposal site relative to other similar sites in the reservoir. The parameter to be monitored could be either an absolute measure of abundance or an index.

   This monitoring recommendation is intended to directly address the concern of this hypothesis. While it is recognized that there will be problems in obtaining high levels of precision the group felt that monitoring predator abundance was important and that it was not possible to identify more tractable surrogates.

   Given the mobility of predators and the expected levels of precision from this type of monitoring it is likely that only large changes in relative abundance (doubling or halving) would be statistically detectable.

2) BENTHOS - monitor the abundance of benthos in the disposal site relative to other similar sites in the reservoir.

   This monitoring recommendation is not strongly linked to this particular hypothesis since it was not thought likely that benthos abundance will have a major effect on the degree of salmonid predation. However, benthic monitoring is more strongly recommended based on the other hypotheses and will be useful in this context to confirm

5.2 HYPOTHESIS NO. 2

5.2.1 Linkages

For a description of Links 1, 2, and 3, see the description for Hypothesis #1.

Link 4: Changes in the bottom topography and cover will result in changes in the habitat available for overwintering adult steelhead in the reservoir.

In true riverine habitats, adult steelhead predictably "hold" in pools or channels with associated instream habitat structures presumably offering velocity refuge and cover. Hence the increased depth at the dredging sites may provide holding habitat for adult overwintering steelhead. Utilization of these habitats would be expected both during the winter and late winter-early spring upstream migration. Whether the pattern of habitat utilization observed in rivers is the same in reservoir systems is uncertain. Since substantial sedimentation during the spring freshet is expected to begin refilling the dredged sites immediately following the completion of dredging operations, the potential effect will likely be over a short period.

Link 5: Changes in the reservoir bathymetry will result in changes in the habitat available for overwintering adult steelhead in the reservoir.

No definitive work describing adult steelhead overwintering habitat was known to the workshop participants. Some uncertainty exists around links four and five and most of the information is anecdotal.

Patterns of fishing effort and success in Lower Granite Reservoir preclude making clear conclusions about adult habitat preferences. Confounding factors include unique features where the fishing activity tends to concentrate (e.g., Lower Granite Dam forebay, confluence of Snake and Clearwater Rivers), shoreline access, and boat ramp access.

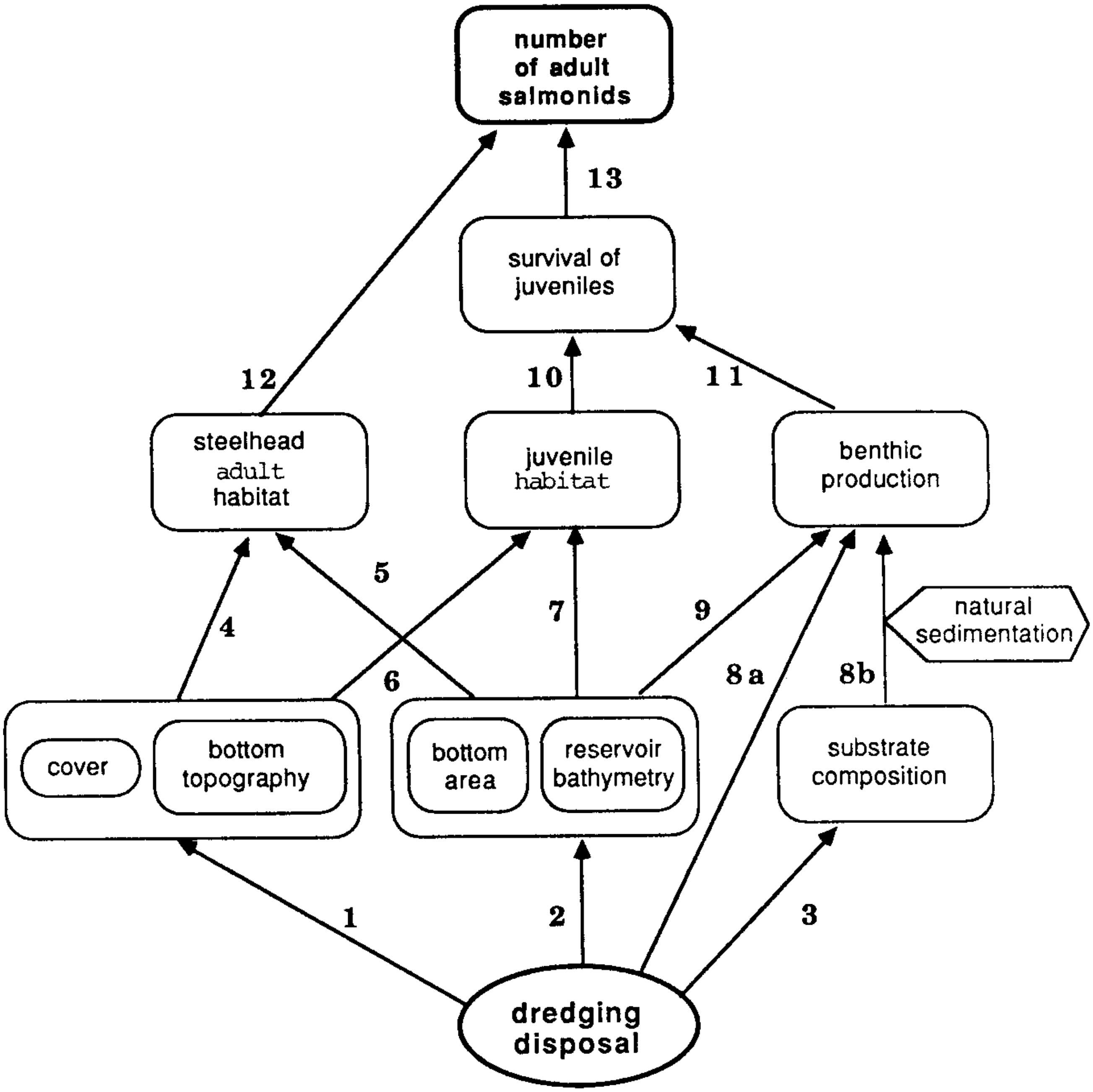

Figure 4:

Hypothesis 2: In-water disposal of dredge materials into the Lower Granite Reservoir will lead to changes in the habitat for juvenile spring/summer chinook, fall chinook salmon, juvenile steelhead trout, and ultimately the number of adult salmonids.

to have relatively brief passage times on the order of 3 days to a week. During this time, they would normally be feeding on material from both benthic and terrestrial sources. Fall chinook juveniles are not normally as advanced and may spend several weeks feeding as they move down through the reservoir. They also tend to prefer lower velocity sites.

Juvenile salmonids are commonly associated with substrate in shallow water areas (15 ft. and less). During peak migration, they are found throughout the reservoir but only in the top 10 to 15 ft. of the water column.

Apart from depth, velocity, and food supply, the other determinant of habitat which may be important is the amount of cover (i.e., macrophytes) and relief of the substrate. In general, spring and summer chinook prefer habitat with some cover to decrease the potential for predation. Conversely, fall chinook are thought to prefer open areas (D. Bennett, pers. comm.).

The only alteration of habitat through sediment disposal, which would likely have a significant impact on summer juveniles, is the creation of new shallow water habitat; the major habitat fall chinook utilize. The magnitude of the increases in juvenile survival through the reservoir, resulting from increasing the amount of this habitat, is unknown.

Juvenile Overwintering Habitat

Overwintering juvenile spring/summer chinook and steelhead have only recently been discovered in the Lower Granite reservoir. The total numbers of overwintering juveniles, their habitat requirements, and their importance to particular fish stocks is unknown.

and standing crop of benthos. The change in benthos will be greatest in areas of new substrate in the shallow water zone (12-20 ft.).

Link 10: A change in juvenile overwintering habitat in the reservoir will result in altered juvenile survival rates for spring/summer chinook and steelhead.

Link 11: Changes in benthic production will affect the health and survival of juvenile salmonids during their downstream migration.

Link 12: Changes in overwintering habitat for adult steelhead will affect adult survival.

Link 13: Changes in the juvenile survival rate will result in changes in the number of adult salmonids returning to spawn.

according to: (a) the similarity between the pre-disturbance and post-disturbance substrate; (b) the degree to which the impacted community is adapted to natural disturbances of similar intensity, frequency, and seasonality; and (c) the availability of propagules in the vicinity of the disturbed substrate. The last two points relate to the reproductive and relocation strategies of the taxa comprising a particular community type.

The Lower Granite project area appears to be inhabited by a diverse freshwater community numerically dominated by chironomid insect larvae and oligochaetes (Bennett and Shrier 1987). A variety of other insect and non-insect taxa, including crayfish are potentially important components of the reservoir benthos.

While the majority of dredged material generated during the proposed test project is coarse textured (see Appendix 2 -- Table A2), it is expected that the sandy nature of the disposal mound will be altered by the accumulation of fine textured sediments at a rate of approximately 2 inches per year. Hence the impact of establishing a coarser textured bottom over the previously finer textured substrate will be modified by the accumulation of fines on the new substrate.

The typical productivity response to disturbance, excepting instances in which the new substrate is comprised of toxic materials, is illustrated in Figure 5.

The length of the recovery period is difficult to predict with certainty. It has been suggested that it may require as long as four years. This estimate is based on the observation that the benthic community inhabits the bottom to a depth of 8 inches, that the productive components of the community do not do well in textured materials, and that it will take four years of natural sedimentation at a rate of 2 inches per year, to achieve 8 inches of fine textured material.

Since most fish are taken within 25 feet of the surface over a variety of bottom depths, filling is not expected to have a great impact at the deep or mid-depth sites. The extent to which dredging may improve holding conditions in the confluence area by creating additional depth, is uncertain.

Link 6: Changes in the bottom topography and cover will result in changes in the habitat available for juvenile chinook and steelhead in the reservoir.

Link 7: Changes in the reservoir bathymetry will result in changes in the habitat available for juvenile chinook and steelhead in the reservoir.

The significance of changes in topography and cover (Link 6) and bathymetry (Link 7) are uncertain due largely to the lack of information on the habitat utilization (requirements) of juvenile and adult salmonids in large reservoirs. Current understanding can be summarized as follows (D. Bennett, pers. comm):

Adult Summer Habitat

Adult salmonids generally move quickly through the reservoir toward their spawning streams. Chinook salmon do not feed during their time in the reservoir, while steelhead feed to a minimal extent.

Adult Overwintering Habitat

Some proportion of adult steelhead that pass the Lower Granite dam in September and October overwinter in the reservoir prior to spawning the following spring. The proportion of fish that remain in the reservoir and their habitat requirements are unknown.

Juvenile Summer Habitat

Spring/summer chinook and steelhead juveniles are normally smolting as they move through the reservoir and tend

Link 8: **A) In-water disposal of dredge material will bury the benthic community and change production at the disposal site in the short term. B) An increase in the grain size of the substrate will reduce the benthic productivity and rate of recolonization of the disposal site in the short term. Long term benthic productivity will depend upon the substrate composition, the natural sedimentation rate and other disposal activity and erodability of surface substrate.**

Dredging and in-water disposal of dredged material will affect benthic community composition and production. Immediately after the dredging operation, the resulting increase in the grain size of the substrate will reduce benthic productivity and the rate of recolonization at the dredging and disposal sites. Long term benthic productivity will depend upon the composition of the dredge material, the natural sedimentation rate, and other sources of substrate disturbance including additional dredging and dredged material disposal activities.

Benthic macroinvertebrate communities respond to disturbances, either physical or chemical, in a qualitatively predictable fashion. For the purposes of this discussion, it has been assumed that the dredging and disposal activity will destroy most, if not all, of the benthos that inhabited the dredged channel and the disposal site. The thickness of the disposal mound will likely vary with the size of the disposal area, the volume and character of the material, and the mode of disposal. It is possible that thinner portions of the deposit near the fringes of the mound will be inhabited by survivors from the original community. It is also possible that areas immediately adjacent to the mound may be influenced by small amounts of dredged material originating from disposal or sediment transport following disposal. The amount of each material may be difficult to detect.

Investigations on the response of benthic macroinvertebrate communities to substrate disturbances have generally indicated that the rate of recovery will vary directly

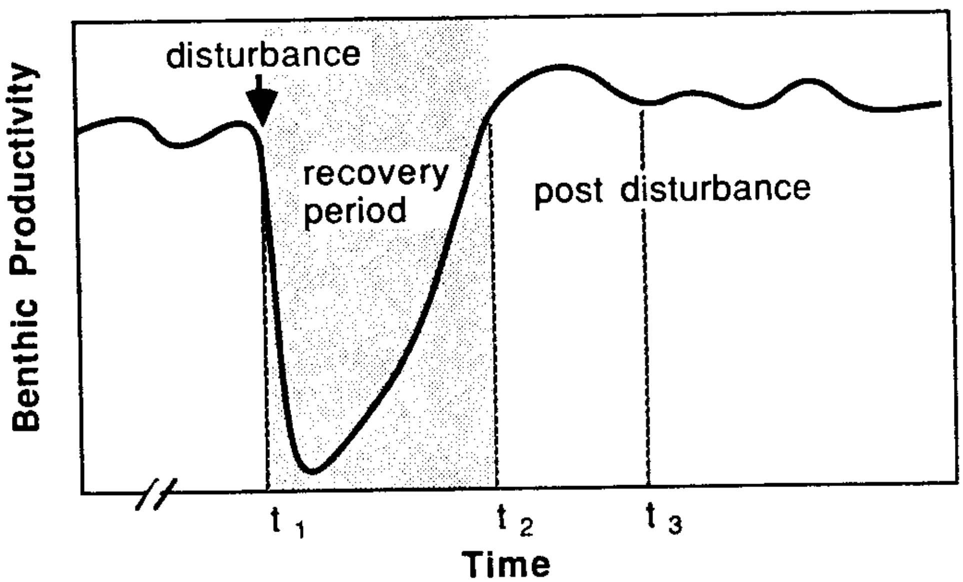

Figure 5: Typical response of benthic productivity to non-toxic disturbance.

Link 9: **A change in the reservoir bathymetry (that results in a reduction in the mean depth of the reservoir) will lead to a change in the production and standing crop of benthos. The change in benthos will be greatest in areas of new substrate in the shallow water zone (12-20 ft.).**

Benthos biomass, production, and overall community diversity typically increase as depth decreases due to increasing abundance and diversity of food for the benthic community. This gradient is associated with traditional limnological zones as illustrated in Figure 6. This pattern has been documented by Brinkhurst (1975 - Benthos of Lakes), Ericsson, and others. It has also been observed in Lower Granite and Little Goose reservoirs, two and seven years respectively after filling (Dorband 1979).

In the Lower Granite reservoir, the peak in benthic production (cf. Figure 6) occurs near the 12 ft. depth and is influenced largely by the production of the numerically dominant chironomid and oligochaete taxa that tend to be higher in finer textured substrates containing organic material.

Link 10: **A change in juvenile overwintering habitat in the reservoir will result in altered juvenile survival rates for spring/summer chinook and steelhead.**

Link 11: **Changes in benthic production will affect the health and survival of juvenile salmonids during their downstream migration.**

Link 12: **Changes in overwintering habitat for adult steelhead will affect adult survival/fl.**

Link 13: **Changes in the juvenile survival rate will result in changes in the number of adult salmonids returning to spawn.**

Intuitively, a change in habitat may lead to a change in survival, for any life stage. However, quantitative

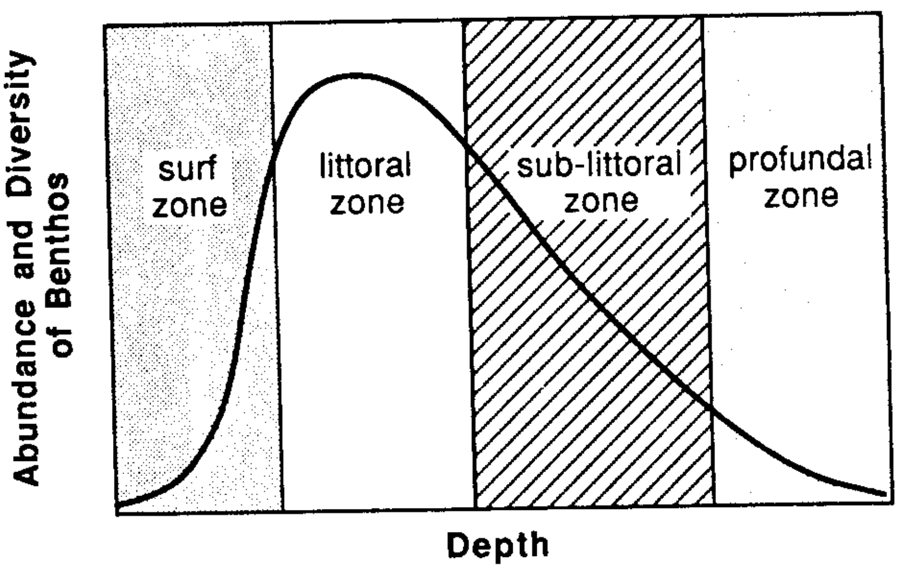

Figure 6: Typical gradient of benthic productivity.

relationships between the "amount of habitat" and fish productivity have not generally been developed, since different components of the habitat may be limiting in different situations. Consequently such relationships are difficult to demonstrate due to the large variance between measures of habitat and production. In this particular case, the habitat requirements for both juvenile and adult salmonids in large reservoirs are uncertain.

In view of the proportion of the total reservoir area to be affected in any one year by the disposal operation it is unlikely the short term reduction in benthic productivity will effect juvenile salmonid survival. In the long term, the reduction in depth should increase total benthic productivity and hence the availability of food for juvenile salmonids.

Overwintering juvenile spring/summer chinook and steelhead have only recently been observed in the Lower Granite reservoir. The total numbers of overwintering juveniles and their importance to particular fish stocks is unknown. Similarly, their habitat requirements and consequently the significance of the proposed physical changes are uncertain.

Since juveniles appear to utilize shallow water habitat more than mid-depth or deep areas it is possible the creation of additional shallow water habitat will increase survival of juveniles. However, in view of the generally poor understanding of habitat requirements, there is substantial uncertainty about the significance of the change.

Similarly, the habitat requirements of adults are uncertain with respect to both the summer and winter periods. Adult salmonids migrating upstream generally move through the reservoir quickly. Chinook salmon do not feed during this time and steelhead feed only minimally, consequently effects on adults are likely not significant.

5.2.2 Conclusion

The proposed disposal program would likely lead to changes in salmonid habitat that could result in a change in survival. However, it will not be possible to detect the change at the population level due to the large number of other confounding factors. Since the major uncertainty with respect to the hypothesis is concerned with habitat requirements it is suggested that the creation of new, highly diverse habitat would provide a unique opportunity to evaluate habitat utilization by salmonids. Research and monitoring could then be carried out to begin developing a set of habitat indices for reservoirs similar to those now available for stream systems.

5.2.3 Monitoring

Monitoring in relation to this hypothesis could be carried out at three different levels. At the highest level, that of adult salmonid populations the group felt that it would be extremely hard to do any useful work. It was felt that some useful information could be gained by looking at the relative abundances of salmonid juveniles at the disposal site.

At the lowest level impacts and changes are fairly predictable. It was felt to be useful, however, to monitor physical and other habitat factors such as bathymetry and substrate composition to confirm the changes and to provide the basis for examining changes in factors of more immediate interest such as fish distribution.

The most tractable and useful level of monitoring for this hypothesis is at an intermediate level with the emphasis being on benthos.

The recommended monitoring for this hypothesis includes three major components:

1) SALMONID UTILIZATION - to assess the utilization of the new habitats by juvenile salmonids to a) determine the spatial pattern of habitat utilization relative to observed gradients in measures of habitat variables (e.g., velocity, depth); and b) to document the feeding patterns of salmonids utilizing the habitat.

   This is recommended to address this hypothesis as directly as possible and answer the question of whether the habitat that is created at the disposal site is utilized by salmonids and if there are measurable differences between the disposal site and other comparable reference sites in the reservoir. It is recognized that the levels of precision on estimates of abundance will not be high so that only major differences will be detectable.

2) BENTHOS - monitor the response of the benthic community through time. Monitoring changes in species composition and production relative to other similar sites in the reservoir.

   This is recommended as the variable which is most directly implicated in this hypothesis which it is possible to monitor with some level of precision. Aside from being of direct interest it will provide important information to aid in the interpretation of the distribution of salmonid juveniles.

3) HABITAT VARIABLES - characterize the changes in the habitat including slope, relief, grain size, water velocity, and zooplankton.

   As noted above the primary reason for monitoring these habitat variables is to provide information to help to interpret the patterns seen in other factors such as fish distribution and benthos levels. Due to the current poor understanding of habitat requirements of fish in reservoirs it will not be possible to say directly whether any of these factors is of concern unless they are very different from the existing conditions.

Zooplankton is included in this list as a low priority item due to the perception that there could be quite large changes in the zooplankton food supply for juvenile salmonids inside an extensive island.

To increase the utility of the information suggested in the above three areas, it is recommended all variables be collected at three locations: the disposal site, an area similar to the pre-treatment condition of the disposal site (a reference site), and another area similar to the post-treatment condition (depth and topography) of the disposal site (a post-treatment site). This will facilitate comparison and a more acceptable analysis of possible changes.

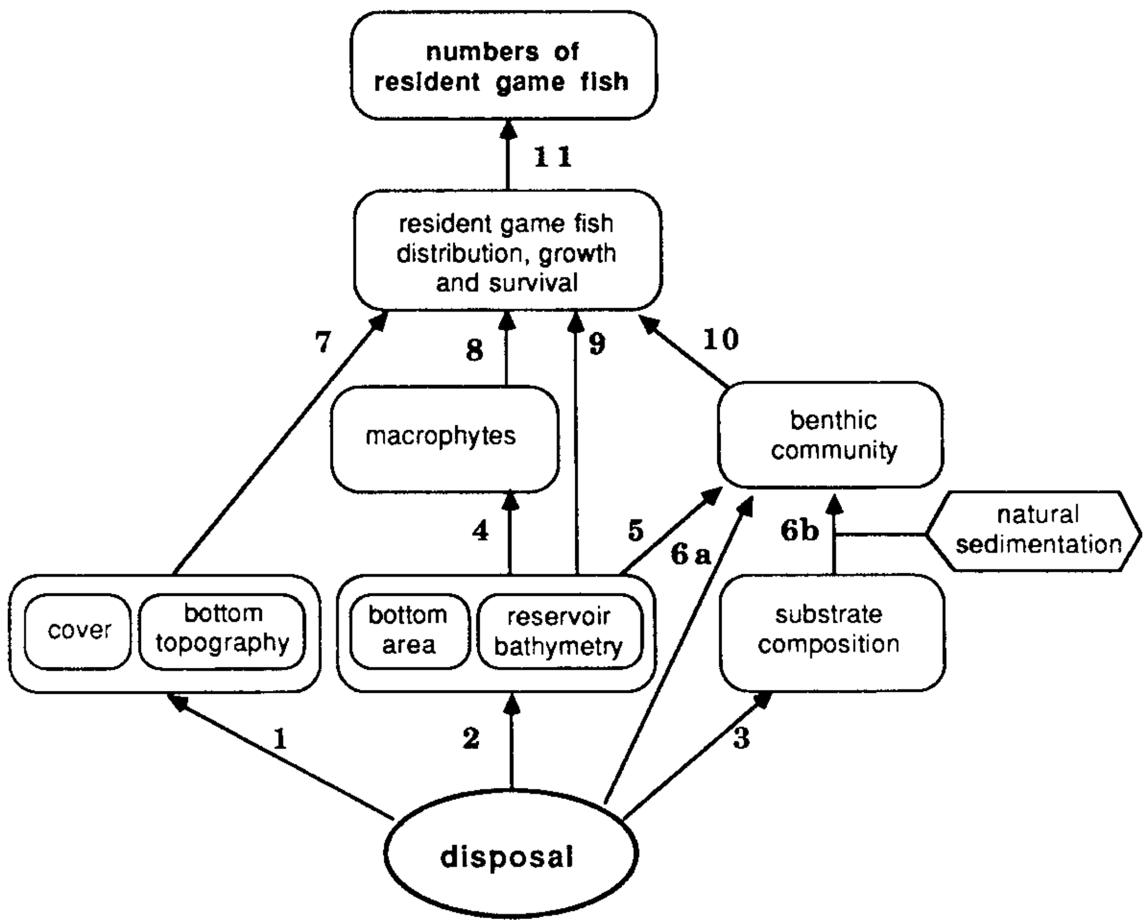

Figure 7:

Hypothesis 3: In-water disposal will lead to changes in the numbers of resident game fish (i.e., smallmouth bass, sturgeon) in the Lower Granite Reservoir.

HYPOTHESIS NO. 3

In-water disposal will lead to changes in the numbers of resident game fish (i.e., smallmouth bass, catfish, sturgeon) in the Lower Granite Reservoir.

Link 1: In-water disposal of dredge materials in the lower reservoir will cause changes in the bottom topography (local patterns of relief) and cover for salmon and their predators.

Link 2: In-water disposal of dredge materials in the lower reservoir will change the bathymetry of the reservoir. This will result in changes in the relative amount of substrates in the very shallow (5 - 12 ft.), shallow (12 - 20 ft.), mid-depth (20 - 60 ft.), and deep water (> 60 ft.) zones within the reservoir.

Link 3: In-water disposal of dredge materials will cause a short-term change in the grain size of the substrate at the disposal site.

Link 4: A change in the reservoir bathymetry that changes the amount of substrate in the very shallow water zone (5 - 12 ft.) will lead to changes in the area of macrophyte beds within the reservoir. A change in the reservoir bathymetry that does not change the area of the very shallow water zone will not lead to changes in the total area of macrophytes.

Link 5: A change in reservoir bathymetry that results in a reduction in the mean depth of the reservoir will lead to a change in the production or standing crop of benthos. Changes in the benthos will be greatest in areas of new substrate in the shallow water zone (12 - 20 ft.).

Link 6: A) In-water disposal of dredge material will bury the benthic community and affect production at the disposal site. B) A short-term change in the grain size of the substrate will affect benthic productivity and community composition. Long term benthic productivity will depend upon the substrate composition, the natural sedimentation rate and other dredging activities in the reservoir. Disposal sites are expected to be recolonized within one growing season after disposal is complete.

Link 7: Changes in topographic relief and cover will lead to changes in the distribution, growth, and survival of resident game fish populations.

Link 8: Changes in the area of macrophytes will lead to changes in the distribution, growth, and survival of resident game fish populations.

Link 9: Changes in reservoir bathymetry will lead to changes in the distribution, growth, and survival of resident game fish populations.

Link 10: Changes in the abundance of benthos will lead to changes in growth and survival of resident game fish.

Link 11: Changes in growth and survival will lead to changes in the abundance of resident game fish in the reservoir.

5.3 HYPOTHESIS NO. 3

5.3.1 Linkages

Description of linkages 1 to 6 can be found in the section describing hypothesis 1.

Link 7: Changes in topographic relief and cover will lead to changes in the distribution, growth, and survival of resident game fish populations.

Bass are predominantly found in areas of rubble or cobble bottom type. It is widely recognized that cover may be limiting for bass, especially for older age classes. Creating a more homogeneous substrate thus has the potential to decrease abundance of older age classes of bass. Certainly if cover is removed from some areas a redistribution of adult bass should result.

Sturgeon are typically found in low cover areas. There is no evidence cover is important for this species except where velocity may be high; this is not a factor in Lower Granite Reservoir.

According to farm pond studies, catfish require cover for spawning but not for rearing. Provided very shallow water areas (< 12 ft.) are unaffected by disposal, catfish populations should not be impacted. If, on the other hand, cover is removed from these areas some negative impacts on catfish spawning success may occur.

There is presently very little information on the existence and distribution of mid-water habitats currently in the reservoir with significant amounts of cover. If these areas do exist, and are likely to be removed by mid-water disposal, it will be important to document the potential magnitude of this loss, in order to adequately assess the potential impact of mid-water disposal on resident fish, especially bass.

Link 8: Changes in the area of macrophytes will lead to changes in the distribution, growth, and survival of resident game fish populations.

Filling mid-depth areas to 15 - 20 ft. could enhance macrophyte production if natural sedimentation continues to reduce depth beyond the 12 ft limit for macrophyte development. Macrophytes provide important cover for juvenile largemouth bass and may also enhance smallmouth bass rearing. In general, one would expect increases in macrophytes to enhance largemouth bass production relative to the other species. However, the importance of macrophyte beds for the growth and survival of other resident game fish, including smallmouth bass, is not well understood.

Link 9: Changes in reservoir bathymetry will lead to changes in the distribution, growth, and survival of resident game fish populations.

For both bass and catfish, changes in bathymetry are only expected to affect growth and survival via changes in cover, macrophytes or benthos. These pathways are already addressed in Links 7, 8, and 10, so no further discussion is necessary.

Sturgeon captured in Lower Granite Reservoir during recent population assessment studies (Bennett and Shrier, 1986) have mainly been found at deep and mid-depth sites. It is therefore possible that a reduction in sturgeon success in Lower Granite Reservoir could result from deep and mid-depth habitat losses due to dredge disposal. There is, however, no direct evidence to support this.

Link 10: Changes in the abundance and composition of benthos will lead to changes in growth and survival of resident game fish.

Studies of bass in Idaho reservoirs (D. Bennett, pers. comm.) suggest that temperature, not food (i.e., benthos) is the primary factor limiting growth rates (especially in their first year). Only if food is limiting will this link be clearly true. Evidence to date from Lower Granite Reservoir also suggests the greater importance of temperature.

The low abundance of sturgeon in Lower Granite Reservoir suggests that food supply is not currently an issue of concern, but rather that spawning habitat is limiting. There are indications that growth rates of sturgeon in reservoirs are less than for downstream, non-reservoir populations, but the reasons for this are not documented. Minor changes in the abundance of benthos in Lower Granite Reservoir will very likely have little effect on the growth and survival of the relatively small population of sturgeon in Lower Granite Reservoir.

Link 11: Changes in growth and survival will lead to changes in the abundance of resident game fish in the reservoir.

If the changes in growth and survival are sufficient to overcome compensating factors, this link is almost certain to be true. Nevertheless, any changes in growth and survival that do occur will be difficult, if not impossible to detect directly, as will any consequent changes in abundance.

5.3.2 Conclusion

The hypothesis is possibly true but changes will be very difficult to detect at the population level, at least over any reasonable monitoring time scale (i.e., < 10 years). However, given the potential concerns over long term changes in resident fish population, especially those that prey on salmonids, it is recommended that monitoring be carried out to examine the validity of several of the habitat linkages in this hypothesis. If these linkages turn out to be true (i.e., disposal==>habitat==>fish utilization), then it should be possible to draw inferences about long term change based on far better information than presently available.

5.3.3 Monitoring

On the basis of this conclusion, the following monitoring items are recommended:

1) FISH UTILIZATION - monitor the utilization by fishes of existing and newly created habitats, including macrophyte areas.

   As was the case for hypotheses 1 and 2 the direct monitoring of fish abundance and utilization of the disposal area in relation to reference areas is recommended as an important component of the monitoring program. The assessment should include detailed monitoring of new habitats, using methods such as gillnetting and electrofishing.

2) BENTHOS - monitor the benthos recolonization rates in newly created habitats.

   This is recommended in order to assess the changes in food supply for fish populations. Measurements should document not only changes in total standing crop, but also shifts in species composition.

3) NEW SEDIMENT ACCUMULATION - monitor the rates of new sediment accumulation in disposal areas.

   This would be used to monitor the rate at which the substrate composition in a disposal area returns to its pre-disposal condition in order to aid in the interpretation of the benthos results. In addition this monitoring would document the rate at which reservoir depth decreases due to natural processes. Sediment traps could be used for this assessment.

4) MACROPHYTES - assess the suitability of newly created shallow water habitat for macrophyte development.

Macrophyte development can have important effects on fish habitat and should be monitored if suitable very shallow water habitat is created. This could be accomplished by assessing the physical characteristics of the new habitat and comparing them to habitats already supporting macrophyte beds. Probably the two most important physical parameters to measure would be light penetration and substrate composition.

5) SYNOPTIC SURVEYS - monitor existing habitat structure at mid-water depths and carry out a synoptic assessment of fish distribution throughout the reservoir.

Synoptic surveys are not recommended as part of the monitoring program that is directly linked to addressing the hypothesis that is being discussed here. However, these surveys do address an important information gap and the results would make it significantly easier to address the potentials for impact and enhancement in the in-water disposal activity.

The main intent of this assessment is to identify the distribution and abundance of habitats offering potential (or actual) cover for resident fish species, especially smallmouth bass. Hydroacoustic methods should be used to carry out this assessment, and some additional ground-truthing using divers would be desirable.

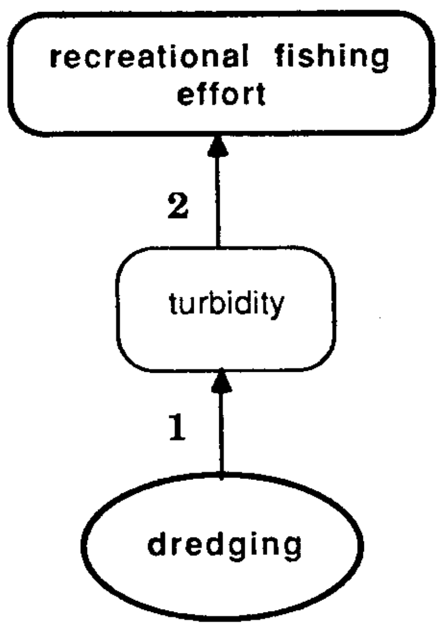

Figure 8:

Hypothesis 4: Dredging in the upper reservoir and in-water disposal of dredge materials into the Lower Granite Reservoir will lead to a reduction in the effort expended in the steelhead recreational fishery.

HYPOTHESIS NO. 4

Dredging in the upper reservoir and in-water disposal of dredge materials into the Lower Granite Reservoir will lead to a reduction in the effort expended in the steelhead recreational fishery.

Link 1: The dredging and disposal operations will create turbidity plumes.

Link 2: The presence of the turbidity plume will discourage anglers from using the areas immediately adjacent to the dredging operation and disposal operations and lead to reductions in the amount of fishing effort.

5.4 HYPOTHESIS NO. 4

5.4.1 Linkage

Link 1: The dredging and disposal operations will create turbidity plumes.

There will be a turbidity plume at both the dredging and disposal sites. The turbidity plume has been assessed at the dredging site during the past years' dredging activity downstream from the confluence of the Snake and Clearwater Rivers and in the Clearwater River.

Dredging Sites

Characteristics of the observed plume and the expected background conditions are summarized in Table A1 in Appendix 2. In the table, characteristics of the plume are expressed in two systems of measurement: standard turbidity units (ntu - the light scattering property of the plume material) and concentration units (mg/l). Although there is a general correlation between these measures, factors such as the mineralogy of different sediments require that the relationship be calibrated for different sediments.

Latitudinal extent of the plume, as observed from the air, has typically varied from 10% to 15% of the river width. The downstream extent is estimated to be approximately 425 m, at which distance, no detectable level above ambient conditions was observed.

The plume resulting from future dredging activities will vary with four major attributes of the dredging, namely:

1) The location within the reservoir. The two areas where dredging activities are planned during the present test evaluation differ substantially with regard to their silt and clay content. In future, it is anticipated that areas further downstream will also be dredged. In general, these areas are

predominantly sandy, however, some areas have a relatively high silt content, including one of the two sites designated for dredging in 1988.

The turbidity level arising from dredging in areas of relatively high silt content will be higher than observed to date. Due to the variations in the relationship between turbidity and suspended sediment concentrations, however, it is not possible to predict this accurately. Increased turbidity from a factor of 2 to an order of magnitude are possible.

2) The mineralogy of the dredged sediment. When compared at equal concentrations, some clays produce much higher turbidity (light scattering) relative to others due to differences in their particle shape.

3) The percent moisture content (pmc) of the material also affects the turbidity caused by a given mass of suspended material.

4) Climatic events, such as extreme runoff events, will increase the background concentrations of sediment and thereby reduce the visual observation of the turbidity plume. At the same time, the additional sediment from the runoff will increase the total concentration of suspended sediment. Such events will also have several other effects from the associated increase in velocity, including more rapid mixing of the plume and increased lateral extent of the plume.

Disposal Sites

At the disposal sites, turbidity will arise from entrainment of dumped material into the water column and from bottom sediment which will be resuspended upon impact of the dumped material. The sediment at the lower portion of the reservoir is predominantly silt (based on surface grabs). Based upon an estimate of 1% entrainment of dumped material, expected flows ranging between 0.4 and 1.5 ft./sec., and an assumption of complete mixing, the extent of the plume zone is estimated to be approximately 100 m laterally and 500 m downstream. Average concentrations within the zone are estimated to be 80 mg/l above ambient. The characteristics of the turbidity plume at the disposal sites, however, cannot be accurately predicted.

Link 2: **The presence of the turbidity plume will discourage anglers from using the areas immediately adjacent to the dredging operation and disposal operations and lead to reductions in the amount of fishing effort.**

The assertion that anglers will avoid the area of the plume is based upon the assumption that they will respond to the reduced aesthetics of the area and an expectation of reduced catch rates in turbid waters. Their response should also depend upon whether they can visually detect the plume.

In general, conflicts between anglers and dredging operations conducted in coastal estuaries has not been a problem, although areas used by anglers are avoided for dredging where possible (J. Lunz, pers. comm.). For example, hopper dredging of sand deposits in Oregon coastal ports produced no significant conflict with the local troll fishery. Similarly there were no complaints by anglers during previous dredging operations in the Lower Granite Reservoir. In part this may be due to the temporal pattern of the fishery. Studies by the Washington Department of Wildlife indicate that the peak fishing effort at dredging site number one occurs in December. This site will not be dredged until January. Dredging at site number two will occur during December but no angling has been previously observed in this area. Consequently, the temporal pattern of dredging may reduce the potential for conflict with anglers.

The potential for conflict in the lower reservoir disposal areas is uncertain and is thought to be insignificant. Angling tends to concentrate near the dam forebay while upstream it tends to be dispersed and patchy. Boat access is available within one-half mile downstream and one to two miles upstream. It is possible that the effect of anglers avoiding the immediate disposal area would be to relocate effort rather than to reduce it. Since the fishery tends to move up into the Clearwater River beginning in January the timing of the disposal operation may lead to little if any conflict.

Studies by the Idaho Department of Fish and Game found no correlation between turbidity and catch rate and participants were not aware of any evidence to refute this. The degree to which anglers may nevertheless avoid the turbidity plume is not known.

5.4.2 Conclusion

It is unlikely the dredging and disposal operations will lead to significant conflict with the angling fishery. It is not expected that effort would be reduced although it may be relocated from the immediate vicinity of the dredging and disposal operations.

Concern was raised for angler safety where anglers in small craft may be exposed to the wake of barges moving between the dredging and disposal areas. It is uncertain whether this may be a problem and it is not an issue with respect to the monitoring program. However, it was recommended the public be advised of the danger in order to minimize the potential hazard.

5.4.3 Monitoring

Both the Washington Department of Wildlife and the Idaho Department of Fish and Game operate creel surveys. Aside from continuing these surveys, no special monitoring initiatives were recommended for this hypothesis.

5.5 Summary

The monitoring recommendations from the four hypotheses fall into four main categories:

1) fish abundance and utilization relative to reference areas in the reservoir, including predators, salmonid juveniles, and other resident species;

2) benthos abundance and species composition followed through time after the disposal activity;

3) various habitat characteristics including such things as substrate composition, water quality and bathymetry; and

4) synoptic and long term surveys of fish utilization in the reservoir as a whole linked to large scale surveys of habitat characteristics.

The first three of these are directly linked to addressing issues in the hypotheses while the fourth is intended to address a general lack of understanding of the existing distribution of fish in relation to habitat variables.

The detailed monitoring recommendations, and the links they address, have been summarized in Table 4. The section headings in the following chapter correspond to these items and are presented in the same order. The table is organized under two major headings: disposal site and reservoir to emphasize the difference between the disposal site oriented monitoring and the more synoptic and long term monitoring.

Table 4. Summary of monitoring recommended actions developed at second workshop. Under "links": H=hypothesis, L=link.

Monitoring Recommendation	Links	Scale of Observation	
		Disposal Site	**Reservoir Wide**
Physical habitat changes at dredge and disposal sites	H2 - L1,2,3	Bathymetry Velocity Substrate Composition	
Habitat structure at mid-water depths throughout lower part of reservoir	H3 - L7 H1 - L7,9		Bathymetric
Sediment accumulation rate at disposal sites	H3 - L3	Accumulation of New Sediment	
Benthic recolonization rates in abundance in newly created habitats and speciation	H1 - L11,16 H2 - L8(a,b), L9 H3 - L6(a,b)	Benthos	
Rate of macrophyte development at new shallow sites	H3 - L4	Macrophytes	
Utilization of existing and newly created habitat by s salmonids and resident fish	H2 - L4,5,6,7 H3 - L7,8,9,10	Zooplankton Fish Utilization Fish Feeding	
Synophic survey of fish distribution in reservoir	H1 H2		Synoptic Survey of Fish Use
Predator abundance at disposal site and other similar undisturbed sites	H1		Long term Predator Abundance

6.0 DESIGN CONSIDERATIONS

This section describes a proposed configuration for the disposal site and a detailed design for the recommended physical and biological monitoring. The level of detail is intended to be sufficient to form the terms of reference for carrying out the monitoring activities.

Each monitoring recommendation described in section 5 is addressed. Special attention has been paid to the details of experimental design and the value of collected information in answering critical uncertainties.

There are two key problems in designing a monitoring program to address the uncertainties identified in Chapter 5:

1) practical methods are not available to directly address many of the uncertainties; and

2) many other activities are taking place within and outside of the reservoir at the same time as the in-water disposal test activity.

To address the first problem the approach taken was to develop surrogate questions and then make any necessary assumptions to infer conclusions about the key issues. For example, it is not practical to directly measure the effect of new habitat at the mid water disposal site on the population dynamics of squawfish. However, it is practical to measure squawfish presence at the new habitat and, if it is significantly greater than at control sites, infer some benefit to the population as a whole.

As for the second problem it is hard to control for the effects of other activities occurring at the same time as the test. Such activities include the general aging of the reservoir, changes in the resident fishery, and changes in a variety of factors that affect salmonid populations. In the short term, and on the spatial scale of the disposal site, some of these factors can be controlled for by replicating disposal activities across a number of years and examining differences in response. In the long term factors such as the aging of the reservoir are hard to accommodate.

The object of this test disposal program is not solely to evaluate the impacts of realistic disposal options but also to learn about the potential for beneficial in-water disposal of dredge material in reservoirs. Thus, the proposed disposal site design represents an extreme option intended to provide the maximum amount of information on fish and benthos response; it is not necessarily intended to be a recommended method of disposal outside the bounds of this test, although such a conclusion is certainly possible at the end of the test. The risks of major impacts associated with such an extreme test are considered to be minimal since a very small proportion of the reservoir area will be affected.

6.1 Configuration of Disposal Site

The configuration of the disposal sites depends on the questions to be addressed by the overall experimental design. In the deep water disposal site there is only one option: to raise the level to a certain depth. The design of the mid water site is more complex.

Mid Water Site

There are two basic objectives for the design of the mid water disposal site:

1) assess the biophysical impacts of the proposed disposal method; and

2) design the disposal site to specifically address the identified uncertainties in fish response to alterations in their habitat.

Both of these objectives can be addressed in the mid water disposal area by placing material in two different structures: one designed to learn about fish responses to in-water disposal in general (Mid Site 1); and the other designed to learn about responses to the proposed disposal method (Mid Site 2).

The design of the Mid 1 disposal site was defined by the need to improve understanding of fish response to habitat changes. Given the relatively crude ability of most monitoring techniques to detect change, a design most likely to yield useful information was selected. In other words, the design is intended to produce the most radical changes in fish distributions and populations. The participants at the second workshop felt that the design most likely to produce measurable changes in fish and other indicators was an island that broke the surface and was parallel to the shore. This design results in a wide variety of depths, underwater area, surface area and new shoreline versus existing shoreline and should provide the most radical changes in fish response by producing complex and varied habitat types. The island site provides the potential for maximizing beneficial use as compared to the submerged plateau site which, while expected to be beneficial over its previous existence as mid-depth habitat, may not be a large enough or significant enough event to create a detectable response within a short time.

The proposed mid water disposal area thus consists of two separate sites.

MID 1 an island (a berm which breaks the surface) parallel to the shore, approximately 100 feet wide at the top and 1000 feet long; and

MID 2 a submerged plateau, within 15 feet of the surface at high pool, between 500 and 1000 feet long and extending from the 15 foot bottom contour out to the edge of the shelf.

The minimum effective size for both these structures is thought to be approximately 1000 feet long. This is because a smaller structure might not be large enough to cause a detectable response as there would be too much in and out migration of fish.

Ideally these two structure types would be replicated in two ways:

1) replicating within each year would yield valuable information on spatial variability in biophysical responses; and

2) repeating the construction of each type in several consecutive years would allow for the determination of the effects of initiating treatment in different years.

To obtain true replication and an estimate of spatial variability and avoid pseudo replication (Hurlbert 1984) it would be necessary to replicate the structures across the whole reservoir and not just along the bench currently proposed.

Unfortunately the quantity of material likely to be available for site construction severely limits the number and scheduling of structures. With a limited amount of material it is more important to ensure a significant effect by producing the largest structures possible in each year.

At the second workshop it was proposed that both the mid sites would be constructed in the first year. Following the workshops, further analysis was carried out and it became clear that based on the current schedule of dredging it was unlikely that there would be sufficient material available to build both mid sites and the deep site all in one year. There are a number of different approaches that could be taken to this problem:

1) The best approach from the view of examining the effects of in-water disposal is to increase the quantity of material dredged so that all the sites can be constructed in the first year and possibly replicated in future years. This approach gives the maximum amount of information in the shortest time. While this is the best approach it was felt that it was unlikely for this to be possible in the first year due to the shortage of time to discuss and organize this major change in dredging.

2) Given a fixed amount of dredge material (about 800,000 cubic yards per year) the various sites can be constructed over a three year period as shown in Figure 9. This was chosen as the option that would be described in most detail here since it does not depend on any major changes in other plans for dredging.

3) It is possible that it will be feasible to dredge substantially more material in the second year of the study. If this were to occur then the best use of that material would be to produce the island all in one year instead of over two. This is a better option as it gives more years for monitoring and so will provide results sooner.

Exactly which of these options is followed depends on the amount of material that is available for building the mid and deep water sites. It is not possible to decide finally between these at this point since the amount of material that will be available in year 2 is not yet known. The basic rule should be that the mid site 2 and a deep site should be built first with the highest priority and then the island (mid site 1) should be built as fast as possible. If the island cannot be built in one year then an additional deep site could be constructed in year 2.

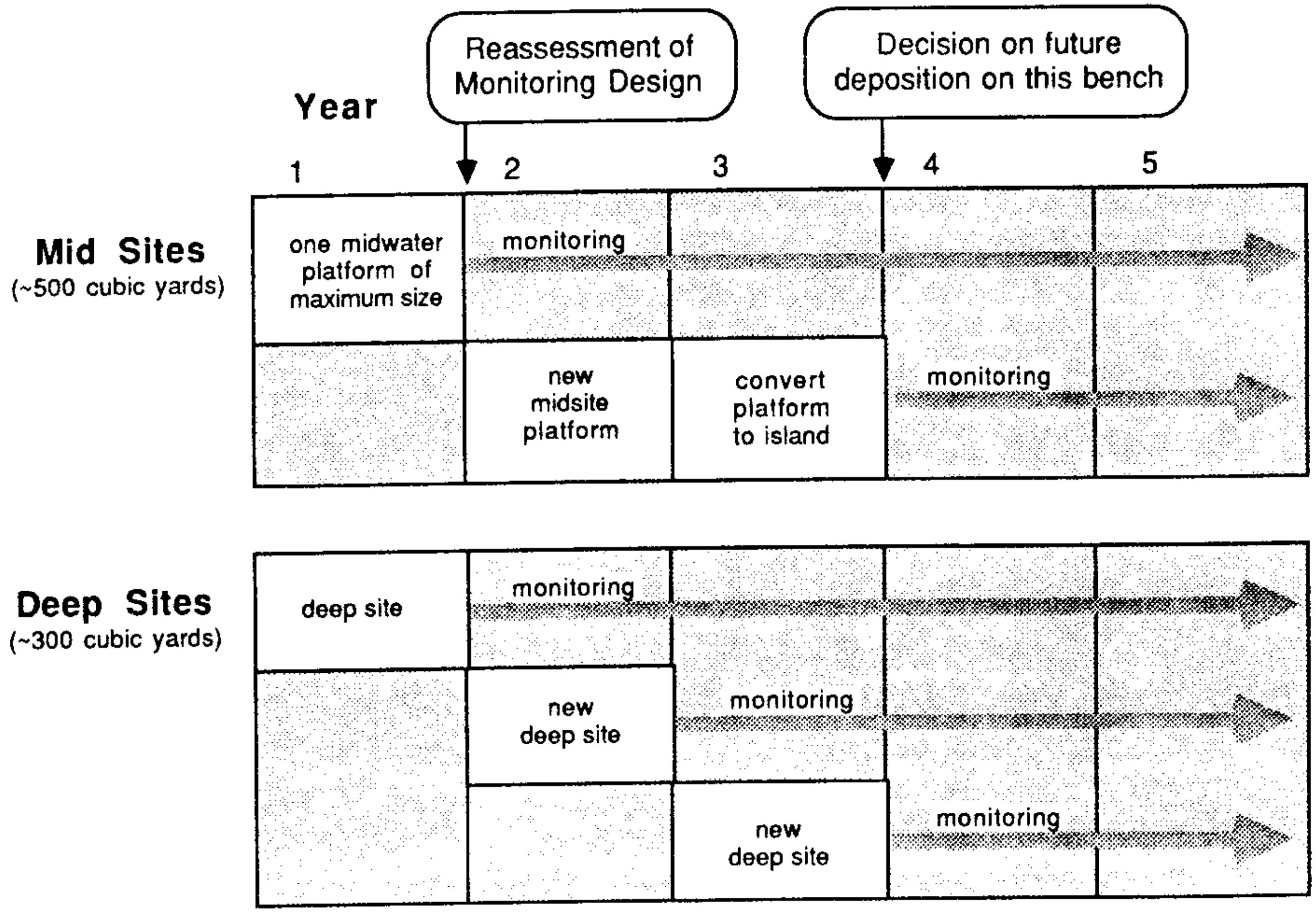

Figure 9: One of the proposed schedules for construction of mid and deep water disposal sites. Mid sites would be constructed on one bench and deep sites away from that bench.

Based on the second option above the proposed schedule for construction of the mid and deep water structures is shown in Figure 9. This schedule is based on the disposal of approximately 800,000 cubic yards of material each year, as noted above if this figure changes then other schedules for construction may be followed after the first year. This schedule proposed has the following features:

- o the construction and monitoring program is carried out over a five year period;
- o a deep water site is constructed in each of the first three years;
- o a midwater platform (i.e., mid 2) is constructed in the first year and is then monitored for the following four years;
- o a midwater platform (i.e., a second site like mid 2) is constructed in the second year and converted to an island (i.e., mid 1) in the third year and then monitored for the fourth and fifth years.

This sequence results in two midwater sites being constructed and monitored within a five year period.

The mid depth structures should be constructed on non-complex habitat and in water initially between 20 and 60 feet deep with the majority of the area in the 40 to 60 foot depth range. The minimum depth between the resultant island and the shore should be 15 feet.

One way of constructing the island would be to rework material by first dumping it from the scows in water greater than 15 feet deep and then moving it up to create the island. It is critical the island surface be above high pool since an extensive area of very shallow water could cause significant local turbidity problems.

To increase their stability, the mid depth structures should be constructed from dredge material relatively high in sand content. However the island will still require maintenance since it is unlikely that the island will be stable in the long term. Further, the effect of storm flows on island stability is not known; the surface layers of silt could be removed or there could be a major redistribution of material.

The creation of the island will likely result in the development of riparian habitat of unknown quality, the loss of some aquatic habitat, and the loss of some reservoir peaking capacity. However, the loss in peaking capacity and aquatic habitat will be minimal in the five-year test.

Deep Water Site

The proposed configuration of the deep water site has been kept simple based on the relatively simple hypotheses to be addressed at this site. The design consists of a single mound of material (approximately 300,000 cubic yards) the top of which is raised to within approximately 60 feet of the surface (670 foot level). The deep sites should be somewhat remote and downstream from the mid water sites to prevent interactions due to changes in hydrodynamic conditions. The deep water site should be constructed using the material which is higher in silt.

6.2 Disposal Site Observations

The observations proposed for the disposal site are designed to assess the short and medium term responses of the physical and biological system to the disposal activity.

There are eight different habitats to be sampled:

1) the area inside of the island. This will consist of very shallow water and somewhat deeper water down to 15 feet. The deeper areas will, in some cases, require different sampling techniques;

2) the area outside of the island. This will also consist of a range of depths from very shallow to deeper water;

3) the shoreline area inside of Mid Site 2 which is less than 15 feet deep at high pool;

4) the area on top of Mid Site 2;

5) a shallow water reference site with simple topography. This would consist of very shallow and deeper water in the same way as sites 1 and 2;

6) a mid depth reference site with simple topography;

7) the deep water disposal area; and

8) a deep water reference area outside of the influence of the disposal activity.

The choice of the reference sites is critical. To act as reasonable controls they must be as similar as possible to the main disposal sites and should not be unusual in substrate or location. If possible it would be desirable to have a number of different reference sites at both shallow and mid depths. Due to the evolving nature of the reservoir before and after comparisons are liable to be of limited use. In view of this, the reference sites should not be chosen solely because they may have been sampled prior to this test activity; it is more important to pick sites that resemble the disposal sites.

The following sections outline nine separate program elements recommended for the disposal sites. Several program elements deal with physical and chemical changes to the environment. In addition, three program elements deal with changes in invertebrate populations, zooplankton and macrophytes. In each case the purpose of these studies is to assess whether the newly created habitat is better or worse fish habitat than the present environment. As long as a direct assessment of the benthic community is made, studies which provide direct information on fish habitat conditions (e.g. bathymetry) are more important than others which are primarily related to assessment of potential benthic productivity (e.g., sediment accumulation and composition).

The major portion of this section describes the details of the methods and design for each of the monitoring program elements at the disposal sites. In Chapter 7.0, the relative value of the different program elements is discussed and ranked. The focus in this section is on the design and description of the minimum necessary program for the first year of monitoring and for the 5 year framework. This minimum necessary program was defined in the technical meetings subsequent to the two main workshops and represents the best judgement of the people at those meetings as to what is necessary for a defensible program.

6.2.1 Bathymetry

Information on the bathymetry of the disposal sites will be used to assess suitability as fish habitat. The area of newly created habitat in different depth zones, the topographic relief of the site, and the composition of the substrate surface (i.e., whether sand or silt) are all important components of this assessment. The conditions at the site shortly after dredge disposal, and in subsequent years, are important to assessing the temporal development of fish habitat.

Data on the bathymetry of all treatment and control sites is sought to provide information on the net change in site topography and elevation. The specific needs are:

1) changes in site topography resulting from the sediment disposal,

2) changes in site topography resulting from sediment slumping or episodic relocation of sediment after high flow events; and

3) changes in site elevation resulting from the accrual of sediment due to natural sedimentation.

To yield the maximum amount of information, the method chosen must provide information on the composition of surface substrates (i.e., distinguish between sand, clay, and silt). This will be important to interpretation of changes in bathymetry with respect to points 2 and 3 above.

Approach/Methods

The proposed approach consists of a bathymetric survey technique that provides data on water depth, corrected for pond elevation, over the treatment and sample sites. Both "Lowrance" and "White Line" technologies, or equivalent methods of measurement with equivalent accuracy, are acceptable. For bathymetric purposes the method chosen should provide accuracy to about .5 ft (approx. 0.1 m).

The "White Line" technology has the advantage of yielding data on substrate composition but is significantly more expensive. This part of the study could be used to assess natural sediment accrual in which the "White Line" method with an accuracy of 0.5 in (approx. 1. cm) would be essential; however, this information could almost certainly be obtained through other more cost effective means (see section below on Accumulation of New Sediment).

Sampling Intensity

Temporal

The bathymetric survey should be conducted prior to disposal activities at all disposal and control sites. It should be repeated as soon as possible following the termination of disposal activities in the spring and then repeated once annually for the duration of the study. It is recommended these annual surveys be conducted in September. The initial survey will be used to describe the exact quantity and pattern of disposal while the other annual surveys will describe the bathymetry following sorting, stabilization and periods of high flow. Continued sampling at the reference sites will allow a description of the changes in sites unaffected by disposal.

Spatial

A sufficient sampling intensity is required to permit development of a contour map of each treatment and disposal site. This should provide sufficient horizontal resolution to distinguish hummocks in the disposal field arising from a single barge load.

The proposed design consists of horizontal transects at right angles to the shore with a spacing of 50 feet. Vertical resolution should be approximately 0.5 m to distinguish gently rolling or discontinuous terrain. The spatial extent of the survey must be sufficient to determine the extent of the disposal field and should therefore extend beyond the formal boundaries of the disposal area.

Analysis, Interpretation and Stopping Rules

In the first year following disposal, the bathymetry survey should yield a contour map indicating the shape and roughness of the disposal field at each site.

The results of the bathymetry survey will be used to both verify the structure of the sites created and to provide more detailed information which will be useful in interpreting the fish and benthos data. The data should be presented in graphic form and as transects to facilitate qualitative evaluation.

The annual survey should be repeated for 2 to 3 years. If the data indicate significant changes in site topography from slumping or erosion the survey should be continued until either site stability or a stable trend in site flux has been established. After this time it is recommended that the survey be repeated after flow events which significantly exceed those recorded during the study period.

6.2.2 Substrate Composition

Information on substrate composition at disposal sites is required for assessment of potential site productivity for aquatic invertebrates. The site suitability for invertebrate populations is, in turn, important to determining fish food production. Information from this program element will be used in conjunction with the benthic survey to explain the rates of development and final levels of the benthic population. This will increase understanding of the suitability of the newly created habitat as a source of fish food. Each site should, therefore, be characterized with respect to the percent composition of major substrate components (i.e., sand, silt, clay) and its organic content.

Approach/Methods

The approach used should provide for an overall assessment of the sediment characteristics at the disposal and treatment sites. Substrate samples should be collected and analyzed for grain size composition. Care should be exercised in sampling to reduce loss of fine surface organic sediments. Consequently the use of a Ponar grab, a gravity corer or a Shipek dredge (or equivalent) is recommended to ensure a high rate of capture of surface fines.

For the purposes of this study it is necessary to distinguish between greater than sand; sand; and less than sand. It is not necessary to distinguish silts and clays although this may be required for other (e.g., permit) purposes.

Sampling Intensity

Temporal

This program should proceed in conjunction with the sampling program for benthic invertebrates. Refer to the section on benthos for the details of sampling intensity.

Spatial

This program should proceed in conjunction with the sampling program for benthic invertebrates. Refer to the section on benthos for further detail on sampling intensity. Initial sampling intensity should be high enough to characterize within-site variation in substrate composition. For example, it is desired to determine whether there is variation between the crests and valleys within a rolling terrain. Sites uniform in topography may subsequently be subject to a reduced sampling intensity.

Since the intent of the program is to assess the suitability of substrate for benthic production the depth of vertical sampling of the substrate need not exceed 6 - 8 inches.

Analysis, Interpretation and Stopping Rules

Samples should be subject to standard grain size analysis to distinguish percent sands, silts, and clays. To provide additional resolution of fine particles, inclusion of hydrometer analysis is desirable but not mandatory. Analysis for organic content should determine only total volatile solids (Note: analysis for total organics is not required).

The results of this monitoring would be used to describe the changes in substrate composition in a qualitative sense, and would assist in the interpretation of the benthos sampling. In particular this would assist in assessing the link between substrate composition and benthic production that was identified in the hypotheses.

Termination of this program component will coincide with termination of the benthic sampling program (see the section on benthos).

6.2.3 Accumulation of New Sediment

The information sought is the depth of new sediment accumulating annually over the disposed dredge material. This will be used to determine the suitability of substrates at the disposal sites for the development of a benthic community and the time course over which the community develops. Since the program already incorporates an element for the direct assessment of the benthic community production this information will not be used to predict production but, rather, to qualify the interpretation of the benthic invertebrate survey.

If new sediment accumulation rates are large then they may be inferred to a large extent from the bathymetric survey. In that case, the measurements described in this section will not be considered a necessary program component. It is highly likely, however, that it will be necessary to supplement that survey with some other more accurate methods of measuring accumulation to distinguish the relative contribution made by sedimentation to any net change in bathymetry.

The measurement of sediment accumulation will likely form part of other Corps monitoring programs as part of the disposal activity. The methods and sampling intensity described here are intended to describe a minimum acceptable level of effort.

Approach/Methods

The survey should employ the use of dredging, sediment traps or other means for measuring the accumulation of sediment. Methods which have inherent sampling bias are less desirable (e.g., sediment traps). Alternative methods such as the placement and visual inspection of elevation reference stakes may be appropriate. Annual cross-sectioned surveys will describe large changes in bottom bathymetry.

It may be appropriate to use sonar methods to obtain sub-bottom profiling. Although the equipment to do this is expensive it would allow the collection of extensive information a number of years after the disposal activity.

Sampling Intensity

Temporal

As per the bathymetric surveys this program element should be completed once each year during the mid to late summer period of low flow.

Spatial

This assessment should be made for all treatment and control sites. Sufficient within site stratification should be employed to detect differences in the rate of accumulation of sediment with depth and distance from shore.

Analysis, Interpretation and Stopping Rules

These results of the sediment accumulation study should be presented in graphic form. These results when used along with the sediment composition study will help in the interpretation of the results of the benthos sampling.

The same criteria as the bathymetric survey should be applied to stopping this activity.

6.2.4 Benthos

Information on benthic invertebrate populations is sought to determine the suitability of the disposal site as fish habitat. This information will be used to assess whether, relative to the control sites, the newly created habitats produce invertebrates of suitable size and number to provide a source of food for fish. In addition, the recovery period of the invertebrate populations after disposal will allow estimation of the quality and quantity of recovery from impacts due to disposal. During the first two years following disposal, the program should monitor the numerical abundance of major taxa known to be important as a source of forage for fish, especially salmonids. In the third year of the program additional effort should be applied to estimate the total annual production of the various taxa.

At each site the number of stations to be employed will be determined by a pre-study survey to determine the variance within and between sampling stations, especially as this may be related to different productivity with depth.

Approach/Methods

The benthic survey should employ a series of sampling stations within each treatment and control site. At each station, collection of benthic samples should be made using a bottom dredge. A Shipek dredge or other sampling device with comparable or better sampling characteristics (e.g., a PONAR grab) should be employed. Samples should be sieved with a U.S. standard #30 mesh screen. A #60 mesh (250 micron) screen would give more complete information on production but this is not required for this study. Raw unsorted samples should be preserved with formalin acetic acid alcohol (FAA) followed by 70% alcohol and retained for later analysis. Samples should be analyzed to identify the different taxa present in each sample and to provide a count of the numbers of each taxa present within predetermined size classes.

Sampling Intensity

Temporal

The benthic survey should be made once at each site during May each year for the first two years after disposal. During the third year, samples should be taken monthly to estimate total benthic production (based on time series of size frequencies) at each disposal and control site.

Spatial

The benthic survey should be made at all sites (i.e., 1 to 8). At sites (3) through (8) a sufficient number of sample stations must be employed to characterize each site as a single sample frame. At sites (1) and (2) a stratified random sample design should be employed to provide a more detailed within site analysis of benthic production. Stratification at these sites should be as follows:

Site (1): stratification between areas with and without macrophytes (2 strata), and

Site (2): stratification by depth (3 strata).

Each sample (station X sample period X stratum) should be composed of five hauls each of which should be individually counted and analyzed.

Analysis, Interpretation and Stopping Rules

During the first and second years of the study, subsamples (hauls) should _not_ be pooled but should be analyzed separately to determine a mean sample size and variance for each station. The data for the various stations within each site should then be analyzed to estimate the total standing crop by taxa and size for each site as numbers and biomass. The estimated totals and 95% confidence intervals for the estimates should be reported for each site and, at sites 1 & 2, for each stratum.

The level of taxonomic identification and size classification required should be based upon the results of monitoring chinook and steelhead salmon feeding. These data are available in Bennett and Shrier (1987). At a minimum, this classification should provide information on major taxa (i.e., chironomids, oligochaetes) and at the level of genera for Dipterans. It is not necessary to classify species.

The preceding specification shall apply during the third year of the study as well. During this year, however, samples should also be analyzed to determine dry weight. Separate determination should be made for each classification group (taxa x size). These values should be reported in conjunction with the numerical data and an estimate developed of the total annual benthic production from each site.

The program should be terminated when one of the two following criteria are met:

1) no important differences are detected between treatment and control sites (or strata) at comparable depths; or

2) annual (year to year) variation in production at the treatment sites are statistically equivalent to that observed at the control sites.

6.2.5 Macrophytes

The information sought from the macrophyte survey is the areal extent of macrophyte development and the density of cover provided by macrophytes. This information will be used in assessing the volume of macrophyte habitat available to the various fish species.

Approach/Methods

A two tiered approach is recommended. The first level would involve an areal survey using visual (diving) inspection and/or dragging equipment to determine the areal extent of macrophyte development.

The second level of the survey would involve a more detailed analysis within areas of macrophyte development. This should employ a randomized quadrat sampling design with, at a minimum, 5 to 10 quadrats at each site sampled. Quadrats should be at least 0.25 m2 (0.5 m on a side). Within each site, macrophytes should be removed by clipping, identified by species, and the dry weight of each species determined.

Sampling Intensity

Temporal

The macrophyte survey is tied to the creation of the island since this is the activity which would result in the creation of habitat suitable for macrophyte development. The survey should be initiated once the island has been constructed and should be carried out once each year during the late summer when biomass is peaking.

Spatial

The survey should be conducted at sites 1, 2, 3, and 5 (see Section 6.2 for definition of sites). The survey of areal extent should be made over the entire shore line of each site and should extend offshore from each surface feature to a sufficient depth to ensure macrophyte development is not missed (approximately 4 m depth below the high pool elevation). Within each major area of development, a sufficient number of quadrats should be employed to determine the average density of macrophytes (on the order of 5 - 10 quadrats).

Analysis, Interpretation and Stopping Rules

The data should be presented in graphic form displaying the areas of macrophyte development and estimated standing crop of macrophytes in each area.

The survey of macrophytes is important if very shallow water habitat is created since macrophytes are an important aspect of fish habitat.

This study of macrophytes does not form a part of the minimum necessary program. It is recommended that it be carried out once as described above to examine in particular the effects of island construction. The program should be continued until the area of macrophytes within the treatment sites no longer increases between years.

6.2.6 Zooplankton

Information on the abundance of zooplankton may be used to further assess the availability of fish food at the treatment sites. This study does not form part of the minimum necessary study.

Approach/Methods

In the event that this program is instituted, a series of vertical plankton tows (10 areas recommended) should be taken at random points within site (1) and also at site (5). These should be made using standard methods and equipment for zooplankton sampling.

Sampling Intensity

Temporal

One time only, during late summer in the third year of the program. This will be during the year in which frequent sampling of benthic invertebrates is made to estimate benthic productivity.

Spatial

Random samples over sites (1) and (5).

Analysis, Interpretation and Stopping Rules

Samples should be analyzed to determine the species composition of the zooplankton (numerical abundance) and the community biomass (all species combined).

The rationale for this monitoring is that zooplankton communities might be expected to be very different behind a long island parallel to the shore. This could have an effect on juvenile salmonid feeding.

This study of zooplankton does not form a part of the minimum necessary program. It is recommended that it is carried out once as described above to examine in particular the effects of island construction.

6.2.7 Fish Utilization

Two key, but interrelated, questions are being addressed by this monitoring:

1) Is juvenile salmonid survival improved by the new habitat?

2) Are the survival rates for salmonid predators and other resident fish improved by the new habitat?

As discussed in Section 5 it is not possible to directly measure whether the habitat is "better". What can be measured is whether the fish are present in the habitat, and perhaps some other indicators of use such as studies of feeding habitat (see below). As a first indicator of habitat utilization we, therefore, propose to measure presence and absence of fish, as well as to assess relative abundances at different sites where possible.

The assessment of relative fish abundance is driven by three specific questions:

1) Do relatively high densities of post-larval and juvenile squawfish rear in the very shallow water created at the edge of the island (Hypothesis 1, link 9)? (sites 1 and 2)

2) Are there increased abundances of adult squawfish and other predators at the disposal sites?

3) Are juvenile salmonids (especially fall chinook) present in increased numbers in the new habitat at the disposal site?

To address these questions it will be necessary to produce estimates of the relative abundance of post-larval, juvenile and adult fish. This will clearly require a range of different gear types.

Approach/Methods

The range of different gear types required to assess the relative abundance of the different fish species and life history stages are summarized in Figure 10. The use of different gear types for the same life history stage at different sites will result in difficulties in comparing those sites; this problem will be discussed further in the later section on interpretation and analysis.

Post-larval squawfish could be captured with a variety of different gear types depending on the conditions at the study site. These could include hand tow nets, larval nets, and drop traps. It is important that a single method be chosen and standardized for all sites, as non-standardized methods will make comparison of sites virtually impossible.

Assessment of juvenile salmonids, squawfish, and bass young of year (YOY) will require the use of a number of different gear types in water of different depths:

- in shallow water close to either the island or to the shore, beach seines should be used;

- in water greater than 10 feet deep, the lower levels close to the substrate could be sampled with a bottom trawl while the surface layers should be sampled using a two boat surface trawl; and

- some fish may also be caught in the electro fishing described below. This, however, would not be the method of choice for these juvenile fish.

To aid in the comparison between sites the number of different methods used should be limited. It seems inevitable, however, that different gear types will have to be used for the shallow (< 10 feet), and deeper (> 10 feet) substrate and surface samples.

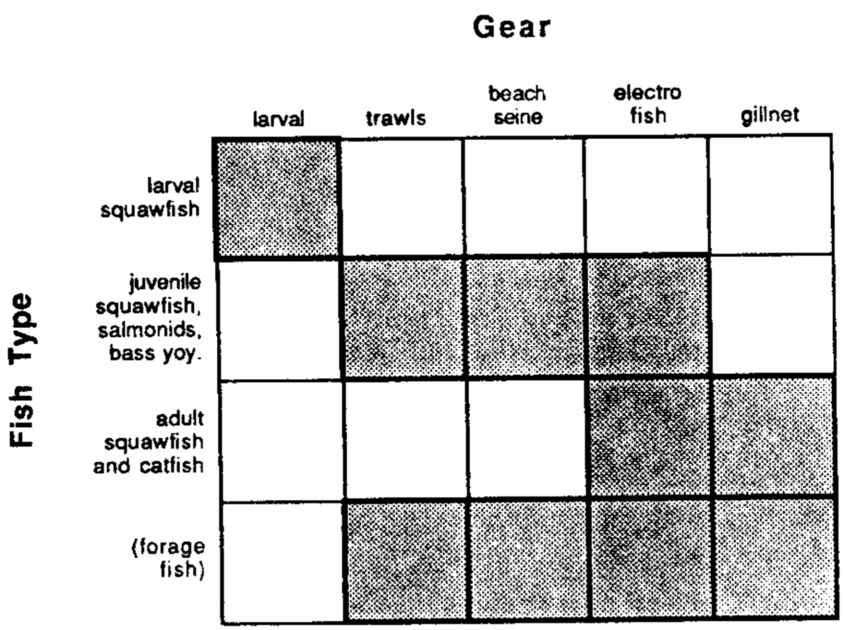

Figure 10: Fish types vulnerable to the different gear types proposed for the monitoring program.

The best method for adult resident fish (mainly squawfish) is the use of gillnets. This will be effective in water deeper than 10 feet and will be most effective for squawfish. Bass do not appear to be very catchable in gillnets. To better assess bass and sample the shallower water for adults, electrofishing is recommended.

It is expected that there will be a high level of variability in the catch rates in gillnets. This is likely to result in a relatively poor ability to distinguish anything but very gross differences between areas and times.

In the process of gathering information on the species identified above, forage fish of various species will also be caught. While it is not the intention to specifically design studies to assess these species, they may provide useful ancillary information to describe the changes in the fish community at the disposal site.

Sampling Pattern

Figure 11 summarizes the temporal sampling pattern proposed for the different gear types at the different sites. It should be noted that sites 1, 2, and 5 have both a very shallow (< 10 feet) component in which it is possible to use larval gear, electro fishing or beach seines, as well as a deeper component, where it is possible to use gillnets, bottom trawls and surface trawls. The gear type used will automatically distinguish between these two depth zones within each site.

The pattern of sampling shown in Figure 11 is driven by the need to cover a wide range of different times to assess presence of certain fish throughout the year, and the need to intensively study certain critical times of the year. In general the period from the start of April to the end of September represents the most intense period. This is the time when juvenile salmonids and squawfish are present and predation occurs at a relatively high rate in the warmer water.

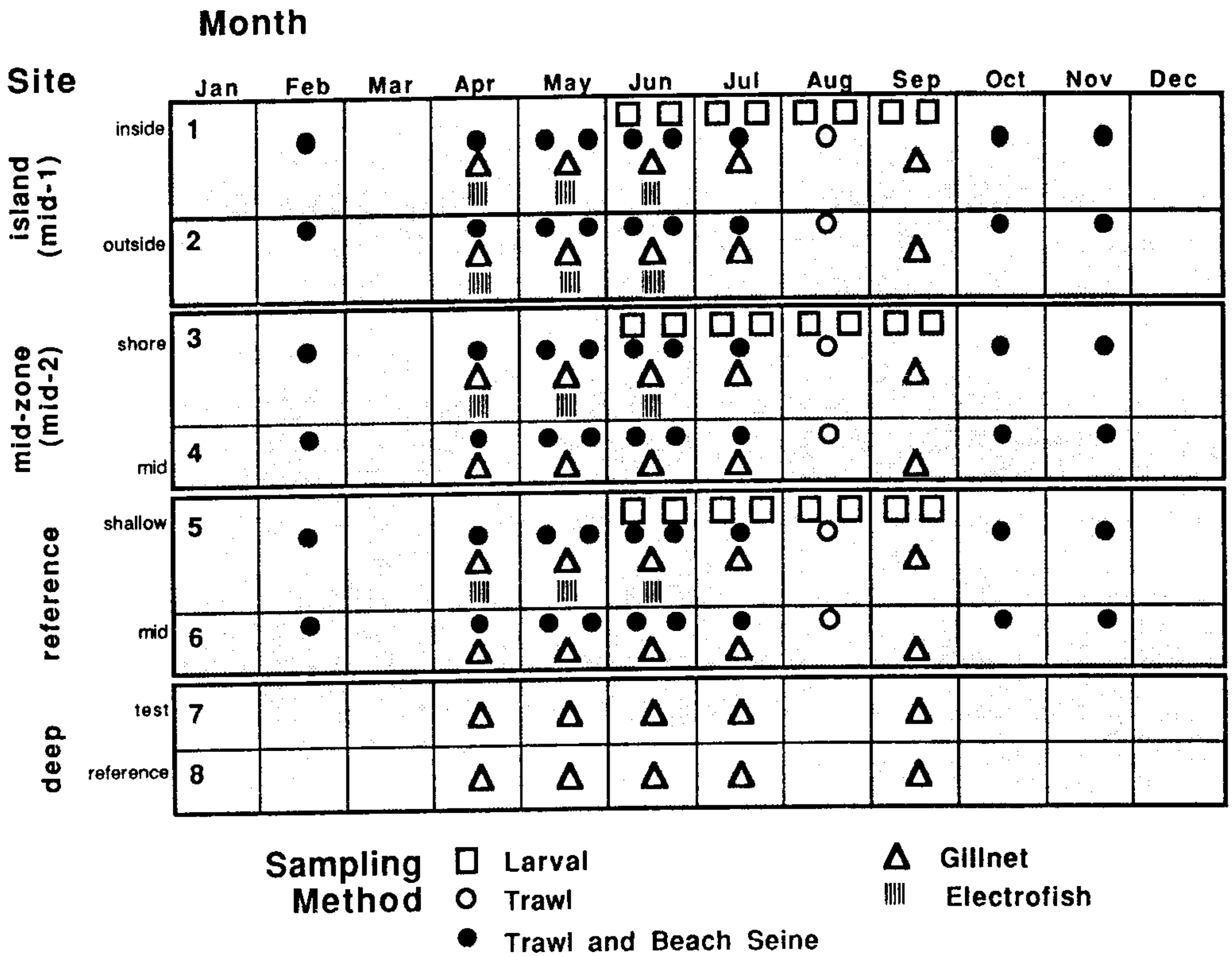

Figure 11: Detailed annual schedule for sampling for fish utilization. Sites 1 and 2 and all larval work would only be carried out after island construction.

NOTE: Based on Dr. Bennett's recommendation, the September gillnetting effort is shifted to October (to better assess overwintering stocks). Also, #3 and 5 should show beach seining only, not trawling (Tim Webb, pers. comm. 1/15/88)

Squawfish smaller than 30 mm and Bass YOY should be vulnerable to larval gear and beach seines in shallow water in between June and September, and to bottom and surface trawls in deeper water in the same period. Sampling every other week should be sufficient to track the pattern of presence in these areas.

Migrating and resident juvenile salmonids will be vulnerable to bottom trawls, surface trawls and beach seines. In the period from the beginning of April through to the end of June, migrating juveniles will be present. Outside of this period, a small number of samples should be taken to assess the presence of overwintering juveniles. An appropriate sampling frequency would be once in April, once every two weeks in May and June when fall chinook are present, and once in July, August and September.

Squawfish juveniles between 30mm and 300m should be vulnerable to the same gear as salmonids. The same pattern of sampling is recommended.

Adult squawfish, catfish and sturgeon will be vulnerable to gillnets in water deeper than 10 feet. The critical period to assess their presence is in the months of April, May and June when salmonid prey are present. Less frequent assessments in July through September will give a more complete picture of their presence at the disposal site when overwintering juvenile salmonids may be present. The frequency of samples should parallel those taken for salmonid juveniles: once a month in April through July, and once in September. It is not considered necessary to take any samples in the winter since at this time predation rates are likely to be very low.

Adult bass represent a problem in obtaining good representative samples. They are not very vulnerable to gillnets although the program described above for other adult resident fish will give some indication of presence and absence. To give some additional information on bass abundance, an electrofishing program is proposed in the shallow waters of sites 1, 2, 3, and 5. This program should include monthly sampling in the April to June period.

Sampling Intensity

The sampling intensities described here represent those recommended for the first year. A reassessment of levels of variability and precision is essential after the first year to refine the levels of sampling effort.

Gillnetting should be carried out at a total of 8 sites once the island has been constructed and 6 sites prior to this. At each site there should be 5 sets for 4 nights to give a total of 20 replicates per site. Methods should be used to try to reduce variability, including using a single mesh size of 1.5 inches and just using subsurface sets to maximize catches of squawfish at mid sites. Deep sites should only be deep set with a variable mesh.

Bottom and surface trawls should be carried out at the mid depth sites (1, 2, 4 and 6). At each site three non overlapping replicates of surface and bottom trawls should be made over the site parallel to the shore. This results in a total of 24 trawls per site per sampling period.

Beach seines should be continued at the same intensity as the current sampling effort in the Lower Granite reservoir. Levels of variability and sample sizes should be reassessed after the first year.

Electrofishing should be carried out for three 15 minute current periods at each site 3 times per month in the months identified in Figure 11. This level of sampling should be reassessed following an analysis of the first years data.

Larval gear should be used in an experimental fashion in the first year (prior to island construction) to determine levels of variance and appropriate levels of sampling effort at the shallow water sites.

Analysis, Interpretation and Stopping Rules

The recommended analysis and interpretation of the fish utilization survey consist of comparisons of the relative abundances of each life history stage at the different sites. Sites 5 (shallow reference), 6 (mid reference), and 8 (deep reference) are thus essential to the interpretation of the results. At some disposal sites there may be the possibility of some limited before versus after comparisons.

Most of the analysis proposed here for the fish data (and also for benthos) is based on a comparison between sites within years. Although there is the possibility of before and after comparisons both with currently existing data and during the monitoring program this type of comparison should be used with caution. The main reason for caution is the uncontrolled variation in confounding factors from year to year. Year to year comparisons of juvenile salmonids will be of little value without some way of controlling for the number of juveniles entering the reservoir from natural and hatchery sources. Similarly predator distributions and possibly populations could be affected by salmonids and also by weather.

In order to facilitate comparisons between sites (and between years) it is important that the results of the fish (and benthos) surveys be presented in a form that is appropriate for a wide range of analysis. Since the major comparisons will be between the catch rates for different species in different time and site combinations this means that the raw data should be catch per individual set for each species along with the associated parameters of time and location. This will allow the relatively rapid calculations of means and variances and will facilitate the use of more complex statistical procedures. Naturally all data should be maintained in machine readable form.

The main results expected from the sampling program are related to the three questions noted above to structure the design: is the very shallow water habitat utilized by juvenile squawfish; do abundances of adult predators increase at the disposal site; and are juvenile salmonids present at the disposal site in increased numbers.

The results of this monitoring will directly address the the first three hypotheses which are all basically concerned with impacts on fish. While the study will not be able to address population effects due to its limited spatial and temporal extent, it will be able to use fish abundance, as indexed by the various sampling techniques, to provide an indication of habitat suitability for the fish species of interest.

Juvenile squawfish - the relative abundance of juvenile squawfish in the very shallow habitat can be assessed by comparing the catch per effort in the larval and other gears used to sample at the very shallow portions of sites 1, 2 and 3, with the very shallow water at site 5, and larval abundances at sites 4 and 6.

Comparisons between sites 1 and 2, and site 5 will provide information on the relative suitability of newly created habitat as opposed to habitat which has existed for a longer period of time.

Comparisons between sites 1 and 2, sites 3 and 4, and sites 5 and 6 will give an indication of the relative suitability of the new very shallow habitat versus new, somewhat deeper habitat, and the original mid water habitat. This is an important comparison since, if relative abundances are similar in all three of these areas, then effects of the disposal activity on squawfish rearing could be assumed to be minimal.

<u>Adult predators</u> - the relative abundance of predators in the disposal test sites (1, 2, 3, 4, and 7) as compared with the reference sites (5, 6, and 8) will provide information on the relative preference of predators for the newly created habitat.

<u>Juvenile salmonids</u> - comparisons of the relative abundance of juvenile salmonids in the disposal test sites (1, 2, 3, 4, and 7) as compared with the reference sites (5, 6, and 8) will provide information on the suitability of the newly created habitat for salmonids. This will be especially important for the time periods in which fall chinook may be rearing, and for assessing the importance of different areas for overwintering juveniles.

Given the level of variability expected in the data, it is likely that only relatively large changes in abundance will be distinguishable. The ability to detect changes should be reassessed after year 1.

While the major questions we can answer with this data relate to fish presence and relative abundance our real concern is with the utilization of the habitat. The link between presence and feeding in any given area is discussed in the next section.

The ability of these studies to distinguish any effects due to the disposal activity will depend on both the intensity of sampling and the number of years through which this sampling is carried out. One year of data following disposal will give some information on any gross changes but an absolute minimum of two years of both disposal and monitoring is required to be able to make firmer statements about the effects of disposal. Five years of data would provide significantly more certainty in any conclusions drawn.

6.2.8 Fish Feeding

Data on what fish eat in an area is important to help make the step from fish presence to utilization. A common method of observing this link is to carry out analysis of fish stomach contents. However, for this form of analysis to be useful, especially at the level of the disposal site, it is necessary that fish either remain at the site for an extended period of time, or there be some particular food item at the site not found elsewhere. If neither of these criteria hold then stomach contents analysis can only be used to give a very general indication of food habitat.

Even in the limited context of providing a general guide to patterns of consumption, good information on the fish food habitat is relatively hard to obtain. In particular adult feeding measurements may be of limited use due to small sample sizes of adult predators and large variation in stomach contents. However, it should be possible to get reasonable sample sizes of juvenile fall chinook stomachs from beach seines used for the abundance sampling. More accurate determination of sample sizes will require the use of data resulting from a pilot program.

We do not recommend an extensive study of stomach contents as an initial part of this monitoring program. To provide a general indication of consumption patterns and to provide information on levels of variability, stomach contents should be analyzed from fish sampled in the fish utilization study described earlier. If it is determined to be useful a more detailed study of fish feeding could be initiated in the second or third years of the study.

6.2.9 Wildlife

Observations of wildlife do not form a major component of the proposed monitoring program but there is a potential for effect given that an island is to be constructed.

It is recommended that there be opportunistic observations of the island crest in the first few years of the test disposal activity simply to check on utilization. It should not be necessary to design a specific survey but rather rely on information reported by fish survey crews and input from other agencies with responsibilities for wildlife.

6.3 Reservoir Wide Observations

The reservoir wide observations differ from those proposed for the disposal site in both spatial and temporal scope. The studies proposed here are either oriented at:

1) better understanding the current structure and patterns of habitat and fish distribution, independent of the disposal activity; or

2) attempting to measure long term changes in physical and biological parameters of the reservoir.

While neither of these categories directly relates to the short term test, there are important reasons for initiating both types of study as soon as possible. By better understanding the current structure of the reservoir (especially the occurrence of complex habitat) and fish usage of different habitat types, it will be possible to make better predictions about the impacts of different disposal strategies in the future. Initiating studies of long term trends in fish abundance now will give a few more data points in the long term. As with any long term study, however, it is important to generate the longest time series possible.

The synoptic surveys of bathymetry and fish distribution do not form part of the minimum necessary monitoring design. These surveys could, however, provide a very useful record of long term changes and large scale patterns in the reservoir. If these surveys are to be carried out it will take a significant effort to refine the designs of these studies and to investigate the capabilities and cost effectiveness of methods based on modern hydroacoustic methods.

6.3.1 Bathymetry Survey

The purpose of a reservoir bathymetry survey is two-fold:

1) In the short term, to provide information on the distribution of "complex habitats" within the reservoir. Complex habitats are defined as areas with significant relief in bottom topography which provide cover for fish species, and/or bottom areas in which the substrates are composed of either gravel or cobble material.

2) In the long term, to provide information on the rate and spatial pattern of sediment accumulation within the reservoir. In addition, provide information on the long term changes in the area of habitats in different depth zones (shallow, mid, deep) within the reservoir.

Approach/Methods

The approach recommended is a continuous recording, transect based survey of the reservoir using acoustic sounding equipment. In some areas of special interest supplemental analysis with side scan sonar may be desirable. The use of "White Line" sounding equipment would have the advantage of providing information on the substrate composition in addition to changes in bathymetry.

Since the sampling requirements to meet the first objective are more stringent than for the second, it is recommended that existing information be used to select sites within the reservoir most likely to have a complex structure. Pre-impoundment photographs of the reservoir lands should be inspected to select areas with significant relief or exposed rocky material. Selected areas should be inspected by diving surveys and/or the use of side scan sonar equipment to determine whether or not sediment accumulation in these areas has rendered them essentially homogeneous with respect to other bottom substrates.

Sampling Intensity

Temporal

The first objective of this program should be met by completion of an initial survey during the period of the test disposal program. This information will then be used for screening the acceptability of other disposal sites in the event that long term in-water disposal is approved.

Spatial

The spatial requirements to meet the long and short term objectives are different. More intense sampling and analysis is required to meet the second objective and will be dependent on the results of initial analysis of existing data.

Analysis, Interpretation and Stopping Rules

The appropriate product will be a map of the bathymetric profile and distribution of different types of substrates within the reservoir.

This information is only of interest in combination with the synoptic fish survey described below. The two synoptic surveys together will provide a much more detailed picture of what habitat types are important to the different fish species.

6.3.2 Synoptic Survey of Fish Use

One of the major unknowns in developing this monitoring strategy has been the suitability and current level of use of different types of habitat within the reservoir. This information gap could be resolved through a reservoir wide survey of fish distribution. The important question to be asked by this survey would be: What areas of the reservoir are important habitat for resident and anadromous fish species?

Approach/Methods

Two methods could be used to give a synoptic picture of fish distribution within the reservoir: methods based on nets or traps; and methods based on hydroacoustics with ground truthing using nets or traps.

Net based methods would be expensive to implement and would suffer from problems of differential catchability of different species. Specifically it would be very difficult to get a good estimate of the distribution of bass using this approach.

Hydroacoustic methods represent a cheaper and more rapid way of estimating fish distribution, however, species identification and ground truthing can be a problem.

It seems likely that further investigation of the hydroacoustic option would be the best approach. This could either result in the use of advanced systems, that can better distinguish species without extensive ground truthing, or a more broad scale survey to simply determine where fish are found in the reservoir.

To give a good picture of fish distribution within the reservoir, such a survey would have to be carried out at a number of different times of the year (both in summer and winter) and would ideally be continued for a number of years to obtain an estimate of the year to year variability.

Analysis, Interpretation and Stopping Rules

After each synoptic survey the resulting information should be presented in a graphical form and used to aid in decisions concerning the best pattern of in-water disposal.

This survey is intended to be carried out in combination with the synoptic bathymetric survey described above.

This type of survey should continue for at least two years so as to obtain an estimate of year to year variability. The survey could also be repeated intermittently over the long term to assess changes in fish distribution.

6.3.3 Long Term Predator Abundance Monitoring

One of the major concerns in using in-water disposal is whether this will result in a long term increase in the abundance of resident predator species. This can only really be addressed through monitoring abundance over a large number of years of in-water disposal.

Approach/Methods

The only practicable method at present of generating an index of the abundance of resident fish in the reservoir is through the use of a test fishing program designed to generate an average catch per effort for each year. Alternatives to such a program might be mark/recovery methods and hydroacoustic methods. Mark/recovery methods are expensive and are liable to have problems with the mixing of marks into the population in this system. Hydroacoustic methods may be an alternative although there would be problems in ground truthing such an extensive study.

A possible test fishing program could consist of a number of gillnet sets over the reservoir in a set pattern repeated each year. Because of the problems in assessing bass abundance through the use of gillnets it is likely that such a program would mainly give information on squawfish abundance. The use of other methods such as electrofishing should be investigated if this monitoring element is to be considered in detail.

In the first year of the study, a number of gillnet sites would be chosen on a random/stratified basis designed to provide a good index of overall abundance in the reservoir. A time of year would be chosen to provide relatively high levels of catchability (probably June or July). Then in each subsequent year the pattern of gillnet sets, in space and time, would be replicated to give a consistent index of abundance.

Sampling Intensity

Based on experience in other reservoirs in the Columbia system a test fishing program of this type would require between 50 and 100 one hour gillnet sets. This level of sampling would require a 2 man crew for approximately 2 weeks with 2 nets.

Analysis, Interpretation and Stopping Rules

The interpretation of the results of this type of a study represents something of a problem. It will be very difficult to demonstrate a cause and effect relationship between predator abundance and the in-water disposal activity. Over the same period, a number of other factors which could also affect predator populations, will also be changing, including the age of the reservoir and man caused effects to other components of the system. Without being embedded in a larger scale study, this long term monitoring would indicate changes but could not be used to say why observed changes had occurred.

For this type of study to be useful it is essential that it continue for a substantial period of time. In order to track the changes in predator abundance as the in-water disposal activity proceeds it would be necessary to continue for at least 20 years and preferably longer.

7.0 OVERVIEW AND INTERPRETATION

7.1 Summary of Monitoring Program

Following the second workshop two further technical meetings were carried out to refine the design of the monitoring program. At these meetings a "minimum necessary program" was defined which consisted of the minimal subset of the monitoring actions proposed. The minimum necessary monitoring program is outlined in Figure 12; this program design includes both the construction of the disposal sites and the biophysical monitoring.

A critical feature of this 5 year program is the reassessment of the design following the first year and the reassessment of continued disposal site construction after year three. The reassessment after year one will allow a more detailed examination of the levels of precision produced by the monitoring program and a re-examination of the criteria (see below).

7.2 Relative Priorities

The monitoring program described in this section comprises a total of 13 different elements. While each of these has been described (Chapter 6.0) they are not all of equal importance and it is important to distinguish the relative priorities of the different elements. The minimum configuration for the monitoring program is described in the summary above and in the detailed descriptions in section 6.

The program elements fall into three main groupings:

1) core elements which are the most important part of the program;

2) supporting elements providing data to help interpret information gained from the core elements; and

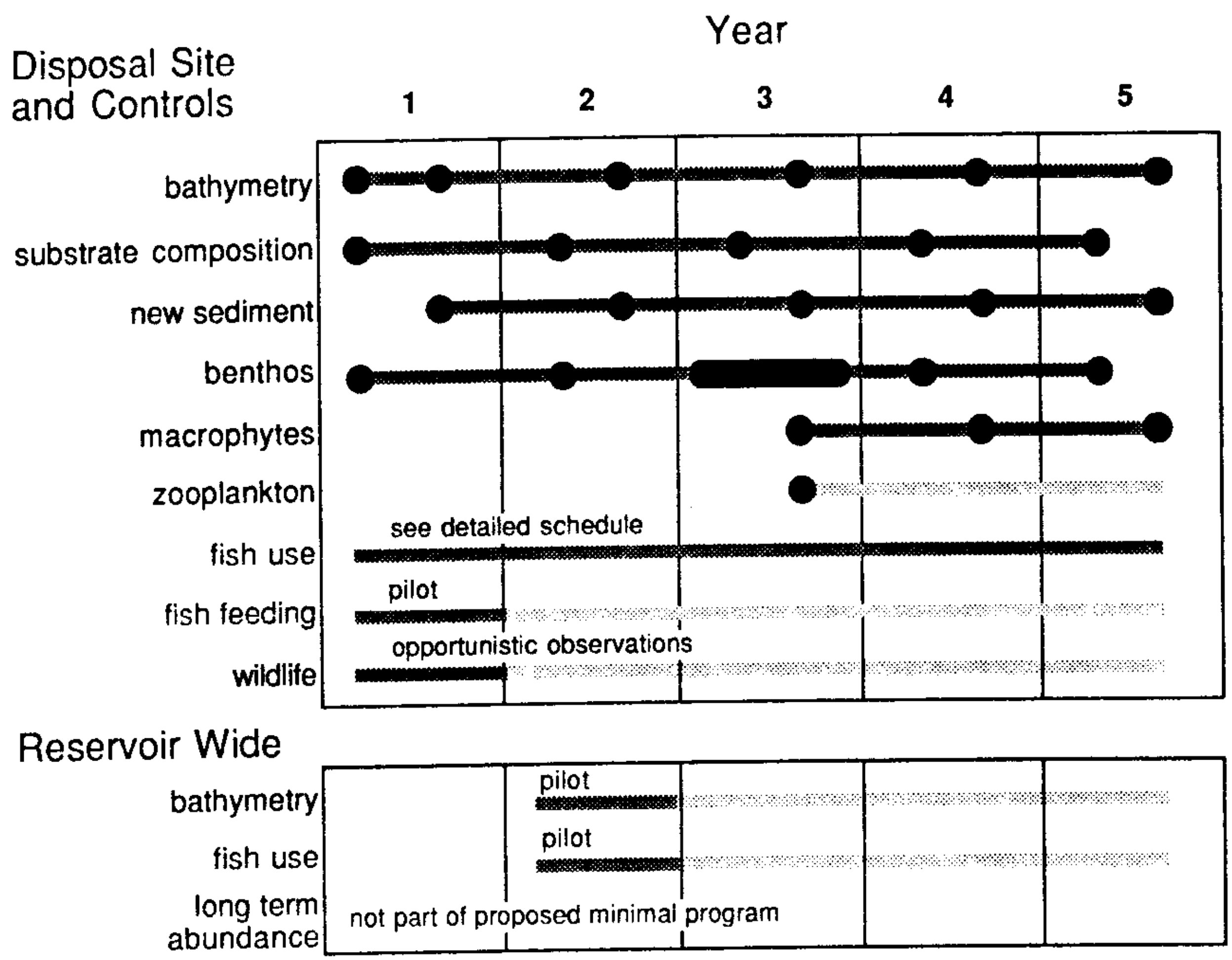

Figure 12: Summary of schedule of monitoring proposed for the 5 year program. The details of monitoring for years 2 through 5 would be reassessed following the results of the first year's studies.

3) synoptic and long term survey elements providing background information but which are not essential parts of the test disposal monitoring.

The core elements of the monitoring program are:

- o fish utilization, and
- o benthos.

These represent the primary items of interest in the whole program and could stand alone without the rest of the program although it might be hard to interpret some of the results.

The supporting elements (in order of priority) consist of:

- o 6. feeding studies;
- o 1. new sediment;
- o 2. substrate composition;
- o 3. bathymetry;
- o 4. macrophytes; and
- o 5. zooplankton.

These elements provide supporting information to help determine reasons for relative fish and benthos abundances.

As they relate to habitat, the relative priority of the various program elements was determined by subjecting them to a pair-wise value ranking. This process considers each pair of program elements and poses the question "If you could only have one of these two elements, which would you choose?". In the event that a clear choice could not be made a value of 0.5 is assigned to each element. Otherwise the selected element is awarded a score of 1.0 and the other a score of zero (Table 5). Clearly the most important program element is the determination of the benthic productivity of the newly created habitat. This is reasonable since benthic productivity is most closely related to the likely suitability of the habitat for fish production. Other measures which ranked near the top of the priority list are the accumulation of new sediment and substrate composition. In the absence of direct measures of benthic production these program elements would be most valuable in estimating the suitability of the habitat for benthic production. However, if benthic production is determined directly the other elements are less important and their value will likely be limited to providing information for interpretation of differences in benthic productivity.

There are three program elements which fall into the synoptic/long term category. These are:

- o synoptic survey of fish use;
- o reservoir bathymetry survey; and
- o long term predator abundance monitoring.

These elements represent attempts to gather information to fill important information gaps and be useful in predicting responses to long term in-water disposal. However they are not directly tied to the five year test disposal activity discussed here. The reservoir wide surveys of bathymetry and fish use go together and should be carried out at the same time or not at all. They will provide information very useful in designing future in-water disposal activities.

The long term predator abundance monitoring provides a direct way of looking at changes in reservoir predator populations. Unfortunately it will be very difficult to interpret these trends given other confounding factors such as reservoir age. This long term monitoring has a lower priority than the synoptic surveys of fish and habitat.

Table 5: Pair-wise value ranking of research priorities for habitat observations*.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	Total Priority
Bathymetry	(1)	-	.5	1	.5	0	1	1	0	1	5.0
Substrate Composition	(2)	.5	-	1	.5	0	1	1	.5	1	5.5
Benthos	(5)	1	1	1	1	-	1	1	.5	1	7.5
Plankton	(6)	0	0	0	0	0	-	0	0	0	0.0
Macrophytes	(7)	0	0	.5	0	0	1	-	.5	1	3.0
New Sediment	(8)	1	.5	1	1	.5	1	.5	-	1	6.5
Reservoir Bathymetry	(9)	0	0	1	0	0	1	0	0	-	2.0

* The values in the table represent the priority assigned to each pair of program elements. The table is read by comparing both entries for any pair of program elements. A value of 1 (in the program element row) indicates that this part of the program would be done in preference to the corresponding (column) element. Tied priorities are each assigned a value of 0.5. The row sums reflect the overall priority for the program element.

7.3 Evaluation of Results

Evaluation of the results of the monitoring program will consist of two separate processes:

1) interpretation of the biological significance of the results, from the viewpoints of different aspects of the biophysical system; and

2) objective analysis of the results and the determination of conclusions which can be drawn from the data.

The objective analysis of results can be based on statistical principles. The interpretation of the biological significance of the results is a more subjective process due to the large amounts of uncertainty in system parameters and behaviors. The determination of the biological significance of results depends on the utilization of the expertise of a range of specialists.

7.3.1 Biological Significance

The determination of what can be considered a biologically significant result is a complex issue that influences the initial design of required levels of precision, the setting of criteria, and the final interpretation of experimental results. There are two problems with defining rigid criteria and definitions of biological significance at this point:

1) the information required to firmly tie levels of sampling effort to precision is not currently available; and

2) the process of interagency consultation and consensus building needs to continue to further refine the rationale for criteria and to develop an agreed upon structure for the interpretation of the results.

The first of these problems is the reason that the monitoring program proposed in this report consists of an initial year followed by a detailed reassessment of the experimental design. With the results from the first years data it should be possible to substantially improve the estimates of required sampling effort for different levels of precision.

It is not possible at present to determine the costs of detecting changes associated with different criteria. Thus it is very difficult to reach consensus on just which criteria should be applied. It is therefore strongly recommended that the process of reaching a consensus among experts and agencies on appropriate criteria be carried on in parallel with improvement of the experimental design.

7.3.2 Analysis and Criteria

The program elements fall into two groups depending on the type of analysis which can be applied to them:

1) those which can be analyzed using statistical techniques to look for significant differences between the test and reference sites: fish utilization, benthos, and zooplankton; and

2) those which provide descriptive data which can help to interpret differences between test and control sites: bathymetry, substrate composition, velocity, water quality, macrophytes and new sediment.

The primary interpretation of the effects of disposal will be based on the statistical comparison of fish and benthos in the test sites versus the reference sites. Other information will be used to aid in the explanation of the observed differences.

The term 'statistical significance' is used here to indicate that the difference in abundance of a particular organism as measured by a series of samples is unlikely to have occurred by chance. In most studies of this kind, the critical probability is taken to be .05 (a 95% confidence level). In other words if a series of benthic samples were taken from two sites we might be able to specify (based on statistical theory) that the probability that the differences observed were due to chance was less than .05.

The difference between two samples (sets of measurements) which must be observed for the differences between them to be statistically significant depends on two main factors:

1) the level of variability between individual measurements within each sample; and

2) the number of measurements taken in each sample.

The level of variability within samples of fish and benthos has been assessed using information from previous surveys in the Lower Granite reservoir (Bennett pers. comm.). These initial analyses suggest that with the levels of sampling proposed (5 samples per station for benthos and 20 sets per station for fish) differences on the order of 60% will be detectable with a confidence of 95% for both fish and benthos.

These estimates are based on a fairly small amount of data not specifically designed to assess levels of variability. Actual levels of variability will likely be somewhat less so that slightly smaller differences may be detectable. Following the first year of data collection, further analysis will allow a significant improvement in these estimates of ability to detect changes in benthos and fish abundance.

The key criteria for demonstrating a negative impact are statistically significant differences (relative to the reference sites) in the following directions:

- o increases in adult predator abundance;
- o increases in juvenile squawfish in the very shallow water around the island;
- o decreases in juvenile salmonid use; and/or
- o decreases in benthic production of food for juvenile salmonids.

The key criteria for demonstrating a positive impact are statistically significant differences in the following directions:

- o increases in juvenile salmonid use;
- o decreases in adult predator abundance; and/or
- o increases in benthic production of food for juvenile salmonids.

If the differences in these measures are not significant then the conclusions that can be drawn about the effects of the disposal activity are much weaker. After the first year of the 5 year program it will be possible to determine the power of the test for these impacts a lot more accurately. At this time the appropriateness of the levels of sampling effort should be reassessed.

In addition to the criteria on fish and benthos abundance the other, more descriptive, data can be used to form another criterion:

- o habitat for juvenile salmonids should not be degraded outside the range that normally occurs in the reservoir.

In this case the habitat will be measured in terms of water quality, sediment composition, depth, velocity, bathymetry and macrophyte production. Determination of the appropriate levels for these variables should be determined as soon as possible. More information will be available after the first year of the monitoring program but it is not necessary to wait until then.

7.4 Design Issues

Any experimental design represents a compromise between competing needs and resource availability. The main problem with the design presented here is the lack of replication of the disposal and reference (control) sites.

An ideal design would have replicate disposal sites of each type constructed both in the same year and in consecutive years at randomly selected locations throughout the reservoir. This design would allow a better characterization of the effects of spatial and temporal variability on the impacts of disposal, and would allow stronger statements to be made about comparisons between test and control sites. Unfortunately this type of design would require an extremely large quantity of dredge material and is, at this time, unrealistic.

7.5 Conclusions

Based on the workshops, the technical meetings and further analysis we recommend the following steps as being critical to the continued success of this monitoring program:

1) the process of interagency consultation and consensus building needs to continue to further refine the rationale for criteria and to develop an agreed upon structure for the interpretation of results;

2) following the first year of data collection a significant effort needs to be applied to data analysis and further design work to refine the monitoring program design;

3) work to define preliminary criteria for habitat variables can be initiated immediately, results of the first years program will significantly aid this process; and

4) prior to the second year (and subsequent years) of the study the plan for construction of the mid and deep water test sites should be re-evaluated based on the potential availability of dredge material.

8.0 REFERENCES

Beamesberfer, P.G., B.E. Rieman, J.G. Elliott, A.A. Negro, and D.L. Ward. 1987. Distribution, abundance, and population dynamics of northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, 1986. Annual progress report to Bonneville Power Administration, Contract No. DE AI79-82B835097. Portland, Oregon.

Beanlands, G. and P. Duinker. 1983. An ecological framework for Environmental Impact Assessment in Canada. Federal Environmental Assessment Review Office, Hull, Quebec. 132 pp.

Bennett, D.H. and F.C. Shrier. 1986. Effects of sediment dredging and in-water disposal on fishes in Lower Granite Reservoir, Idaho-Washington. For U.S. Army Corps of Engineers. 146 pp.

Bennett, D.H. and F.C. Shrier. 1987. Monitoring sediment dredging and overflow from land disposal activities on water quality, fish and benthos in Lower Granite Reservoir, Washington. For U.S. Army Corps of Engineers. 33 pp. and appendices.

ESSA Environmental and Social Systems Analysts Ltd. 1982. Review and Evaluation of Adaptive Environmental Assessment and Management. Supply and Services Canada. 116 pp.

Everitt, R.R., D.A. Birdsall and D. Stone. 1986. The Beaufort Environmental Monitoring Program. In: Integrated Approaches to Resource Planning and Management. R. Lang (ed.). Banff Centre School of Management. p 251-266.

Faler, M.P., L.M. Miller, and K.J. Walke. in press. Effects of variation in flow on distributions of northern squawfish (Phychocheilus oregonensis) below McNary Dam on the Columbia River. Transactions of the American Fisheries Society.

Holling, C.S. (ed.). 1978. Adaptive Environmental Assessment and Management. John Wiley and Sons, Chichester, 377 pp.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs, 54(2):187-211.

Li, H. et al. 1981. Habitat requirements for resident fishes in the reservoirs of the Lower Columbia River. U.S. Army Corps of Engineers. Contract #DACW57-79-C-0012

Rieman, B.E. and R.C. Beamesberfer. (in prep.). Population dynamics of northern squawfish and potential predation on salmonid smolts in a Columbia River reservoir. Final report to Bonneville Power Administration, Contract No. DE AI79-82BP35097. Portland, Oregon.

Shepherd, J.G. and D.H. Cushing. 1980. A mechanism for density dependent survival of larval fish as the basis of a stock recruit relationship. J. Conseil 39(2):160-167.

U.S. Army Corps of Engineers. 1986. Lower Granite Lock and Dam: Sedimentation Feasibility Study. Phase I - Reconnaissance Level Analysis. 29 pp. and appendices.

U.S. Army Corps of Engineers. 1987. Snake River 1987 Interim Report: Flood Control Dredging. 14 pp.

Walters, C. 1986. Adaptive Management of Renewable Resources. MacMillan, New York. 374 pp.

APPENDIX 1

Issues Raised at First Workshop

APPENDIX 1

ISSUES RAISED AT FIRST WORKSHOP

During the first workshop the participants were asked to identify what they felt were the key biophysical issues related to the potential impacts of in-water disposal. These are repeated here without any editing or evaluation. Although they are recorded here, this should not be interpreted as agreement on the part of the workshop participants that these issues will remain intact and ultimately be dealt with in the monitoring program. Rather they served as one aspect of the bounding activity designed to initiate development of the conceptual model and hypotheses.

- Physical changes to the habitat, including: grain size, organic content, depth, slope, velocity, configurationa, and bathymetry. These will drive changes in fish populations.
- Direct impacts of dredging on fish; for example, entrainment.
- Maintenance of the riparian and littoral zone.
- Effect of changes in habitat on anadromous and resident fish production, including predator production.
- Other actions which could enhance habitat; for example, introduction of large grain material such as gravel, boulders, or logs. This would provide additional cover for fish.
- Cumulative impacts of long term, in-water disposal.
- What is the present functional value of deep and mid-water habitats?
- Manipulation of habitat to enhance "native" species and limit introduced species of fish; for example, bass, crappies, bullheads, and catfish.
- Sediment quality: chemicals in the dredge sediments from the nearby pulp mill. What are the concentrations and significance, if any, for pollution of the lower reservoir?
- Water quality changes (e.g., temperature, dissolved oxygen, suspended solids)

- Effects of habitat change on predator-prey interactions, especially with regard to predation on salmonids.

- Importance of shallow water habitat to salmonids.

- Potential to enhance the sport fishery in the reservoir.

- Importance of the turbidity plume to overwintering steelhead and the sport fishery.

- Change in the hydraulic regime of the reservoir and the effect, if any, on the residence period of migrating salmonids.

- Can dredging be both environmentally sound and economically effective?

- Cost of the dredging program, and how it is affected by constraints placed on the contractor.

- Effects of the dredging and in-water disposal program on the quality fishing in terms of effort and success.

- What is the linkage between habitat and productivity of the various fish populations? Will the change in habitat be reflected in changes in the fish populations? If so, then by how much?

- Effects on fish using deep water habitat; e.g., sturgeon.

- What is the relative value of shallow, mid-depth, and deep habitats? Should we be creating shallow habitat from mid-water habitat or mid-water habitat from deep water habitat or moving existing shallow water into riparian?

- Stability of the new habitat. How will it change over time especially due to "large" events (e.g., storm surges)?

- What effects will there be on fish from the turbidity plume?

- The pattern of dredging: it is expected that there will be extreme flood events which will lead to periodic, large introductions of sediment. This could necessitate more dredging effort in some years. Concern is for the feasibility of completing the necessary dredging within the allotted time window.

- What is the combined impact on benthos production within the reservoir from reductions in populations at both the dredging and disposal sites? What is the significance of this for changes in fish populations?

- The dredging window: which end of the window is the most sensitive time with respect to potential effects on fish populations or the fishery? If it became necessary to extend it, which end would have the least impact on the fish populations and the recreational fishery?

- What is the potential for an increase in either the magnitude (strength, duration) or frequency of summer algal blooms arising from a change to the mean depth of the reservoir?

- Will there be an increase in the production of macrophytes within the reservoir?

- Other actions besides dredging; e.g., channel restrictions to increase velocity and reduce sedimentation in the present problem area.

- What effect will there be on the survival of fish, either migrating salmonids or resident species? Will the project increase or decrease their survival or fitness?

- What effect will there be on the upstream migration of salmonids?

- What is the production value of the created habitat in relation to naturally created habitat areas?

- Can we even measure changes in fish populations or their habitat usage?

- Value of habitat for specific fish life functions (e.g., forage, cover, overwintering, migration, reproduction) versus conditions affecting the populations indirectly (e.g., predation, competition).

- How do we connect the possible short term effects to the more longer term considerations.

- What constitutes overwintering habitat.

- What are the potential changes caused by disposal on the littoral and riparian areas? How might these affect wildlife (e.g., ducks, geese)?

APPENDIX 2

First Workshop Subgroup Reports

APPENDIX 2

First Workshop Subgroup Reports

1.0 PHYSICAL AND CHEMICAL HABITAT SUBGROUP

1.1 Introduction

The physical and chemical habitat subgroup discussed how information currently available could be used to predict changes in key components of habitat. The discussions focused on the prediction of changes in habitat components identified in the interaction matrix as being of concern to the subgroups considering changes in either migrating salmonid or resident fish populations. Several of the items listed in Table A1 are easily defined (for example, the proximity of the disposal site to access points) and were not discussed during the subgroup meeting.

Two sites have been designated for dredging during the first year of the in-water disposal test (Figure A1). Site number one is located at the confluence of the Snake and Clearwater rivers and has accumulated a mixture of silt, sand, and clay. Site number two is located immediately downstream of the confluence of the two rivers. The sediments at this site are predominantly sand.

1.2 Turbidity Plume

There will be a turbidity plume at both the dredging and disposal sites. The turbidity plume has been assessed at the dredging site during the past years' dredging activity downstream from the confluence of the Snake and Clearwater Rivers (site number two).

1.2.1 Dredging Sites

Characteristics of the observed plume and the expected background conditions are summarized in Table A1. In the table, characteristics of the plume are expressed in two systems of measurement: standard turbidity units (ntu - the light scattering property of the plume material), and

Table A1: Relative measures of suspended sediment and turbidity at dredging site.

A) Background Conditions - Sediment Concentration *

200 mg/l - typical high flow runoff

500 mg/l - extreme runoff event

* data from the U.S. Geological Survey

B) Observed Turbidity

i) Background:

< 5 ntu - typical turbidity during winter months

54 ntu - observed during mid-February to March freshet

100 ntu - maximum turbidity during January - February

ii) No overflow dredging regime:

1 - 20 mg/l - increase over ambient conditions within mixing zone

iii) Overflow dredging regime:

11 - 40 mg/l - increase over ambient conditions within mixing zone

2 - 4 ntu - average increase at 90 m downstream from dredge location

39 ntu - maximum increase at 90 m downstream

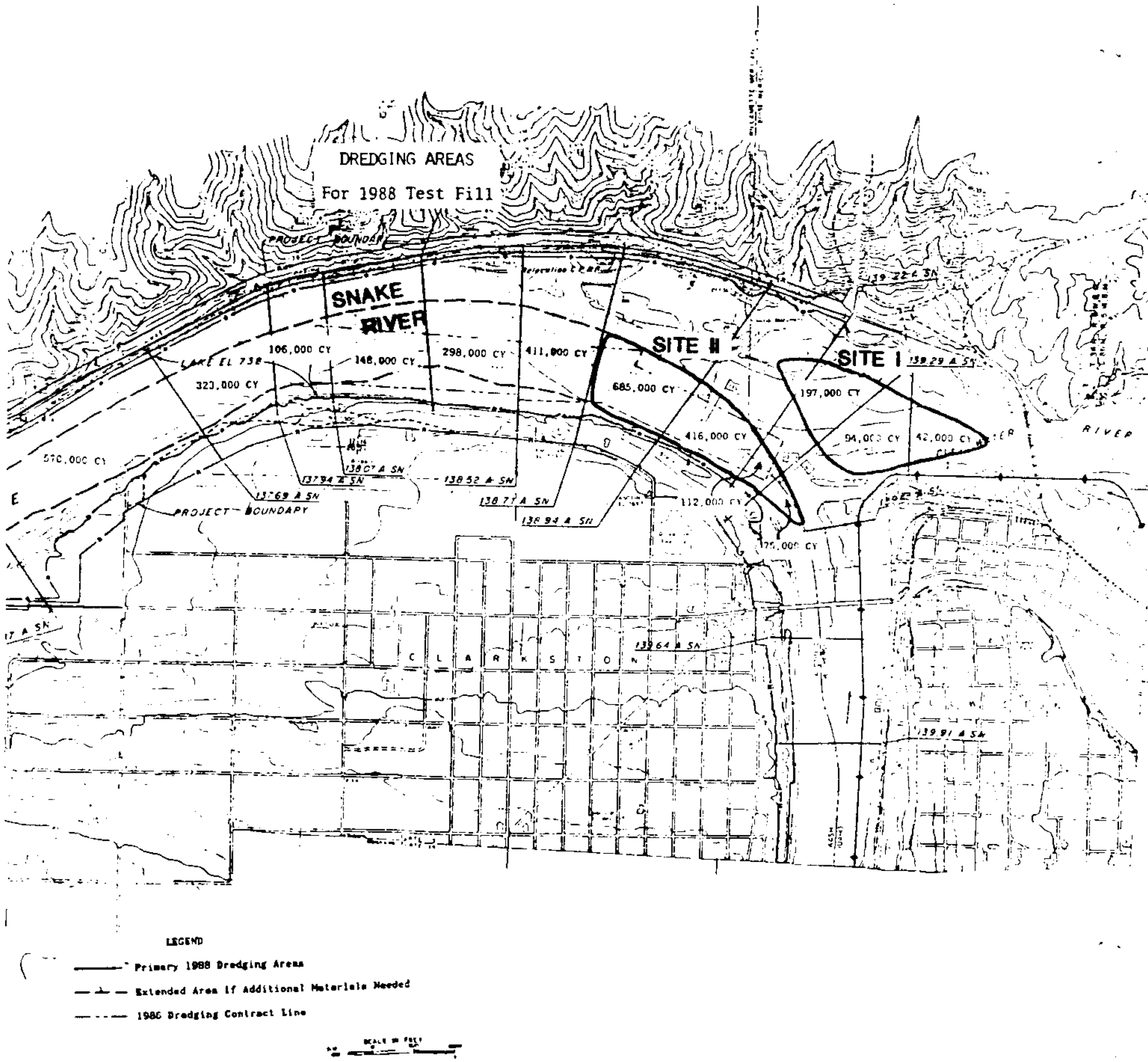

Figure A1: Location of proposed dredging sites for test periord. Adapted from: Environmental Assessment. Position Paper, July 2, 1987. Clearwater/Snake River Confluence Dredging, Winter 1987/88 Dredging Window.

concentration units (mg/l). Although there is a general correlation between these measures, factors, such as the mineralogy of different sediments, require that the relationship be calibrated for different sediments.

Latitudinal extent of the plume, as observed from the air, has typically varied from 10% to 15% of the river width. The downstream extent is estimated to be approximately 425 m, at which distance, no detectable level above ambient conditions was observed.

The plume resulting from future dredging activities will vary with four major attributes of the dredging, namely:

1) The location within the reservoir. The two areas where dredging activities are planned during the present test evaluation differ substantially with regard to their silt and clay content. In future, it is anticipated that areas further downstream will also be dredged. In general, these areas are predominantly sandy, however, some areas have a relatively high silt content, including one of the two sites designated for dredging in 1988.

   The turbidity level arising from dredging in areas of relatively high silt content will be higher than observed to date. Due to the variations in the relationship between turbidity and suspended sediment concentrations, however, it is not possible to predict accurately. Increased turbidity from a factor of 2 to an order of magnitude are possible.

2) The mineralogy of the dredged sediment. When compared at equal concentrations, some clays produce much higher turbidity (light scattering) relative to others due to differences in their particle shape.

3) The percent moisture content (pmc) of the material also affects the turbidity caused by a given mass of suspended material.

4) Climatic events, such as extreme runoff events, will increase the background concentrations of sediment and thereby reduce the visual observation of the turbidity plume. At the same time, the additional sediment from the runoff will increase the total concentration of suspended sediment. Such events will also have several other effects from the associated increase in velocity, including more rapid mixing of the plume and increased lateral extent of the plume.

1.2.2 Disposal Sites

At the disposal sites, turbidity will arise from entrainment of dumped material into the water column and from bottom sediment which will be resuspended upon impact of the dumped material. The sediment at the lower portion of the reservoir is predominantly silt (based on surface grabs). Based upon an estimate of 1% entrainment of dumped material, expected flows ranging between 0.4 and 1.5 ft./sec., and an assumption of complete mixing, the extent of the plume zone is estimated to be approximately 100 m laterally and 500 m downstream. Average concentrations within the zone are estimated to be 80 mg/l above ambient.

The characteristics of the turbidity plume at the disposal sites cannot be accurately predicted and monitoring will be needed to confirm present estimates. Measurements suggested for this include concentration of sediment (mg/l), turbidity (ntu), depth of dump site, and current velocity. Since the shape and intensity of the plume will vary with depth, it was suggested that these measurements should be made near the surface, and in both mid-water and near bottom strata of the water column.

1.3 Chemicals

Water quality monitoring was conducted during the previous years of dredging and the results were found to be within the federal and state criteria for protecting aquatic resources. Additional compliance monitoring will be conducted during the experimental monitoring period.

During the subgroup discussions, questions were raised about whether the dredge sediments contain significant amounts of chemicals discharged by a nearby pulp mill. The primary concern was for the possible bioaccumulation of chemicals, such as acid resins, being relocated to the lower reservoir. To date, repeated tests over the last four years indicate that this is not a problem.

1.4 Substrate Composition

The composition of the substrate at the proposed dredging and disposal sites is summarized in Table A2. From the table it is apparent that, immediately following disposal of the dredged material, grain size at the disposal sites will be increased. An increase relative to the dredging sites is also expected due to the entrainment of silt into the water column. This is estimated to be approximately 1% of the total material deposited and would thus be a marginal increase in grain size relative to the source sites.

Since the formation of the Lower Granite Reservoir, approximately 24 in. of silt has been deposited in the lower reservoir. Variations in the annual rate of accrual are expected with variation in runoff, but over this ten year period, the observed accumulation represents an average deposition rate of approximately 2 in./yr. Consequently, a return to the present grain size of exposed material is expected within one year of the deposition of dredged material.

Table A2: Substrate composition at dredging and disposal sites.

Location	Substrate Composition: Sand (%)	Silt (%)	Clay (%)	Volatile Organics (%)	Oil & Grease (ppm)
Dredge Site Number 1					
(at the confluence of the Clearwater and Snake Rivers)	30 - 40	40 - 60 (50) *	< 11	6 - 7	300
Dredge Site Number 2					
(downstream of the confluence of the Clearwater and Snake Rivers)	80 - 98 (90-95)	2 - 20	0	0.7	50
Disposal Sites					
(both mid-depth and deep sites)	10 - 18	65 - 80	10 - 18	8 - 9	300 - 1,000

* Numbers in parentheses are average values.

1.5 Topography of the Disposal Site

The final topography of the disposal site will be determined by the spatial pattern of dumping within the disposal zone, the settling characteristics of the sediment, the current velocity at the time of disposal, water depth, and long term stability of the disposed material. Large grain material such as sand will settle more rapidly and disperse over a smaller area than small grain materials disposed over the same depth of water. As water depth increases, the field over which a single dump of material will settle on the bottom increases and the corresponding relief of the dumped material decreases.

At a depth of 50 ft., a typical settling field would be approximately 100 m in diameter. Assuming downstream motion of barges while dumping, an elliptical disposal field from any single dump is likely. An initial slope of the dumped material of 25 degrees is considered likely. After a period of further settling and erosion during periods of high flow, the slope is expected to be reduced to an eventual relief of 10 degrees. [1]

Variations in topography within the overall disposal field will arise primarily from the pattern of dumping. During the workshop there was considerable discussion of the type of pattern desired to enhance or maintain salmon habitat, and for the purposes of obtaining a good experimental design. The possible topographic characteristics of the disposal field at the proposed mid-water disposal site are illustrated in Figure A2. The mid-water disposal site is approximately 1,000,000 sq. ft.(1000 ft. x 1000 ft.), and assuming that 400,000 cy of material is deposited, the average reduction in depth over the site would be approximately 10 ft. At 2,000 cy/scow this would require a total of 200 individual scow loads. In order to achieve a uniform pat-

[1] WES estimated slope (V/H) to be 1/10. "Percent" should be used instead of "degrees" in this paragraph.

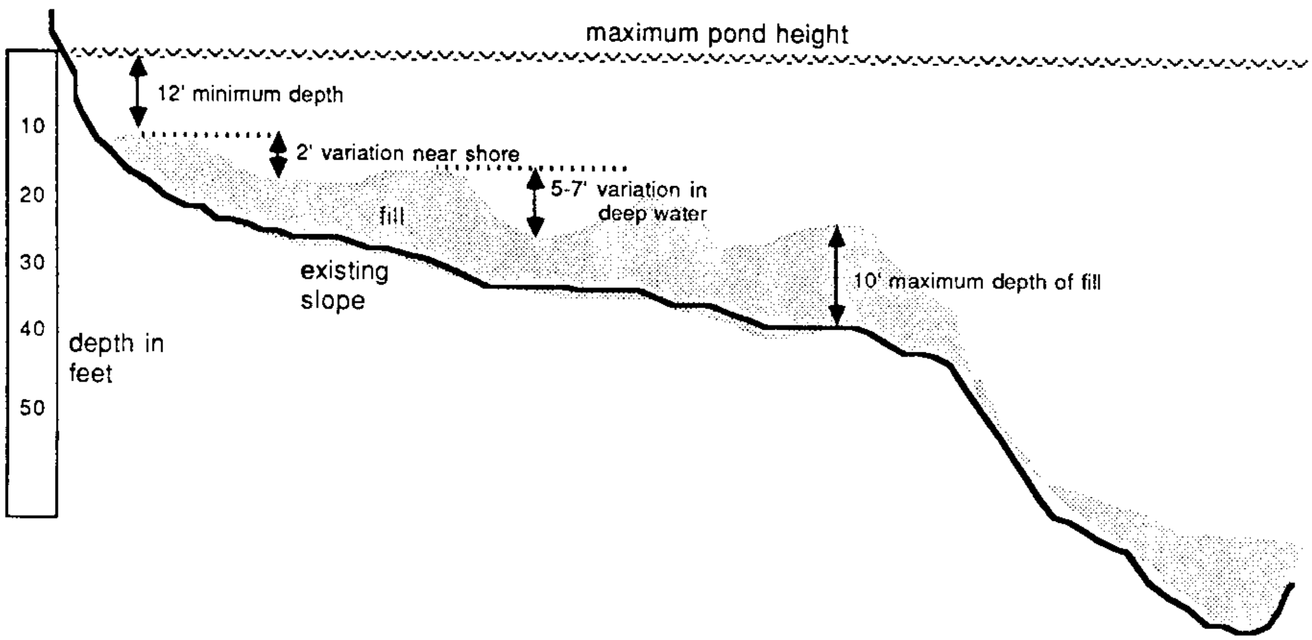

Figure A2: Possible topographic characteristics of the disposal field at the proposed mid-water disposal site.

tern of dumping within the area, the average separation between the center of each load's settling field would have to be 50 to 60 ft.

1.6 Change in Flow

Estimates of change in flow have been made for the reservoir as a whole but not on a local basis. These estimates are for the expected condition after the completion of an extended period of in-water disposal (117 years) and do not reflect the likely increase during the two year test period. The estimated increase in average cross-sectional flow velocity is 20%. Discussions during the meeting indicated that, in shallow areas toward the sides of the reservoir, reducing the depth of the substrate would be expected to reduce local flow velocity. Consequently, for the net cross-sectional velocity to be increased, flow in the main channel is expected to increase more than the average estimate.

1.7 Change in Temperature

During periods of the year in which the temperatures within the reservoir are homogeneous, no change in temperature over the new habitat is expected. Only during the summer period are differences likely to occur and only over long-term disposal.

Temperature profiles in the Lower Granite Reservoir are available from the recent studies by Bennett and Shrier (1987). These studies did not find a strong thermocline within the reservoir. It was agreed that these profiles should provide a reasonable estimation of temperature over the newly created habitat.

1.8 Change in Dissolved Oxygen

Due to the relatively low organic content of the dredge sediments, no significant reduction in dissolved oxygen is expected at either the time of disposal or in the long term.

A slight reduction in dissolved oxygen concentrations may occur in the immediate disposal and dredging plumes. Due to the periodic nature of the disposal process, this should be more transient at the disposal site than at the dredging site. During the dredging activity in 1986, the mixing zone specified for dissolved oxygen by the Washington State Department of Ecology extended 425 m downstream from the dredge and disposal site. At this distance, there was no significant difference in dissolved oxygen concentrations relative to ambient conditions.

1.9 Change in Macrophytes

Macrophytes in the lower reservoir are usually limited to areas between 5 and 12 ft. below maximum pond elevation. Consequently, in the short term, no additional areas of macrophytes are predicted if the in-water disposal does not raise the substrate to within 12 ft. of maximum pond elevation.

In the long term, the total area of macrophyte habitat should increase as the natural accrual of sediments in the lower basin raises substrate elevations into this zone. As noted previously in the discussion of substrate composition a relatively rapid rate of sedimentation has been observed within the Lower Granite Reservoir and averages approximately 2 in./yr.

Therefore, it is expected that increases in the distribution of macrophytes could occur regardless of the in-water disposal program. By reducing the mean depth in the lower reservoir, in-water disposal will, however, accelerate the rate at which this will occur. Limitation of the long term rate of development of macrophytes should be feasible through limitation of the maximum elevation of newly created habitat. This will vary between sites due to variations in the local rate of sediment accrual.

1.10 Change in Benthos

Recent studies by Bennett and Shrier (1986) indicate that the primary components of the benthic community with respect to their importance for forage are oligochaetes and dipterans. Recolonization, due to downstream drift, of benthic communities in riverine environments after substrate disturbance is typically rapid. This is consistent with the observations of Bennett and Shrier at sites dredged during 1985 and 1986 where they found recolonization of both taxa began within 3 months.

Benthic production and standing crops are usually greater in sediments with higher organic contents. Given the relatively high sand content of the dredge materials, recolonization by benthic organisms is expected to depend upon the rate of siltation at disposal sites and the rate of invasion of organisms from surrounding areas. As noted above with regard to macrophytes, this does vary among shallow sites.

Assuming an average accrual of 2 in./yr., recolonization of dipterans is expected to occur with the first year. Furthermore, the rate of recolonization is expected to be maximized by disposal during the winter months since sediment deposition from spring runoff and recolonization by first instar larvae will occur shortly after disposal. Since dipterans inhabit the upper layers of the substrate, initial recolonization could be as high as 60% of the original biomass and productivity after one year, and should be fully recovered within two to three years.

Similarly, recolonization of oligochaetes is also expected to begin in the first year. Since oligochaetes use deeper strata within the sediment, up to about 8 in. of depth, their recovery should be slower than that of the diptera. Recovery on the order of 30% - 40% by the end of the first year is likely. Subsequent increases in standing crop and productivity are expected to be a linear function of the rate of accrual of new sediment and could be considered complete when the depth of silt over the disposal sediment reached a depth of 8 in. Alternatively, for areas which currently have less than 8 in. of silt, recovery could be considered complete upon reaching the current silt depth.

1.11 Crayfish

The effects of in-water disposal on local crayfish populations are uncertain. A possible increase in these populations would provide additional forage, primarily for bass, and could therefore lead to an increase in the abundance of this predator. The crayfish inhabiting the reservoir are not a burrowing species and, while they may be found throughout the shallow water habitats, they are expected to be most abundant in shallow rocky areas.

2.0 RESIDENT FISH SUBGROUP

2.1 Introduction

The resident fish group discussed the potential effects of dredging and disposal operations on a number of native and non-native fish species found in the Lower Granite reservoir. All the major resident fish species found in the reservoir were considered (Table A3), with the exception of suckers. The absence of any expected interaction between suckers and other species in the system provided the rationale for excluding this group. In addition, we concluded that our ignorance of the distribution, abundance, and habitat preferences of sculpins in the Lower Granite reservoir made it impossible to judge the impact of dredging and disposal on this group of fishes.

To provide a focus for the discussion of effects, we identified five key processes that might be influenced by dredging and disposal for some or all of the selected species (Table A4). We then examined the potential influence

Table A3: List of fish species discussed by the resident fish subgroup.

Native fishes that prey on salmonids

- northern squawfish
- sculpins

Native fishes that do not prey on salmonids

- sturgeon
- other cyprinids
    - redside shiner
    - chiselmouth chub
    - peamouth chub

Non-native fishes that prey on salmonids

- centrarchids and percids
    - smallmouth bass
    - crappies
    - yellow perch
- channel catfish

Non-native fishes that do not prey on salmonids

- carp

Table A4: List of life history processes discussed by the resident fish subgroup.

- Reproduction (spawning)
- Rearing (young-of-year) success
- Immature and adult success (growth and survival)
- Predation on salmonid juveniles
- Predation by salmonid juveniles

Table A5: Physical, chemical, and habitat changes potentially resulting from dredging and disposal operations whose impacts were considered by the resident fish subgroup.

- Dredging operations:
  - . timing
  - . method (hydraulic, mechanical)
  - . location
- Disposal operations:
  - . barge traffic
  - . physical plume characteristics (turbidity)
  - . chemical plume characteristics
- Physical characteristics of new habitat created from disposal:
  - . depth
  - . substrate composition (particle size)
  - . topography
  - . cover
  - . proximity to other habitats
  - . proximity to access points
- Abundance and composition of benthos in new habitats:
  - . oligochaetes
  - . dipterans
  - . crayfish
- Area and composition of new macrophytes
- Abundance and distribution of juvenile salmonids

of each physical or habitat change identified in the interaction matrix (Table A5) on each process, for each species. In the following text, we summarize the results of our discussions for each potential effect. The overall results are presented in Tables A6-All.

2.2 Dredging Operations

None of the resident species spawn during the time period in which dredging is intended to take place, with the possible exception of yellow perch. Perch, however, do not spawn in the areas where dredging will take place. Therefore, dredging operations are not expected to influence the reproductive success of the resident fish species discussed. Similarly, the timing and location of the dredging operations are such that impacts on the other life history stages and processes are not expected for any of the resident fish species. It should be stressed that this conclusion is largely a consequence of the timing of the dredging operation. Were dredging to occur at a time when larval fish or salmonid smolts were present in the vicinity of the operations, the potential for entrainment and other impacts would have to be considered.

2.3 Disposal Operations

The changes in water chemistry and turbidity expected to result from the disposal operations were not considered to be of sufficient magnitude, spatial extent, or duration to have a significant impact on any of the resident fish species. Once again, this conclusion is, in part, a consequence of the timing and location of the disposal operations. While increased turbidity is known to influence the feeding success of fishes, the disposal plume will be present at a time when turbidity is either already high, or when migrating salmonids are not present. Thus, significant effects on salmonid predation are unlikely. In addition, the timing (winter) and location (mid- or deep-water) of disposal is such that relatively little feeding by resident fish

Table **A6**: Summary of the physical/habitat changes that influence squawfish.

	Reproduction	Rearing	Immature/Adult	Predation on Salmonids	Predation by Salmonids
Dredging	no effect expected due to location and timing of operations				
Disposal	no effect expected due to location and timing of operations			turbidity plume would affect feeding on and by salmonids, but timing of disposal minimizes effect	
Physical habitat - depth - grain size - topography - cover - other habitat - access points	squawfish do not spawn in areas where physical or biological habitat changes are expected to occur therefore no effect is expected	increased shallow water habitat and less habitat structure will enhance rearing success	no strong preference for particular physical habitat features - pelagic distribution implies little or no effect	simplifying habitat (less cover and topographic relief) will favor predation both on and by salmonids	
Benthos		increased dipteran abundance will enhance rearing	increased benthos will have positive effect	increased benthos will decrease predation both on and by salmonids	
Macrophytes		macrophytes may provide cover but less important than for other resident fish	not important	increased macrophyte cover will reduce predation both on and by salmonids	
Juvenile salmonids		some feeding on squawfish by smolts	salmonids are not a major part of squawfish annual energy intake		

Table A7: Summary of the physical/habitat changes that influence sturgeon.

	Reproduction	Rearing	Immature/Adult
Dredging	no effect expected due to location and timing of operations		
Disposal	no effect expected due to location and timing of operations		
Physical habitat - depth - grain size - topography - cover - other habitat - access points	sturgeon do not spawn in areas where physical or biological habitat changes are expected to occur therefore no effect is expected	appear to use all physical habitat types for rearing; thus rearing success effects are not expected	losses of deep water habitat may reduce success juxtaposition of deep and shallow waters may be important
Benthos		increased benthos abundance will enhance rearing	increased benthos will have positive effect
Macrophytes		not important	not important
Juvenile salmonids		not important	not important

Table A8: Summary of the physical/habitat changes that influence other cyprinids.

	Reproduction	Rearing	Immature/Adult
Dredging	no effect expected due to location and timing of operations		
Disposal	no effect expected due to location and timing of operations		
Physical habitat - depth - grain size - topography - cover - other habitat - access points	no effect expected from physical habitat changes	increased shallow water habitat and less habitat structure will enhance rearing success	no strong preference for particular physical habitat features
Benthos	not important	some positive effect of increased benthos in later stages of rearing	increased benthos will have positive effect
Macrophytes	increased macrophytes may benefit redside shiner spawning	macrophytes provide cover	macrophytes provide cover
Juvenile salmonids		some feeding on other cyprinids by salmonid smolts	

Table A9: Summary of the physical/habitat changes that influence centrarchids and percids.

	Reproduction	Rearing	Immature/Adult	Predation on Salmonids	Predation by Salmonids
Dredging	no effect expected due to location and timing of operations				
Disposal	waves caused by disposal barges may reduce perch spawning success	no effect expected due to location and timing of operations		turbidity plume would affect feeding on and by salmonids, but timing of disposal minimizes effect	
Physical habitat - depth - grain size - topography	newly created habitat will not be good centrarchid or percid spawning habitat	increased area of very shallow water (< 2') may enhance rearing	require a mixture of shallow and mid-water habitat	decreased cover will decrease impact of bass predation on salmonids	
- cover - other habitat			reduced habitat diversity would have a negative impact		
- access points			proximity of new habitat to access points will influence sport fishing success		
Benthos		increased benthos abundance will enhance rearing	increased benthos will have positive effect	increased benthos decrease impact on salmonids	
Macrophytes		increased area of macrophytes will enhance rearing	increased area of macrophytes will have positive effect	increased area of macrophytes will increase impact on salmonids	
Juvenile salmonids		not important	not important		

Table A10: Summary of the physical/habitat changes that influence catfish.

	Reproduction	Rearing	Immature/Adult	Predation on Salmonids	Predation by Salmonids
Dredging	no effect expected due to location and timing of operations				
Disposal	no effect expected due to location and timing of operations			turbidity plume would affect feeding on and by salmonids, but timing of disposal minimizes effect	
Physical habitat - depth - grain size - topography - cover - other habitat - access points	newly created habitat will not be good catfish spawning habitat	rearing habitat in Lower Granite reservoir unknown; therefore cannot evaluate potential habitat change effects	reductions in mid- and deep-water habitats would have adverse effect reduced habitat diversity would have a negative impact	decreased cover is expected to decrease the impact of catfish predation on salmonids, although prey are captured in absence of cover	
Benthos			increased benthos will have positive effect	increased benthos decrease impact on salmonids	
Macrophytes			not important	increased area of macrophytes will increase impact on salmonids	
Juvenile salmonids			not important		

Table A11: Summary of the physical/habitat changes that influence carp.

	Reproduction	Rearing	Immature/Adult
Dredging	no effect expected due to location and timing of operations		
Disposal	no effect expected due to location and timing of operations		
Physical habitat - depth - grain size - topography - cover - other habitat - access points	no effect expected from physical habitat changes	increased shallow water habitat and less habitat structure may enhance rearing success	increased shallow waters should benefit carp
Benthos	not important	increased benthos should have positive impact	increased benthos will have positive effect
Macrophytes	increased macrophytes may benefit spawning		macrophytes may provide source of food
Juvenile salmonids			

will be occurring, so effects on rearing and adult success are not expected.

A potential impact of disposal operations identified, however, involves the wave action created by the dredge disposal barges moving down the reservoir to the disposal sites. As mentioned above, yellow perch begin spawning near the end of the dredging period. Perch typically spawn in shallow waters near the shoreline and are, thus, susceptible to having their eggs washed onto land as a result of the wave action generated by moving barges. Thus, barge traffic during March may have a negative influence on perch reproductive success.

2.4 Changes in Physical Habitat Characteristics

Changes in the amount of habitat at different depths in the reservoir are expected to have a number of impacts on the resident fish community. It is not completely clear, however, which of these impacts will be the direct result of changes in physical habitat, and which will be a consequence of the biological changes (e.g., benthos, macrophytes) that result from these physical changes.

Changes in physical habitat are not expected to affect the reproductive success of any of the species considered by the resident fish subgroup. Either spawning does not take place in the areas to be affected (as is the case for sturgeon and squawfish), or the newly created habitat will not provide additional spawning areas. Spawning habitat is not considered limiting for the non-native species, so losses of such habitat are not expected to be significant.

Increases in the amount of shallow water habitat are expected to increase the rearing success of cyprinids, centrarchids, and percids. Rearing success of sturgeon is unlikely to be affected, while the rearing requirements of catfish in this reservoir are unknown. Cyprinid rearing may also benefit from reduced structure (e.g., cover, topographic relief), while the converse is expected for centrarchids and percids.

Increases in shallow and mid-water habitat will tend to favor the older age classes of non-native species except catfish, which generally prefer deeper waters. Immature and adult sturgeon apparently benefit from a mixture of deep and shallow water habitat, so that changes in the relative amounts of these two habitats may be significant. Reductions in habitat structure through losses of topographic relief or cover are expected to adversely affect catfish, centrarchids, and percids. Finally, the creation of good adult centrarchid, percid, or catfish habitat in the vicinity of access points may adversely affect the survival of these species while providing a beneficial effect for sport fishermen.

Changes in physical habitat may also affect the predator-prey interaction between juvenile salmonids and resident fishes. Squawfish predation, as well as salmonid predation on resident fish, will tend to benefit from decreases in cover. Conversely, predation by bass and catfish is expected to benefit from increases in cover. Thus, changes in this habitat characteristic will tend to alter the relative importance of native and non-native predators on juvenile salmonids.

3.0 Benthos

Increases in the overall abundance of benthic invertebrates are expected to benefit both young-of-year and older age classes of all the resident fish species. Different species have different food preferences, however, so that changes in the composition of the benthic community would benefit some species more than others. For example, catfish and bass would respond more than the other species to increases in the abundance of crayfish.

Increases in benthos will also tend to reduce predation on and by juvenile salmonids. For the species that prey upon salmonids, benthic invertebrates provide a source of alternative prey. Similarly, juvenile salmonids prey upon invertebrates as well as fish, and, thus, stand to reduce their feeding pressures on cyprinids and other fish prey when invertebrates are abundant.

3.1 Macrophytes

Increases in the area of shallow water habitat occupied by macrophytes may enhance the spawning success of some cyprinids (redside shiner, carp). In addition, all age classes of cyprinids, centrarchids, and percids are expected to derive some benefits from increases in macrophytes. It is likely that the latter two species groups will be more strongly influenced than the cyprinids. Macrophytes may also supply a source of cover for both the predators and prey of salmonids, and a source of food for carp. Substantial increases in carp abundance may, in fact, lead to reductions in macrophytes.

3.2 Juvenile Salmonid Abundance and Distribution

Changes in the abundance and distribution of juvenile salmonids that might result from dredging and disposal operations are not expected to have significant impacts on the resident fish community. The salmonids are not present in the reservoir for a large enough proportion of the growing season to supply a major source of energy intake for their predators. Similarly, it is considered unlikely that salmonid consumption of resident fish in the reservoir is critical to salmonid growth and survival.

3.3 Other Issues

At the conclusion of our discussions, the subgroup considered the interactions among the resident fish species that might significantly influence the effects of habitat changes on individual species. These interactions are reflected in the conceptual model, presented in Chapter 8.

To summarize, they include predation by bass and squawfish on other cyprinids, and the potential negative impacts on percids and centrarchids due to consumption of macrophytes by carp.

It is important to stress that while it is possible to identify in qualitative terms the differences among the resident fish species in their response to changes in habitat, there remains substantial uncertainty concerning the relative magnitude of these responses. Even if it is possible to describe precisely the changes in habitat expected to occur, predictions of the consequences of these changes for the resident fish community will be largely speculative. Therefore, it may be informative to consider how strong the resident fish species' responses have to be before changes in community structure (or salmonid predation) will be detectable over a reasonable time frame for monitoring. This could be examined using a simple community interaction model coupled to a set of predictions about the changes in habitat that might result from dredging and disposal.

4.0 SALMONID SUBGROUP

4.1 Introduction

The salmonid subgroup discussed the potential direct and indirect effects of dredging and disposal operations on the adult and juvenile salmonids that spend a portion of their lives in the Lower Granite reservoir. Three groups of fish were considered:

1) spring and summer chinook;

2) fall chinook; and

3) steelhead.

Each of these groups consists of a number of separate stocks derived from both natural and hatchery reproduction. For the purposes of this discussion, these finer distinctions were not considered to be important. Since all hatchery steelhead are marked with some type of fin clip, it would be useful to keep track of the differences between hatchery and natural fish in survey work.

Two other species of anadromous salmonids are found in the Upper Snake River. A small number of sockeye migrate through the reservoir, but these are of little importance. Coho have historically spawned above the Lower Granite, but current runs are marginal and there are, at present, no plans to rebuild these stocks. Neither of these species was considered in the subgroup discussions.

Salmonids use the reservoir during two phases of their life history: as juveniles, they migrate downstream during the spring and summer, and as adults, they migrate upstream through the reservoir to their spawning sites. A proportion of spring/summer chinook, fall chinook, steelhead juveniles, and adult steelhead overwinter in the reservoir. The numbers and location of overwintering fish and their habitat requirements are currently poorly understood.

The potential effects of dredging and disposal on salmonids fall into three categories:

1) direct effects of the dredging and disposal activities including the effects of the turbidity plumes, noise, and entrainment into the dredging equipment;

2) effects of alterations in habitat caused by the placement of sediments at the disposal sites; and

3) effects mediated through interactions with other fish species in the reservoir, predominantly through predation.

4.2 Direct Effects of Dredging and Disposal

The subgroup discussions of the direct effects of dredging and disposal on salmonids were restricted to those which would occur in the winter dredging window from January 1 to March 1 with possible extensions back into December or further into March. This choice of dredging window removes many of the potential impacts since the majority of salmonids are not present during that period. There are four potential areas of impact:

1) entrainment of overwintering juveniles and early downstream migrants;

2) turbidity and chemical effects from dredging and disposal plumes on overwintering and early migrant juveniles;

3) disruption of the upstream migration of steelhead adults due to the noise and turbidity plumes from dredging and disposal operations; and

4) direct and indirect effects of dredging and disposal operations on the steelhead fishery.

4.2.1 Juvenile Entrainment

The subgroup did not consider juvenile entrainment to be a significant problem for downstream migrants since the major portion of the juvenile migration does not start until early April. The effects on overwintering juveniles cannot be predicted at this point since their location is not known. Juvenile entrainment, however, has not been detected in previous dredging operations in this area.

4.2.2 Interactions with Plumes

Turbidity plumes could have two effects on juvenile salmonids:

1) a reduction in survival due to either physical effects or the disruption of migration patterns; and

2) an alteration in the effects of predation by visual predators due to the reduction in visibility.

The group felt the increase in turbidity during the time of smolt migration (mid March and on) would not be significant as the reservoir is already very turbid with the spring freshet. In January and early February when the reservoir is relatively clear, the water is also cold and predation pressure on any overwintering juvenile salmonids is low. The group did not, therefore, consider the turbidity plumes would result in a significant impact.

At present, there is no reason to suspect there will be problems from chemical contaminants in the dredging or disposal plumes. Therefore, the group did not consider these potential impacts further.

4.2.3 Interactions with Adult Steelhead Migration

Adult steelhead that had overwintered in the reservoir could be present and migrating upstream during dredging operations in mid to late March. The potential for impact on this migration is unknown but the group felt it was unlikely to be significant.

4.2.4 Interactions with Steelhead Fishery

The choice of the January/February operations window removes the possibility of major interactions with the steelhead fishery, although there is some potential for interaction in late December. The group felt the major potential for impacts is through the aesthetic effects of turbidity plumes and barge traffic and the safety effects of the large washes created by the barges and tugs.

There does not appear to be any objective evidence for an effect of turbidity on catch per hour, although this is widely perceived to be an important relationship.

4.3 Effects of Habitat Alterations

Four different sets of habitat requirements might be expected to be associated with the different uses of the reservoir by salmonids: juvenile use in the spring and summer, and for overwintering, and adult use in the spring, summer, and fall, and for overwintering.

4.3.1 Juvenile Summer Habitat

Spring/summer chinook and steelhead juveniles are normally smolting as they move through the reservoir and tend to have relatively brief passage times on the order of 3 days to a week. During this time, they would normally be feeding on material derived from both benthic and terrestrial sources. Fall chinook juveniles are not normally as advanced and may spend several weeks feeding as they move down through the reservoir; they tend to prefer lower velocity sites.

Juvenile salmonids are only associated with the substrate in the shallow water areas (15 ft. and less). During the peak migration, they are found throughout the reservoir but only in the top 10 to 15 ft. of the water column.

Apart from depth, velocity, and food supply, the other determinant of habitat which may be important is the amount of cover in the form of macrophytes and the relief of the substrate. Generally, the subgroup felt that habitat with little cover was preferred by salmonid juveniles due to the decreased potential for predation.

The only alteration of habitat through sediment disposal, which the subgroup felt would have a significant impact on summer juveniles, was the creation of new shallow water habitat since this is the major habitat they utilize. The magnitude of the increases in juvenile survival through the reservoir, resulting from increasing the amount of this habitat, is unknown.

4.3.2 Juvenile Overwintering Habitat

Overwintering juvenile spring/summer chinook and steelhead have only recently been discovered in the Lower Granite reservoir. The total numbers of overwintering juveniles, their habitat requirements and their importance to particular fish stocks is unknown.

The subgroup proposed that overwintering juveniles might tend to prefer substrate with more relief and would tend to be found in deeper water. There is little evidence to support or refute this in the Lower Granite reservoir, however.

4.3.3 Adult Summer Habitat

Adult salmonids are generally moving through the reservoir fairly rapidly toward their spawning streams. Chinook salmon do not feed during their time in the reservoir, while steelhead will feed to a minimal extent.

The subgroup did not feel that changes in habitat caused by the in-water disposal of sediment would affect this upstream migration in either survival rates or timing.

4.3.4 Adult Overwintering Habitat

Some proportion of adult steelhead which pass the Lower Granite dam in September and October overwinter in the reservoir prior to spawning the following spring. The proportion of these fish which remain in the reservoir and their habitat requirements are unknown.

4.3.5 Summary

In summary, the main interaction between habitat alterations caused by sediment disposal and salmonids would seem to be in the creation or destruction of shallow water habitat. Alterations to the deep and mid-water habitat seem to be of relatively small importance. It should be stressed, however, that the overwintering requirements of both adults and juveniles is not well understood.

4.4 Effects of Alterations in Predation

The subgroup felt the major effect of the dredging and disposal operations was liable to be mediated through changes in predation pressure from resident fish. At present, the magnitude of salmonid mortality due to predation in the Lower Granite reservoir is uncertain. Estimates proposed by the subgroup ranged from 5 to 15%.