US Army Corps
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Walla Walla District

FINAL

Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

APPENDIX D

Natural River Drawdown Engineering

February 2002

FEASIBILITY STUDY DOCUMENTATION

	Document Title
Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement	
Appendix A (bound with B)	Anadromous Fish Modeling
Appendix B (bound with A)	Resident Fish
Appendix C	Water Quality
Appendix D	Natural River Drawdown Engineering
Appendix E	Existing Systems and Major System Improvements Engineering
Appendix F (bound with G, H)	Hydrology/Hydraulics and Sedimentation
Appendix G (bound with F, H)	Hydroregulations
Appendix H (bound with F, G)	Fluvial Geomorphology
Appendix I	Economics
Appendix J	Plan Formulation
Appendix K	Real Estate
Appendix L (bound with M)	Lower Snake River Mitigation History and Status
Appendix M (bound with L)	Fish and Wildlife Coordination Act Report
Appendix N (bound with O, P)	Cultural Resources
Appendix O (bound with N, P)	Public Outreach Program
Appendix P (bound with N, O)	Air Quality
Appendix Q (bound with R, T)	Tribal Consultation and Coordination
Appendix R (bound with Q, T)	Historical Perspectives
Appendix S*	Snake River Maps
Appendix T (bound with R, Q)	Clean Water Act, Section 404(b)(1) Evaluation
Appendix U	Response to Public Comments

*Appendix S, Lower Snake River Maps, is bound separately (out of order) to accommodate a special 11 x 17 format.

The documents listed above, as well as supporting technical reports and other study information, are available on our website at http://www.nww.usace.army.mil/lsr. Copies of these documents are also available for public review at various city, county, and regional libraries.

STUDY OVERVIEW

Purpose and Need

Between 1991 and 1997, due to declines in abundance, the National Marine Fisheries Service (NMFS) made the following listings of Snake River salmon or steelhead under the Endangered Species Act (ESA) as amended:

- sockeye salmon (listed as endangered in 1991)
- spring/summer chinook salmon (listed as threatened in 1992)
- fall chinook salmon (listed as threatened in 1992)
- steelhead (listed as threatened in 1997).

In 1995, NMFS issued a Biological Opinion on operations of the Federal Columbia River Power System (FCRPS). Additional opinions were issued in 1998 and 2000. The Biological Opinions established measures to halt and reverse the declines of ESA-listed species. This created the need to evaluate the feasibility, design, and engineering work for these measures.

The Corps implemented a study (after NMFS' Biological Opinion in 1995) of alternatives associated with lower Snake River dams and reservoirs. This study was named the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). The specific purpose and need of the Feasibility Study is to evaluate and screen structural alternatives that may increase survival of juvenile anadromous fish through the Lower Snake River Project (which includes the four lowermost dams operated by the Corps on the Snake River—Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams) and assist in their recovery.

Development of Alternatives

The Corps' response to the 1995 Biological Opinion and, ultimately, this Feasibility Study, evolved from a System Configuration Study (SCS) initiated in 1991. The SCS was undertaken to evaluate the technical, environmental, and economic effects of potential modifications to the configuration of Federal dams and reservoirs on the Snake and Columbia Rivers to improve survival rates for anadromous salmonids.

The SCS was conducted in two phases. Phase I was completed in June 1995. This phase was a reconnaissance-level assessment of multiple concepts including drawdown, upstream collection, additional reservoir storage, migratory canal, and other alternatives for improving conditions for anadromous salmonid migration.

The Corps completed a Phase II interim report on the Feasibility Study in December 1996. The report evaluated the feasibility of drawdown to natural river levels, spillway crest, and other improvements to existing fish passage facilities.

Based in part on a screening of actions conducted for the Phase I report and the Phase II interim report, the study now focuses on four courses of action:

- Existing Conditions
- Maximum Transport of Juvenile Salmon

- Major System Improvements
- Dam Breaching.

The results of these evaluations are presented in the combined Feasibility Report (FR) and Environmental Impact Statement (EIS). The FR/EIS provides the support for recommendations that will be made regarding decisions on future actions on the Lower Snake River Project for passage of juvenile salmonids. This appendix is a part of the FR/EIS.

Geographic Scope

The geographic area covered by the FR/EIS generally encompasses the 140-mile long lower Snake River reach between Lewiston, Idaho and the Tri-Cities in Washington. The study area does slightly vary by resource area in the FR/EIS because the affected resources have widely varying spatial characteristics throughout the lower Snake River system. For example, socioeconomic effects of a permanent drawdown could be felt throughout the whole Columbia River Basin region with the most effects taking place in the counties of southwest Washington. In contrast, effects on vegetation along the reservoirs would be confined to much smaller areas.

Identification of Alternatives

Since 1995, numerous alternatives have been identified and evaluated. Over time, the alternatives have been assigned numbers and letters that serve as unique identifiers. However, different study groups have sometimes used slightly different numbering or lettering schemes and this has led to some confusion when viewing all the work products prepared during this long period. The primary alternatives that are carried forward in the FR/EIS currently involve the following four major courses of action:

Alternative Name	PATH[1/] Number	Corps Number	FR/EIS Number
Existing Conditions	A-1	A-1	1
Maximum Transport of Juvenile Salmon	A-2	A-2a	2
Major System Improvements	A-2'	A-2d	3
Dam Breaching	A-3	A-3a	4

[1/] Plan for Analyzing and Testing Hypotheses

Summary of Alternatives

The **Existing Conditions Alternative** consists of continuing the fish passage facilities and project operations that were in place or under development at the time this Feasibility Study was initiated. The existing programs and plans underway would continue unless modified through future actions. Project operations include fish hatcheries and Habitat Management Units (HMUs) under the Lower Snake River Fish and Wildlife Compensation Plan (Comp Plan), recreation facilities, power generation, navigation, and irrigation. Adult and juvenile fish passage facilities would continue to operate.

The **Maximum Transport of Juvenile Salmon Alternative** would include all of the existing or planned structural and operational configurations from the Existing Conditions Alternative. However, this alternative assumes that the juvenile fishway systems would be operated to maximize fish transport from Lower Granite, Little Goose, and Lower Monumental and that voluntary spill would not be used to bypass fish through the spillways (except at Ice Harbor). To accommodate this maximization of transport, some measures would be taken to upgrade and improve fish handling facilities.

The **Major System Improvements Alternative** would provide additional improvements to what is considered under the Existing Conditions Alternative. These improvements would be focused on using surface bypass facilities such as surface bypass collectors (SBCs) and removable spillway weirs (RSWs) in conjunction with extended submerged bar screens (ESBSs) and a behavioral guidance structure (BGS). The intent of these facilities would be to provide more effective diversion of juvenile fish away from the turbines. Under this alternative, an adaptive migration strategy would allow flexibility for either in-river migration or collection and transport of juvenile fish downstream in barges and trucks.

The **Dam Breaching Alternative** has been referred to as the "Drawdown Alternative" in many of the study groups since late 1996 and the resulting FR/EIS reports. These two terms essentially refer to the same set of actions. Because the term drawdown can refer to many types of drawdown, the term dam breaching was created to describe the action behind the alternative. The Dam Breaching Alternative would involve significant structural modifications at the four lower Snake River dams, allowing the reservoirs to be drained and resulting in a free-flowing yet controlled river. Dam breaching would involve removing the earthen embankment sections of the four dams and then developing a channel around the powerhouses, spillways, and navigation locks. With dam breaching, the navigation locks would no longer be operational and navigation for large commercial vessels would be eliminated. Some recreation facilities would close while others would be modified and new facilities could be built in the future. The operation and maintenance of fish hatcheries and HMUs would also change, although the extent of change would probably be small and is not known at this time.

Authority

The four Corps dams of the lower Snake River were constructed and are operated and maintained under laws that may be grouped into three categories: 1) laws initially authorizing construction of the project, 2) laws specific to the project passed subsequent to construction, and 3) laws that generally apply to all Corps reservoirs.

REGIONAL BASE MAP

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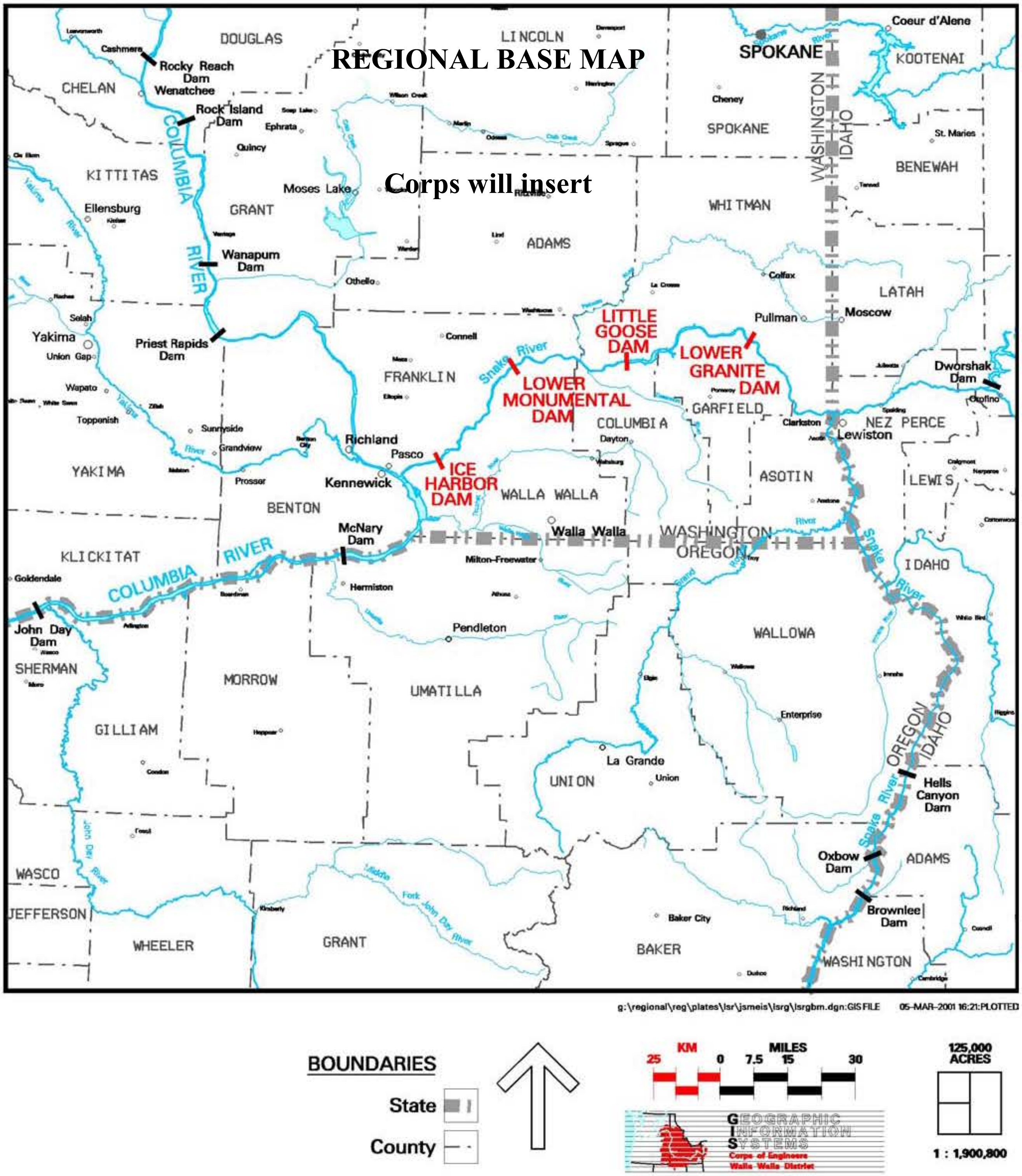

LOWER SNAKE RIVER
Juvenile Salmon Migration Feasibility Study

REGIONAL BASE MAP

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Final
Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

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Appendix D
Natural River Drawdown Engineering

Produced by

U.S. Army Corps of Engineers
Walla Walla District

February 2002

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FOREWORD

Appendix D was prepared by staff of the U.S. Army Corps of Engineers (Corps), Walla Walla District. Other contributors include Washington Infrastructure (formerly Raytheon Engineers and Constructors); American Hydro; Corps Waterways Experiment Station; Voest-Alpine; the Corps of Engineers Hydroelectric Design Center; Thomas, Dean and Hoskins; Montgomery-Watson Engineers; CH2M HILL Engineers; and Project Time and Cost. This appendix is one part of the overall effort of the Corps to prepare the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS).

The Corps has reached out to regional stakeholders (Federal agencies, tribes, states, local governmental entities, organizations, and individuals) during the development of the FR/EIS and appendices. This effort resulted in many of these regional stakeholders providing input and comments, and even drafting work products or portions of these documents. This regional input provided the Corps with an insight and perspective not found in previous processes. A great deal of this information was subsequently included in the FR/EIS and appendices; therefore, not all of the opinions and/or findings herein may reflect the official policy or position of the Corps.

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ACRONYMS AND ABBREVIATIONS

CCP	concrete cylinder pipe
CFR	Code of Federal Regulations
Corps	U.S. Army Corps of Engineers
CWCCIS	Civil Works Construction Cost Index System
DREW	Drawdown Regional Economic Workgroup
Ecology	Washington Department of Ecology
ESA	Endangered Species Act
FCRPS	Federal Columbia River Power System
Feasibility Study	Lower Snake River Juvenile Salmon Migration Feasibility Study
flip lips	spillway flow deflectors
FR/EIS	Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement
GBD	gas bubble disease
GBT	gas bubble trauma
HMU	habitat management unit
MCACES™	Micro Computer-Aided Cost Engineering System
MOP	minimum operating pool
MW	megawatt
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
PATH	Plan for Analyzing and Testing Hypotheses
PCB	polychlorinated biphenyl
PG&E	Pacific Gas and Electric
SBC	surface bypass collector
SCS	System Configuration Study
SNL	speed no load
SWI	simulated Wells intake
TSS	total suspended solids
WAC	Washington Administrative Code
WBS	Work Breakdown Structure
WES	Waterways Experiment Station
WSDOT	Washington State Department of Transportation

Units of Measure

cfs	cubic feet per second
cy	cubic yard
ft	feet
fps	feet per second
gpm	gallons per minute
cm	centimeter
km	kilometer

ACRONYMS AND ABBREVIATIONS

m	meter
m/s	meter per second
m^3	cubic meter
m^3/s	cubic meters per second
mm	millimeter

ENGLISH TO METRIC CONVERSION FACTORS

To Convert From	To	Multiply By
LENGTH CONVERSIONS:		
Inches	Millimeters	25.4
Feet	Meters	0.3048
Miles	Kilometers	1.6093
AREA CONVERSIONS:		
Acres	Hectares	0.4047
Acres	Square meters	4047
Square Miles	Square kilometers	2.590
VOLUME CONVERSIONS:		
Gallons	Cubic meters	0.003785
Cubic yards	Cubic meters	0.7646
Acre-feet	Hectare-meters	0.1234
Acre-feet	Cubic meters	1234
OTHER CONVERSIONS:		
Feet/mile	Meters/kilometer	0.1894
Tons	Kilograms	907.2
Tons/square mile	Kilograms/square kilometer	350.2703
Cubic feet/second	Cubic meters/sec	0.02832
Degrees Fahrenheit	Degrees Celsius	(Deg F –32) x (5/9

Executive Summary

The purpose of the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study) is to evaluate and screen structural alternatives measures that may increase the survival of juvenile anadromous fish through the Lower Snake River Project and assist in the recovery of listed salmon and steelhead stocks. The four alternatives presented in the Feasibility Study are: 1) the existing conditions with currently programmed improvements, 2) maximizing transportation of juvenile salmonids, 3) major system improvements which include a surface bypass and collection program, and 4) a permanent drawdown of the four lower Snake River reservoirs. The Feasibility Study contains numerous appendices that specifically address the economic, biological, social, and engineering aspects of each of these pathways. This appendix, the Natural River Drawdown Engineering Appendix, summarizes the process necessary to implement the drawdown pathway.

The implementation of drawdown of the four Lower Snake River reservoirs requires that five steps be completed: 1) The water in each reservoir must be evacuated, 2) a portion of each dam must be removed to allow the entire river to flow freely 3) a means to channelize the river is necessary to control the river as it flows around the abandoned structures, 4) the abandoned structures must be decommissioned and each facility secured against public access, and 5) numerous structures and facilities in the reservoirs must be modified in order to operate with lower water surface elevations. Four primary criteria guided the development, evaluation, and selection of the engineering alternatives presented in this report:

- Selected measures must benefit the survival of the species.
- The least costly, functionally appropriate alternative should be selected.
- Logical and reasonable modifications and construction operations should be selected.
- Operations must be structured to provide safe working conditions and safe river conditions.

To draw down the reservoirs, the Corps must modify turbines and turbine passages to allow them to be used as low-level outlets. Even though the outlets would operate for only 60 to 90 days while the embankment is excavated to create a new channel, the facility must function properly during this period or risk catastrophic failure of the embankments and other structures.

Embankment removal would be performed concurrently with reservoir drawdown using commercially available, large-capacity excavation and hauling equipment. Over 9 million cubic meters (m^3) (12 million cubic yards [cy]) of material must be excavated and removed to stockpile areas. The work would be performed during the time period between the end of the spill season in August and the start of the next high flow season in January. The construction of channelization levees would immediately follow and be completed in March of the same season. To construct pervious levees, over 1.8 million m^3 (2.4 million cy) of shotrock and riprap must be hauled by barge to the four project sites.

The concrete structures such as the powerhouses, navigation locks, and the non-overflow dams would remain within the channelization levees and would be secured against public access. Disposition of the remaining steel structures would include excessing, salvaging, and abandoning these structures. Similar treatment for mechanical and electrical equipment was investigated. Since most of the equipment is nearing the end of its service life, no cost benefits for salvaged equipment were assumed. The study also investigated methods and costs of demolishing the remaining concrete structures but did not recommend that operation because it was too costly.

Modification of the reservoir infrastructure would be necessary as a result of lowering the reservoirs. These include the following:

- Up to 25 bridge piers must be protected from erosion due to higher velocity river water.
- Railroad and highway embankments must be protected from erosion due to higher velocity river flows and flows through drainage structures down the exposed surfaces.
- After drawdown is completed, repairs to roads and rail beds would be needed as a result of settlement and slope failures of embankments.

Potential modifications in each reservoir related to fish, wildlife, recreation, and cultural resources include the following:

- Extensive modifications to the Lyons Ferry Hatchery to provide production after drawdown
- Alternate irrigation facilities at habitat management units (HMUs) to maintain a short-term operation
- Measures to revegetate the exposed land mass and re-establish boundary fencing to promote habitat development
- Modification and, in some cases, closure of recreation areas as a result of drawdown
- A significant cultural resources protection program is planned to protect over 360 known sites that will be exposed or accessible after drawdown.

A number of major agricultural and industrial modifications would be needed by drawdown. These measures are not included in the implementation plan, but are part of the economic evaluation. They include:

- Concepts for a corporate irrigation system for the major irrigators now using the Ice Harbor Reservoir
- Water intakes for industrial and municipal use
- An industrial effluent diffuser
- A modified river crossing for a gas pipeline
- Modifications to existing water wells.

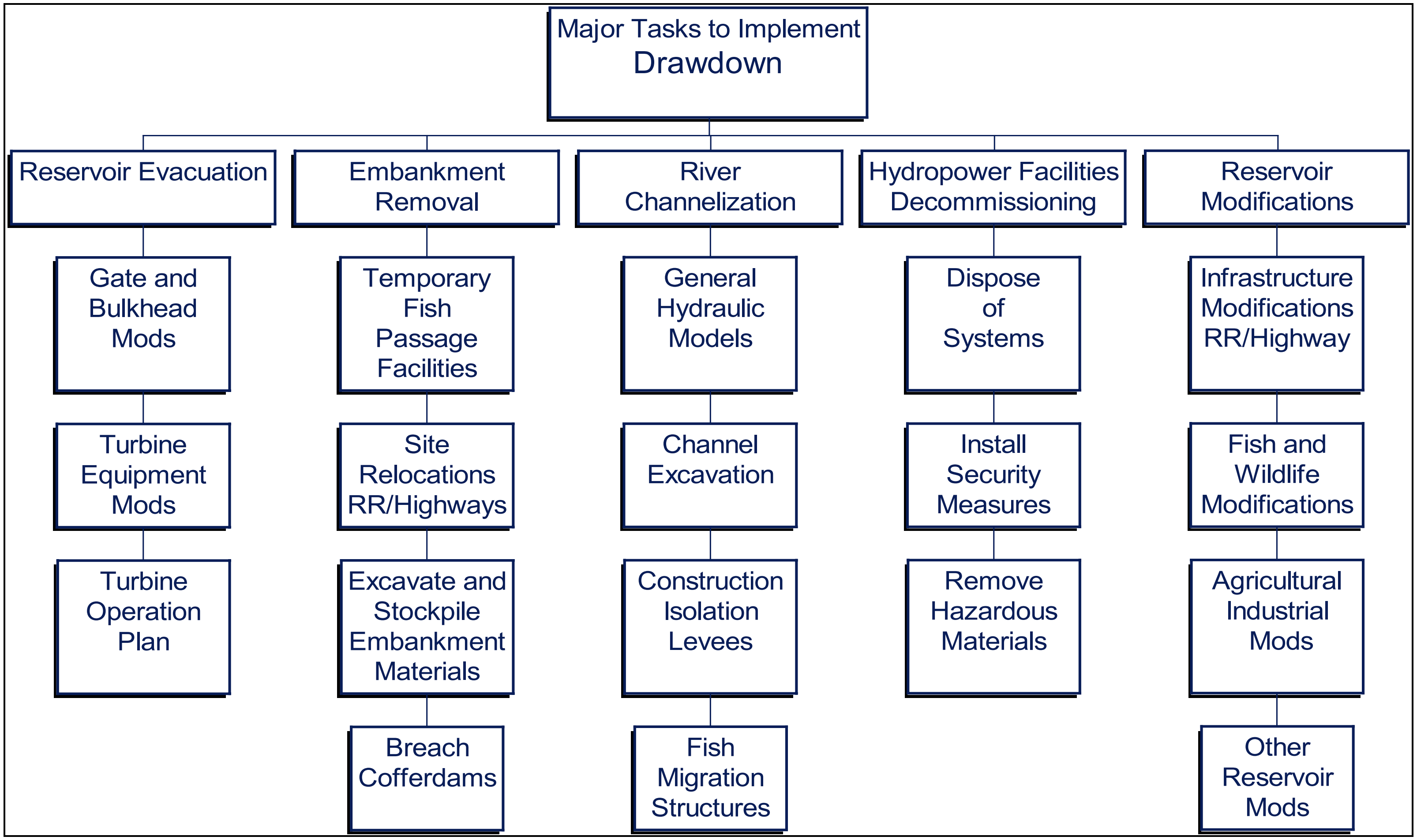
The recommended sequence for implementing drawdown is to concurrently breach Lower Granite and Little Goose dams in one construction season followed by concurrent breach of Lower Monumental and Ice Harbor dams the following construction season. Numerous engineering and construction activities must precede the dam breaching as well as follow dam breaching. The timeframe for implementing drawdown of the four lower Snake River dams is estimated to extend over 9 years with full funding. The cost of all engineering and construction activities to implement drawdown is estimated at $900 million.

1. Introduction

This appendix describes the process necessary for implementing a permanent drawdown of four dams on the lower Snake River: Lower Granite, Little Goose, Lower Monumental, and Ice Harbor. The Regional Base Map shows the location of each of the facilities. The Corps' study team considered a number of options in selecting the methods and procedures necessary to implement the drawdown and mitigate its effects on infrastructure; natural, recreational, and cultural resources; and agricultural and industrial operations. This appendix summarizes those options and the rationale for selecting certain options and provides a comprehensive plan for implementing a permanent drawdown. The major elements of drawdown are: 1) Reservoir Evacuation, 2) Embankment Removal, 3) River Channelization, 4) Reservoir Modifications, and 5) Hydropower Facilities Decommissioning. These elements are shown in Figure 1-1.

In addition, work continues on the two other designated pathways to improve salmon survival related to the Lower Snake River Project: 1) a surface bypass and collection program and 2) other major system improvements. Those pathways are documented in Appendix E in this Lower Snake River Juvenile Migration Feasibility Study (Feasibility Study).

Figure 1-1. Elements of the Comprehensive Plan for Implementing Permanent Drawdown



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2. Background

2.1 General

On March 2, 1995, the National Marine Fisheries Service (NMFS) issued a Biological Opinion for the *Reinitiation of Consultation on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years* (NMFS, 1995). The Biological Opinion established immediate measures necessary for the survival and recovery of Snake River salmon stocks listed under the Endangered Species Act (ESA). A specific decision path for the implementation of long-term alternatives was also identified.

This path identified two major decision points. The first decision point was in 1996 and required an interim status report with a preliminary decision regarding the selection of one of three drawdown alternatives for the lower Snake River in order to proceed with detailed engineering or the elimination of any further consideration of drawdown. In case a decision on drawdown could not be reached in 1996, a second decision point was identified in 1999. At that time, a final plan for drawdown or surface bypass and collection was to be selected, and feasibility evaluations and National Environmental Policy Act (NEPA) documentation were to be completed.

2.2 The Evolution of this Study

The Corps' response to the Biological Opinion issued by the NMFS and, ultimately, this Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study) evolved from a System Configuration Study (SCS) initiated in 1991.

The SCS was undertaken to evaluate the technical, environmental, and economic effects of potential modifications to the configuration of Federal dams and reservoirs on the Snake and Columbia rivers to improve survival rates for anadromous salmonids. This process began in response to the Northwest Power Planning Council's *Fish and Wildlife Program Amendments (Phase Two)*, issued in December 1991 (NPPC, 1991). The Phase I SCS, *Columbia River Salmon Migration Analysis, System Configuration Study, Phase I*, assessed various possible alternatives for improving conditions for anadromous salmonid migration and was to be conducted in two separate phases (Corps, 1994).

Phase I of the SCS was completed in June 1995. This was a reconnaissance-level assessment of multiple concepts, including drawdown, upstream collection, additional reservoir storage, a migratory canal, and several other alternatives. Alternatives that displayed the most potential benefit to anadromous fish were carried into Phase II.

Since 1995, Phase II has developed into a major program containing many separate and specific studies. Structural changes for juvenile salmon migration improvements within the lower Snake River are only a portion of the total program. This growth in the scope of Phase II was considered necessary to adequately and efficiently respond to the requirements for multiple evaluations addressed in the Biological Opinion.

In December 1996, the Corps issued the *System Configuration Study, Phase II, Lower Snake River Juvenile Salmon Migration Feasibility Study, Interim Status Report* (Corps, 1996a) in response to the Biological Opinion requirement for a preliminary decision regarding the selection of drawdown alternatives. Between the genesis of the SCS in 1991 and the interim status report in 1996, the Corps narrowed the drawdown alternatives from 22 that were initially formulated to one called the Natural River Option. The interim status report recommended the Natural River Option as the only drawdown option for further development, basing this recommendation on estimated biological effectiveness, other environmental effects, technical feasibility, cost, and regional acceptance.

The interim status report estimated that the Natural River Option would have the lowest construction cost ($533 million) and the shortest implementation time (5 years) of the primary options under consideration. The report also pointed out, however, that permanent natural river drawdown completely eliminates power production on the lower Snake River, as well as commercial navigation between Lewiston, Idaho, and Pasco, Washington. Cultural resource damage due to the uncovering of sites would be detrimental initially. However, erosion caused by annual reservoir fluctuations would not occur, and sites would eventually be protected by revegetation. Although other environmental impacts are initially substantial, maintaining natural river elevations would allow the ecosystem to achieve equilibrium in the future.

2.3 Drawdown Engineering Study Scope

The concepts, processes, and cost estimates described in this appendix support the single drawdown option considered in this second phase of the Feasibility Study – the Natural River Drawdown Option or Dam Breaching, that was recommended in the interim status report. As mentioned earlier, other options were considered in the Phase I SCS report. The development of concept designs for this Natural River Option engineering study and implementation plan were intended to be done at a feasibility level of design, resulting in a baseline cost estimate. Figures 2-1 through 2-8 provide a plan view drawing and aerial photograph of each of the Lower Snake River projects. Figure 2-9a through 2-9h is a full-system map locating many of the reservoir facilities discussed in this Appendix. Figure 2-10 provides a Drawdown Implementation Schedule Summary. Figure 2-11 provides an estimate project cost for Option A-3a, drawdown dam removal, channel bypass.

2.4 Study Team Composition

The study team consisted of a multidiscipline group from various organizations. The initial team was comprised of the Corps personnel from various engineering division workgroups. This group formulated the Natural River Option documented in the interim status report. Raytheon Engineers and Constructors, teamed with American Hydro, was added to the team to provide a concept evaluation of the use of turbines and turbine passages for reservoir discharge. Further model evaluations and recommendations were provided by the Corps Waterways Experiment Station (WES), Voest-Alpine, and the Corps of Engineers, Hydroelectric Design Center. Raytheon later provided the initial concept design for the embankment excavation, river channelization, and the reservoir infrastructure modifications. Thomas, Dean and Hoskins developed the concept design for the modifications for Potlatch Corporation Water intake and effluent diffuser and the PG&E Gasline River Crossing. The remaining modifications were developed by engineers and scientists of the Walla Walla District, Corps of Engineers. A team of engineers from Montgomery-Watson Engineers, CH2M Hill Engineers, and Project Time and Cost provided independent technical review of the document.

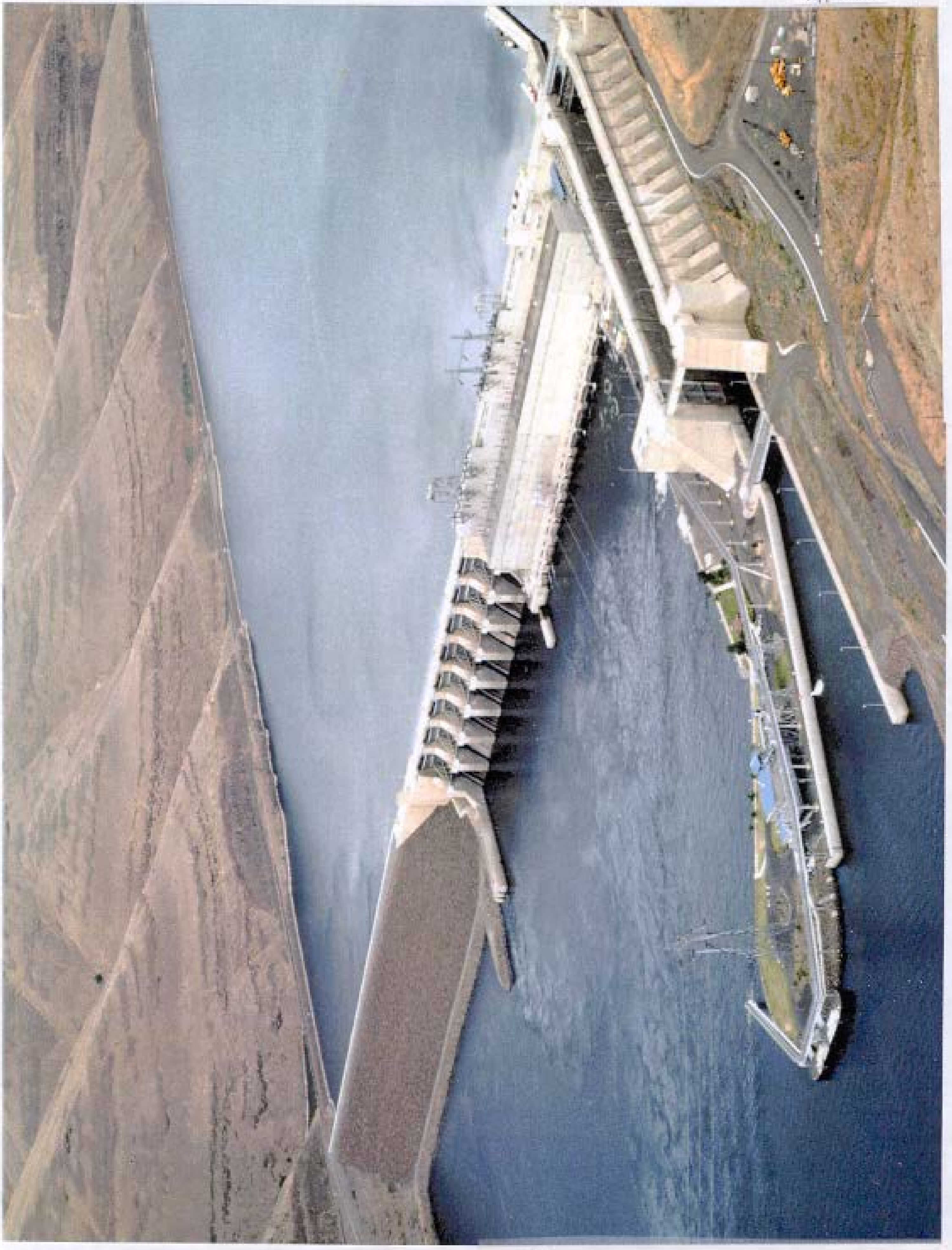

Figure 2-1. Lower Granite Dam – Aerial Photograph

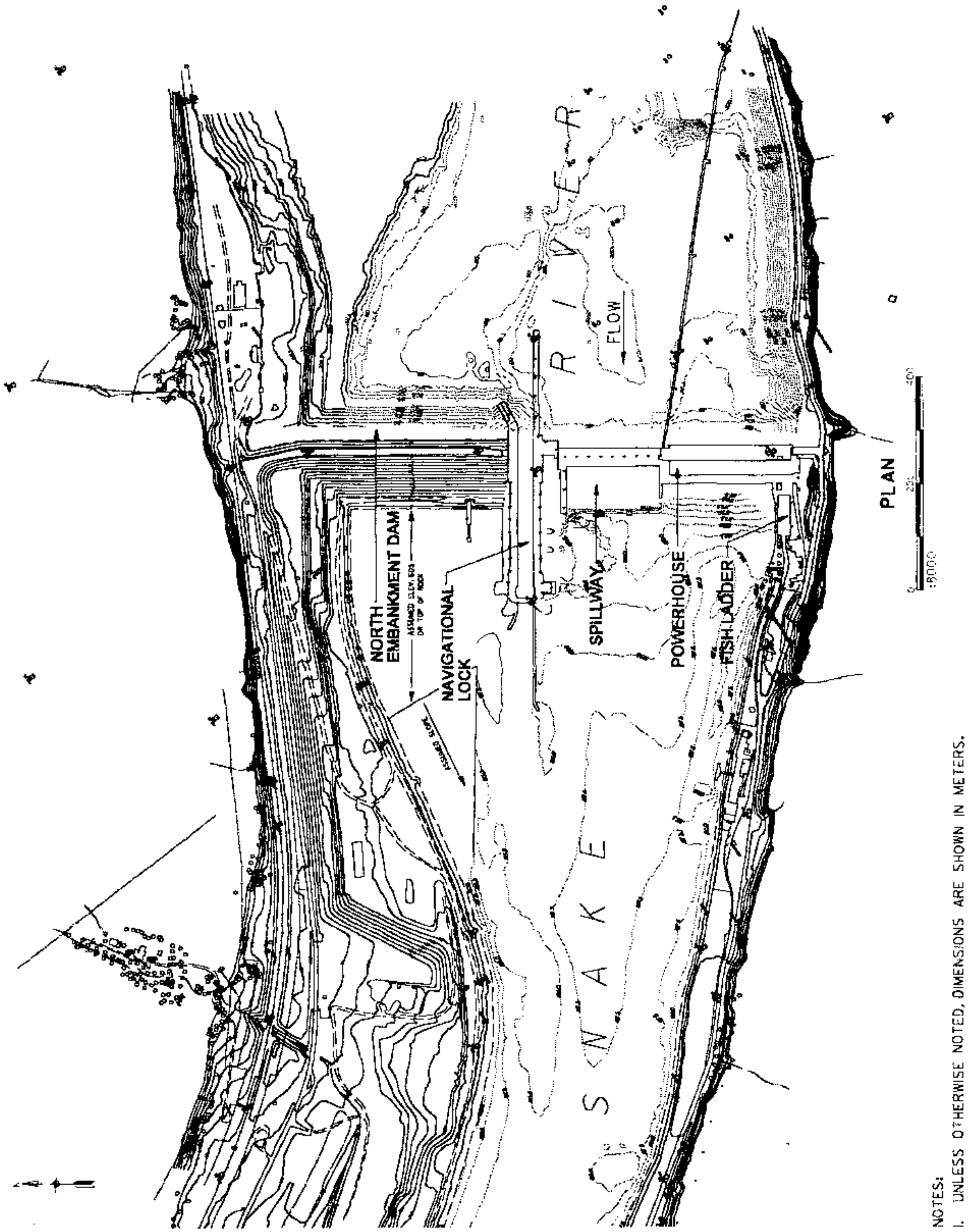

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Figure 2-2. Lower Granite – Existing Project Arrangement General Plan

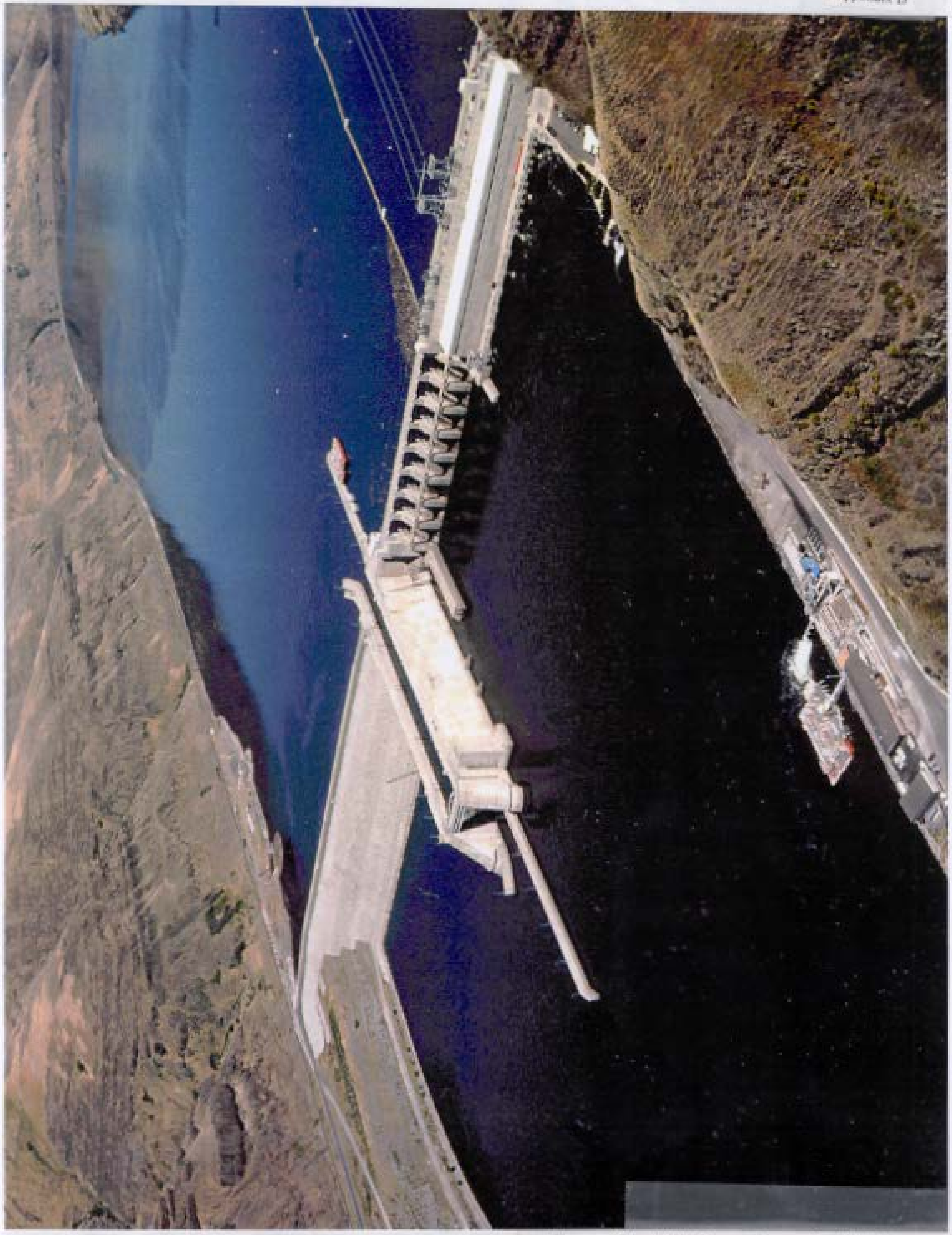

Figure 2-3. Little Goose Dam – Aerial Photograph

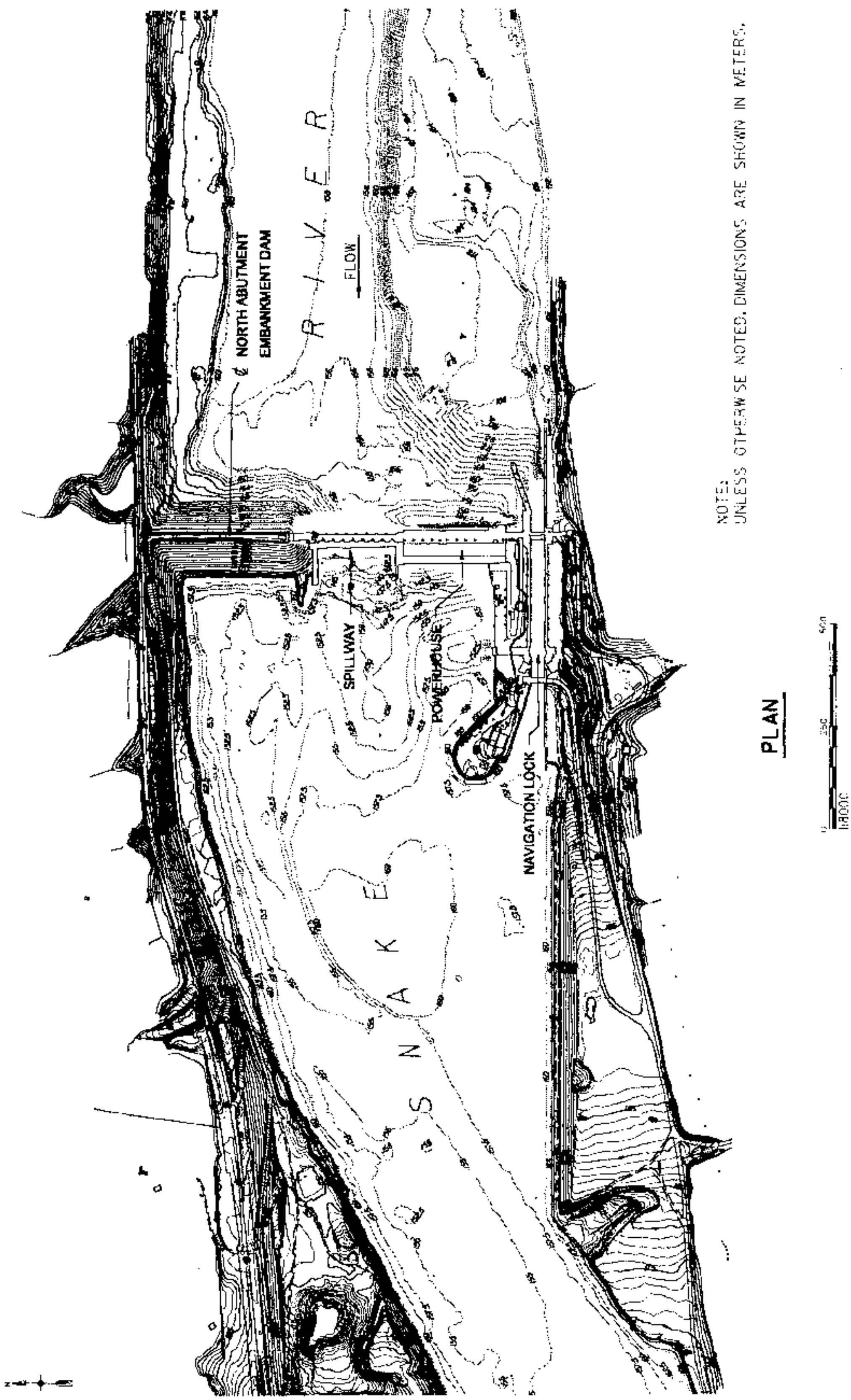

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Figure 2-4. Little Goose – Existing Project Arrangement General Plan

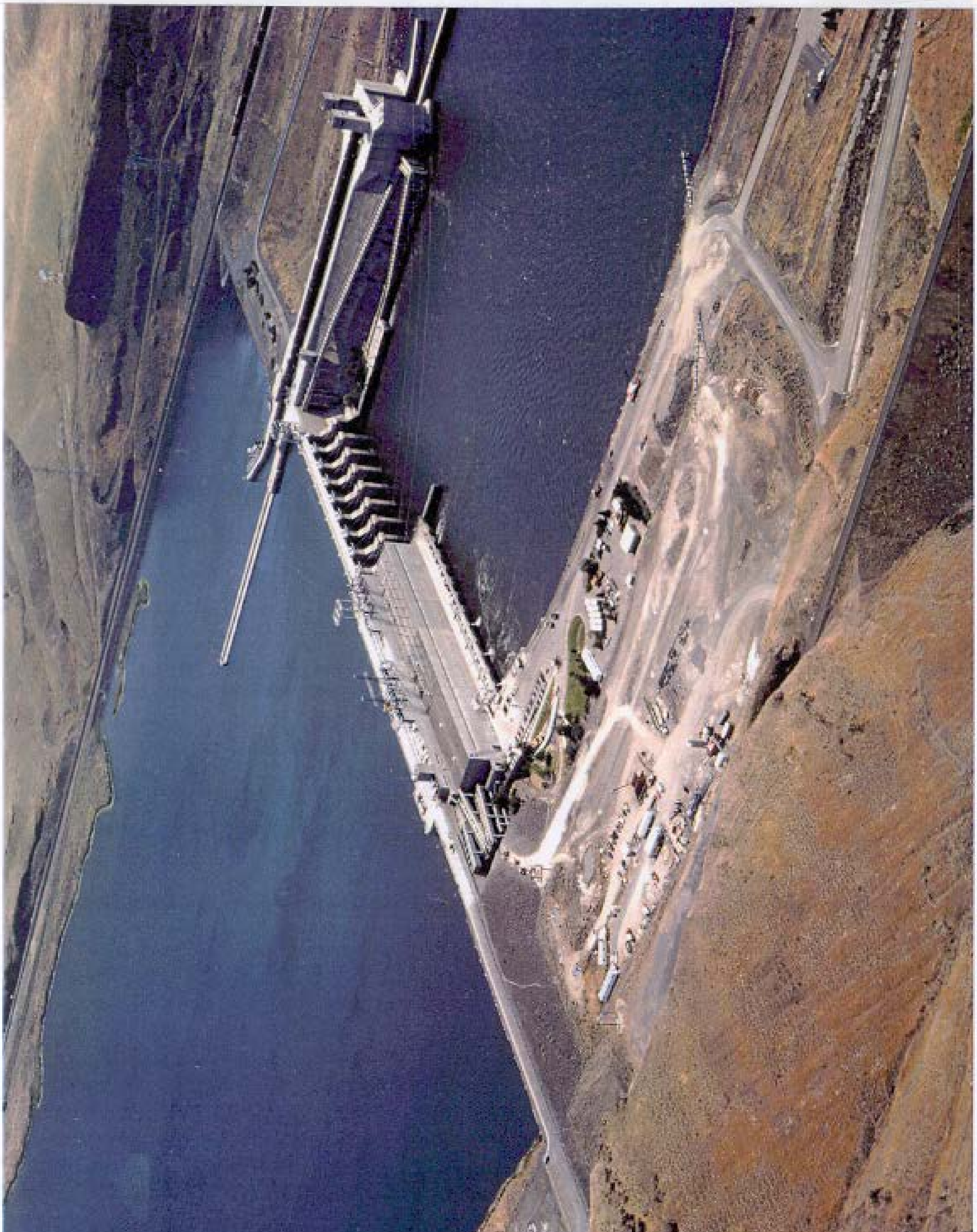

Figure 2-5. Lower Monumental Dam – Aerial Photograph

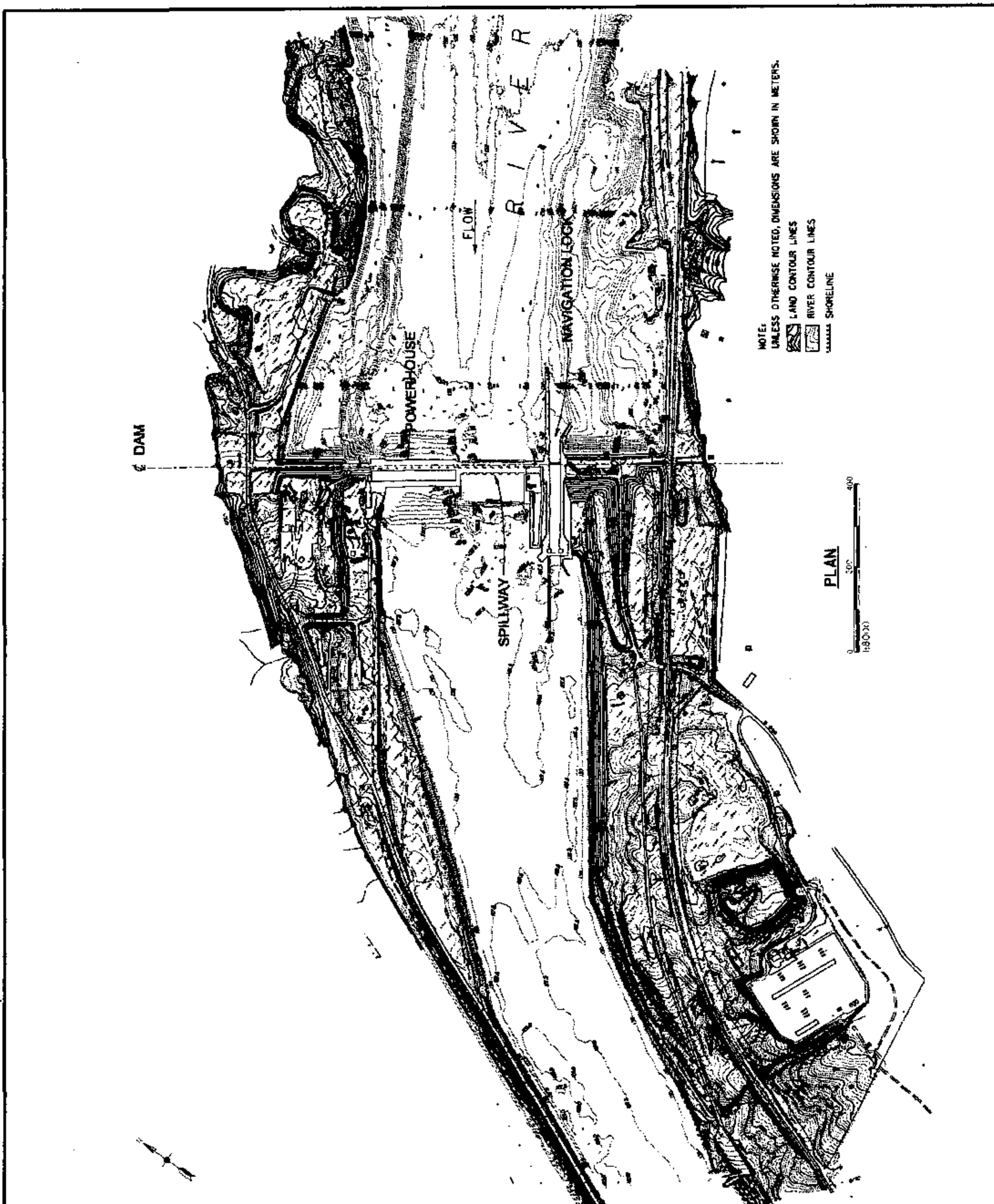

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Figure 2-6. Lower Monumental – Existing Project Arrangement General Plan

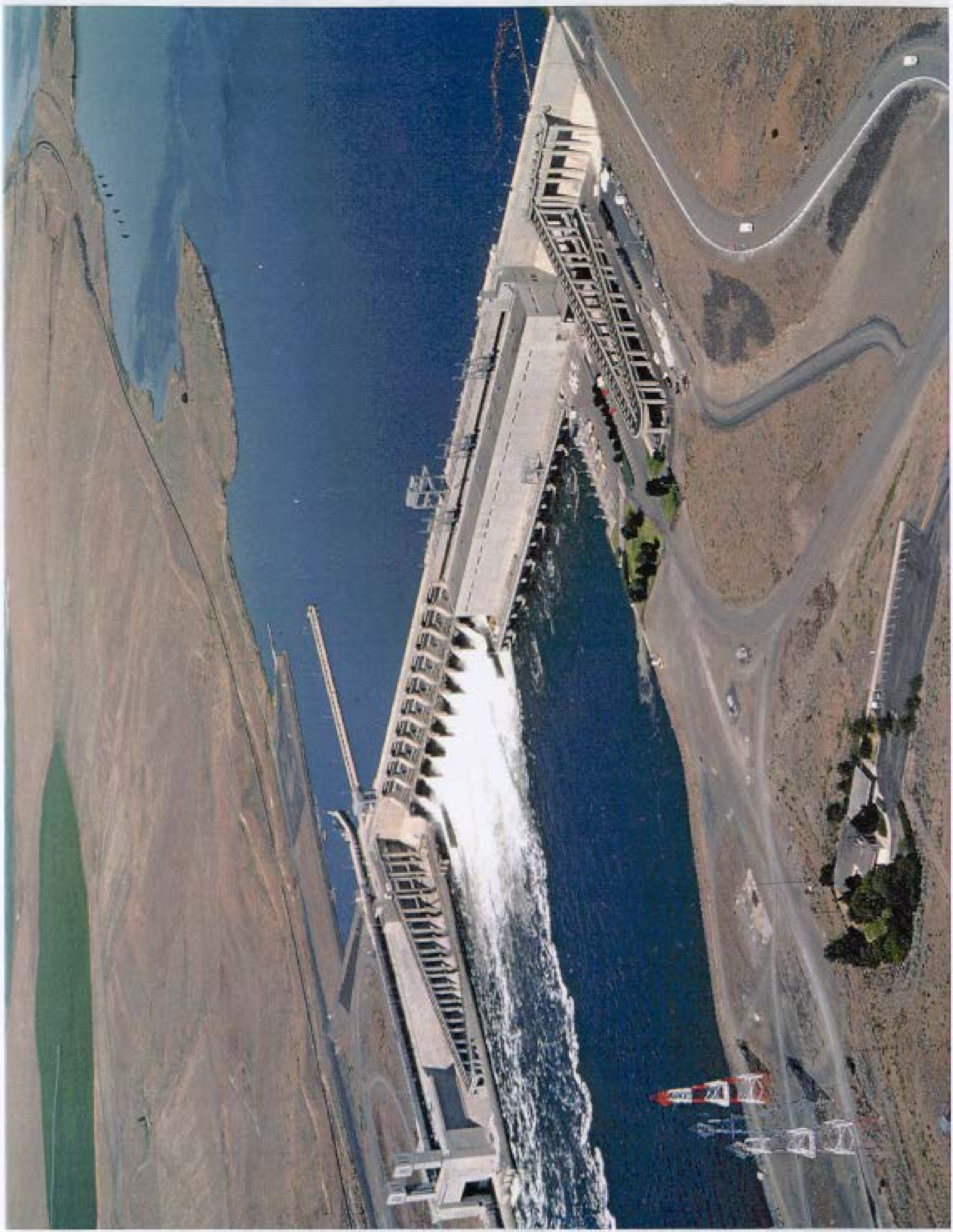

Figure 2-7. Ice Harbor Dam-Aerial Photograph

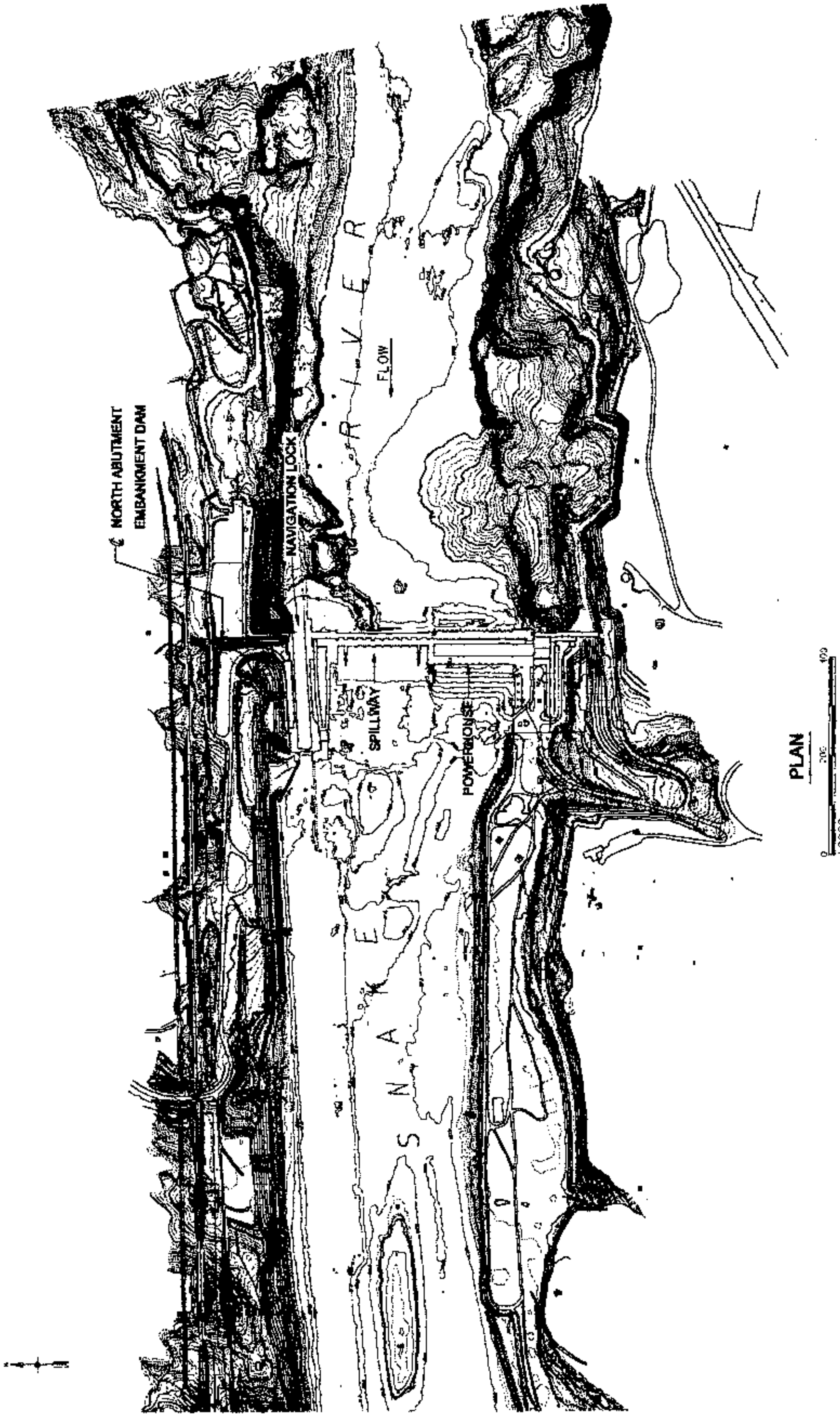

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Figure 2-8. Ice Harbor – Existing Project Arrangement General Plan

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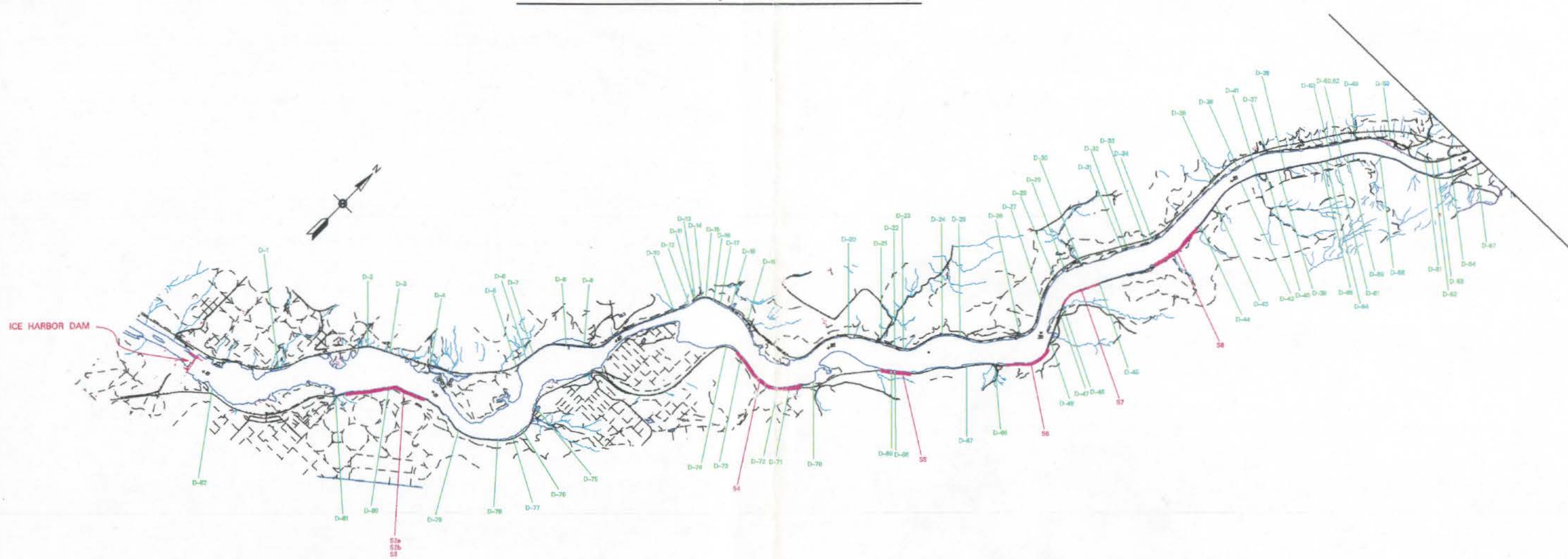
LAKE SACAJAWEA (ICE HARBOR POOL)



LEGEND

D-45 DRAINAGE STRUCTURES

EMBANKMENT RIPRAP LOCATIONS (i.e. N1, S2)

Figure 2-9a. Snake River – General System Arrangement: Lake Sacajawea (Drainage Structures)

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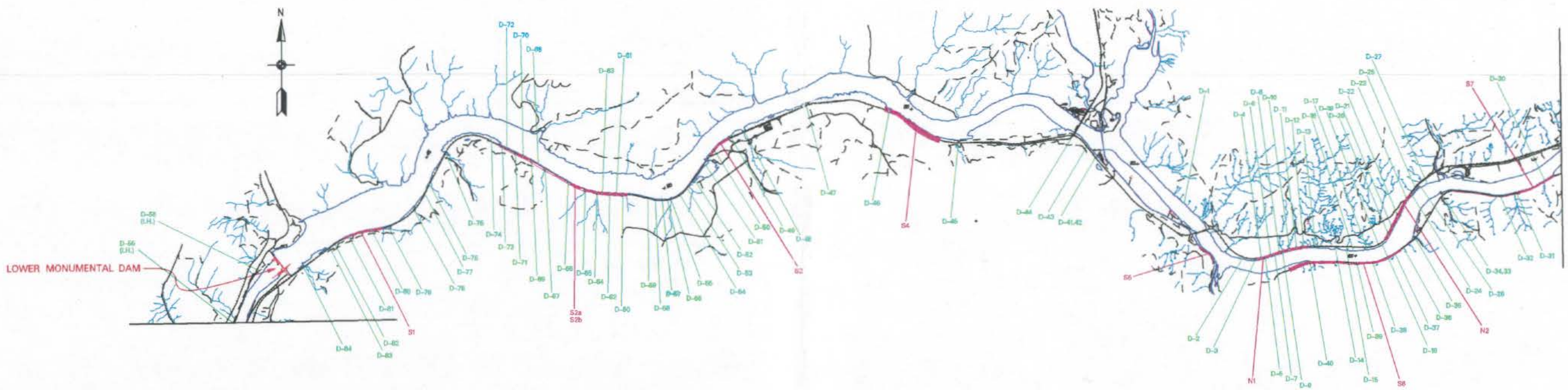
LAKE WEST (LOWER MONUMENTAL POOL)



LEGEND

D-45 DRAINAGE STRUCTURES

EMBANKMENT RIPRAP LOCATIONS (i.e. N1, S2)

Figure 2-9b. Snake River – General System Arrangement: Lake West (Drainage Structures)

VALUE ENGINEERING PAYS

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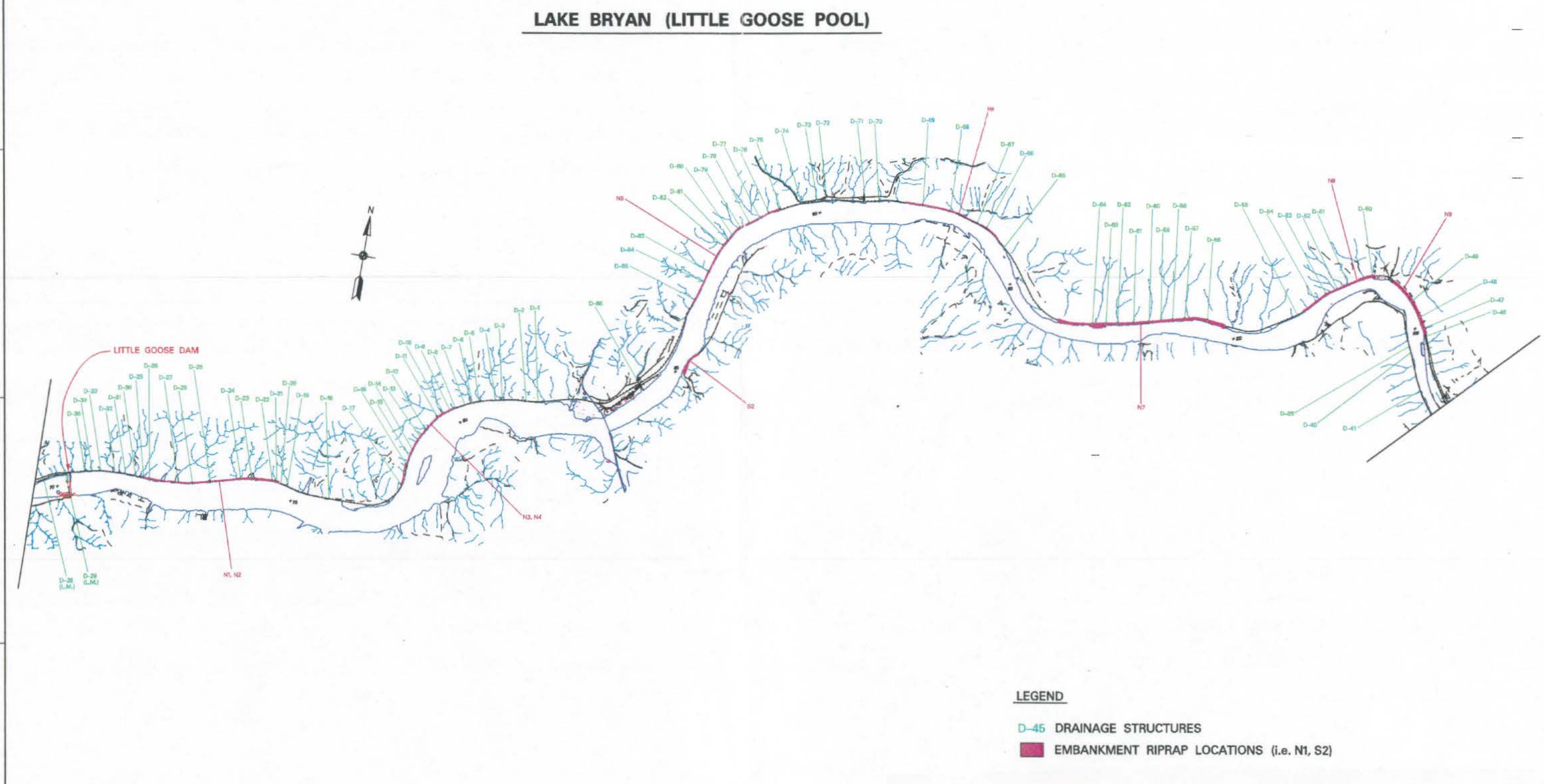

Figure 2-9c. Snake River – General System Arrangement: Lake Bryan (Drainage Structures)

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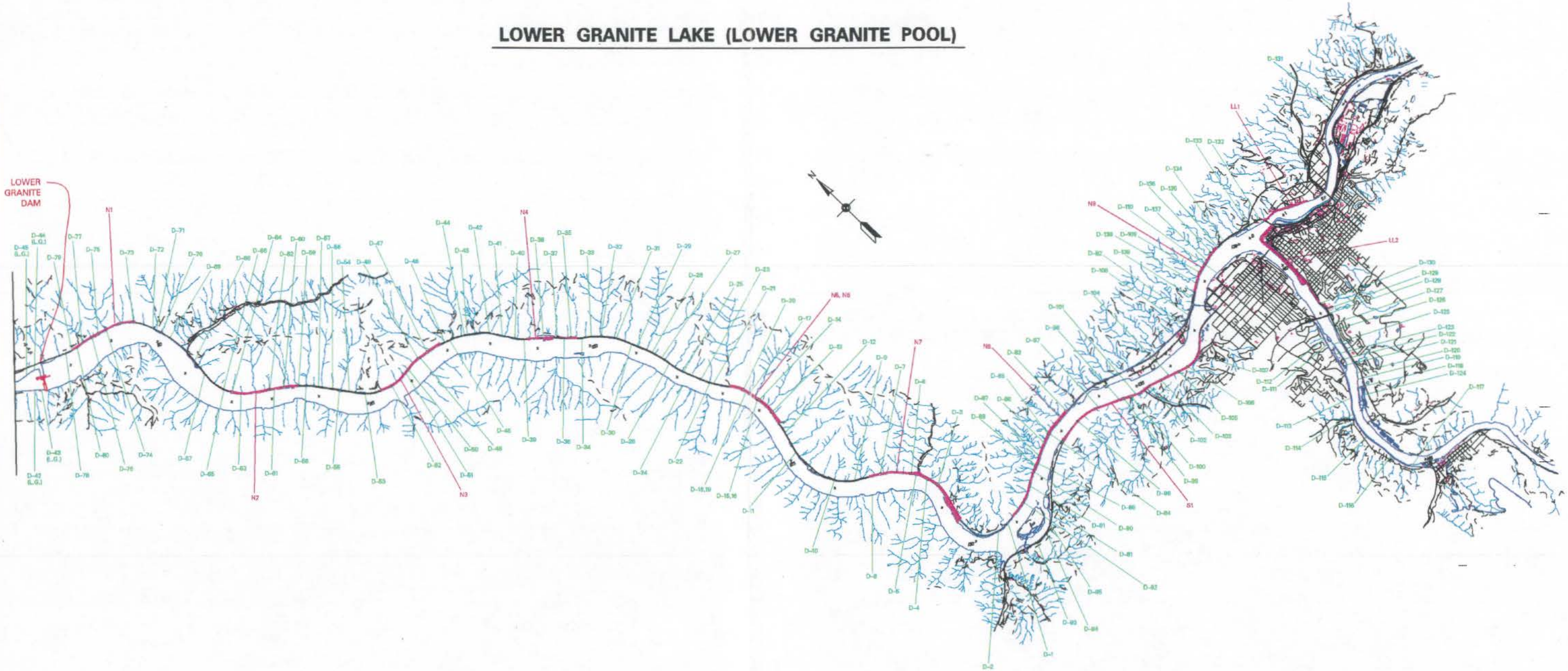
LOWER GRANITE LAKE (LOWER GRANITE POOL)



LEGEND

D-45 DRAINAGE STRUCTURES

EMBANKMENT RIPRAP LOCATIONS (i.e. N1, S2)

Figure 2-9d. Snake River – General System Arrangement: Lower Granite Lake (Drainage Structures)

VALUE ENGINEERING PAYS | CONT. NO.

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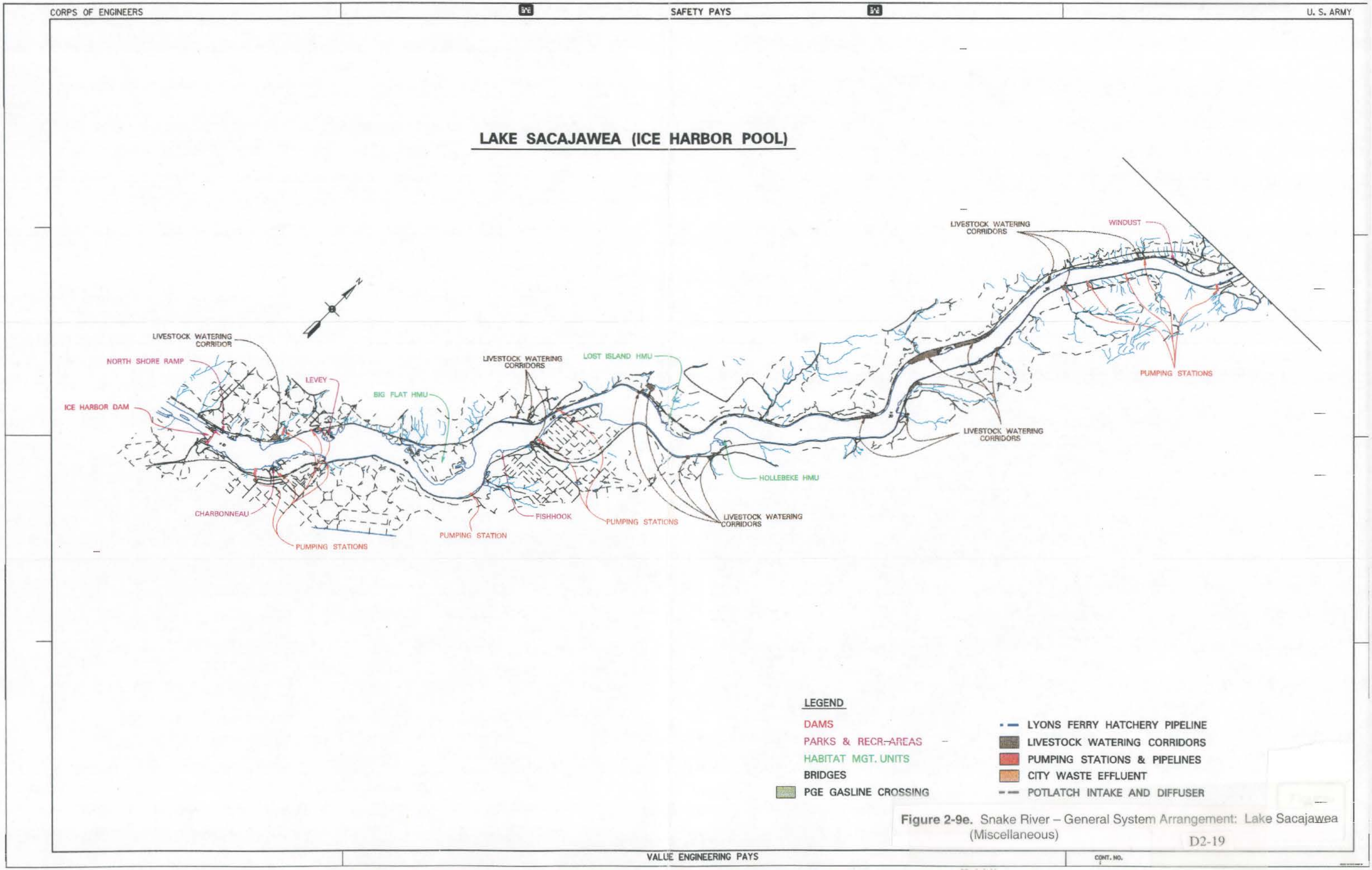

Figure 2-9e. Snake River – General System Arrangement: Lake Sacajawea (Miscellaneous)

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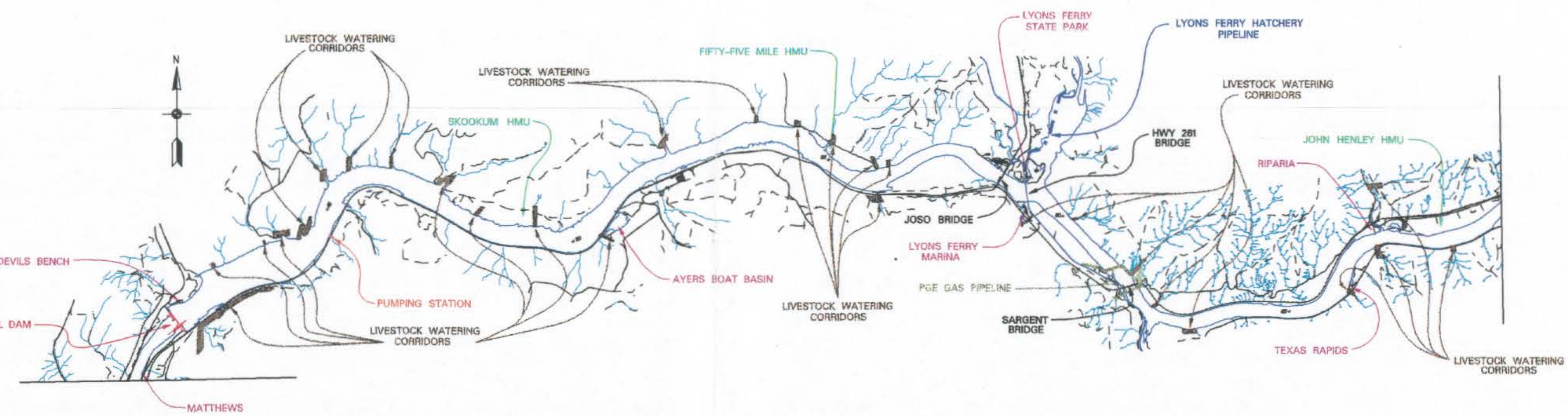
LAKE WEST (LOWER MONUMENTAL POOL)



LEGEND

DAMS	LYONS FERRY HATCHERY PIPELINE
PARKS & RECR. AREAS	LIVESTOCK WATERING CORRIDORS
HABITAT MGT. UNITS	PUMPING STATIONS & PIPELINES
BRIDGES	CITY WASTE EFFLUENT
PGE GASLINE CROSSING	POTLATCH INTAKE AND DIFFUSER

Figure 2-9f. Snake River – General System Arrangement: Lake West (Miscellaneous)

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REFERENCE FILES : PEN TABLES : MAIN SCALE :

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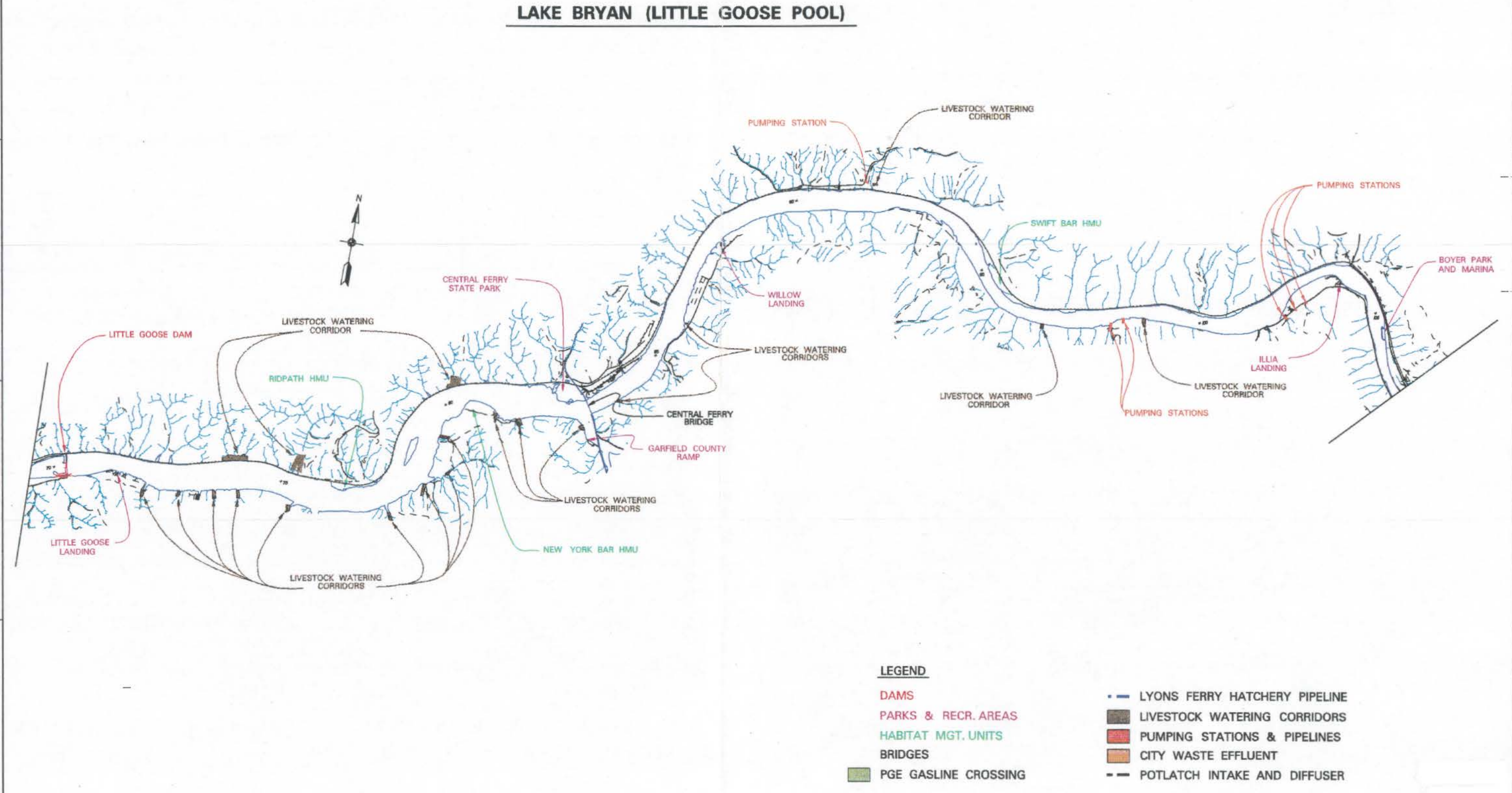

Figure 2-9g. Snake River – General System Arrangement: Lake Bryan (Miscellaneous)

VALUE ENGINEERING PAYS | CONT. NO.

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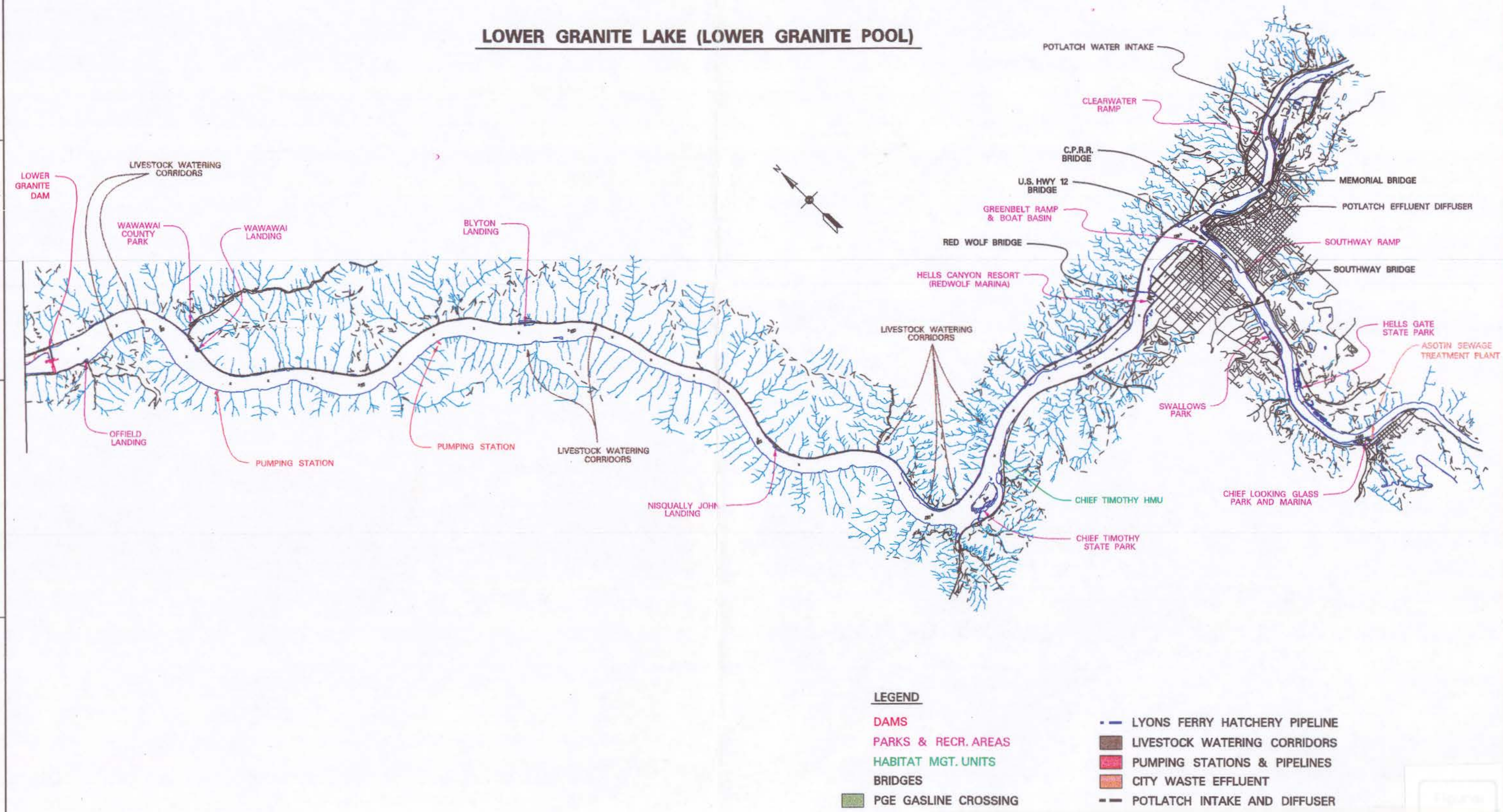


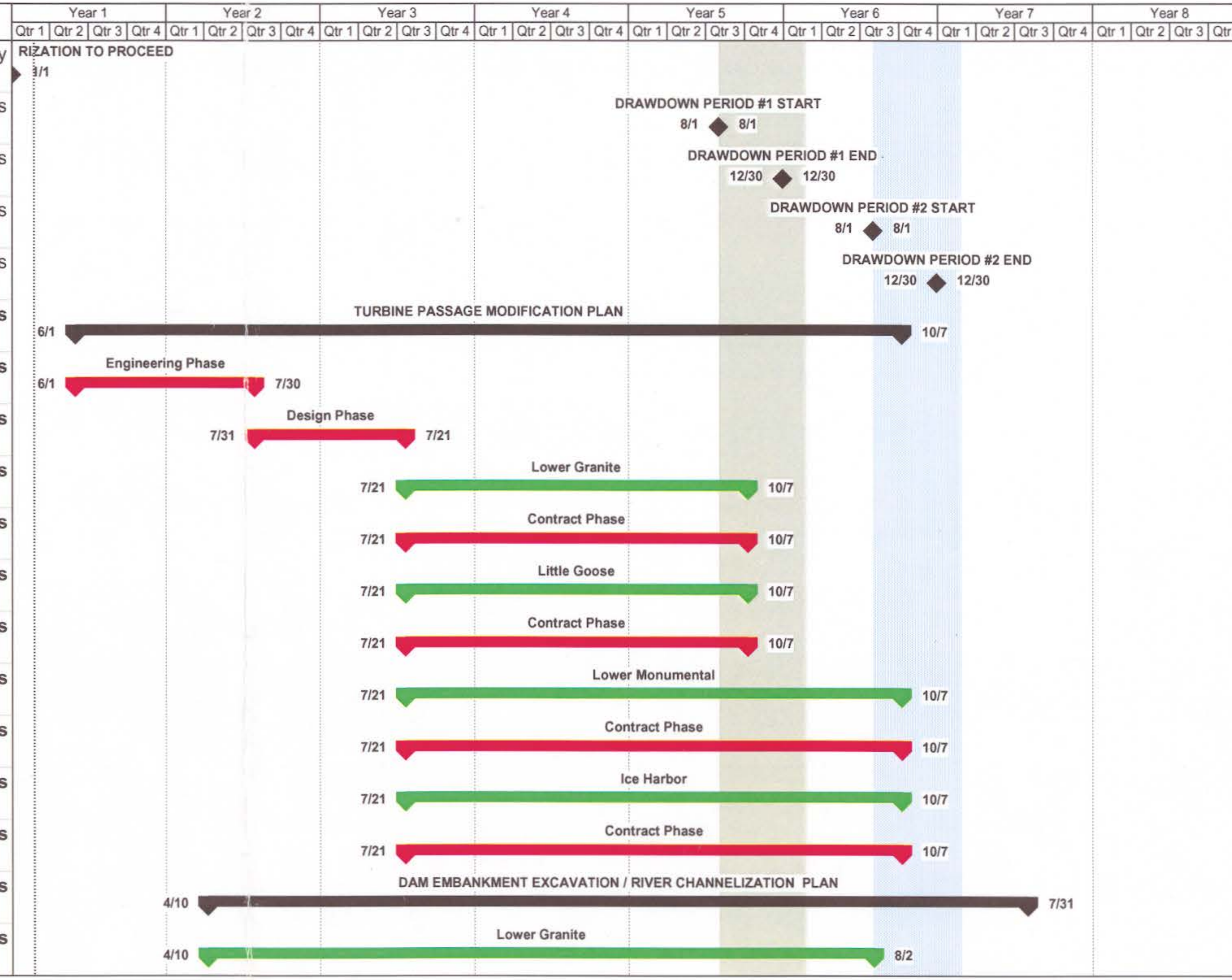
Figure 2-9h. Snake River – General System Arrangement: Lower Granite Lake (Miscellaneous)

VALUE ENGINEERING PAYS | CONT. NO.

REFERENCE FILES : PEN TABLES : MAIN SCALE : DESIGN FILENAME:

Figure 2-10
Drawdown Implementation Schedule

ID	Task Name	Duration
1	CONGRESSIONAL AUTHORIZATION TO PROCEED	1 day
2	DRAWDOWN PERIOD #1 START	0 days
3	DRAWDOWN PERIOD #1 END	0 days
4	DRAWDOWN PERIOD #2 START	0 days
5	DRAWDOWN PERIOD #2 END	0 days
6	**TURBINE PASSAGE MODIFICATION PLAN**	**1694 days**
7	**Engineering Phase**	**364 days**
11	**Design Phase**	**304.2 days**
14	**Lower Granite**	**696.8 days**
15	**Contract Phase**	**696.8 days**
28	**Little Goose**	**696.8 days**
29	**Contract Phase**	**696.8 days**
42	**Lower Monumental**	**1025.8 days**
43	**Contract Phase**	**1025.8 days**
56	**Ice Harbor**	**1025.8 days**
57	**Contract Phase**	**1025.8 days**
70	**DAM EMBANKMENT EXCAVATION / RIVER CHANNELIZATION PLAI**	**1685.5 days**
71	**Lower Granite**	**1368 days**

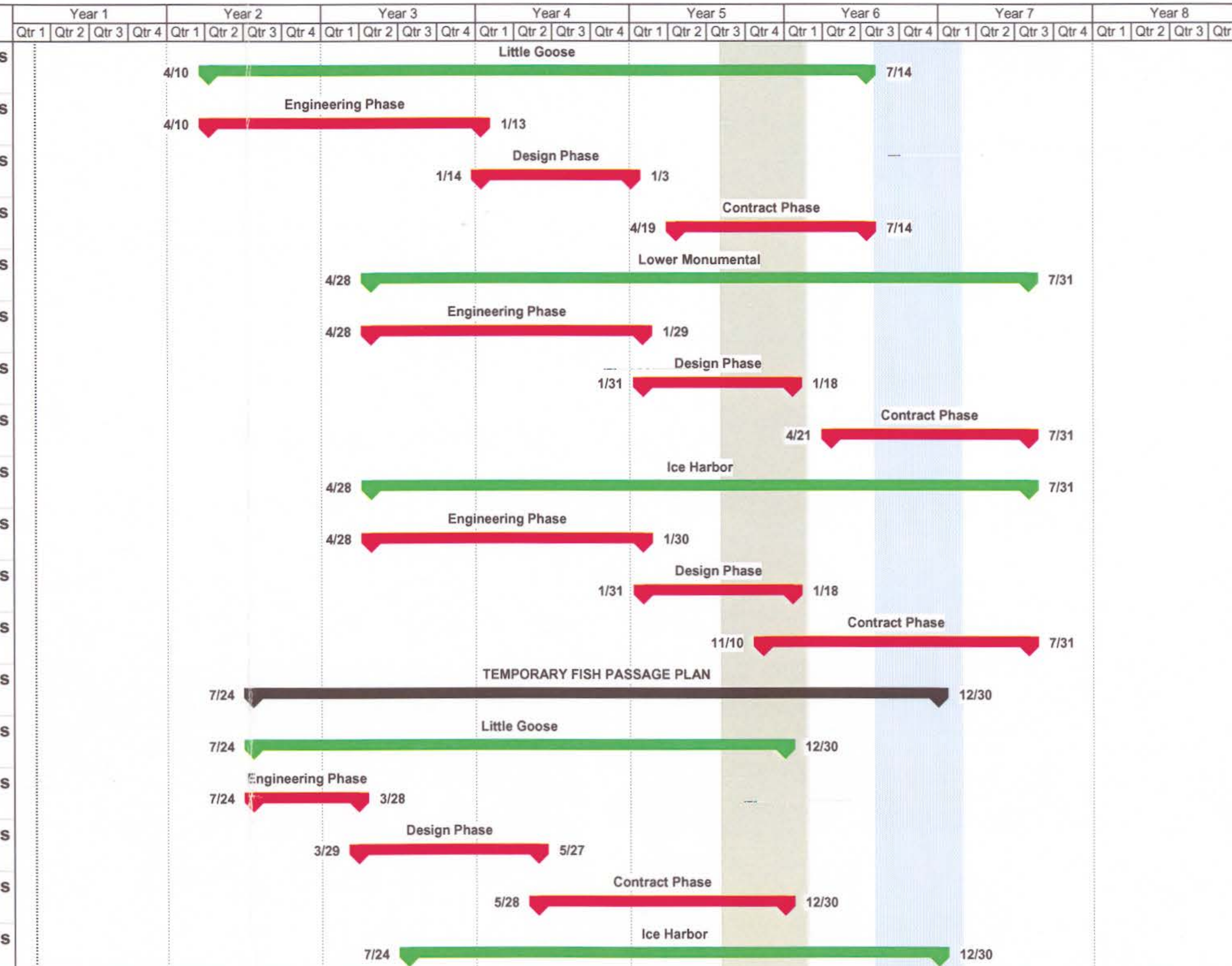


Project: Drawdown Implementation Schedule
Date: Thu 2/22/01

Legend: Task; Split; Progress; Milestone; Summary; Rolled Up Task; Rolled Up Split; Rolled Up Milestone; Rolled Up Progress; External Tasks; Project Summary

Figure 2-10
Drawdown Implementation Schedule

ID	Task Name	Duration
108	Little Goose	1350.5 days
109	Engineering Phase	552 days
113	Design Phase	304.2 days
116	Contract Phase	403.5 days
145	Lower Monumental	1357.5 days
146	Engineering Phase	552 days
150	Design Phase	305.5 days
153	Contract Phase	409.5 days
183	Ice Harbor	1357.5 days
184	Engineering Phase	552 days
188	Design Phase	305.5 days
191	Contract Phase	560.5 days
221	TEMPORARY FISH PASSAGE PLAN	1414 days
222	Little Goose	1079 days
223	Engineering Phase	213 days
226	Design Phase	365 days
229	Contract Phase	501 days
235	Ice Harbor	1101 days



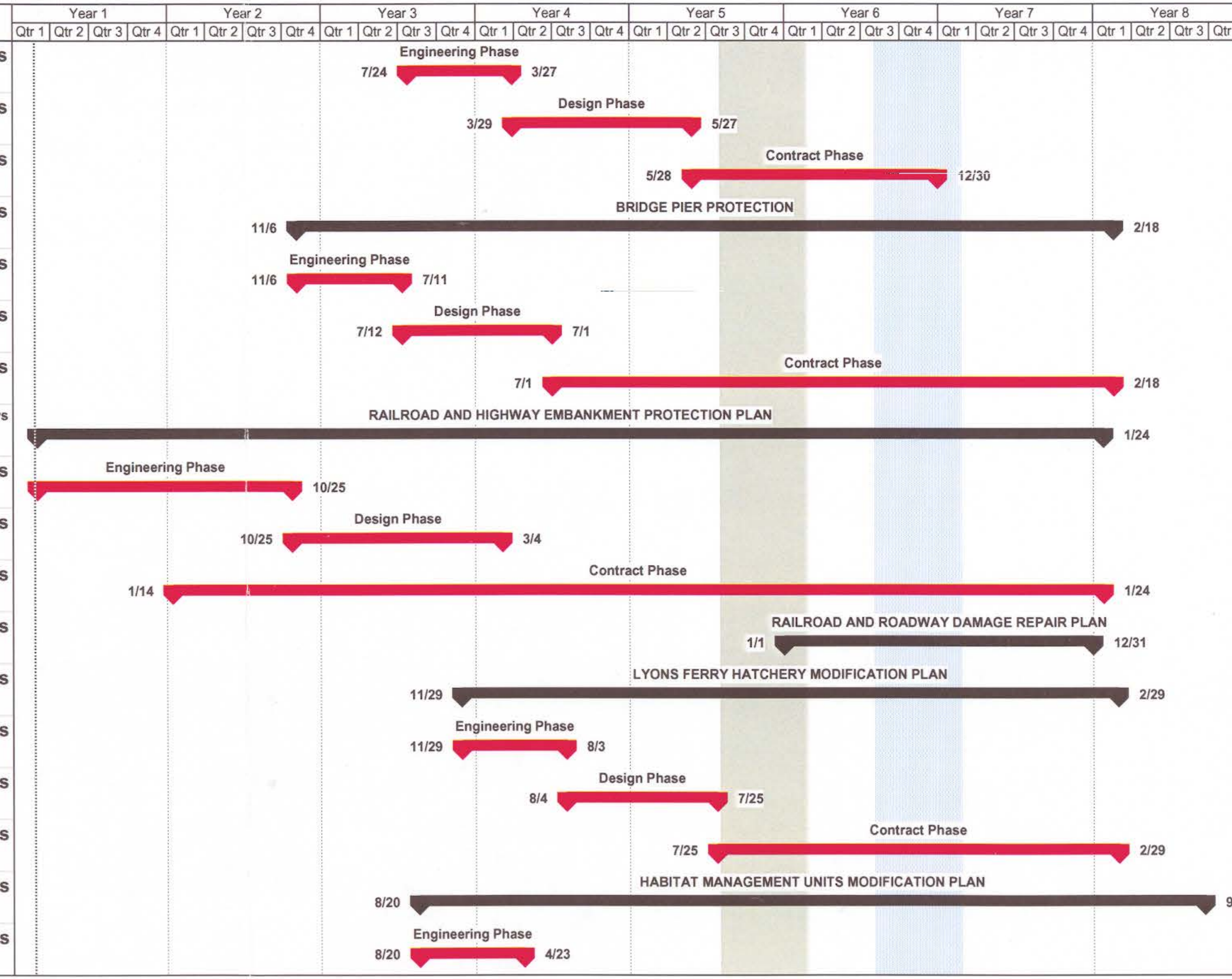
Project: Drawdown Implementation Schedule
Date: Thu 2/22/01

Task		Progress		Summary		Rolled Up Split		Rolled Up Progress	
Split		Milestone		Rolled Up Task		Rolled Up Milestone		External Tasks	

Project Summary

Figure 2-10
Drawdown Implementation Schedule

ID	Task Name	Duration
236	Engineering Phase	213 days
239	Design Phase	365 days
242	Contract Phase	523 days
248	BRIDGE PIER PROTECTION	1678.3 days
249	Engineering Phase	213 days
252	Design Phase	304.2 days
255	Contract Phase	1161.1 days
277	RAILROAD AND HIGHWAY EMBANKMENT PROTECTION PLAN	2185 days
278	Engineering Phase	517.1 days
283	Design Phase	425.9 days
286	Contract Phase	1911.3 days
317	RAILROAD AND ROADWAY DAMAGE REPAIR PLAN	647 days
318	LYONS FERRY HATCHERY MODIFICATION PLAN	1355.1 days
319	Engineering Phase	213 days
322	Design Phase	304.2 days
325	Contract Phase	837.4 days
336	HABITAT MANAGEMENT UNITS MODIFICATION PLAN	1618 days
337	Engineering Phase	213 days

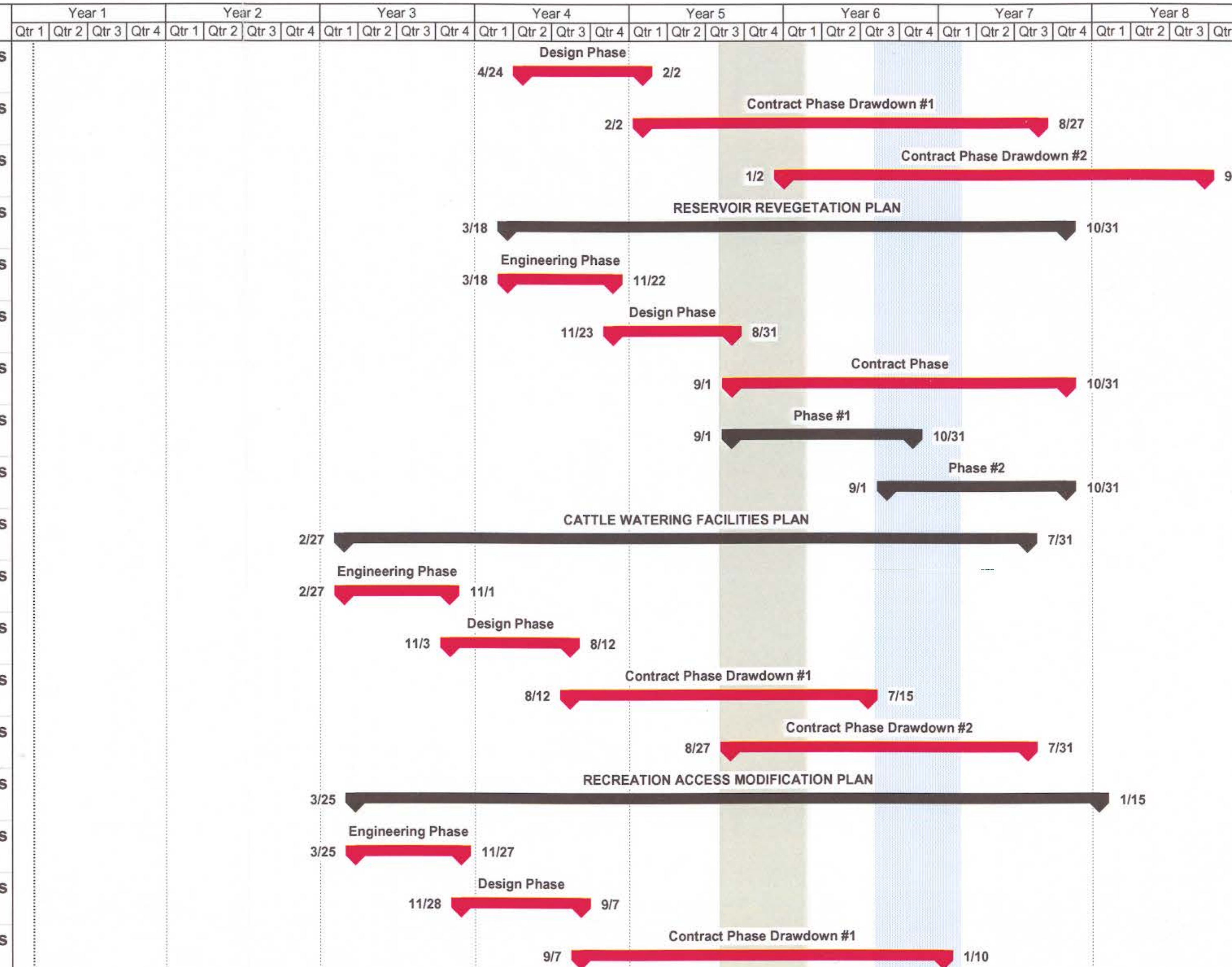


Project: Drawdown Implementation Schedule
Date: Thu 2/22/01

Task	Progress	Summary	Rolled Up Split	Rolled Up Progress	Project Summary
Split	Milestone	Rolled Up Task	Rolled Up Milestone	External Tasks	

Figure 2-10
Drawdown Implementation Schedule

ID	Task Name	Duration
340	Design Phase	243.4 days
343	Contract Phase Drawdown #1	826.6 days
349	Contract Phase Drawdown #2	873 days
355	**RESERVOIR REVEGETATION PLAN**	1157.7 days
356	Engineering Phase	213.7 days
359	Design Phase	243.7 days
362	Contract Phase	700 days
363	Phase #1	384 days
367	Phase #2	371 days
371	**CATTLE WATERING FACILITIES PLAN**	1408.5 days
372	Engineering Phase	213 days
376	Design Phase	243.4 days
379	Contract Phase Drawdown #1	618.6 days
385	Contract Phase Drawdown #2	624.5 days
391	**RECREATION ACCESS MODIFICATION PLAN**	1531 days
392	Engineering Phase	213 days
395	Design Phase	243.4 days
398	Contract Phase Drawdown #1	757.6 days

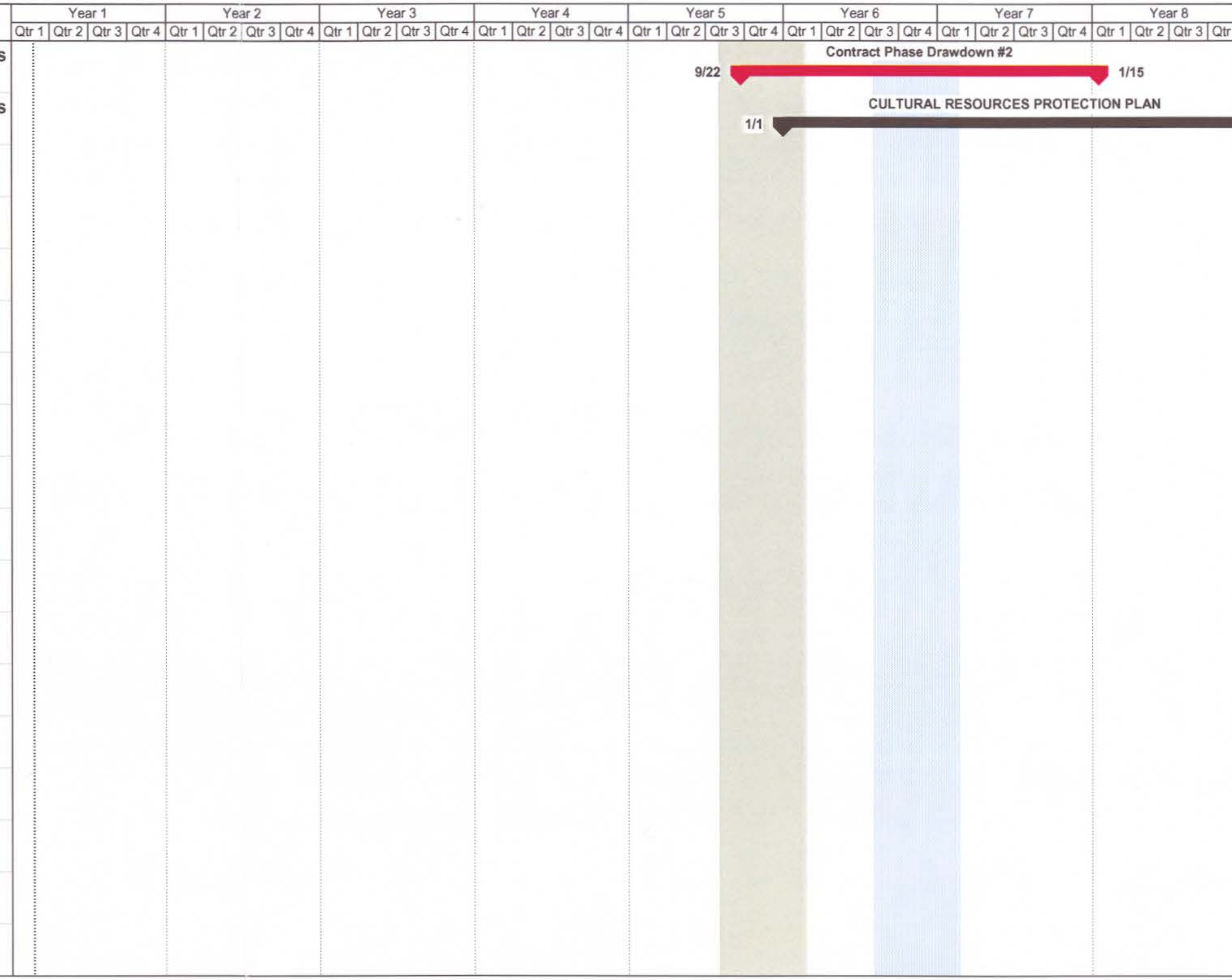


Project: Drawdown Implementation Schedule
Date: Thu 2/22/01

Legend					
Task	Progress	Summary	Rolled Up Split	Rolled Up Progress	Project Summary
Split	Milestone	Rolled Up Task	Rolled Up Milestone	External Tasks	

Figure 2-10
Drawdown Implementation Schedule

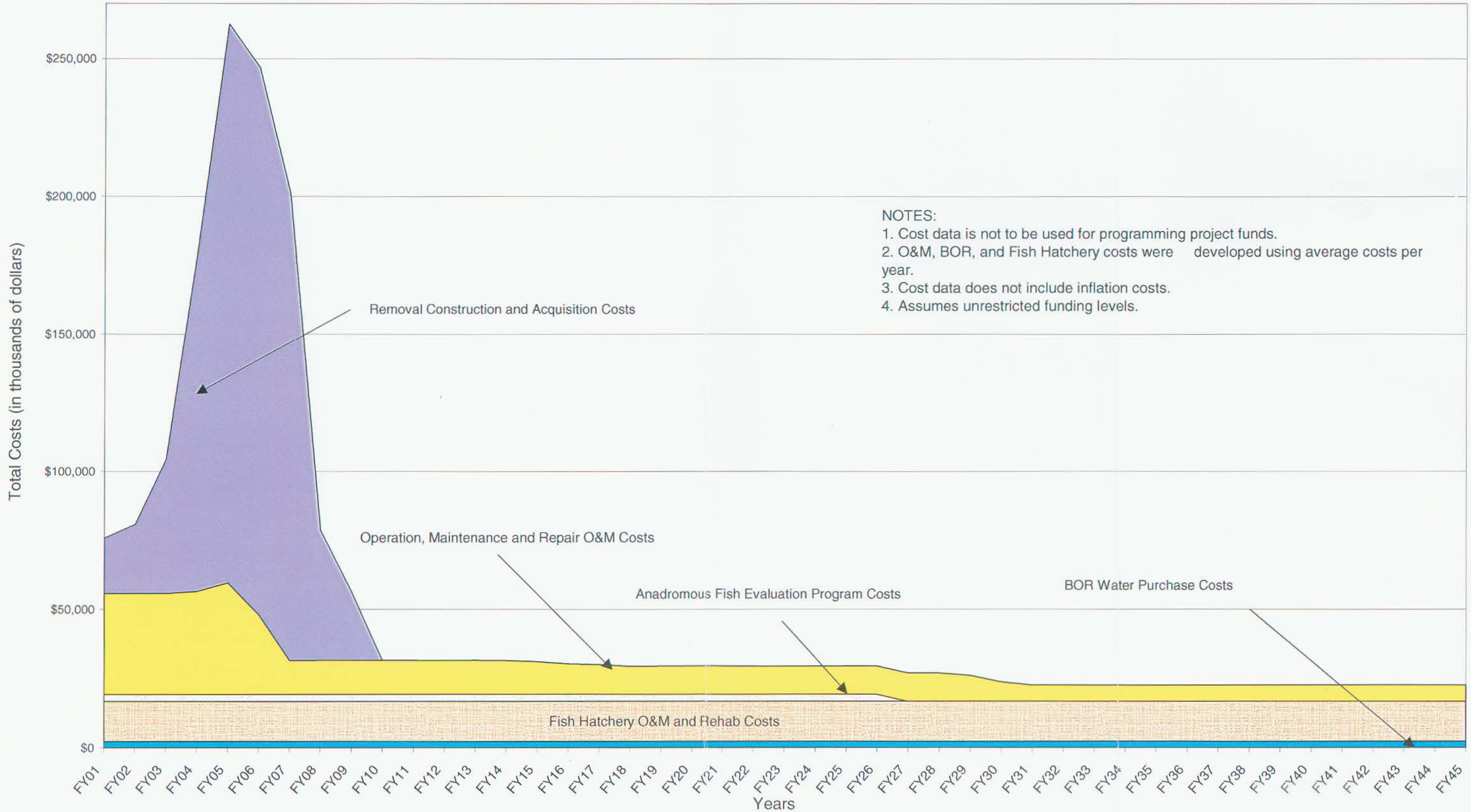
ID	Task Name	Duration
403	**Contract Phase Drawdown #2**	**747 days**
408	**CULTURAL RESOURCES PROTECTION PLAN**	**961 days**



Project: Drawdown Implementation Schedule
Date: Thu 2/22/01

Legend: Task, Split, Progress, Milestone, Summary, Rolled Up Task, Rolled Up Split, Rolled Up Milestone, Rolled Up Progress, External Tasks, Project Summary

IMPLEMENTATION STUDY PROFILE
Drawdown Dam Removal, Channel Bypass
Option A-3a OR Alt. #4
(Earth Portion of Dam, Removal Option)



NOTES:
1. Cost data is not to be used for programming project funds.
2. O&M, BOR, and Fish Hatchery costs were developed using average costs per year.
3. Cost data does not include inflation costs.
4. Assumes unrestricted funding levels.

Figure 2-11. Economic Study Profile: Option A-3A, Drawdown Dam Removal

3. Critical Criteria for Concept Design

This engineering study for implementation of Dam Breaching is based on a number of criteria, assumptions, and key considerations. Three primary goals were established. The first primary goal is to provide a system that operates in a manner that improves fish passage conditions. Structural modifications and construction operations must be structured so that fish benefit over the long term. However, some short term conditions may not provide ideal conditions for fish migration. A second primary goal is to develop modifications that provide satisfactory fish passage at a reasonable minimum cost. Those includes preventing conditions that may result in significant maintenance costs at a later date. The third primary goal is to develop modifications and the associated construction operations that are reasonable, safe, and constructible. Specific criteria resulting from the primary goals are as follows:

- Continuous Fish Passage
  Since the purpose of drawdown is to improve the passage of juvenile stocks, construction activities will be orchestrated in a manner to ensure, so far as possible, that ongoing fish passage is not adversely affected. Many in-water construction operations will be scheduled to be done during the in-water work window.

- No Catastrophic Drawdown
  The evacuation of the reservoirs will be done at a fixed rate of 0.6 meter (2 feet) per day. A higher rate could cause significant slope failures in the reservoirs, putting highways and railroads out of service. Further detailed evaluation of slope materials may allow some modification of this rate. Drawdown rates may vary during the period of drawdown after considering the location of critical embankments relative to the final water surface. An erosion-based method of embankment removal was not considered a feasible option for this study for reasons discussed further in Section 4.2 of this appendix.

- Minimal Cost
  When considering various options for implementing drawdown, the option that satisfies the functional criteria at the lowest cost will be a primary consideration. The goal of this study is to identify the major activities necessary to implement a four-reservoir drawdown and to document a feasible, reasonable method to accomplish those activities.

- Mitigation Measures
  This concept design includes numerous construction activities to implement a drawdown and modify existing structures in the reservoirs. Direct measures are those activities necessary to evacuate each reservoir, remove a portion of the dam structure, and establish a river channel at the project site. In addition to these activities, law or policy requires other activities. These include modifications and repairs to transportation facilities (railroads, highways, etc.) adjacent to and across the river. Legal agreements that allow cattle access to the river for watering purposes require that alternate cattle watering measures be provided. Cultural resources protection is mandated by public law.

  Several discretionary measures are also included since they are authorized under current and anticipated project authorizations. They include modifications to current wildlife lands, modifications to an operating fish hatchery, and measures to provide river access and appropriate recreation facilities.

Measures not authorized under this project are mitigation measures for agricultural, commercial, and industrial users of water, private water wells, utility river crossings, and other commercial and private interests.

- Safety Measures
  The issue of safety will be addressed on several levels. The obvious concerns relate to safety measures implemented for each construction task. Construction activities must be planned and executed in accordance with the Corps of Engineers Safety Manual. This is a comprehensive document that details the requirements to which all construction activities must adhere.

  Safety will be addressed in a more general nature in how the design and construction activities are structured. For example, a critical element in the project design is to develop the risks associated with dam breaching and structure the work to minimize risk of catastrophic failure of the embankment and include provisions to deal with low probability flood waves. In addition, restricting access to the construction areas, the river, and the river shores is part of all construction safety measures. Examples of specific safety issues include, restrictions on boating in the construction areas and restrictions on public access to construction work areas.

4. Reservoir Evacuation Plan

4.1 General Considerations

The four Corps dams on the lower Snake River were constructed without an outlet facility that allows the evacuation of reservoir water to a minimum. Currently, water surface evaluations are controlled over a very narrow range by varying flow through the powerhouse units or varying discharge through the spillway bay. Structural modifications or additions must be done to each project in order to discharge reservoir water outside of this narrow range in a controlled manner. To accomplish a controlled drawdown, the reservoirs can be drafted to near-spillway-crest by discharge over the spillways. To draft the reservoirs below this discharge elevation, a low-level outlet to provide a controlled release of water is necessary so that subsequent structural removal can be accomplished without a significant head of water against the embankment dam structures. Currently water passes the structure through the powerhouse while generating power, when water flows are high or power demands low, water is discharged over the spillways. Water is also discharged over the spillways during the spring and summer months for fish passage. In their current configurations, the projects are incapable of reservoir releases below spillway crest elevation.

In the System Configuration Study (SCS) Phase I report, reservoir releases below spillway crest were planned through construction of a multi-stage cofferdam system that provided a low-level outlet. However, use of sheetpile systems for the anticipated heads and usage was unprecedented, and the foundation conditions might have prevented use of sheetpile systems for such an application. Unfortunately more conventional systems such as excavating a new outlet and gated structure through the embankment, abutment, or concrete structure was not practical given the large quantity of water to discharge at relatively low head.

This study investigated the feasibility of using the existing turbines and turbine passages to discharge water, determined the number of required passages to draft the necessary amount of water, and defined the modifications to the turbine and generator equipment that would be necessary. Controlling the water flows at the varying heads is critical to avoid both short-term structural damage that could lead to a catastrophic release of water, or equally devastating, a reduction in the volume of water passed that would adversely affect the ability to drawdown the reservoir. The turbine passages must operate as outlets during the 46 to 81 day period of reservoir drawdown and continue to operate as outlets until the embankment can be fully excavated to create a new river channel.

As previously mentioned in Section 3, catastrophic release of water in the drawdown is unacceptable. This can occur when embankment removal is performed using explosives or hydraulic erosion. Once water begins to flow over the embankment, the water erodes the embankment material and very shortly removes the embankment. To breach the embankments while impounding a high head would lead to rapid embankment erosion, uncontrolled erosion, and a high rate of water level drop. Rapid drawdown rates would cause serious damage to railroads and high embankments in the reservoir. The rapid embankment erosion could also harm fish passage. Furthermore, there is significant evidence that an erosion-based method of embankment removal would not achieve complete removal of the embankment material. Uncontrolled hydraulic excavation of the material could result in an unsatisfactory channel configuration that would have obstructed access and be difficult to excavate.

The related issues of risk and contingency planning are discussed in various sections of the annexes. After more detailed designs have been established for turbine modifications and the subsequent structures removal and structural stabilization in the reservoir, a more clear picture of the weak elements can be determined. At that time a series of analyses will be performed establishing the probabilities of certain events and failures leading to a quantification of the risk. With risk established, contingency plans can be established for many of the activities to assure that the range of possible problems do not derail the drawdown and protection process.

4.2 Period of Drawdown

Currently, the in-water work window is designated by the National Marine Fisheries Service (NMFS) as December 15 through March 15 of each year. This is the period of time during the year when work activities would impact the least number of fish migrating in the river. However, this time period is not sufficient to perform all the construction activities necessary to produce the new river channel. Furthermore, considering the high probability of excessive river flows during this period, reservoir drawdown must be performed in advance of this period. Otherwise, the risk of catastrophically breaching the embankment is high.

Use of existing turbine passages with proposed modifications for drawdown provides a total discharge capacity of approximately 1,700 cubic meters per second (m^3/s) (60,000 cubic feet per second [cfs]). Snake River flows are below 1,700 m^3/s (60,000 cfs) during only a limited time period. When considering the probabilities of flows exceeding this threshold value, turbine passage usage can only occur during the months of August through December of any year. The probability of flows exceeding 1,700 m^3/s (60,000 cfs) during January are calculated to be 20 percent (termed “the 20-percent chance annual frequency”) and increase significantly through the winter and spring.

Drawdown and concurrent embankment excavation must be initiated shortly after the end of the spill season, when river flows recede to below 1,700 m^3/s (60,000 cfs), and must be completed by the end of December for each project.

4.3 Hydraulic Studies

Initial concepts for reservoir evacuation included the installation of multiple outlets in one or more powerhouse bays, replacing the existing turbines and generators. Such a modification resulting in significant loss of power production and a great potential for consequent increase in spillway discharge. The resulting high saturated gas levels in the river from increased spill can have devastating effects on fish. Alternate concepts were developed where the existing turbine passages and equipment could be utilized as discharge outlets. A number of evaluations were necessary to confirm this approach.

Turbine operating characteristics for the anticipated conditions during drawdown were determined using an operating scale model of a turbine at Voest-Alpine MCE Corporation in Linz, Austria. Hydraulic model studies were also performed at the Corps’s Waterways Experiment Station (WES) in Vicksburg, Mississippi, using a 1:25 section model of a Lower Granite Dam turbine passage to establish the hydraulic characteristics of the passage when the blade had been removed from the turbine. These studies led to the conclusion that, for reservoir flows up to approximately 1,700 m^3/s (60,000 cfs), a reservoir drawdown could be accomplished using the turbines and turbine passages. For the higher head condition, up to three turbines would be operated as the reservoir dropped over a range of 6 meters to 12 meters (20 feet to 40 feet), which is 15 meters to 21 meters (50 ft to 70 ft) below normal operating range. At the lower elevations, flows would shift to the remaining three turbine passages, from which the turbine blades would have been previously removed. These three passages provide the low-head discharge.

The major modifications required for this process at each project include possible installation of alternate cooling water sources and plumbing, modification to existing intake gates, construction of draft tube bulkheads to facilitate turbine operations at low water elevations, and removal of three turbine blades from the turbine units.

At this stage of the reservoir evacuation, the reservoir would be at the lowest elevation possible through turbine discharge. It is estimated that the remaining head on the embankment cofferdams would be between 4 meters and 7 meters (12 feet and 22 feet). This is the head differential that would be present during final excavation of the embankments.

4.4 Turbine Modification and Operation Plan

Modifications to turbines and associated equipment would be necessary to allow the use of the turbine and passages to function as outlets. Modifications must be completed well in advance of drawdown. However, some turbine capacity must be maintained during the previous spill season in order to aid in controlling the saturated gas levels in the river. Excessive spillway use raises saturated gas levels to unacceptable levels. Modifications must be scheduled so that turbine use is maximized and spillway use is limited to acceptable timeframes.

The operating turbine and generator serve to dissipate the energy of a high head and allow the passage of a significant volume of water. In order to make the turbines operate at lower heads than the current operating head, numerous modifications must be made. At each project, three turbine units must be modified to operate over a range of low head conditions. These modifications are as follows:

- Emergency Closure Devices
  Existing emergency closure devices should be in operating condition. The use of these gates is only in the event that conditions develop that could cause failure of the water outlet process and the purpose is to isolate that turbine passage. Currently, the intake gates at each project are either raised (with the hydraulic operators disconnected) or removed for improved fish passage purposes. During a reservoir drawdown, the fish screens would be removed. The intake gates should be connected to the hydraulic operators and stored in the normal position, ready for emergency use. Rebuilding the refurbishing hydraulic operators, controls, gate seals, and other gate features is required to upgrade the emergency closure devices for operation under drawdown conditions.

- Cooling Water System
  The cooling water supply system for turbines and generators must be modified to operate under a variable head condition during drawdown. There are two broad categories of water that need to be provided depending on absolute pool level and whether generation is necessary. The first category is the water required for thrust- and guide-bearing cooling, gland water, air compressors, station service transformers, and heat pumps for cooling the control and computer rooms. This water is required as long as the units are turning, whether they are generating or not. The bearing cooling water can be shut off if the units are stationary. The second category is for cooling water for the air coolers in the generating unit. This cooling water is required only if the generating units are operating. The generating unit transformers are air-cooled.

- Trash Rack Modifications
  Investigation is necessary to assure that the trashrack structures are adequate for debris loads over the range of head pressures to which they will be subject. Some strengthening has been assumed to be necessary for drawdown conditions. The trash racks should be inspected and repaired as necessary prior to drawdown. A significant effort will be required to keep the trash racks clear of debris during drawdown.

- Draft Tube Bulkheads
  When more than one project is drawn down at once, the tailwater of the upstream project will drop significantly. For example, normal minimum tailwater at Lower Granite is el. 193 meters (el. 633 feet). If Little Goose reservoir is also drawn down, the tailwater at Lower Granite will fall to about el. 190 meters (el. 624 feet). This drop in tailwater will cause serious cavitation problems for the turbines. One way to avoid these problems is to partially lower the draft tube bulkheads to a fixed location to create an orifice in the draft tube. This would increase head losses and create an artificial tailwater for the turbines. The loading on the bulkheads and supporting structures would be in the opposite direction from how they were designed, and the forces would no longer be just static loading. A more complete structural analysis would need to be completed before implementing this action. A hydraulic evaluation is also necessary to determine the operating characteristics of these bulkhead and the related operators and controls. Each project only has one set of draft tube bulkheads, so additional bulkheads for the remaining five units would need to be purchased.

- Turbine Blade Removal
  Up to three turbines at each project will require removal of the turbine blades to operate as bladeless runners. This will allow maximum discharge of water through the turbine passages at low heads. Removal is expected to be done several months in advance of drawdown by cutting the blades and removing them through the intake slot or out through the draft tube. The alternate process of unstacking the generator and removing the turbine is too time consuming and too expensive if lost power is considered.

- Performance Instrumentation
  Instrumentation is necessary to monitor conditions of the turbine during out-of-the-ordinary operations. The instrumentation identifies developing conditions that may lead to a failure of the system and may prevent the necessary discharge of water. Early warning provided by instrumentation allows operators to react and implement contingency plans. Instrumentation should measure acceleration, shaft run out, increased leakage, bearing temperatures, structural and mechanical vertical displacement, and pressures at the head cover, intake, and draft tube man doors. There should also be instrumentation installed to detect runner blade impact on the discharge ring.

- Operation
  Detailed procedures would be developed to operate the turbine and generator equipment in the unusual mode. Significant advanced testing is anticipated to establish operational limits and appropriate responses to developing conditions. For example, operation below the speed no load (SNL) condition is possible, but would require direct manual operation. Such operation should only be considered after more critical evaluation. Such operation would require an operator at each turbine to adjust the wicket gates and monitor the turbine speed and other unit parameters. The turbine generators must be disconnected from the power grid by opening the breakers.

- Contingency Plans
  In the event that equipment fails to operate as expected during the reservoir evacuation, contingency plans must be in place in order to continue the drawdown process and complete the embankment breach. Typical contingent operations might be operating turbine units manually at or below speed-no-load status, breaching the embankment cofferdams at higher heads, and/or utilizing a modified intake gate for regulated flow through the turbine passages. The development of specific contingency plans is beyond the scope of this study.

A detailed report on the Turbine Passage Modification Plan is provided in Annex A of this appendix.

5. Dam Embankment Removal Plan

5.1 General Considerations

Each of the four lower Snake River dams is a composite dam comprised of several sections. Each consists of concrete non-overflow sections, powerhouse section, spillway section, navigation lock, and an embankment section. Figure 3 through 10 provide a plan view drawing of each project and an aerial photograph of each project.

A screening-level evaluation was made of several methods for dam breaching. The methods considered were:

- Modify the spillway bays to serve as outlets by removal of ogee sections
- Modify the navigation lock to serve as an outlet by removal of the upper sill block
- Modify powerhouse turbine passages to serve as outlets.

It was soon obvious that the critical element in breaching any part of the structure was that an adequate outlet had to be provided in advance of drawdown. Impacts to navigation prevented continued consideration of measures that removed the locks from service at least 1 year in advance of reservoir drawdown. Outlet construction through the powerhouse modifications would remove turbines from service and seriously increase gas levels in the river for the two spill seasons preceding drawdown. Not enough time was available to make spillway modifications, since they must be done during the period between spill seasons.

The second formidable consideration was that the portion of the dam to be removed must be fully removed during the period between spill seasons. Otherwise significant cofferdams are required to isolate the work area and provide a temporary structure that retains a reservoir at a level where spillway features and fish facilities remain operational. It was clear that excavation of the embankment was the only viable method to meet the time constraints. By contrast, removing concrete sections as a means to breach the structure would require much more preparatory activity and significantly more expense, and might require several construction seasons to accomplish the drawdown and return the river to a free flowing condition. Consequently, this study team selected dam embankment removal as the method for breaching the dams.

5.2 Schedule and Risk Constraints

As discussed in section 4.2, drawdown of the reservoirs can only occur during a period of time when river flows are less than the discharge capacity of the project. The probability of overtopping the embankment increases to unacceptable levels beyond 1 January each year and catastrophic failure of the embankment due to overtopping is unacceptable. Reservoir evacuation cannot commence until early August of any year. Embankment removal must follow reservoir evacuation. To avoid catastrophic breaching of the embankment dam, the embankment dam must be full excavated by early January of the same year.

Design and sequencing the drawdown process requires that risks of overtopping the embankments and cofferdams during the construction period be evaluated. A subsequent failure analysis is necessary to route and contain the flood wave to minimize adverse impacts. Such an analysis provides a means to evaluate contingency plans in order to be prepared for schedule delays and extraordinary hydrologic events. Such analyses are critical to the design of this system. Selecting higher contingency costs for specific features of drawdown provides a means to compensate for the absence of such evaluations at this stage of the project.

5.3 Geotechnical Conditions/Considerations

The existing embankment dams consist of silty, impervious core material; sand and gravel shells; filters; and slope protection comprised of rockfill and riprap. The gravel shell materials were obtained from the gravel terrace borrow sources. The gravel terraces consist of sands, gravels, cobbles, and boulders eroded and deposited by glacial outwash flows. The materials are typically rounded to subangular. The volumes of material in the embankment, cofferdams, and abutments that would be excavated from each of the four dams are summarized in Table 5-1.

Table 5-1. Embankment Excavation Quantities

	Quantity (cubic meters)				
Material	Lower Granite	Little Goose	Lower Monumental	Ice Harbor	Total
Core Material	240,200	138,300	78,300	7,500	**464,300**
Gravel Fill (shell), Including Rockfill and Riprap	1,101,700	978,000	675,200	59,500	**2,814,400**
Cofferdams	276,400	263,900			**540,300**
Abutments and Cofferdams			4,567,340	4,199,480	**8,766,820**
Total Volumes[1]	**1,618,300**	**1,380,200**	**5,320,840**	**4,266,480**	**12,585,820**

1/ The quantity of embankment excavation only. This does not include common excavation from the abutments at Lower Monumental and Ice Harbor.

Riprap and rockfill are present on the upstream and downstream faces of the embankment. Riprap and rockfill for original construction were obtained either from designated quarries or from required excavation for the concrete structures. Although core materials are not required for any aspects of the river channelization, the core material would be excavated and stockpiled separately for potential future use. Core materials would be saturated and would dry slowly.

5.4 Excavation Scheme

Once the elevation of the reservoir has reached an acceptable level, excavation of the embankment material would commence. Excavation would be a coordinated effort involving several excavators and supporting off-road hauling vehicles and dozers. The proposed construction schedule and construction cost estimate assume a rate of material excavation ranging from 764 cubic meters (m^3) (1,000 cubic yards [cy]) per hour for the narrow embankment sections near the top of the dam to 4,128 m^3 (5,400 cy) per hour for the wide embankment sections near the base of the dam. The rock slope protection, the rockfill, filter material, and impervious core material would be hauled to stockpile areas on the respective shores. Since reservoir evacuation initially exposes a minimum volume of embankment, full-scale excavation of the embankment dam is not expected to commence until 4 to 5 weeks later. This operation, using standard high-capacity construction equipment, is expected to easily catch up and keep pace with the reservoir drawdown.

The embankment would be excavated to the foundation, approximately 5 meters (15 feet) below the natural water surface elevation, leaving material in place at the upstream and downstream zones to serve as cofferdams. The Lower Granite and Little Goose embankment dams were constructed with cofferdams that were incorporated into the embankment. With minor modification, these zones could serve as cofferdams again. At Lower Monumental and Ice Harbor Dams, designated zones to act as cofferdams were not previously used as cofferdams. Additional material modifications are anticipated to stabilize these embankment sections.

With the majority of the fine material removed from the river section, the cofferdams would be systematically removed using excavators and draglines. Material would be handled in two groups: 1) silt would be disposed apart from the sands and gravels, and 2) riprap might be stripped from the surface and utilized elsewhere if the rock size were appropriate. Disposal site and stockpile locations for each project have been identified within a 3.2-kilometer (2-mile) haul distance of the excavation.

Because of the permanent upstream pool, upstream gravel and filter zones and the central core are in a saturated condition. The developed production rates for equipment groups account for problems associated with handling saturated materials. Fortunately, the gross quantity of silt core is approximately 12 percent of the total quantity excavated. Specific issues related to handling and stockpiling materials will also need to be addressed. Preparation of disposal areas and haul roads will be done well in advance of the start of drawdown.

The volume of material to be excavated is summarized in Table 5-1. The duration of embankment excavation at Lower Granite and Little Goose dams would be 28 and 21 days, respectively. Cofferdam removal requires an additional 25 days all of which to be done during and following reservoir drawdown. The duration of embankment excavation at Lower Monumental and Ice Harbor dams would be 55 and 61 days, respectively. Cofferdam removal requires an additional 20 to 30 days. The embankment configurations at Ice Harbor Dam and Lower Monumental Dam would require extensive excavation and railroad relocation to form an adequate channel for fish passage. The excavation of abutment and downstream channel sections would be done in advance of drawdown.

The initial breach of each cofferdam would be excavated with a hydraulic excavator or by dragline. The water flow through the breach would erode the silty, sandy , and gravel materials. The downstream cofferdam would be breached first. The head differential across the cofferdam would stabilize quickly and removal of the rest of the cofferdam by dragline could proceed. Breaching the upstream cofferdam would be much more dramatic. The 4- to 7-meter (12- to 22-foot) head differential would result in significant flow velocities that might readily scour the embankment material in the breach section. A breach section of at least 15 meters (50 feet) and up to 33 meters (100 feet) is anticipated. Once the differential head had equilibrated, excavation of the remaining cofferdam would proceed. It is likely that further erosion of cofferdam material might occur during excavation.

A detailed discussion of the Dam Embankment Excavation Plan is provided in Annex B of this appendix.

5.5 Temporary Fish Handling Facilities

It is critical that embankment removal be done during the period of low river flows. Generally that period is between July and March. However, the probability of early-winter runoff and winter storms narrow that safe range to August through December. This time period corresponds to the active period of adult Chinook and steelhead migration. Any construction activity during this period that "blocks" the river must include a provision for passage by these adult fish. Once drawdown begins, the existing facilities would no longer be operable, and no passage could occur for up to 90 days until a free flowing channel is established.

Several options were considered for alternate fish passage. The two options determined to be the most feasible were modifying the existing facilities to operate under variable water level conditions or capturing and transporting the adult fish. These two options are described below.

- Facility modifications would involve extending the entrances to fish ladders to the drawdown river channel and providing supplemental “attraction” water in quantity and orientation to attract adult fish to the ladder. Water pumps and appropriate modifications would be added to supply 2 m^3/s (75 cubic feet per second [cfs]) to the fish ladder. An upstream fish conveyance feature must also be added to allow passing fish to slide down from the ladder to the ever lower reservoir.

- The alternate method would collect all the adult fish at Little Goose Dam during the first drawdown season and at Ice Harbor Dam during the second drawdown season. Collected fish would be transported by truck to a release point upstream of the affected area. This process would involve construction of an adequate trap facility at the two projects and the manufacture or modification of up to 26 semi-trailers for what would be, at times, around-the-clock operation.

On the recommendations of the National Marine Fisheries Service (NMFS), the trap and haul options was selected. NMFS considered this method to have a higher probability of success in assuring the migration of adult fish compared to the facilitation of the in-river migration of fish. In-river conditions during the initial drawdown of the reservoirs could create significant migration problems. A detailed discussion of the Temporary Fish Passage Plan is given in Annex C of this appendix.

6. River Channelization Plan

6.1 Hydraulic Considerations

The goal of river channelization is to provide a hydraulic transition for the river flow around the concrete structures remaining in the natural river channel. In some cases the embankment breach is not located in the natural lay of the river. In order for the river to transition around the structures, levees must be installed. Without these levees, the flow conditions around the structure are very unpredictable and could lead to erosion that could prevent the migration of fish during certain flow conditions.

The ultimate determination on the effectiveness of levees in providing a smooth river transition and preventing erosion damage at higher flows will be based on large-scale model studies of each project. Specific details regarding levee geometry and ancillary features cannot be formulated without the use of such a tool. Detailed discussions on the character and transport of sediments are contained in Appendix F, Hydrology Appendix. Detailed discussions on the environmental and biological effects of sediments and contaminants are contained in Appendix C, Water Quality Appendix, Appendix B, Resident Fish Appendix, and Appendix A, Anadromous Fish Appendix.

6.2 Channelization Approach

Hydraulic concerns require the use of channelization levees in forming a natural river. Model studies will determine whether both upstream and downstream levees are necessary. This Lower Snake River Juvenile Migration Feasibility Study (Feasibility Study) assumes that the complete channel around the structures will be formed by a levee.

Once the embankment structure is fully removed, the river must route itself around the concrete structures that remain. In most cases the river has to dogleg back in a manner that is not consistent with the meander of the river. A channelization structure must be added to provide a smooth flow transition for this alternate routing. The goal of this channelization is to provide a smooth transition around the structure so as not to create a condition that may impede fish passage at the full range of operational flows from 600 m^3/s to 5,000 m^3/s (20,000 cubic feet per second [cfs] to 170,000 cfs). In addition, the channel must operate without damage for flows of up to 13,000 m^3/s (450,000 cfs) so that, when water flows recede, the channel remains operational for fish passage.

The channelization levees would be constructed of shotrock manufactured as a by-product of the production of bank protection rock. The levees need not be impervious (except for the option that was developed for the cost estimate in which the concrete structure is removed). They are configured to provide freeboard through the 100-year flood (10,000 m^3/s [350,000 cubic feet per second [cfs]). (Freeboard is the distance the water surface is maintained below the top of the excavation.) The levees for each site require 6,000 m^3 to 8,000 m^3 (200,000 cubic yards [cy] to 300,000 cy) of material to be placed during the time period just following embankment removal and the start of spring runoff, November through March.

In addition to their channel function, the levees would serve as a security barrier to keep people out of the abandoned site. Security fencing will be installed on the levees and linked to the perimeter fencing to prevent entrance to the abandoned site.

6.3 Levee Design

During construction of the four lower Snake River dams, extensive hydraulic model studies were performed on various cofferdam configurations. The cofferdam configurations for Lower Granite, Little Goose, and Ice Harbor dams, the cofferdam configurations were very similar to the proposed levee configurations. Those model studies provide a reasonable basis for comparison to the numerical evaluations of this Feasibility Study.

Construction methods used during construction of the cofferdams are similar to those assumed for the levees in this study. The approach is simply to deposit material from trucks into the river to form a levee section and advance this section from the shore to the structure. Placement of slope protection and any other special features would follow.

There is no need to dewater the area within the levee. As noted earlier, the concrete structures would be abandoned. Ground contours just upstream and downstream of each powerhouse show very deep excavations to facilitate intake and discharge for the powerhouse. These excavations would remain deep pools. If water flow were blocked to the interior of the levee, the water quality in this area might deteriorate to undesirable conditions. Consequently, the levees would be constructed to be permeable. The levee material will allow the passage of water through the levee, creating a slow flow condition within the levee. Passage of water through the structure will facilitate the complete change of water within the levee.

Construction-era cofferdams were primarily natural sands and gravels excavated from borrow sources in and adjacent to the future reservoir. Silts used for the impervious core of these cofferdams was not as common and required significant processing to separate it from sands and gravels. The sand-gravel composition of the cofferdam was satisfactory for a temporary facility where constant monitoring and repair capability was present. That configuration is unsatisfactory for long-term levees subject to flow velocities that can be quite damaging. The levees, therefore, will be constructed of shotrock, that is angular basalt rock ranging up to 300 millimeters (12 inches) in diameter. This material is a byproduct of riprap production necessary for railroad and highway embankment protection (see Annex F for more details). Processing of the several million cubic meters of waste from the riprap production should net sufficient material for levee construction. The required quantity of shotrock will be barged to each project site in advance of drawdown and stockpiled for later use in constructing the levees.

6.4 Fish Passage Features

Under ideal circumstances, the breach in the embankment dams would be sufficient to allow fish passage, as river velocities with flows up to approximately 170,000 cfs would not impede the upstream migration of fish. This appears to be the case for Lower Granite and Little Goose Dams. The velocity conditions through the embankment dam breaches at Lower Monumental and Ice Harbor are higher. Model studies, should design efforts proceed to the next stage, will provide more detailed information on velocity and flow direction at specific locations. Such conditions will necessitate the construction of in-water features to aid fish in migrating through the high velocity reaches.

Criteria for fish passage through this new channel were developed based on published information of appropriate velocity-reach data for various species of fish (FFHA, 1990), (Corps, 1991). Table 6-1 provides the criteria used for locating fish passage features. Simply stated, channel velocities below 1.5 meters per second (m/s) (5 feet per second [ft/s]) require no supplemental fish passage features. Channel velocities above 1.5 m/s (5 ft/s) require features in the river to produce rest areas. The higher the velocity, the more numerous and frequent the rest areas.

Normal river features that provide rest areas are eddies formed by features such as bends, sand, gravel bars, other deposits, and rocks. A range of options are available to provide these rest areas for this new channel. They range from boulders strategically placed along the river to anchored boulders, anchored concrete features, and a full-scale fish ladder. The selection of which feature is most appropriate will also depend on model studies of how each feature functions over the range of river flows.

For this study, it was assumed that a series of precast concrete units, anchored to the river bottom, would provide suitable resting points in the channel and would withstand the forces generated by the range of river flows.

Table 6-1. Required Spacing of Fish Passage Features

Velocity of Flow		Sustained Distance	
(m/s)	(ft/s)	(m)	(ft)
0.6	2		Indefinite
0.9	3		Indefinite
1.2	4		Indefinite
1.5	5		Indefinite
1.8	6	61	200
2.1	7	37	120
2.4	8	24	80
2.7	9	15	50
3.0	10	9	30
3.4	11	6	20
3.7	12	3	10

For flows where velocities do not exceed 5 ft/s, no fish passage enhancements are necessary. As flow velocities increase from 5 ft/s to 12 ft/s, the addition of fish passage enhancements must be done. The spacing of these features ranges from about 200 feet at 5 ft/s to 10 feet for 12 ft/s. Model studies will provide the final verification of performance.

This criterion presumes that flow velocities approaching and exiting the new channel are less than velocities in the channel. The existing concrete structures would create a flow constriction in the channel that increases the velocity. However, if velocities along the bank are more than 1.5 m/s (5 ft/s), channel enhancement features such as anchored boulders that provide eddies and pools could be added along the bank to provide resting locations.

The maximum flow against which adult fish are assumed to swim upstream is 4,813 m^3/s (170,000 cfs), which is approximately the flow within the 2-year return interval.

For more details concerning the River Channelization Plan, see Annex D of this appendix.

7. Other Implementation Plan Modifications

7.1 General Considerations

A wide range of planned modifications and mitigative actions are necessary as a result of reservoir drawdown and are integral parts of the drawdown implementation plan. Modifications to stabilize and repair the infrastructure are addressed in the subsequent sections titled Bridge Pier Protection, Railroad and Highway Embankment Protection, Drainage Structure Protection, and Road and Railroad Damage Repair. Wildlife and habitat issues are addressed under sections on the Lyons Ferry Hatchery Modifications, Habitat Management Unit (HMU) Modifications, Revegetation, and Cattle Watering Facilities. Issues regarding Recreation Access and Cultural Resource Protection are discussed in sections on their respective plans, as follows.

7.2 Bridge Pier Protection

Nine highway or railroad bridges cross the reservoirs and up to 15 bridges cross tributary rivers to the reservoir. Drawdown of the reservoirs would result in high velocity river flows at most of these bridge sites. Because of scour that might result from the high velocity flows, modifications would be required to stabilize the bridge piers and abutments. This study concluded that, based on the boundaries of the natural river and the condition of the existing piers, 25 bridge piers would require stabilization by rock placement or sheetpile installations, in addition to bank protection at each of the bridges.

In general, the modification process would be to access each bridge by barge and install a sheetpile ring around each designated pier. This would be followed by placement of the appropriate fill material within the cells and on the abutment slopes. Final cutting of sheetpile and placement of concrete would be completed after drawdown.

For more details on the Bridge Pier Protection Plan, see Annex E of this appendix.

7.3 Railroad and Highway Embankment Protection

More than 130 kilometers (80 miles) of railroad and highway adjoin the existing reservoirs. Many of these thoroughfares were relocated to their existing location as part of constructing the lower Snake River projects. In some cases, drawdown of the reservoir will not directly impact the function of the road or rail beds, and no modifications are required. The only sections of concern are those sections constructed on engineered fills that will be in direct contact with the natural river. Of the 130 kilometers (80 miles) of railroad and highway embankment which are on engineered fill sections, 72 kilometers (45 miles) would be exposed to river flows at the new lower river elevations. Preliminary assessments indicate that the exposed slopes must be protected with properly sized rock to prevent slope erosion and undermining of the rail or road beds. Because access to many of these locations is difficult and access to some would be impossible after drawdown, the rock needed for the embankments would be transported by barge in advance of drawdown.

It is anticipated that basalt rock for riprap will be processed at three quarry locations. Extensive reconnaissance and exploration would be necessary to establish a viable rock source for the size and quantity of required rock. See Annex F for details and locations. Rock from each site would be used to service an appropriate reach of the river to minimize transportation costs.

Processed rock would be hauled from the quarry to a barge loading area and loaded onto rock barges for transportation. The rock would be transported to several underwater stockpile locations. Stockpile sites have been tentatively located by evaluating the geomorphology data presented in Appendix H, Fluvial Geomorphology. Sites were identified where pre-drawdown and post-drawdown water velocity conditions, water depth, and substrate conditions were least detrimental to migrating and spawning fish. After drawdown of the reservoirs, access to the stockpile locations and bank protection sites would be made using existing roadways and construction-era roadways exposed by drawdown. Nearly 750,000 centimeters (1 million cubic yards) of rock would be needed to provide the required bank protection.

A detailed discussion of the Railroad and Highway Embankment Protection Plan is contained in Annex F.

7.4 Drainage Structures Protection

Concurrent with the efforts to protect embankments, protection would need to be provided for over 400 drainage structures that run through these embankments. These structures were designed to allow passage of water from existing upslope drains through highway and railroad embankments into the reservoirs created by the dams. A majority of the drainage structures require protection on the slope so that discharge water does not erode the embankment. Such protection would be placed during the placement of bank protection rock. Modifications to the existing drainage structures would offer some logistical challenges. Because the drains are spaced far apart, have difficult land access, and require placement of narrow strips of riprap extending down steep slopes, it is not practical to treat these slopes in advance of drawdown. Access to rock and each site would be made using existing roadways and construction-era roadways exposed by drawdown. See Annex G of this appendix for more details regarding the Drainage Structures Protection Plan.

7.5 Railroad and Roadway Damage Repair

In addition to the modifications that are needed in advance of drawdown for certain railroad and roadway embankments, as described earlier, some of these embankments will undoubtedly also be damaged during the drawdown itself. As drawdown occurs, areas of the embankments along the river are anticipated to fail due to steep slopes, saturated soils, and pore pressure increase. The location and extent of embankment failures is extremely difficult to predict based on the uncertainty and variability of materials used in constructing the embankments. Consequently, the study team determined that a prudent estimate of damage could be done based on the recorded embankment damage data from the 1992 drawdown of Lower Granite Reservoir.

Most of the anticipated damage to embankments will occur within the first year following drawdown. Since the lowering of the reservoir is the prime cause of such damage, measures cannot be implemented in advance of drawdown. However, it will be necessary to initiate embankment repairs immediately so that interruption of rail transportation is minimized. A complete discussion of the Railroad and Roadway Damage Repair Plan is provided in Annex H of this appendix.

7.6 Lyons Ferry Hatchery Modifications

The Lyons Ferry Hatchery, at the confluence of the Palouse and Snake rivers, was constructed to serve as mitigation for fish and wildlife habitat lost or altered by construction of the four lower Snake River dams. Fish raised at the Lyons Ferry Hatchery include steelhead, Chinook salmon, and trout for release into the Snake River and its tributaries. This study initially assumed that hatchery operations cannot be fully interrupted by drawdown. This is based on a National Marine Fisheries Service (NMFS) determination that fish hatchery operations will continue in the region during and after drawdown. This is due, in part, to the determination that recovery of fish stocks will not be immediate, but will take several years. However, since groundwater conditions are significantly effected by drawdown, it cannot be determined whether adequate supplies of water will be available after drawdown. Drilling wells in advance of drawdown is not practical.

A total of eight water wells, located adjacent to the reservoir 3.2 kilometers (2 miles) upstream of the hatchery, supply over 114 m^3/min (30,000 gallons per minute [gpm]) of process water for hatchery operations. The water is transported 2,966 meters (9,730 feet) via a 1,524-millimeter (60-inch) diameter concrete cylinder pipe (CCP), 1,920 meters (6,300 feet) of which is submerged in the reservoir and supported by 104 pipe pile bents. When the reservoir is drawn down, the wells may not produce the required quantity of water. New wells, drilled after drawdown, will be needed to compensate for any deficit. The underwater pipe supports are not sufficient to support the supply pipe. Additional pipe bents must be added to stabilize the pipe sections since installing a new pipeline along an alternate pipe routing in advance of drawdown is not feasible. Numerous other modifications are necessary to maintain an operational hatchery. These details are presented in Annex I of this appendix.

7.7 Habitat Management Unit Modifications

There are designated lands along the reservoirs that provide protected wildlife habitat areas to replace lands lost because of the reservoirs. Operation of these areas will continue until such time as the natural habitat develops and eliminates the need for these managed units. There are over 30 HMUs on the river with nine of them intensively managed. Intensive management means primarily that irrigation systems have been installed to water certain lands. Modifications resulting from the drawdown would include re-fencing lands to prevent access to HMUs and reconfiguring irrigation systems to operate under new water surface conditions.

The complete HMU Modifications Plan is presented in Annex J of this appendix.

7.8 Reservoir Revegetation

As the water surface drops, up to 6,000 hectares (14,000 acres) of land will be exposed. Development of native plants on these lands would need to be encouraged and the growth of undesirable plants would need to be discouraged. The timing of drawdown makes planting and seed germination challenging. A systemic aerial application of seed and fertilizer is planned following the drawdown. Additional seeding and willow and cottonwood plantings are planned for subsequent seasons. See Annex K for more details concerning the Reservoir Revegetation Plan.

7.9 Cattle Watering Facilities Modifications

Original land use agreements allowed cattle ranchers access to the reservoir for water for their cattle. In order to honor these pre-existing agreements, new cattle watering facilities would need to be developed. Nearly 70 cattle corridors currently exist on the river. To avoid possible damage by cattle to habitat and spawning areas along the new river, cattle corridors would be grouped where possible and wells would be installed that would provide water via solar powered pumps to stock watering tanks. Fencing would be installed to form a barrier to cattle access to the river banks. The modifications must be done following drawdown when the groundwater conditions have stabilized.

Details of the Cattle Watering Facilities Plan are shown in Annex L of this appendix.

7.10 Recreation Access Modifications

A system of 33 recreational facilities provide numerous sites for camping, boating, moorage, day use, and hiking on the affected reach of the river. While there is no doubt that recreation pursuits will continue after drawdown, the nature of recreation may shift. A plan has been developed to determine what modifications would be necessary to the existing sites based on current assumptions concerning recreational use.

Marinas would be eliminated from the recreation sites. While camping and motor camping would continue, some sites would no longer maintain river access. It is anticipated that 11 sites would be completely abandoned and demolished. Fifteen sites would be modified to discontinue certain activities. At 15 sites, boat ramps or other features would be relocated to better access the new river. New recreation facilities to better meet the evolving opportunities on this river system are beyond the scope of this implementation plan and were not studied.

For more details regarding the Recreation Access Modification Plan, see Annex M of this appendix.

7.11 Cultural Resources Protection

Over 360 known cultural resource sites exist along the river. Several legal and regulatory mandates exist that require protection of these and other identified sites. (See Cultural Resources Appendix N). The sites include villages, campsites, cemeteries, and rock shelters. A range of treatments has been developed depending on the degree of protection and the public accessibility to the site. The Cultural Resources Protection Plan developed for the drawdown would offer protection measures for these sites, as detailed in Annex N of this appendix.

8. Non-Federal Modifications

The majority of the issues previously discussed in this appendix are modifications necessary to implement a river drawdown or modifications necessary as a result of a river drawdown. Those modifications are considered an integral part of the drawdown implementation plan and were included as part of the projects funding requirements.

There are significant other impacts resulting from a river drawdown that are necessary to maintain certain commercial operations or private enterprise, but were not included as part of the projects funding requirements. Several of those are discussed in this section because they either represent a significant engineering and construction effort or are modifications that are similar in nature and scope to modifications that are part of the implementation plan. These items have been considered in the economic analysis. If a Natural River alternative is selected, Congress may or may not choose to fund these non-federal modifications. Estimated costs for the non-Federal modifications are shown in Table 8-1.

Table 8-1. Non-Federal Modifications Summary of Costs, in $1,000

Project	Direct Costs	Contingency	Escalation	Total
Ice Harbor Project				
Irrigation System	$224,216	$67,264	$54,693	**$346,174**
Groundwater wells	$9,188	$9,185	$3,450	**$21,823**
Lower Monumental				
Groundwater wells	$6,233	$6,228	$2,339	**$14,800**
PGE Gasline Crossing	$5,916	$2,071	$1,573	**$9,560**
Little Goose				
Groundwater wells	$3,901	$3,896	$1,461	**$9,258**
Lower Granite				
Groundwater wells	$8,909	$8,906	$3,346	**$21,161**
Private water users	$551	$166	$133	**$851**
Potlatch water intake and effluent diffuser	$7,912	$2,772	$2,091	**$12,775**

Notes:

1. Direct costs include lands, administration, engineering, and construction management.
2. Contingency percentage is specific to each item.
3. Escalation is to mid-point of construction.
4. Private water users are Atlas Sand and Rock, Lewiston Country Club, and Clarkston Municipal Golf Course.

8.1 Irrigation System Modification Plan

There are eight active large-scale pumping plants in the 21-kilometer (13-mile) reach of the Snake River upstream of Ice Harbor Dam. They supply irrigation water for vineyards, orchards, pulp trees, and numerous row crops. Water is required between the months of February and October. The peak demand for water supplied by these pumping plants currently totals 19 m^3/s (680 cubic feet per second [cfs]). This peak demand is required for a sustained period of 2 to 3 months, depending on the weather conditions.

A modified water supply system would be required for irrigation following drawdown. Modifications to each plant were considered, but rejected. They included relocating intakes, adding sedimentation ponds, modifying and replacing pumps. The shallow depth of the natural river, the heavy sediment loads, and the 4.6-to 6.1-meter (15-to-20-foot) fluctuation in river level made individual modifications unreliable. A corporate system using a single intake structure and a pressure pipeline was selected instead. One iteration of concept development was done in order to determine the scope of the modifications. More comprehensive design requires that the system be reconfigured for the actual number of viable water users weighing the specific requirements of individual users.

A 19-m^3/s (680-cfs) water intake would be sited in the narrow river section upstream of the irrigated lands. This narrow, self-scouring reach of the river maintains a water depth of over 12 meters (40 feet) during low flow conditions under natural river flows of 600 m^3/s (20,000 cfs). This intake would consist of five bays with the appropriate trashracks and fish screens. Pumps configured for approximately 30,000 horsepower would be required to supply 19 m^3/s (680 cfs) at flow rates of 2 m/s (8 ft/s) through the piping system at the appropriate pressures. The piping system would consist of 13 miles of pipe with mainline diameters ranging from 3.7 meters to 2.1 meters (12 feet to 7 feet). At two locations, 1,066-millimeter (42-inch) branches would cross the river to provide water to the existing pumping stations on the north shore. The pipeline would interface with individual distribution systems via manifold systems to booster pump stations.

The presence of heavy sediment load in the river water remains a major problem. One alternative is to pump water to a 202-hectare (500-acre) reservoir to provide some silt separation and surge protection for the system. The water is subsequently pumped into the pressure pipe distribution system.

The work would be done in advance of the irrigation season preceding drawdown. Two to 4 years of design and construction activity may be needed to complete all necessary tasks.

Complete details on the Irrigation System Modification Plan are provided in Annex O of this appendix.

8.2 Water Well Modifications

Water wells existing along the lower Snake River supply domestic water, agricultural water, and some commercial uses. The study team assumed that most of the commercial use of water other than for agriculture is supplied by municipal water systems. These water wells range from shallow wells collecting water from surface sources to deep wells drawing from the deep basalt formations. Drawdown of the water surface in the four reservoirs ranges from a change of only a few feet at the upstream end of the reservoirs to as much as 24 meters (80 feet) upstream of each dam site. The aquifers adjacent to the river could be greatly affected by the change in water surface. The degree of impact will depend, in part, on the geologic formation supplying the water to the well, the proximity of the well to the river, and the depth of the well. While it is not possible to characterize each well along the affected river reach, in general the most adverse effect from drawdown will be to wells drawing water from the shallow aquifers.

An inventory of the existing water wells within approximately 1 mile of the Snake River was developed from information presented on the logs of the drilled wells. The well logs were obtained from the records of the Washington Department of Ecology (Ecology) office at Spokane, Washington. There are approximately 180 recorded water wells in the designated study area. A detailed evaluation of each well was not done. The response of the aquifers to variations in water surface is a complex relationship and far beyond the scope of this overview. Instead, it was more prudent to evaluate a representative sample of the 180 recorded wells and proportionately apply those modifications to the whole. For each of those sample wells, modifications included increasing the depth of the well below the estimated new groundwater surface and installing a new pump and associated hardware to pump against the increased head.

The well modifications must be done following drawdown when the groundwater conditions have stabilized. Measures to provide temporary water during drawdown were not investigated.

Details of the Water Well Modification Plan are presented in Annex P.

8.3 Water Intakes

The Potlatch Corporation in Lewiston, Idaho, manufactures and supplies wood, paper, and consumer products. The primary plant water intake is located on the Clearwater River in the Lower Granite Reservoir. The intake has a peak capacity of 1,500 m^3/s (52,000 cfs). The lower water surface elevation resulting from drawdown of the reservoir is expected to be too low during low flow periods to allow this intake to function properly. To address this issue, the study team proposed installing auxiliary intakes in deep water to supply the existing wet well. Four screened inlets constructed within sheetpile enclosures would be used. See Annex Q of this appendix for more details concerning the Potlatch Corporation Water Intake Modification Plan.

Several other private water intakes exist along the Lower Granite Reservoir. Atlas Sand and Rock maintain an intake for water supply for rock crushing and concrete operations south of Lewiston along the Snake River. The cities of Clarkston, Washington, and Lewiston, Idaho, each operate a water intake to supply irrigation water to golf courses. Trailer-mounted pumps with flexible intakes and appropriate connections and controls are proposed to restore the capability of these users to access surface water from the Snake River. See Annex R of this appendix for more details regarding Other Water Intakes Modification Plan.

8.4 Wastewater Effluent Diffusers

Potlatch Corporation discharges effluent to the river. Treated effluent from the plant is conveyed from the plant through a buried pipeline to an in-water diffuser near the confluence of the Clearwater River with the Snake River. Drawdown of the Lower Granite Reservoir would expose the top of the polyethylene diffuser. The proposed modification is to relocate the diffuser to a deeper reach of the river downstream from its current location. Various reaches of new pipeline and diffuser would be installed using sheetpile sections to dewater the work areas. Other measures to treat effluent water currently under evaluation are not included in this study. See Annex S of this appendix for more details concerning the Potlatch Corporation Effluent Diffuser Modification Plan.

8.5 Utility River Crossings

The only utility crossing the Snake or Clearwater rivers necessitating modification is the Pacific Gas and Electric (PG&E) natural gas transmission line that crosses the Snake River near Lyons Ferry State Park. One 914-millimeter (36-inch) gas line was installed across the river in the 1950s, and a second line was installed in the 1980s. Replacement of the gas lines is necessary since scour conditions may damage the existing pipe. Installation would occur after drawdown of the reservoir using sheetpile systems to enclose and dewater the work area. In addition to new concrete-encased pipe sections, costs are estimated for stabilizing adjacent banks and abandoning the existing pipe. See Annex T of this appendix for more details concerning the PG&E Gas Transmission Main Crossings Modification Plan.

9. Hydropower Facilities Decommissioning

9.1 General Considerations

The process of lowering the reservoirs and breaching the dam embankments would eliminate navigation and hydropower, two significant uses of the four lower Snake River dams. After breaching of the embankments, the remaining dam structures would consist of a navigation lock, a powerhouse, spillway, concrete and embankment non-overflow dams, fish facilities, and other support facilities. The study team for decommissioning these projects considered two major actions:

- Breaching the embankment dam and, by constructing levees, permanently channeling the river around the remaining dam structures, and leaving the dam structures in place.
- Breaching the embankment dam, temporarily channeling the river around the remaining dam structures, and removing the dam structures from the river.

The term decommissioning as used in the FR/EIS refers to removing structures and equipment from service. The term deauthorization as used in this FR/EIS refers to a congressional action to eliminate the purpose or mandate for existence of the project. In the case of a drawdown, both may be utilized.

Although the study team concluded that leaving the concrete dam facilities in the river would be the major action selected for this implementation plan, the team did develop a concept for demolition and removal of the existing dam structures. Both actions are discussed in more detail below. For a detailed discussion of the Hydropower Facilities Decommissioning Plan, see Annex U of this appendix.

9.2 Decommissioning while Leaving the Dam Structures in Place

9.2.1 Disposal Options

In addition to the two options for abandoning the structures, the study team initially considered the option of moth-balling the projects. The purpose of the Mothball Option is to protect and preserve the existing equipment so that the equipment can be restored to operating condition at a later date, or to at least maintain the option for future restoration until such time as that decision can be made. The scope and costs of such operations were based on current maintenance requirements for the Lower Granite Dam.

The Abandon Option would involve ceasing all operations, removing all salvageable equipment, and securing the structure from public access. Only minor maintenance activities would be performed to maintain project lighting and site security.

The four lower Snake River hydropower facilities range in age from 23 to 48 years old. It is clear from the maintenance records that the older facilities are exhibiting problems associated with aging equipment. Much of the equipment is at the extreme end of its useful life and would likely require replacement during a project restart. It would not be economical to maintain the equipment for 20 years and then have to replace it if the hydropower project is restarted.

Furthermore, the cost of removing and relocating equipment, considering its age, is excessive. Much of the equipment is customized for its current location and would require modification for use by other Federal projects. The study team concluded that, as a whole, there is no economic salvage value for the equipment at each of the plants. Consequently, this implementation plan is based on abandoning the dam facilities.

The Abandon Option requirements associated with decommissioning will be performed during and after drawdown. The only item that needs to be completed before drawdown is the construction associated with providing power from the public utility. Power for lighting and security will be needed when power production is stopped at the facility.

9.2.2 Disposition of Industrial Waste

Each project contains numerous materials or items that can be classified as hazardous/dangerous materials, substances, chemicals, or wastes under Federal and state laws. When the projects are decommissioned, all items that are designated as solid wastes will need to be identified, characterized, and disposed of in accordance with Federal, state, and local regulations and codes. A detailed summary of identified materials and disposition is contained in Annex U of this appendix.

9.3 Removing and Disposing of the Concrete Structures

The abandoned structures consist primarily of mass concrete for the navigation locks, spillways, powerhouses, and non-overflow sections. Other structures that would be abandoned include embankment sections, steel structures, and numerous support facilities on the site. Only a cursory effort to develop demolition quantities was undertaken in the development of this concept.

A large volume of concrete exists below the elevation of the river bottom. For this concept, it was assumed that concrete removal would be done to an elevation two meters below river bottom. This means approximately 40 percent of the structures would be removed. The concrete rubble would be placed along the old river bank. Steel structures and debris would be hauled to waste areas or salvage areas as necessary. This work would be performed during the year following breaching of the embankment.

Full removal of the concrete structure would require construction of an impervious cofferdam/levee around the demolition site that would be subsequently removed. The levees in this approach must be able to prevent much of the water from leaking through or under the cofferdam. Permanent levees are not required since, after removal of the structures, the river can flow on its natural alignment. However, channelization would be required during the time that the concrete structures are being demolished and removed.

Construction-era cofferdams included a cutoff trench with impervious fill. The construction process involved end-dumping sandy gravels to form the cofferdam section. Once the section was complete, a trench was excavated in the center of the section using a bentonite slurry to hold the trench open. This trench was subsequently filled with a thick formulation of sandy silt and water and allowed to displace the bentonite slurry. This fill made the cofferdams relatively impervious. After dewatering the interior of the cofferdams, any resulting leakage was collected and pumped back to the river.

The same cofferdam construction method would be used for the drawdown if concrete structures were to be removed. The shotrock would not be used for these cofferdams. Local sources of sand

and gravels that are readily available at each dam site would be used instead. Silt materials might be easier to collect since deposition has occurred over the past 20 to 40 years.

The cost of drawdown engineering and construction nearly doubles when considering full removal of the concrete structures. A detailed description of the Concrete Structures Removal Plan is provided in Annex V.

10. Implementation Schedule

10.1 General

The general process for implementing the various drawdown actions is to perform a three-step process consisting of 1) preparation of a detailed design report, 2) preparation of contract documents, and 3) performance of construction.

The detailed design report, formerly designated a General Design Memorandum or a Feature Design Memorandum, details the process of identifying, evaluating, and selecting a design option. The activities often are precluded by a survey of each construction site to establish the land configuration. Subsurface explorations using intrusive methods such as drilling, excavating, and sampling and/or geophysical methods such a pulse-velocity, radar, or other subsurface logging methods are conducted at this stage. For some features, hydraulic models must be constructed and flow conditions evaluated for a range of flow and physical conditions. Options are developed for the feature and detailed evaluations are made to select the most favorable option. The selected option is often further developed so that a reliable schedule and cost estimate may be generated.

After review and approval of the detailed design report, preparation of the plans and specifications can proceed. This phase requires completion of the feature design and the development of contract documents. The documents must be prepared in a manner that allows bidders to prepare a realistic bid proposal, that presents features in manner that is constructible, and that provides implementation and operation measures that address the relevant environmental concerns.

Once a contract has been awarded, the construction can begin. The short-term nature of many of the tasks coupled with the complexity of implementation will require the participation of many individuals and organizations. Construction activity spans a time period of approximately eight to nine years. During the peak years, expenditures are estimated at $200 million in a single year. The bulk of the work is performed during a 3-month period. Extensive contractor participation is necessary for this level of effort. Significant administration and construction management participation is also required.

The schedules in Annex W reflect reasonable time durations to perform these efforts. They identify time for producing detailed design reports, contract documents, peer and policy reviews, advertising periods, and construction operations.

10.2 Overall Implementation Schedule

The construction actions associated with implementation of drawdown may be grouped into three distinct phases. The preparatory phase includes the work necessary to be done in advance of drawdown in order to be able to perform drawdown and the work necessary to continue operations during drawdown. The drawdown phase is the work required during and immediately following drawdown of the reservoirs. Numerous tasks are anticipated that will need to be performed following drawdown during the post-drawdown period. The period of time that all these occur is shown in Annex W.

A key decision in implementing drawdown is the sequence of dam breaching. There are many options ranging from concurrent breaching of all four dams in a single construction season to individual breaching of each dam during different seasons, with many combinations within this range.

Breaching individual dams on different years greatly simplifies construction operations and focuses attention on one project at a time. The first project provides a troubleshooting opportunity so that subsequent projects can be breached more effectively. Events that may lead to delays that prevent breaching during the designated season are more effectively controlled increasing the likelihood of on-schedule completion. Funding is less difficult to secure because annual requirements can be spread out over a longer period of time.

Breaching of an embankment structure will generate the migration of embankment silts and sands down river. A much more significant effect is the migration of silt deposits and higher velocity river flows that erode those deposits. Silts suspended in the water may be at very high concentrations during the drawdown period of August to December and possibly higher levels during the high flow months of January through June. The effect of this silt and sediment is expected to have a serious negative effect on adult fish migration and a lesser effect on juvenile migration.

If the four dams are breached simultaneously, then this condition will be concentrated to the shortest time period thereby minimizing the negative effects on migrating fish. Biologists expect that expanding this situation as long as four consecutive years could be detrimental to the species (see Appendix C, Water Quality). Breaching the four dams over two consecutive years provides for realistic implementation of all the construction activity. This two season breaching is considered less devastating than other options that require longer time periods.

An aggressive schedule to simultaneously breach four dams needs much more detailed evaluation. An evaluation of risks and impacts of specific construction activities is necessary to produce a plan that contains the appropriate backup plans and contingencies to guarantee that the work can be completed in the short timeframe. At the current level of study, the study team has determined that that too many factors may go wrong that may force the project into a 2-year breach schedule. Until those uncertainties can be resolved, a 1-year breach schedule cannot be considered.

Figure 12 summarizes the implementation schedule for the major work items for a breach plan where two dams are breached during one construction season and the remaining two dams are breached the following construction season. For more detailed implementation schedules, see Annex W of this appendix.

11. Implementation Cost Estimate

11.1 General

The study team developed construction costs from the engineering concept-level designs for this Lower Snake River Juvenile Migration Feasibility Study (Feasibility Study). The costs are based on the scope of work, assumptions, and methodology presented in the engineering annexes (Annexes A through V of this appendix). Estimates were completed for two options for returning the lower Snake River to natural flow conditions: 1) removing the earthen embankment dam then channeling the river around the remaining concrete structure, and 2) full removal of the earthen and concrete dam structures.

Conceptual design report and supporting documents to identify the estimated construction costs of modifications required to bring the lower Snake River back to natural stream flow conditions were prepared by the Corps and a number of supporting organizations. Two separate reports, titled *Embankment Excavation River Channelization and Removal of Concrete Structures* (Raytheon, 1998) and *Lower Snake River Reservoir Stabilization Plan* (Raytheon, 1997), document the assumptions and quantities used in the estimates for the construction efforts involving the reservoirs, dams and locks. Three conceptual design reports concerning the installation of natural gas river crossings (TDH, 1998c) and the modification of water intake (TDH, 1998a) and effluent diffuse (TDH, 1998c) facilities for Potlatch Corporation were prepared by Thomas, Dean, and Hoskins, Inc. of Lewiston, Idaho. The Corps' Walla Walla District developed concepts and quantities for the remaining mitigation and modification projects. Details regarding assumptions, project design concepts, and quantities prepared by the various contractors and the Corps are documented in Annexes A through V of this appendix.

The level of detail for design and subsequent development of costs is at the concept-level. Price levels are for October 1998. The construction costs were developed using cost estimating software. Subsequent summary spreadsheets add engineering, construction management, administration, and contingency costs. Administrative and management costs are estimated at 1.5 percent of the construction cost. Engineering costs for development of detailed design documents and subsequent contract documents are estimate at 8.3 percent. Environmental compliance is estimated at 1 percent. Large design costs for aerial, land, and underwater surveys, foundations and materials explorations, and hydraulic model studies were estimated separately and included with the appropriate design task. Construction management costs and engineering during construction are estimated at 9 percent. Cost escalation due to inflation assumes that project activity begins at the start of the calendar year 2000 and is projected to the mid-point of construction of each major task. The mid-points range from 2003 for the early engineering activities to 2008 for the last options.

11.2 Methodology

A feasibility-level cost estimate was developed for each of the two options. The cost estimates include costs for construction, real estate, cultural resources, engineering and design, construction management, and project management. Construction costs were prepared using the Micro Computer-Aided Cost Engineering System (MCACES) software. The estimate is based on a work breakdown structure (WBS) that was developed to seven levels, as follows: project, feature, subfeature, element, bid item, assemblies, and detail.

The major assumptions used in preparing the estimate are as follows:

- Drawdown of the reservoirs and breaching of the dams will occur at a rate of two dams per year.
- Fish passage around the projects will be maintained during construction.
- The Lyons Ferry Fish Hatchery will remain operating as near to current capacity as possible.
- The rock sources identified will have enough material available.
- In-water work will be allowed to occur during normal fish window closures. Some in-water work must occur outside the normal fish window closures.

Other assumptions are documented in the detailed estimate.

The environmental fish windows normally regulate the construction periods on the lower Snake River. This study team assumed that these requirements would have to be waived in order for this project to go forward. To accomplish the embankment breach construction, the excavation of the embankment dams must start by mid to late August (during minimum river flow), so that it will be completed by December or January. This would minimize the danger of high flows overtopping the partially removed embankments. Bridge stabilization activities and rock stockpiling tasks must be done outside the normal work windows. Bank stabilization following drawdown must take place outside the work windows to be completed in a reasonable time period.

Because of the deadline to complete work prior to increased river flows, overtime is required for portions of this estimate. Specifically, it is required for production, transportation, and placement of rock and riprap; excavation of the embankments; placement of the levees; and adult fish collection and transportation. Work hours for these tasks were assumed to be two 10-hour shifts per day, five to six days a week.

Access to the sites was also considered. The locations of most work tasks could be accessed via county and state roads. The exceptions are the tasks to stabilize the embankments, re-vegetate the reservoirs and protect the cultural resources. Remote sites can be accessed via unimproved roads with off-highway vehicles, or by boat or helicopter.

Sand and gravel required for the various construction efforts is assumed to be available within one mile of each dam site. Rock and riprap are assumed to be quarried from a number of sites located along the Snake River. Quarries for overland haul of riprap and materials are available along the Lower Granite Reservoir. Quarries for barge hauling materials are proposed at river kilometer 35, 98, and 214 (river miles 22, 61, and 133). Disposal areas are assumed to be within 1 mile of the dam locations.

The estimates are based on use of common equipment and standard construction techniques. Equipment is assumed to be available on the West Coast and is reflected in the mobilization/demobilization costs. A sufficient labor force is assumed to be available in the Tri-Cities, Washington region and the Lewiston, Idaho/Clarkston, Washington area.

11.3 Basis of Estimate

Costs are based on a typical contract bidding process with some supply contracts. The estimate assumes contracts would be awarded separately for each dam, and one contract would be awarded for procurement and placement of rock. More efficient contract combinations may be possible when work tasks are better developed. The determination of the number of contracts will ultimately depend on the schedule of work and the cost effectiveness of contract combinations.

Markups (Field Office overhead, Home Office overhead, profit and bond) were applied to the proposed prime contractors and subcontractors. Rates used were based on historical averages for similar-sized jobs.

Estimate documents include contingency and present escalation to the midpoint of construction. A contingency analysis was performed by a team of personnel knowledgeable about each phase of the project and the risks and uncertainties involved. Escalation was calculated to reflect the cost of inflation using the *Civil Works Construction Cost Index System* (CWCCIS), EM1110-2-1304.

The estimate uses Davis-Bacon Labor Rates from general decision WA980001, Modification 9, dated August 28, 1998.

Equipment rates are from *Construction Equipment Ownership and Operating Expense Schedule* EP 1110-1-8, Volume 8, September 1997.

Material pricing was obtained from vendor quotes, supply catalogs, and the MCACES Unit Price Book 96/97.

11.4 Contingency Analysis

Contingencies were developed by the study team for each task based on the team's analysis of the risk factors and uncertainties involved and in accordance with the contingency guidance provided in ER 1110-2-130-2, *Civil Works Cost Engineering.*

Annex X of this appendix lists the contingencies determined for each task and the rationale for that determination. The weighted-average contingency value for drawdown is 35 percent and for the recommended implementation actions.

11.5 Project Cost Summary

Annex X of this appendix provides a summary of the drawdown implementation costs. The costs are summarized by project and by task. The total cost of the recommended implementation action is $881 million. This cost includes required monitoring activities, operation and maintenance costs, and other related costs.

Previous estimates of cost have ranged from a high of approximately $5 billion to a low of approximately $600 million. The high cost features of earlier concepts have been eliminated and replaced with features more appropriate considering the available construction methods. The previous low estimates were revised as more details were developed for stabilization, modification, or mitigation measures.

12. Summary and Conclusions

1. Reservoir drawdown and embankment removal must be done during the time period between spill seasons. Spillway discharge to pass the spring freshet and to aid in juvenile migration ends on approximately 1 August. River flows are below 60,000 cubic feet per second (cfs) and remain low until 31 December. The probability of flows in excess of 60,000 increases significantly after 1 January. After 1 January, powerhouse discharge cannot be relied upon to be the sole means of flow passage.
2. Breaching of each dam must be done by removal of the embankment section of the dam. Removal of concrete sections requires more time than available.
3. Embankment removal can be done with conventional excavation equipment. The quantity and type of equipment anticipated for this work is not extraordinary and is not impossible to secure.
4. A key element to making this drawdown concept feasible is the use of existing turbines and passages for primary reservoir discharge. Modifications are required for this equipment to operated under the unusual low-head conditions.
5. In order to be prepared for reservoir drawdown, the turbine modifications must be done in advance of drawdown. This requires some of the turbine units to be out of service during the previous spill season. The result is that up to 3 units per project may be unavailable during part of the spill season and will result in higher saturated gas levels in the river.
6. The physical effects of migrating sediment may have a negative impact of water intake systems in the river.
7. Fish passage is unaffected just prior to drawdown. After drawdown, fish passage will be through the new breach section of each project. During the 90 to 120 day drawdown, adult fish will be collected and transported around the construction and sediment-rich areas.
8. A major task is the production of rock for riprap bank protection of the railroad and highway embankments that border the river. Approximately 72 kilometers (45 miles) of shoreline requires rock placement. Over 750,000 million cubic meters (1 million cubic yards [cy]) of riprap must be produced, barge transported, and stockpiled prior to drawdown. Underwater stockpile locations have been identified in areas that are considered poor spawning areas under current conditions and will be accessible and above the water surface after drawdown. Rock production and transportation requires continuous operation for up to 3 years prior to drawdown.
9. Several in-water construction activities must be done during non-work window periods. These include the stabilization of bridge piers and the placement of riprap on banks.
10. The implementation schedule requires 9 years to implement drawdown. Physical drawdown of Lower Granite and Little Goose reservoirs would occur in year 5 and physical drawdown of Lower Monumental and Ice Harbor reservoirs would occur in year 6. It is unlikely that a more accelerated schedule can be implemented.
11. The cost of the implementation is approximately $900 million. Approximately 60 percent of these costs are for modifications in the reservoirs.
12. A number of modifications have been identified that are not currently considered federal costs. They are included in this study in order to estimate the costs for inclusion in the economic evaluations. Only Congress can authorize project funding for these items. They include private irrigation systems, private water wells and water intakes, private effluent diffusers and utility crossings.

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40 CFR 273. Title 40, Protection of the Environment, *Code of Federal Regulations*, Part 273, “Standards for Universal Waste Management,” as amended.

40 CFR 279. Title 40, Protection of the Environment, *Code of Federal Regulations*, Part 279, “Standards for the Management of Used Oil,” as amended.

40 CFR 403. Title 40, Protection of the Environment, *Code of Federal Regulations*, Part 403, “General Pretreatment Regulation for Existing and New Sources of Pollution,” as amended.

40 CFR 503. Title 40, Protection of the Environment, *Code of Federal Regulations*, Part 503, “Standards for the Use or Disposal of Sewage Sludge,” as amended.

40 CFR 761. Title 40, Protection of the Environment, *Code of Federal Regulations*, Part 761, Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions, as amended.

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14. Glossary

Alternative 1—Existing Conditions: The existing hydrosystem operations under the National Marine Fisheries Service's 1995, 1998, and 2000 Biological Opinions. The Corps would continue to increase spill and manipulate spring and summer river flows as much as possible to assist juvenile salmon and steelhead migration. Juvenile salmon and steelhead would continue to pass the dams through the turbines, over spillways, or through the fish bypass systems. Transportation of juvenile fish via barge or truck would continue at its current level.

Alternative 2—Maximum Transport of Juvenile Salmon: The existing hydrosystem operations plus maximum transport of juvenile salmon, without surface bypass collectors. The number of juvenile fish transported via barge or truck would be increased to the maximum extent possible.

Alternative 3—Major System Improvements: The existing hydrosystem operations, but with additional major system improvements (such as surface bypass collectors) that could be accomplished without dam breaching.

Alternative 4—Dam Breaching: Natural river drawdown of the four lower Snake River reservoirs.

Anadromous fish: Fish, such as salmon or steelhead trout, that hatch in fresh water, migrate to and mature in the ocean, and return to fresh water as adults to spawn.

Bulkhead channel: Channel through which fish are carried upward through the turbines via a bulkhead slot if they are not diverted by turbine intake screens.

Bypass channel: Fish diverted from turbine passage are directed through a bypass channel to a holding area for release or loading onto juvenile fish transportation barges or trucks.

Collection channel: Holding area within the powerhouse that fish enter after exiting the bulkhead slot.

Cultural resources: Archaeological and historical sites, historic architecture and engineering, and traditional cultural properties.

Dam breaching: In the context of this FR/EIS, dam breaching involves removal of the earthen embankment section at Lower Granite and Little Goose, and formation of a channel around Lower Monumental and Ice Harbor.

Dissolved gas supersaturation: Caused when water passing through a dam's spillway carries trapped air deep into the waters of the plunge pool, increasing pressure and causing the air to dissolve into the water. Deep in the pool, the water is "supersaturated" with dissolved gas compared to the conditions at the water's surface.

Drawdown: In the context of this FR/EIS, drawdown means returning the lower Snake River to a near-natural unimpounded yet controlled river condition via dam breaching.

Drawdown Regional Economic Workgroup (DREW): A group of regional economists studying the economic issues associated with alternative actions on the lower Snake River.

Endangered species: A native species found by the Secretary of the Interior or Secretary of Commerce to be threatened with extinction.

Federal Columbia River Power System (FCRPS): Official term for the 14 Federal dams on the Columbia and Snake rivers.

Fish collection/handling facility: Holding area where juvenile salmon and steelhead are separated from adult fish and debris by a separator and then passed to holding ponds or raceways until they are loaded onto juvenile fish transportation barges or trucks.

Flow augmentation: Increasing river flows above levels that would occur under normal operation by releasing more water from storage reservoirs upstream.

Foraging habitat: Areas where wildlife search for food.

Gas bubble disease or trauma (GBD or GBT): Condition caused when dissolved gas in supersaturated water comes out of solution and equilibrates with atmospheric conditions, forming bubbles within the tissues of aquatic organisms. This condition can kill or harm fish.

Habitat management units (HMU): Corps lands that have their management focus directed toward development, enhancement, and maintenance of wildlife habitat.

Hydrographs: A graphic representation of stage, flow, velocity, or other characteristics of water at a given point and time.

Hydrology: The science dealing with the continuous cycle of evapotranspiration, precipitation, and runoff.

Inundation: The covering of pre-existing land and structures by water.

Irrigation: Artificial application of water to usually dry land for agricultural use.

Juvenile fish transportation system: System of barges and trucks used to transport juvenile salmon and steelhead from the lower Snake River or McNary Dam to below Bonneville Dam for release back into the river; alternative to in-river migration.

Lock: A chambered structure on a waterway closed off with gates for the purpose of raising or lowering the water level within the lock chamber so ships can move from one elevation to another along the waterway.

Lower Snake River Project (LSRP): The four hydropower facilities operated by the Corps on the lower Snake River: Lower Granite, Little Goose, Lower Monumental, and Ice Harbor.

Megawatt (MW): One million watts, a measure of electrical power or generating capacity. A megawatt will typically serve about 1,000 people. The Dalles Dam produces an average of about 1,000 megawatts.

Minimum operating pool (MOP): The bottom one foot of the operating range for each reservoir. The reservoirs normally have a 3-foot to 5-foot operating range.

Mitigation: To moderate or compensate for an impact or effect.

Navigation: Method of transporting commodities via waterways; usually refers to transportation on regulated waterways via a system of dams and locks.

pH: An index of the hydrogen ion concentration in water, measured on a scale of 0 to 14. A value of 7 indicates a neutral condition, values less than 7 indicate acidic conditions, and values greater than 7 indicate alkaline conditions.

Piping: Soil erosion process in which the pore pressure increases cause a vertical type fracture in the soil; this process can be a precursor to larger mass wasting failures.

Plan for Analyzing and Testing Hypotheses (PATH): Refers to a multi-agency, multi-participant process charged with applying a life cycle model to historical data, establishing historical trends in reproduction and components of survival, generate hypotheses about sources of mortality, and generate estimates or variability in the underlying process.

Pumping stations: Facilities that draw water through intake screens in the reservoir and pump the water uphill to corresponding distribution systems for irrigation and other purposes.

Recovery: The process by which the ecosystem is restored so it can support self-sustaining and self-regulating populations of listed species as persistent members of the native biotic community. This process results in improvement in the status of a species to the point at which listing is no longer appropriate under the ESA.

Reservoir fluctuation area: Area between the minimum and maximum pool levels of a reservoir, which includes the littoral, wave-action, and inundation zones.

Resident fish: Fish species that reside in fresh water throughout their lifecycle.

Riparian: Ecosystem that lies adjacent to streams or rivers and is influenced by the stream and its associated groundwater.

Rule curves: Water levels, represented graphically as curves, that guide reservoir operations. See critical rule curves, energy content curves, and flood control rule curves.

Run-of-river: This describes hydropower facilities that do not have storage or the associated flood control capacity; run-of-river facilities essentially pass through as much water as they have coming in, either through the turbines or over the spillways.

Scouring: Concentrated erosive action, especially be stream or river water, as on the outside curve of a bend.

Simulated Wells Intake (SWI): Modified turbine intake that draws water from below the surface so that the surface is calmer and juvenile fish are less influenced by turbine flows. This allows juvenile fish more opportunity to discover and enter the SBC.

Slumping: A landslide; the separation of a land or soil mass from a land surface and its movement downslope.

Spawning: The reproductive process for aquatic organisms which involves producing or depositing eggs or discharging sperm.

Spill: Water released through the dam spillways, rather than through the turbines. Involuntary spill occurs when reservoirs are full and flows exceed the capacity of the powerhouse or power output needs. Voluntary spill is one method used to pass juvenile fish without danger of turbine passage.

Spillway flow deflectors (flip lips): Structures that limit the plunge depth of water over the dam spillway, producing a less forceful, more horizontal spill. These structures reduce the amount of dissolved gas trapped in the spilled water.

Surface bypass collector (SBC) system: System designed to divert fish at the surface before they have to dive and encounter the existing turbine intake screens. SBCs direct the juvenile fish into the forebay, where they are passed downstream either through the dam spillway or via the juvenile fish transportation system of barges and trucks.

Surface erosion: Movement of soil particles down or across a slope, as a result to gravity and a moving medium such as rain or wind. The transport of sediment depends on the steepness of the slope, the texture and cohesion of the soil particles, the activity of rainsplash, sheetwash, gullying, dry ravel processes, and the presence of buffers.

Surficial deposits: Unconsolidated alluvial, residual, or glacial deposits overlying bedrock or occurring on or near the surface of the earth.

Survival: The species' persistence beyond the conditions leading to its endangerment, with sufficient resilience to allow for potential recovery from endangerment. The condition in which a species continues to exist into the future while retaining the potential for recovery.

Terracing: Creation of a relatively level bench or step-like surface, breaking the continuity of a slope.

Threatened species: A native species likely to become endangered within the foreseeable future.

Total suspended solids (TSS): The portion of the sediment load suspended in the water column. The grain size of suspended sediment is usually less than one millimeter in diameter (clays and silts). High TSS concentrations can adversely affect primary food production and fish feeding efficiency. Extremely high TSS concentrations can impair other biological functions such as respiration and reproduction.

Turbidity: An indicator of the amount of sediment suspended in water. It refers to the amount of light scattered or absorbed by a fluid. In streams or rivers, turbidity is affected by suspended particles of silts and clays, and also by organic compounds like plankton and microorganisms. Turbidity is measured in nephelometric turbidity units.

Turbine intake screens: Standard-length traveling fish screens or extended-length submerged bar screens that are lowered into the turbine bulkhead slots to divert fish from the turbine intake.

Turbine intakes: Water intakes for each generating unit at a hydropower facility.

Wetland: An ecosystem in which groundwater saturates the surface layer of soil during a portion of the growing season, often in the absence of surface water. This water remains at or near the surface of the soil layer long enough to induce the development of characteristic vegetative, physical, and chemical conditions.