Department of the Army
Portland District
Corps of Engineers

Contract DACW57-96-D-0016
Order No. 004

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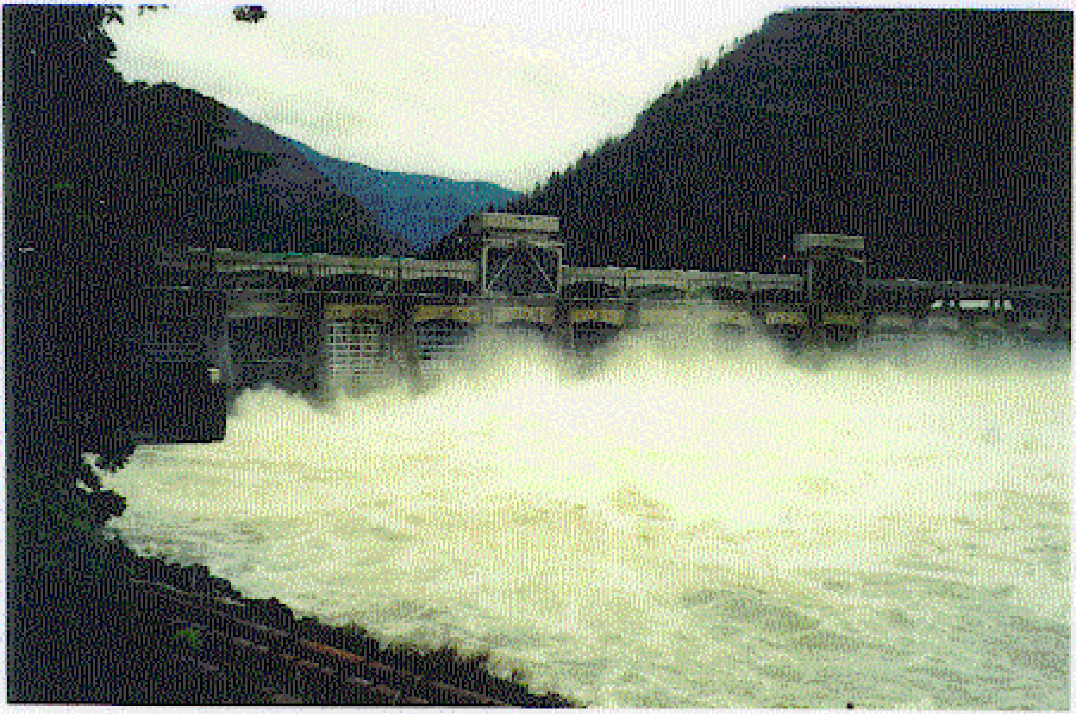
DISSOLVED GAS ABATEMENT STUDY



Investigations of Gas Abatement Alternatives at Bonneville Dam

Final Report

Submitted by:
Northwest Hydraulic Consultants

In Association with:
Summit Technology Consulting Engineers

May 1998
20854

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Contract DACW57-96-D-0016
Order No. 0004

DISSOLVED GAS ABATEMENT STUDY

Investigations of Gas Abatement Alternatives at Bonneville Dam

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April 1998
Final Report

Submitted by:

nhc
Northwest Hydraulic Consultants, Inc.

In Association with:

Summit Technology Consulting Engineers

May 1998

EXECUTIVE SUMMARY
Bonneville Gas Abatement Alternatives Analysis
Final Report Submittal

The purpose of this final report submittal is to summarize the results of the structural gas abatement spillway alternatives study for the Bonneville Dam project. This report evaluates 18 different conceptual structural alternatives for abating Total Dissolved Gas (TDG) production by the existing Bonneville Dam spillway. At high spillway discharges, the existing spillway causes TDG levels in the downstream channel to rise well above the maximum allowable limit set by state and federal water quality standards. High TDG levels can cause injury to fish inhabiting or migrating through affected waters. The 18 alternatives developed in this study ranged in complexity and cost from concepts as simple as modification of existing spillway flow deflectors to replacement of one of the powerhouse structures with a hydrocombine design powerhouse. The number of feasible alternatives was reduced significantly by matrix evaluation in which individual alternatives were independently scored on their effectiveness in meeting seven different criteria. The four highest scoring alternatives in the matrix evaluation were developed to a greater level of detail in this study. The more detailed analysis provided determination of feasibility and developed total construction cost, as well as operation and maintenance considerations for each of the four selected alternatives. The four selected alternatives include Alternative 1 - extended spillway flow deflectors, Alternative 2 – raised tailrace, Alternative 3 – new spillway gates, and Alternative 4 – submerged sluices through existing spillway monoliths.

Alternative 1 - Extended / Stepped Deflectors

Alternative 1 consists of extending the existing spillway flow deflectors downstream a total of about 60 feet, with one upstream horizontal deflector surface at elevation 14.0 ft MSL, and a downstream horizontal deflector surface at elevation 4.0 ft MSL, and the two surfaces connected by a smooth curved surface. The purpose of the extended, or stepped, deflector is to widen the range of tailwater elevations over which the deflector will produce desirable skimming flow characteristics in the stilling basin. Extended deflectors are expected to be more effective over a wider range of discharges and tailwater submergence than the existing deflectors. Data from an early model study report on spillway deflectors for Bonneville Dam (TR 104-1, dated September 1984) suggest that extended and lowered deflectors at the Bonneville Dam spillway would provide for more effective reduction in TDG levels over a wider range of flow than the existing deflectors. Recent model study tests of the extended/stepped deflector concept show performance to be somewhat less successful than expected with regard to production of ideal skimming flow characteristics. However, more detailed model tests should be undertaken to optimize deflector design and define hydraulic characteristics. Total estimated construction cost of this alternative is about $23,160,000 and it would take about 2 years to complete construction.

Alternative 2 - Raised Tailrace (Fill Deep Holes in Spillway Exit Channel)

Alternative 2 consists of filling a portion of the length of the spillway exit channel with large, grouted armor rock to about elevation 5.0 ft MSL. The desired effect will be to cause shallow, fast moving flow to pass over the raised channel section. Similar conditions at The Dalles Dam spillway exit channel can successfully reduce high TDG content in the flow after it exits from the stilling basin. In this alternative, the large area downstream of the stilling basin that varies in elevation from -60.0 ft MSL to -16.0 ft MSL would be filled to an elevation of -16.0 ft MSL. On top of that fill, a 350 foot long section extending nearly fully across the entire exit channel will be raised to elevation 5.0 ft MSL. The main purpose of this alternative is to eliminate the deep holes in the tailrace, and secondarily to duplicate spillway exit channel conditions observed at The Dalles Dam. As a result of the shallow channel, aerated spillway flow exiting from the stilling basin will not plunge to such great depths as in the existing spillway exit channel. This should both reduce additional gas absorption and allow previously absorbed gases to effuse into the atmosphere. However, because of the widely variable tailwater elevation at the Bonneville Dam, TDG reduction may be less successful because the depth of aerated flow even in the raised channel section becomes significant, which increases the potential for gas to be absorbed. This alternative may not be successful in meeting the state and federal water quality standard for TDG, though it should prove moderately successful at lowering the TDG content generated by the spillway. Total estimated construction cost of this alternative is about $120,390,000 and it would take about 2 years to complete construction.

Alternative 3 - New Spillway Gates (to Pass Un-Aerated Flow)

Alternative 3 consists of replacement of existing split leaf vertical spillway crest gates with very large radial tainter gates located downstream of the crest. The existing sill beams for the crest gates is at about elevation 24.0 ft MSL, and the proposed new radial gate sill beam will be located on the existing spillway chute surface at about elevation 0.0 ft MSL. The desired effect will be to fully submerge the spillway discharge jet below the tailwater surface, affording no opportunity for aeration prior to entering the stilling basin. This gate seat elevation should submerge the jet under most operating conditions during the spring migration period. The jet would also be directed downward into the stilling basin by the angle of the upstream face of the radial gate and the spillway chute surface. The proposed alternative would require very high and large radius tainter gates, perhaps larger than any other gates on the Columbia River system, and these gates would operate in a partially submerged condition. Partially submerged tainter gates of this large size have not been used before, and vibration problems associated with downstream turbulence may prove them infeasible. Vertical gates similar to those used on the existing spillway could be implemented instead of radial gates, but potential vibration problems would not be eliminated. However, this alternative is very attractive because it permits the Bonneville Dam project to pass forebay TDG level without increasing it further, and the existing spillway discharge capacity is not adversely impacted. This alternative also does not adversely impact adult or juvenile fish passage facilities. More detailed model studies of both the tainter gate and vertical gate concepts should be performed to verify the feasibility of this concept. Total estimated construction cost of this alternative is about $212,500,000 and it would take about 3.5 years to complete construction.

Alternative 4 - Sluices Underneath Existing Spillway
Alternative 4 consists of excavation and replacement of each of the existing spillway crest monoliths and primary stilling basin with new monoliths into which sluice conduits have been cast. The upstream entrances of these sluice conduits will be submerged well below the forebay water surface, and the exit portal will be submerged well below the tailwater surface downstream of the primary stilling basin floor. The desired effect will be to pass forebay TDG levels directly to the stilling basin without increase. Each spill bay would have two conduits, each designed to discharge a maximum of 7,400 cfs. The downstream end of the sluices would be provided with a very gradual expansion section to reduce the flow velocity at the exit portal. The sluices would discharge into the tailrace where the existing step in the stilling basin is located at the downstream end of the elevation –16.0 ft MSL floor. A vertical lift gate will be provided at the upstream end of the sluice conduits for positive closure, but not for discharge control. The sluices are designed to operate fully open only. Vacuum relief for the sluice conduit downstream of the gate during closure will be provided by small air vents with closure valves. The existing spillway bays above the sluices would be operated concurrently with the sluices. More detailed model studies of the submerged sluice concept must be undertaken to optimize sluice design and define operating parameters. This alternative and alternative 3 are perhaps the most attractive of the four selected alternatives from the standpoint of meeting the TDG criteria. However, the two are also the most costly. Total estimated construction cost of this alternative is about $273,900,000 and it would take about 4 years to complete construction.

STATEMENT OF WORK
Contract No. DACW57-96-D-0016
Task Order No. 0004

DISSOLVED GAS ABATEMENT STUDY

INVESTIGATIONS OF GAS ABATEMENT ALTERNATIVES AT BONNEVILLE DAM

1. BACKGROUND.

Dissolved gasses in river water increase when large quantities of water spill over existing spillway configurations at most large dams. High levels of dissolved gasses can cause mortality in juvenile and adult migratory fish, resident fish, and other organisms. Washington State Department of Ecology and Oregon State Department of Environmental Quality require that Total Dissolved Gas (TDG) levels not exceed 110% for river discharges up to the 7-day, 10-year flood event. This flood event is approximately 471,000 cfs on the Lower Columbia River.

The Corps' Dissolved Gas Abatement Study (DGAS) is attempting to define and evaluate potential methods to control dissolved gasses created during spill operations at the Lower Columbia and Snake River dams. The application of the structural gas abatement alternatives developed to date by DGAS is questionable at Bonneville. The existing spillway at Bonneville is a significant gas producer on the Columbia River system and requires an effort toward determining potential gas abatement measures. The purpose of this task order is to identify and evaluate gas abatement measures specifically for Bonneville Dam.

2. STATEMENT OF WORK.

a. GENERAL. The Contractor shall identify, investigate, and document the potential structural gas abatement alternatives for Bonneville Dam. The Government and the Contractor shall select four alternatives for the Contractor to evaluate further. The Contractor shall prepare preliminary designs for implementing the four alternatives at Bonneville Dam. The Government and the Contractor shall select two of the four alternatives for physical hydraulic model investigations. The Contractor shall complete the feasibility analysis and construction cost estimation of the four alternatives and oversee the physical hydraulic model investigations for the two selected alternatives.

b. TASKS. The contractor shall provide all labor, equipment, materials, and items incidental thereto except as noted to complete the following tasks.

1) Site-specific Analysis. Examine and document site constraints at Bonneville Dam. The analysis shall include hydraulic, structural, civil, geotechnical, mechanical, electrical, and navigational considerations.

2) Alternative Identification Workshop. Organize and host a workshop meeting in Portland, Oregon, to identify potential gas abatement measures for Bonneville Dam within 5 days following Notice to Proceed. The Government will select the date for the workshop. The Government will provide a meeting room in the Portland District Office for the workshop. Participants at this workshop should include representative of the Contractor, the Contractor's consultants, the Government, and regional fisheries agencies. The Government will be responsible for inviting representatives from the Government and regional fisheries agencies to the workshop. The Contractor shall document all alternatives identified at the workshop regardless of feasibility in the 30% Draft Report. The documentation shall include conceptual sketches and written descriptions of the merits and weaknesses for all alternatives identified.

3) Alternative Selection. At the 30% Review Meeting, the Government will select four gas abatement alternatives for further evaluation, determine discharge capacity requirements for each alternative, and identify proximity within the project site for each alternative. Reasons for the alternative selection, discharge capacity, and proximity shall be documented by the Contractor in the technical report.

4) Alternative Analysis. Prepare and document a preliminary design analysis for each of the four selected alternatives. The analysis shall include all necessary appurtenances in the design and documentation. Operation and maintenance requirements and concerns shall also be documented. The Contractor shall also note potential impacts to upstream and downstream fish passage without actually performing analyses of the fish passage impacts. At the 60% review meeting, the Government will select two of the four alternatives for a physical hydraulic model investigations.

5) Physical Hydraulic Model Coordination. Develop and coordinate physical model investigations of the two selected alternatives with the Government's Point of Contact (POC) and the Principal Investigator at the Waterways Experiment Station. The physical hydraulic model investigations shall be performed at the U.S. Army Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi, and shall be funded by the Government separately from this task order. The existing physical models include a 1:40 scale sectional spillway model and 1:100 scale general model which represent the existing project. The Contractor's labor, materials, transportation, and other items related to coordination and oversight of the physical model investigation shall be included within the scope of this task order.

6) Define Assumptions and Unknowns. Examine and identify any assumptions used and define any physical model tests, geotechnical investigations, etc. which are required to verify assumptions in the designs of the four alternatives.

7) Drawings. Prepare drawings illustrating a site plan view for each of the four alternatives selected at the 30% review meeting. Prepare plan and sectional view drawings of each of the four alternatives. Prepare additional drawings illustrating any other appurtenances deemed necessary such as guidewalls, gates, etc.

8) Cost Estimate. Prepare a detailed cost estimate for constructing each of the four alternative designs selected at the 30% review meeting. The cost estimates shall include engineering, design, and construction costs including details of labor, materials, and other significant costs.

9) Design and Construction Schedule. Prepare a design and construction schedule for each of the four gas abatement alternatives selected at the 30% review meeting. Also prepare text describing construction methods, duration, and sequence for each of the four alternative designs.

10) Report Preparation. Prepare 30% draft, 60% draft, 90% draft, and final reports. The 30% draft shall include the site-specific analysis (Task 1) and the documentation of the alternative identification workshop (Task 2). In addition to the analysis presented in the 30% draft, the 60% draft shall include documentation of the alternative selection (Task 3), and preliminary designs for the four selected alternatives. In addition to the information presented in the 60% draft, the 90% draft shall include the detailed alternative analysis for the four selected alternatives (Task 4), summary and conclusions drawn from physical hydraulic model studies of the two selected alternatives (Task 5), the discussion of assumptions (Task 6), the design drawings (Task 7), the cost estimates (Task 8), and the design and construction schedule (Task 9). The final report shall include the information presented in the 90% draft revised as necessary in response to comments provided by the Government.

11) Meeting Minutes. The Contractor will take minutes of each meeting and distribute those minutes to attendees within seven days following the meeting.

12) OPTIONAL Trips to Waterways Experiment Station (WES). The Contractor shall make up to three round trips to WES if authorized in writing by the Contracting Officer's Representative. These trips are in excess of the required mandatory trip. Unless stated otherwise, each notice exercising an optional trip will exercise only one round trip. Optional services shall be paid based on the number of units and not the total quantities.

3. REVIEW AND MEETINGS.

One technical workshop and two progress review meetings shall be held. The technical workshop will be documented in the 30% draft report. The progress review meetings will occur following submittal of the 30% and 60% draft reports. The progress review meetings will be held in the Portland District Office at least 14 calendar days after the reports are submitted (to allow time for the Corps to review and comment). The Contractor will be responsible for initiating the technical workshop and review meetings.

4. GOVERNMENT FURNISHED INFORMATION.

The Government will provide the following items upon request.

a) As-built drawings, if available.
b) Aerial photos, if available.

5. DELIVERABLES.

a. Report Format. The report shall be written in easily understandable language and presented in clear, concise, and logical format that describes in detail the technical analysis of the data collected for this task order. The report shall be single-spaced and laser printed on 8-1/2 by 11-inch paper.

In addition, one unbound reproducible copy and one electronic copy of the final report shall be provided on high density 3-1/2 inch floppy disk(s). The electronic copy of the document shall be compatible with the following software: Microsoft Word version 6.0; Microsoft Excel version 5.0; Intergraph MicroStation version 5.0.

b. Government Review. The Government shall review the draft reports and provide comments at the designated draft review meetings.

c. 30% Draft Report. Ten copies of the 30% draft report shall be provided for Corps review and comment not later than 45 days following the NTP.

d. 60% Draft Report. Ten copies of the 60% draft report shall be provided for Corps review and comment not later than 90 days following the NTP.

e. 90% Draft Report. Ten copies of the 90% draft report shall be provided for Corps review and comment not later than 165 days following the NTP.

f. Final report. Fifteen copies of the final report shall be provided to the POC no later than 190 days from NTP.

g. Meeting Minutes. The Contractor shall record minutes of each meeting held and submit copies to each attendee within seven days following each meeting.

6. PRODUCT SCHEDULE.

The following schedule is based on calendar days following NTP.

Item	Schedule
Alternative Identification Workshop	5 days following NTP
Submit 30% Draft Report	60 days following NTP
30% Draft Review Meeting	75 days following NTP
Submit 60% Draft Report	100 days following NTP
60% Draft Review Meeting	115 days following NTP
Submit 90% Draft Report	165 days following NTP
Submit Final Report	190 days following NTP

7. COORDINATION.

The Contractor shall assign a Project Manager to act as POC for this delivery order. The Government's initial POC for all technical matters concerning this scope of work is Ms. Kim Fodrea, CENPP-PE-HD, at (503)326-6405.

8. ADDITIONAL WORK.

The Contractor shall not perform any services under this agreement required by the Government, orally or in writing, which are considered by this Contractor to be a change in the work or services required by this agreement requiring adjustment in the price and/or schedule without the written consent of the Contracting Officer. The Contractor will be in contact with many Government representatives. Only the Contracting Officer and the Contracting Officer's Representative (COR) have the authority to modify the contract. No work beyond the agreed upon scope shall be done by the Contractor without written direction from the Contracting Officer.

9. REVIEW OF DELIVERED WORK.

Review and acceptance of delivered work shall be the basis for final payment. The Contractor shall be responsible for the professional quality and technical accuracy of all services furnished under this contract. The Contractor shall, without additional compensation, correct or revise any errors or deficiencies in the services, and shall resubmit the work within seven calendar days after request for such services is made by the Contracting Officer.

10. CORRECTION OF UNSATISFACTORY WORK.

The Contracting Officers Representative maintains the right to reject any work that is found to be in error, incomplete, illegible, or in any way not conforming to the specifications outlined in this contract. The Contractor shall be liable for all costs in connection with correcting such errors. Corrective work may be performed by Government forces or by Contractor forces at the discretion of the Contracting Officer.

11. PAYMENTS.

The Contractor shall submit monthly invoices indicating actual work and services performed to date for approval by the Government. Payment will be made, in the amount of 90 percent of the value of services shown on the monthly invoice, upon approval of the Contracting Officer and in accordance with the payment clause of the contract.

12. CONTRACTOR RELEASE.

The Contractor shall submit a written “Release of Claims” signed by the firm’s president, with the final invoice for services rendered under the terms of this contract.

13. RELEASE OF INFORMATION.

The information developed, gathered, and assembled in fulfillment of the contract requirements as defined in or related to the Statement of Work shall not be released by the Contractor, his subcontractors, or their associates without prior coordination with and approval of the Contracting Officer.

14. USE OF INFORMATION.

The information developed, gathered, assembled, and reproduced by the Contractor, his consultants, his subcontractors, or their associates in fulfillment of the contract requirements as defined in or related to the Statement of Work will become the property of the Government and will, therefore, not be used by the Contractor for any purpose at any time without the written consent of the Contracting Officer.

15. SAFETY.

The Contractor shall conform to all safety standards of the U.S. Army Corps of Engineers Safety and Health Requirements Manual EM-385-1-1, dated Oct 92, and all subsequent additions and amendments. The Contractor shall report the total man-hours expended in field operations monthly by all employees, including Contractor and Sub-Contractor, supervisor, and labor. The reporting period shall end at midnight on the last day of the month. the report shall be made by telephone or FAX to Cheryl Frank by the 5th of the following month. Ms. Frank’s telephone number is 503/326-6901 and her FAX number is 503/326-6332.

16. PARTNERING.

This task order is expected to be mutually managed in compliance with the mission statement and objectives as defined by the A-E Contract Partnering Agreement.

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Dissolved Gas Abatement Study
Investigation of Gas Abatement Alternatives at Bonneville Dam

FINAL REPORT

1.0 INTRODUCTION

DISSOLVED GAS ABATEMENT. The Dissolved Gas Abatement Study is one of several studies within the Columbia River Salmon Mitigation Analysis aimed at improving the survival of anadromous fish in the Lower Snake and Columbia River System. Other studies within the program are currently investigating drawdown, surface attraction of juveniles, bypass systems for juveniles, transportation, turbine rehabilitation, spill patterns, and light and sound applications as means of improving fish passage through the Lower Snake and Columbia River projects. Voluntary spill is currently used at most of the projects to meet passage goals of juvenile salmonids. Involuntary spill during high spring flood flows occurs when there is insufficient powerhouse capacity to pass river flow. Unfortunately, these spillway releases result in high concentrations of total dissolved gas (TDG) supersaturation.

This part of the Dissolved Gas Abatement Study (DGAS) is an attempt to define and evaluate potential methods to control dissolved gasses created during spill operations at Bonneville Dam. The application of most of the structural gas abatement alternatives developed to date under the DGAS program is questionable at Bonneville for two primary reasons; widely variable tailwater unlike any of the other Columbia and Snake River projects, and lack of sufficient areas for development of auxiliary spillways. The existing spillway at Bonneville is a significant gas producer on the Columbia River system. To meet the goals of the Dissolved Gas Abatement Study, potential gas abatement measures must be developed for specific application to Bonneville Dam.

High TDG levels are caused by operation of the existing spillway/stilling basin configurations at most large dams. High concentrations of TDG can cause mortality in juvenile and adult migratory fish, resident fish, and other aquatic organisms. The problem of high TDG concentrations is not new. Literature pertaining to the TDG supersaturation problem dates back to the beginning of the present century. And, dissolved gas control was a major issue in the Pacific Northwest during the late 1970's, which resulted in the construction of spillway deflectors at five of the eight U.S. Army Corps of Engineers (Corps) dams on the Columbia River system in order to reduce dissolved gas supersaturation. Recently, operation of the Corps projects has been modified to accommodate more 'fish-friendly' system-wide changes in response to the decline in salmon runs and their listing as an endangered species. Voluntary spillway releases are being made to assist fish passage, but the spillway releases are limited in order to comply with water quality standards pertaining to TDG concentration. The current state and federal water quality standards require that TDG concentrations do not exceed 110 percent saturation except when stream flow exceeds a 10-year, 7-day average flood event. This flood event would typically result in large involuntary spillway discharges. The states generally issue waivers allowing up to 120 percent saturation, but the spillway releases are still limited enough that some projects do not achieve desired fish passage percentages. Thus, TDG supersaturation remains a major regional concern.

2.0 AUTHORIZATION, PURPOSE, AND SCOPE OF STUDY

The purpose of this study is to identify, investigate, and document gas abatement measures which can be implemented specifically at Bonneville Dam. These gas abatement measures should be directed at improvement of the existing spillway system and should be designed to prevent the TDG level from exceeding 110% for total project outflows up to the 10-year, 7-day flood event (471,000 cfs at Bonneville Dam). Four of the most promising alternatives for gas abatement at Bonneville Dam will be developed to the preliminary design stage. Feasibility analysis and construction cost estimates for the four selected alternatives will be completed.

3.0 SITE ANALYSIS

3.1 Spillway / Stilling Basin Configuration.

The spillway at Bonneville Dam has a total length of 1,070 ft (including 17 intermediate piers) and consists of 18 gate-controlled bays, each 50 ft wide. Piers, 10 ft in width, separate the bays. The elevation of the spillway crest is 24 ft MSL. Spillway discharges are controlled by 18 vertical lift gates that are 50 ft wide. Twelve of the gates are 50.75-ft high vertical lift tractor gates, and six are 60-ft high vertical lift wheel gates. The design capacity of the spillway is 1,600,000 cfs with a corresponding maximum pool of 87.5 ft MSL. Bonneville's normal operating range of pool elevation is 71.5 - 76.5 ft MSL. At pool El. 75.5 ft MSL the spillway will pass a maximum of 1,300,000 cfs. The energy of water discharging through the spillway is dissipated by a hydraulic jump in a horizontal apron-type stilling basin. The stilling basin is 147 ft long with an invert elevation of -16 ft MSL for the first 71 ft, then it drops to a 76 ft long secondary basin varying in elevation from -22 ft MSL to as low as -50 ft MSL. Spillway deflectors 12 ft long at El. 14 ft MSL are installed in bays 4 through 15 and bay 18 of the 18-bay spillway. Two rows of baffles (6 ft high, 14 ft long, and of varying widths) in the stilling basin floor dissipate the energy of the hydraulic jump. The stilling basin has no end sill, and was designed to contain the hydraulic jump for discharges up to 1,600,000 cfs. Refer to Plate 2 for a detailed cross section of the existing spillway at the Bonneville Dam project.

3.2 General

3.2.1 Hydraulic Design

This project has a complex geometry. It consists of two powerhouses, one on either side of the river, and a center spillway section. Two navigation locks are located on the left bank, which is extensively developed. The proximity to the navigation lock makes construction of a major new spillway or discharge facility in this area quite unlikely.

Bradford Island separates the First Powerhouse from the spillway. Both the upstream and downstream ends of the island are quite high in elevation. Excavations on the order of 120 ft would be required in these areas to reach bedrock. The center of the island has better topography for development of additional discharge facilities, but space is both limited and substantially developed. Offices, the visitor facility, and the adult fish ladders are all located in this area. Cascade Island, between the spillway and the Second Powerhouse, appears to offer the most practical location for a major additional discharge facility. Major construction on the right bank to the north of the Second Powerhouse would require relocation of the highway, possibly the railroad and other facilities currently located there.

Bonneville Dam is unique among the Columbia River projects in that its tailwater elevation varies over a wide range of approximately 30 to 35 ft. This variation makes the typical design of many good TDG reduction discharge facilities impractical at this site. For example, spillway flow deflectors would be very difficult to implement at Bonneville Dam unless their position on the spillway could be changed with varying tailwater elevation. Other Columbia and Snake River dams with spillway deflectors are successful in reducing TDG levels only when tailwater elevations vary by less than about 5 to 7 ft. For successful implementation of additional facilities which require stable tailwater elevations, artificial multiple tailwater elevation controls must be provided. An example would be a shallow, sloping spillway exit channel, or multiple end sill control structures.

The most effective features for TDG reduction at Bonneville would likely be those that do not depend on elimination of deeply plunging, high energy, aerated flow from the spillway. An example of these types of systems would be submerged sluices or submerged-jet spillway gates. Submerged intakes draw flow from deep within the forebay and discharge it to the tailrace without entraining large amounts of air, eliminating potential high dissolved gas levels. Submerged jet spillway gates also pass flow into the stilling basin without entrainment of air. Another example would be those concepts that dissipate the energy of spillway flow prior to entrance into the tailrace. Baffled chute spillways are very effective at dissipating energy of spillway flow prior to its entrance into the receiving body of water, eliminating plunging of high energy flow to deep depths. However, baffled chute spillways and others of that type are really only effective over a fairly low range of unit spillway discharges, resulting in very large structures to accommodate high spill discharges. Turbines can be very effective in reducing TDG levels as well, since, as for the submerged intakes discussed above, they draw from deep within the forebay and discharge at great depths with no entrained air.

In general, the application of TDG reduction measures at Bonneville Dam suffers from a lack of available space for large structures. Also, any modifications to the existing spillway structure which might result in reduction in maximum spillway discharge capacity can not be accommodated without either constructing additional spillway facilities, or accepting the risk of inadequate spillway capacity.

3.2.2 Structural Design

The original Bonneville Lock and Dam was developed in two river channels. The existing Bonneville Dam, spillway, and fishways are located in the north channel. The original south channel was selected for the First powerhouse, Old navigation lock and fishways located on Bradford Island. The Second powerhouse was constructed on the north bank of the Columbia River. After the approach channel and tailrace channels were excavated, a new Cascade Island was formed. The scope of the dissolved gas abatement study will consider all features discussed below.

The First powerhouse was designed to accommodate anticipated flows for a major portion of the year and to fit within the physical dimensions of the south channel. The powerhouse structure has ten generator bays, adult fish passage facilities, an assembly bay, and station service units. The spillway and powerhouse bays were designed as gravity monoliths with full uplift pressure.

The adult fish passage facilities were the first systems to be designed for the Columbia River. Adult fish passage problems were recognized in the early planning for Bonneville, and the issues are equally important today.

The original navigation lock was designed as a gravity section with a portion of the downstream section cut into bedrock. The old lock chamber is 76 ft wide, 500 ft long, lower sill at El. -16 MSL and upper sill at El. +40.0 MSL. Miter gates were used for both upstream and downstream gates. The Old navigation lock is presently in a mothballed status, and it has been designated a National Historic Monument.

As the Columbia River basin was developed and additional upstream storage facilities were built, it became feasible to authorize and build the Second powerhouse. The Second powerhouse has 8 new larger turbines and generators than originally used in the First powerhouse. The Second powerhouse turbine discharge draft tubes are about 30 ft lower than those designed for the First powerhouse. The Second powerhouse erection bay contains space for generator repair and other auxiliary features.

The new navigation lock is larger than the original and conforms to the present criteria used for navigation on the Lower Columbia and Lower Snake Rivers. The lock chamber is 86 ft wide, 675 ft long, with a lower sill at El. -14.0 MSL and an upper sill at El. +51.0 MSL. The filling and emptying systems are state-of-the-art for time to cycle and to reduce internal currents. A pair of supply and discharge tubes exits downstream. The new lock was placed in a rock cut that minimized the total volume of concrete and provided a very stable structure. The new downstream channel is of sufficient size to have tow moorage for barge tows to split for multiple lockages.

Any adverse impacts to any of the existing project features resulting from implementation of the alternatives previously discussed will be restored to the operating condition following construction of the selected alternative.

3.2.3 Civil Design

The existing Bonneville Lock and Dam has a complex system of roads, underground utilities, and communications systems that are essential for project operation. The project is the most visited water resources development in the Columbia River Basin. Any alternatives selected for future study will be designed to make a minimal impact to both the project operations and visitor enjoyment. All roads that are impacted will be restored to provide access and continuity. All utilities impacted by the proposed developments will be restored to existing performance.

3.2.4 Geotechnical Considerations

(1) General

The Bonneville Lock and Dam is located on the Columbia River and within a complex geologic formation. The original project was sited within a river reach that had a single land mass, Bradford Island, within the river at river mile 146. The geology within the project boundaries consists of bedrock, siltstone/mudstone, landslide debris, pre-slide alluvium including gravels, cobbles, boulders, crystal sand, silts, lathic sand and active river deposits. The new concrete structures will be placed on bedrock or a competent pile foundation. The gravels and other water deposited materials are a combination of rock types found in the upper reaches of the Columbia River tributaries. Any type of proposed development will have an extensive exploration program to evaluate the geologic conditions prior to design.

(2) Geologic Perspective

The geology of the area consists of a deep river channel that was created during the last ice age, over 10,000 years ago. The bedrock surface beneath the site slopes to the southeast and ranges for a high of El. -100 ft to a low of El. -150 ft or deeper. Overlying the bedrock surface and making up all but the uppermost 3 to 6 ft of the overburden materials, is a thick sequence of alluvial materials that has been deposited since the end of the last ice age. These alluvial materials consist of stratified and interbedded silts, sands, and gravels. The alluvial materials continued to be deposited until approximately 800 years ago. The alluvial deposition was disrupted by the Bonneville Landslide that originated from the Washington side of the Gorge and briefly dammed the Columbia River. The breaching of the debris dam that formed created a high-energy deltaic deposit that extended downstream of the project. The energy associated with the breach formed a heterogeneous deposit of mostly sandy gravel with admixtures of silt and boulders and rock blocks to 20 ft in size. However, the succeeding floods were not as energetic as those associated with the breach and were unable to transport the large size fragments any significant distance. Instead, the finer materials were eroded from around the immovable blocks, eventually concentrating them into a continuous to discontinuous deposit of boulders. These deposits are designated as lag deposits.

(3) Structural Geology

The spillway dam was constructed within the original north river channel. Plate 29 shows the original top of rock contours and the geological section along the axis of the dam. A representative number of the original exploration drill holes are also shown on the base of dam profile. A majority of the explorations shown extends below MSL El. -80.0 and two drill holes were drilled to MSL El. -200.0. The spillway structure is shown in profile on Plate 18, which adds perspective as to the physical dimensions of the structure. The original Bonneville Power Navigation Project exploration drill hole logs identify the following main groups of materials:

- alluvium
- river deposit of fine micaceous sand and silt, impervious
- landslide deposit of tuffaceous and scorcaceous materials and large andesite boulders, impervious
- buried river deposits of sand, gravel, and boulders, pervious
- bedrock

- tuffaceous sediments of Eagle Creek formation tuff agglomerate
- tuffaceous sediments of Eagle Creek formation, accompanied by nearby intrusive andesite
- intrusive andesite lava

The required rock excavation for the original construction removed the surface layer of the Eagle Creek formation that was weathered and founded the concrete structure on sound bedrock. The project design utilizes an upstream cutoff trench that extended below the base of the dam by about 20 ft. The other interesting feature pertaining to the foundation treatment is the undulating or saw tooth excavated shape. The purpose of this technique was to provide more sliding restraint for the structure above. The top points were about 40 ft apart and the hollows about 8 ft deep. The characteristic is shown on Plate 9. The original dam design also obtained additional friction restraint at the construction lift lines by tilting the left surface on about a 1 vertical on 8 horizontal slope and rising in the downstream direction. This construction procedure is also shown on Plates 9 and 16. The base of the dam varies from MSL El. -45.0 at the north abutment to MSL El. -77.0 at the south abutment.

(4) Under Drainage System

The anticipated joint leakage was collected in two longitudinal collectors. The downstream tunnel is oval in shape, 3 ft 6 inches wide by 6 ft high and is located about 96 ft downstream of the construction base lane (CBL). Drainage from this collector is carried upstream by 5 cross tunnels of the same shape at 240-ft centers to the main upstream drainage and grouting gallery located 17 ft upstream of the C.B.L. This main drainage gallery is 5 ft wide and 8 ft tall and slopes from north El. -30.0 MSL to south El. -35.0 MSL. Foundation grouting was also performed from this gallery through 3-inch diameter grout pipes placed on 5-ft centers. The grouting extended through the cutoff trench into bedrock. An impervious blanket was placed to a height of El. -10.0 MSL upstream of the structure. Existing piezometers in Bay 13 are accessible from within this gallery.

3.2.5 Electrical Design

The existing electrical system is both overhead and underground. All new developments will require the relocations of any existing pier supply, communication lines for telephone, project code calls, security cameras, lighting, and system controls. The design criteria requires that all operations are controlled from the powerhouse control room. A new fiber-optic, digital control cable will link the powerhouse control room with any new development.

3.2.6 Mechanical Design

The existing project has original equipment that may be in excess of 60 years old and new mechanical systems that were state-of-the-art at the time of installation. Any new alternative development would upgrade all mechanical systems affected in the modification. These may be tainter or drum gates, lifting cables and assemblies, hoist cable drums, gear boxes, bearings, bulkhead gate guides, lifting beams, sectional bulkheads, trunnion anchorages, yokes, lubrication systems, tainter and drum gate drains, gantry crane rail extensions, and spillway drains. New hydraulic systems will be used as necessary to provide the required response for operations.

3.2.7 Navigation Design

Navigation on the Columbia River in the vicinity of the Bonneville Dam project consists of primarily large commercial barge tows, with smaller pleasure craft utilizing specific areas of the river both downstream and upstream of the project. Barge tows pass the project upstream and downstream through the navigation lock. During high total river discharges, approach conditions to the navigation lock can become undesirable and it is difficult to maneuver barge tows into the lock approach channels. The new navigation lock downstream approach channel is oriented well downstream of the converging First Powerhouse, spillway, and Second Powerhouse channels, and thus is not seriously impacted by variable discharges through these project features. Likewise, the upstream lock chamber approach channel is protected from the First Powerhouse and spillway forebay by a bedrock island that extends a considerable distance upriver. Additional or modified spillway facilities for TDG reduction would generally be located on the other side of this bedrock island from the navigation lock as a result of limited space available elsewhere. Thus, additional facilities should not pose a serious impact to navigation concerns.

4.0 DESIGN CRITERIA

The general purpose of the Bonneville Dam Dissolved Gas Abatement Study is to define and develop feasible alternatives for dissolved gas abatement measures to be implemented at Bonneville Dam. General dissolved gas abatement guidelines for the Columbia River system provide that TDG levels are not to exceed 110% for combined project discharges up to the 10 year recurrence interval, 7-day duration event. At Bonneville Dam, this is approximately 471,000 cfs, of which the two powerhouses would pass about 188,000 cfs. Alternatives identified in this report are evaluated based on their respective ability to reduce TDG levels to 110% for spillway discharges up to 283,000 cfs, or the difference between the maximum powerhouse capacity and the total river flow. These spillway discharge values represent approximately 60% of total project outflow during the 10-year, 7-day event. For the alternatives analysis, the forebay elevation was assumed to be about 75.0, and the tailwater elevation was assumed to be about 20.0 for the 120,000 cfs spillway discharge and about 35.0 for the 10 year, 7-day event discharge (see rating curves from plate 2 of 'Information Bulletin - Fish Passage Facilities Bonneville Dam, Report No. 66-1'). Tailwater rating curve for Bonneville is shown in Figure 1. Pertinent data for Bonneville Dam may be found in Figure 2. Tidal influence on tailwater elevation at Bonneville is limited to the very lowest range of spillway discharge.

See **Figure 1 - Tailwater Curves Bonneville Dam** on the following page. The figure was extracted from Report No. 66-1, "Information Bulletin - Fish Passage Facilities, Bonneville Dam. Columbia River, Oregon and Washington," which was produced by the Bonneville Hydraulic Laboratory for the Portland District, U.S. Army Corps of Engineers, in April 1958. Location of the river gage to which these rating curves apply was not given in the report. However, one can assume that these were developed from observed data during and after project construction, and from physical hydraulic model study results.

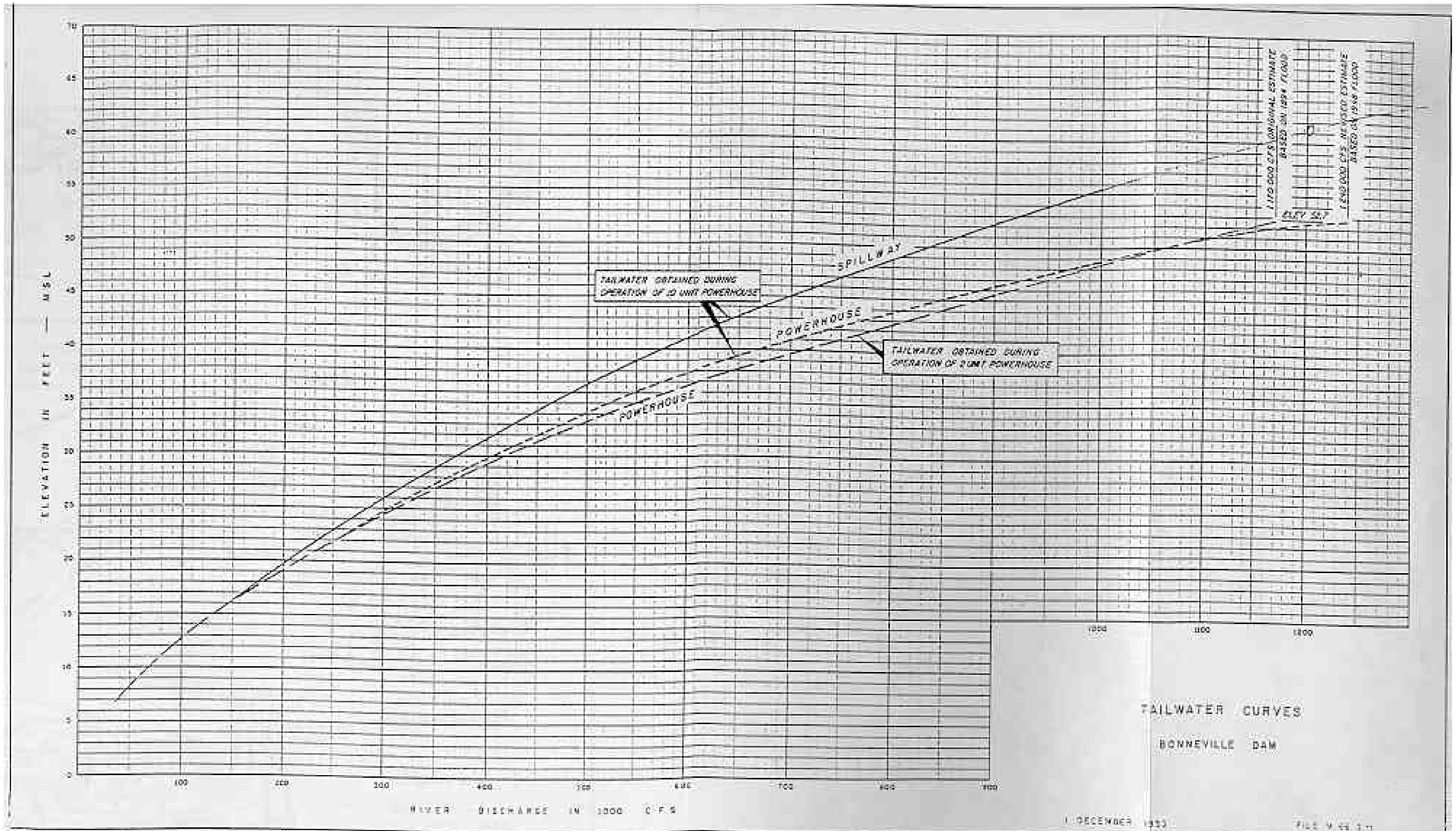

TAILWATER CURVES
BONNEVILLE DAM
ELEVATION IN FEET — MSL
RIVER DISCHARGE IN 1000 C.F.S.
SPILLWAY
POWERHOUSE
POWERHOUSE
TAILWATER OBTAINED DURING OPERATION OF 10 UNIT POWERHOUSE
TAILWATER OBTAINED DURING OPERATION OF 21 UNIT POWERHOUSE
1 170 000 CFS ORIGINAL ESTIMATE BASED ON 1894 FLOOD
1 240 000 CFS REVISED ESTIMATE BASED ON 1948 FLOOD
ELEV 52.7
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
100
200
300
400
500
600
700
800
900
1000
1100
1200
1 DECEMBER 1953

Figure 1

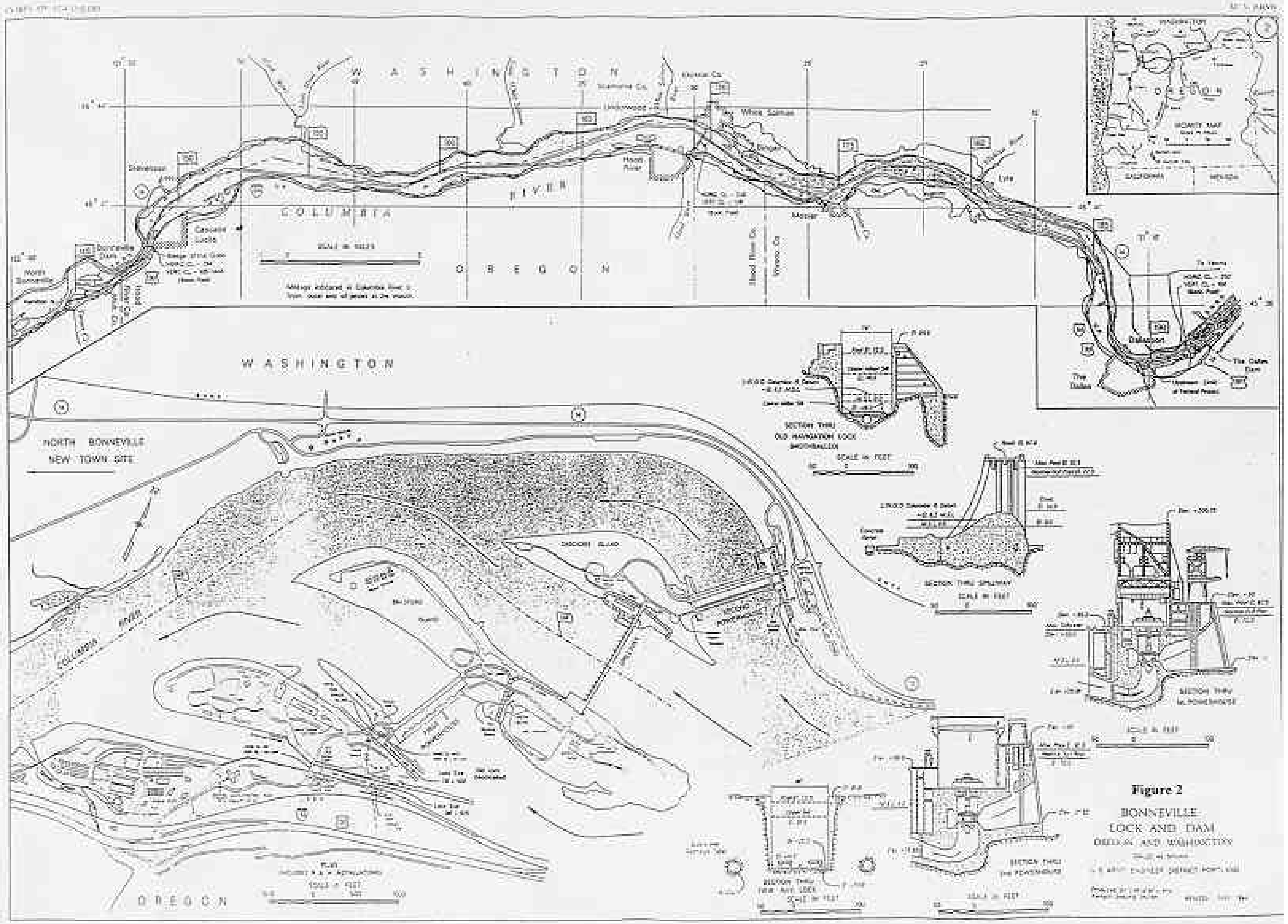


Figure 2

BONNEVILLE
LOCK AND DAM
OREGON AND WASHINGTON

5.0 ALTERNATIVE DESIGN SELECTION

5.1 Alternatives

TDG reduction alternatives were developed to the conceptual level for application at the Bonneville Dam Project. Each of the alternatives was evaluated for its respective ability to meet the study objectives. The list of 18 alternatives (20 when variations are included) is presented below.

1. Extended Deflectors
2. Relocated/Moveable Deflectors
3. Submerged Sluice Outlets In Spillway
4. Submerged Pressure Conduits Through Spillway (4a - Submerged gated vertical slots, 4b - Submerged ungated vertical slots)
5. Raised Stilling Basin
6. Raised Tailrace
7. Additional Spillway
8. Additional Spillway Bays
9. Overshot Spillway Gates
10. Modified Baffles in Stilling Basin (10a - Modified baffles on spillway & stilling basin, 10b - Modified baffles in stilling basin)
11. Downstream End Sill Control Structure
12. New Spillway Gates
13. Convert Some Turbines to Sluices
14. Wells Dam Hydrocombine
15. V-shaped Spillway
16. Relocated Spillway Downstream
17. Sluices Under Existing Spillway
18. Pressure Conduit Through Old Navigation Lock

Alternatives 1, 6, 12, and 17 were selected for further analysis in this report. A brief discussion of each of the alternatives follows Section 5.2. Conceptual drawings of the 14 alternatives not selected for further analysis in this report are provided in Appendix A. Detailed drawings for Alternatives 1, 6, 12, and 17 are provided in the Plates following this text.

5.2 Alternative Evaluation Matrix

The 18 alternatives (20 when variations are included) were subjectively evaluated by rating them according to performance in seven general categories. Each of the seven general categories was weighted with a value representing the relative importance of that particular consideration in the evaluation of each alternative. A weighting factor of 1 represented low importance, 2 represented moderate importance, and 3 represented high importance. The alternatives were ranked on a scale of 1 for low performance and 2 for high performance in each of the categories by the measure against which they met the objectives of the study. The results of the matrix evaluation and scoring results are presented in the Table 1, with the four highest scoring alternatives in bold type. The seven general categories of considerations used in the evaluation are discussed below.

Spillway design flood capacity: (weighting value of 3). The existing spillway design flood capacity may be compromised by implementation of the alternatives. In the interest of dam safety, the selected alternatives must not reduce the total design project outflow capacity. If the particular alternative compromised this capacity in any way, it received a ranking of 1 for poor performance. If the particular alternative did not affect spillway design discharge capacity or enhanced the project capacity, it received a ranking of 2 for good performance.

TDG reduction efficiency: (weighting value of 3). The selected alternative must be capable of effectively reducing the Total Dissolved Gas (TDG) levels below the dam to the desired 110% level, or that of the forebay water, whichever is higher. Not all the alternatives evaluated can reduce TDG to the desired 110%, and not all can reduce the TDG over a large range of discharges. Also, some alternatives may reduce TDG to 110% overall well downstream of the project facilities, but still produce much higher TDG levels in the immediate vicinity of the dam. Performance of some alternatives for TDG reduction may not be known at present, and physical scale modeling may be required to verify the hydraulic conditions which can lead to a reduction in gas saturation or to identify performance characteristics for which excessive gas saturation can occur.

Construction duration and difficulty: (weighting value of 2). Some alternatives will require multiple construction seasons for completion. Cofferdams may be required to dewater construction areas. Demolition and/or construction may adversely affect integrity of existing structures. Some alternatives are considerably more complex to construct than others. Allowable in-water work periods may restrict the amount of work that may be completed on a particular alternative in any one construction season, and may lengthen construction schedule considerably. Construction activities may adversely affect navigation uses of the project as well.

Project operations and hydropower impact: (weighting value of 1). Project operations impacts must play a significant role in the evaluation matrix. Operation of existing features of the project should not be compromised with the new facilities. In addition, Congress has mandated that overall O&M staffing must decrease over time, thus any new project facilities must not require additional project staffing to operate and maintain. Also, existing safety standards and navigation use must be maintained for the project with implementation of the proposed facilities.

Juvenile fish passage impacts: (weighting value of 3). Some alternatives may be very successful in providing for safe passage of juveniles, while others probably will not. Some of the alternatives may adversely affect the overall Fish Passage Efficiency of the project or Fish Guidance Efficiency of the powerhouses, while others may improve the FGE of the powerhouses. Selected alternatives will require significant biological modeling to determine their net effect upon juvenile passage.

Adult fish passage impacts: (weighting value of 3). Some alternatives will require reconstruction of existing adult fish ladder entrances or exits. Modifications to existing facilities required for implementation must not increase adult injury rates through fallback passage or increase adult delay in passage upstream.

Costs: (weighting value of 2). Total cost of implementation must include capital construction costs, future O&M costs, lost hydropower generation revenue loss, increased manpower costs, and others. Although total cost will play a very large part in the future development of the selected alternatives, the group felt that the biological and operational considerations should be weighted more than costs at this stage. Since no detailed cost estimates were available, relative estimated gross costs were used in the evaluation .

The evaluation and selection method was entirely subjective. However, such an evaluation was necessary to determine which of the 20 concepts were likely to best meet the goals of the Dissolved Gas Abatement Study program.

Table 1

Alternative	Spillway Design Flood Capacity (3)	TDG Reduction Efficiency (3)	Construction Duration & Difficulty (2)	Project Ops & Hydropower Impact (1)	Juvenile Passage Impacts (3)	Adult Passage Impacts (3)	Costs (2)	Sum
Bonneville Dam Gas Abatement Alternative Ranking (Ranked from 1 (poor) to 2 (good))								
12 - New Spillway Gates	2	2	1	2	2	2	2	**32**
1 - Extended Deflectors	2	1	2	2	2	2	2	**31**
6 - Raised Tailrace	2	1	2	2	2	2	2	**31**
17 - Sluices Under Existing Spillway	2	2	1	1	2	2	1	**29**
2 - Relocated / Moveable Deflectors	2	1	2	1	2	2	1	28
8 - Additional Spillway Bays	2	1	2	2	2	1	2	28
13 - Convert Some Turbines to Sluices	2	2	2	2	1	1	2	28
16 - Relocated Spillway Downstream	2	1	1	2	2	2	1	27
5 - Raised Stilling Basin	2	1	1	2	1	2	2	26
14 - Wells Dam Hydrocombine	2	1	1	1	2	2	1	26
7 - Additional Spillway	2	2	2	1	1	1	1	25
18 - Conduit through Old Navigation Lock	2	1	2	1	1	1	2	24
15 - V-Shaped Spillway	2	2	1	1	1	1	1	23
3 - Submerged Sluice Outlets	1	2	1	2	1	1	1	22
9 - Overshot Spillway Gates	1	2	1	2	1	1	1	21
10a - Modified Baffles Spillway/Stilling Basin	2	1	1	2	1	1	1	21
10b - Modified Baffles Stilling Basin	2	1	1	2	1	1	1	21
11 - D/S End Sill Control Structure	2	1	1	2	1	1	1	21
4a - Submerged Conduits with Gated Slots	1	2	1	1	1	1	1	20
4b - Submerged Conduits with Ungated Slots	1	2	1	1	1	1	1	20

The four highest rated alternatives, shown in bold font on Table 1, are: 1) Extended Deflectors, 2) Raised Tailrace, 3) New Spillway Gates, 4) Sluices Under Existing Spillway.

5.3 Alternatives Description

1. Extended Deflectors

a) *Hydraulic Design*: This alternative includes reconstructed deflectors with two horizontal surfaces at different elevations. The existing deflectors perform reasonably well at producing ideal skimming flow over a narrow range of tailwater elevations. By providing two horizontal deflector surfaces connected by a smooth parabolic shaped invert, the stepped deflector should be capable of producing ideal skimming flow over a wider range of tailwater elevations. In this concept, the upper horizontal surface is at elevation +14.0 ft MSL and the lower surface is at elevation +4.0 ft MSL. The parabolic shaped surface connecting the two is about 50 ft long. Horizontal surface elevations of +14.0 and +4.0 were selected to produce ideal skimming flow over a tailwater range of about +7.0 to about +35.0. Recent model study evaluation of preliminary conceptual stepped deflector configurations has shown that the stepped deflector does not produce optimum skimming flow conditions quite as anticipated. More detailed model study evaluation must be conducted to finalize deflector shape and elevation, stilling basin capacity, and document stilling basin hydraulic conditions over the desired range of spillway discharges and tailwater elevations.

b) *Structural Design and Constructibility*: This alternative consists of two horizontal deflector surfaces, the upper surface at elevation +14.0 and the lower surface at elevation +4.0, connected by a smooth parabolic surface. The downstream end, or lip, of the lower deflector surface extends about 60 ft downstream from the lip of the existing deflector. Although detailed physical hydraulic model studies have not been performed to verify hydraulic loads, pressures, and velocities, loading conditions on the proposed deflectors are expected to be severe. High velocities are expected to expose the new deflector surfaces to potential cavitation damage. A floating bulkhead could be used to de-water the work area for each spill bay. The construction duration is estimated to be about 2 years. See Plates 7 through 10 for details.

c) *Advantages*:

- Construction can be performed with minimal impact on project operations
- Extended deflectors may provide ideal skimming flow characteristics over wider range of tailwater elevations
- Work takes place within a single spillway bay at a time
- Minimal effects on adult fish passage

d) *Disadvantages*

- Limited expected reduction in TDG (<20%)
- Costs associated with de-watering may be high

2. Relocated/Moveable Deflectors

a) *Hydraulic Design*: This alternative includes deflectors that can be moved from elevation 1.5 to elevation 17.2. As discussed in Alternative 1 above, ideal deflector elevations vary with tailwater elevations at Bonneville; from elevation 6.0 for tailwater elevation 20.0 to about elevation 16.0 for tailwater elevation 35.0. Properly positioned deflectors have been shown to be effective in reducing TDG below Ice Harbor Dam, and are expected to accomplish some degree of TDG reduction at Bonneville as well. However, the effectiveness of moveable deflectors at Bonneville Dam may be limited by the widely varying submergence of the stilling basin for the range of flows selected for this study. In addition, the very large hydrostatic and momentum loads applied to the moveable deflector under high spillway discharge conditions may result in very difficult and complex design of reliable movement and attachment mechanisms. Moveable deflectors do not compromise the existing maximum spillway capacity of 1,600 kcfs.

b) *Structural Design & Constructibility*: This alternative would involve modification of the existing spillway to accept the track or roller mounted deflectors with the capability to adjust the deflective surface from elevation 1.5 to elevation 17.2. This alternative includes an extensive amount of mechanical equipment required to operate in a submerged condition. A floating bulkhead could be used to de-water the work area for each spill bay. Because of the complexity of this design and the limited construction window, the construction duration is estimated to be 3 to 4 years. See Plates 7 through 9 of Appendix A for details.

c) *Advantages*:

- Construction can be performed with minimal impact on project operations
- Moveable deflectors have a large operating range for effective TDG reduction
- Work takes place within a single spillway bay at a time
- Would not affect adult fish passage

d) Disadvantages:

- Limited expected reduction in TDG (<20%)
- Costs associated with de-watering may be high
- Reliability of mechanical equipment is questionable

3. Submerged Sluice Outlets In Spillway

a) *Hydraulic Design*: Alternative 3 includes replacement of spillway bays 5 through 14 with twenty submerged sluices controlled with vertical lift gates. Maximum capacity of the modified spillway would be significantly reduced from the existing spillway configuration with this alternative. The end spillway bays were not modified, in order to minimize interference with the adult fish attraction flow to the existing fish ladder entrances. The conduits are 15 ft wide and 24 ft high with a flared entrance that is 25 ft by 32 ft. The flared entrance was designed to guide the flow uniformly into the sluice and minimize possible control gate vibration problems. The existing spill bay openings are 50 ft wide, which allows sufficient space for two sluices per bay. The vertical lift gates would provide a maximum capacity of about 14 kcfs per sluice and a total discharge of about 283 kcfs with all twenty sluices operating and the remaining spillway bays discharging up to the 110% TDG discharge limit per bay. Individual sluices would only be operated with a fully open gate and closing would be accomplished as rapidly as possible. Discharge regulation would be accomplished by opening fully opening sluices. This alternative would either require additional spillway capacity of up to about 650 kcfs to provide maximum spillway capacity discharges of 1,600 kcfs, or it would require the Corps to accept the risk of deficient spillway capacity. Operation of these sluices in the fully open position may result in very low ambient pressures inside the conduit, possibly low enough to cause cavitation. Verification of the pressure profile can be made with a physical model of the modified spillway and sluices, and the design can be modified such that cavitation is no longer a potential problem.

b) *Structural Design*: This concept replaces ten of the eighteen existing spillway bays with a two new submerged sluiceways in each bay, for a total of twenty sluiceways. The sluiceway entrances would be bell mouth shaped, with a height of 32 ft and a width of 25 ft. The sluiceway would be 24 ft high and 15 ft wide downstream of the control gates, with invert elevation -16.0. A splitter wall 10 ft thick would divide the two sluices. All new construction would be completed within the existing crest width of 50 ft, to avoid modification to the existing spillway piers. The existing spillway was constructed by first building the piers, then building the spillway crest by mass concrete fill between the piers. The existing stilling basin baffles will be removed in order prevent the jet emanating from the proposed sluices from being deflected upward, potentially causing greater air entrainment. See Plates 10 through 12 of Appendix A for details.

c) *Constructibility*: The submerged outlets in-line with spillway flow will require an extensive cofferdam scheme for the upstream face and downstream stilling basin areas. The deep holes downstream of the existing stilling basin slab would be filled with rock or excavated concrete and capped with tremie-fill concrete or grouted jetty armor rock (Class A 20,000 lb or larger). Hydraulic model studies are required to determine the effectiveness of the submerged sluiceways for reducing TDG levels. The proposed alternative would require six to seven years for construction if normal in-water work windows were to apply, or somewhat less time if a change to the present in-water work window criteria could be made.

d) *Advantages*:

- Good potential in reducing TDG as shown by ongoing model studies of Ice Harbor Spillway with sluices
- Work area may be isolated easily by cofferdams
- Would not affect adult fish passage
- Could be designed into existing spillway
- May be combined with stilling basin modifications

e) *Disadvantages*:

- Moderate impact to project operation
- High costs for new sluiceways/bulkhead gates/intake structure/cofferdam construction
- Reduces spillway capacity - will need new spill facilities to compensate for loss of capacity, or else accept significant risk of deficient capacity

4. Submerged Pressure Conduits Through Spillway (4a - Submerged gated vertical slots, 4b - Submerged ungated vertical slots)

This concept was developed as an alternative to the submerged sluices in order to reduce the energy of re-entrant jets by increasing their total number and reducing their size. To do so requires an extended length of conduit to feed the system of slots, as proposed.

Alternative 4 includes two options:

- Submerged conduits with vertical slots.
- Submerged conduits with controlled orifices.

In each of these options for this alternative, several spillway bay crest monoliths would be replaced with large, cast-in-place concrete pressure conduits extending through the spillway and well downstream into the spillway exit channel. These pressure conduits will be about 23 ft wide by about 26 ft deep, with an invert elevation near elevation -16.0, and the total length of the conduit differs between the two options.

Alternatives 4A - Submerged Gated Vertical Slots

a) *Hydraulic Design*: This concept includes twelve discharge conduits located in spillway bays 4 and 5, 9 and 10, and 14 and 15, with two conduits in each spillway bay. Each discharge conduit would be 26 ft high by 23 ft wide, separated from the adjacent conduit by an intermediate support wall about 4 ft thick. Maximum discharge capacity of each conduit would be about 21 kcfs. Downstream of the spillway monolith, each set of four adjacent conduits combine into one large discharge conduit which extends several hundred feet downstream (about 490 ft for spillway bays 4 and 5 and bays 14 and 15, and 250 ft for spillway bays 9 and 10). Each large conduit passes discharge into the spillway exit channel through 32 vertical slots in the sidewall of the conduit. The two large conduits at either end of the spillway have slots on the channel side only, while the center conduit has slots on both sides. Each vertical slot will be 5 ft wide by 15 ft deep with invert elevation -5.5, they will be spaced 10 ft apart, and they will be controlled by vertical slide gates. Discharge capacity of the spillway with this alternative while meeting the TDG goals for the 10 year, 7-day event is about 283 kcfs, with about 252 kcfs discharging through the vertical slots and about 31 kcfs through the unmodified spillway bays. Maximum capacity of the spillway, with all vertical slots open and all unmodified spillway bays open, is about 1,300 kcfs. This alternative would require additional spillway capacity to pass the existing spillway discharge capacity of 1,600 kcfs.

b) *Structural Design*: The right and left bank developments would have two water passages extending 490 ft downstream from the spillway toe, and the center development would have a water passage extending 250 ft downstream from the spillway toe. Each of the submerged conduits would have a dry service gallery housing mechanical and electrical equipment. Gate operators would consist of hydraulic hoists to control the gate opening and discharge through each slot, and they would be mounted on the exterior walls of the service gallery. To construct this alternative, the concrete within the spillway crest of each modified bay would be removed to elevation -16. The existing spillway piers will be modified by adding an extension with bulkhead slots extending from the top deck down to elevation -16. The existing stilling basin baffles in the modified bays would be removed, and a new concrete discharge slab would be constructed alongside the conduits below the vertical slots and extending out from the slots. A new access bridge would span from the existing spillway structure (elevation 90.0) to the service deck of the control structure (elevation 64.0). See Plates 13 through 16 of Appendix A for details. This alternative would require about 4 years to construct.

c) *Constructibility*: This alternative would be difficult to stage for the required de-watering, both upstream and downstream of the existing spillway dam. The established in-water work periods would limit the time for construction.

d) *Advantages*:

- Produces TDG nearly equivalent to that of forebay
- Outlets discharge at spillway apron elevation, eliminating plunging flow
- Could be designed into existing spillway

e) Disadvantages:

- Spillway stilling basin not designed for crossflow
- May present adult fish attraction problems
- Energy dissipation may not be adequate in stilling basin for high velocity jets
- Reduces spillway capacity - will need new spill facilities to compensate for loss of capacity, or else accept risk of deficient capacity

Alternative 4B - Submerged Ungated Vertical Slots

a) *Hydraulic Design*: Alternative 4B is similar to 4A, except that the discharge conduits are 600 ft long, each of which has 60 submerged vertical slots 1 ft wide by 20 ft high located along the sides of each of the conduits. The intake entrances to the conduits would be 50 ft wide and about 43 ft high, and the conduits would be 50 ft wide by 26 ft high, with the ceiling and floor at elevations +10.0 and -16.0 ft, respectively. A large vertical lift gate will provide closure for each intake entrance. This gate would not be used to control discharge into the conduits, and would be either fully open or fully closed. Dewatering of the conduit would be accomplished by closure of the vertical lift gate at the conduit entrance and placement of bulkheads at each vertical slot opening. The vertical slots would be spaced 10 ft apart to maximize energy dissipation between each jet. Maximum discharge capacity of each of the six conduits would be about 43 kcfs. Discharge capacity of the spillway with this alternative while meeting the TDG goals for the 10 year, 7-day event is about 283 kcfs, with about 252 kcfs discharging through the vertical slots and about 31 kcfs through the unmodified spillway bays. Maximum capacity of the spillway, with all vertical slots open and all unmodified spillway bays open, is about 1,300 kcfs. This alternative would require additional spillway capacity to pass the existing spillway discharge capacity of 1,600 kcfs.

b) *Structural Design*: The invert at the conduit entrance would be set at elevation -16.0 and the entrance ceiling would extend to elevation +27.3, and have an emergency gate slot for closure. Each vertical slot would be provided with a bulkhead for closure. All of the existing spillway crest concrete would be removed in the modified spillway bays in this alternative. Three new access bridges would span from the existing spillway deck at elevation 90.0 and slope to the service deck of each conduit a elevation 64.0. The existing spillway baffles would be removed with this option. See Plates 17 through 20 of Appendix A for details.

c) *Constructibility*: This alternative would be difficult to stage for the required de-watering, both upstream and downstream of the existing spillway dam. The established in-water work periods would limit the time for construction.

d) *Advantages*:

- Produces TDG nearly equivalent to that of forebay
- Outlets discharge at spillway apron elevation, eliminating plunging flow
- Could be designed into existing spillway

e) Disadvantages:

- Spillway stilling basin not designed for crossflow
- May present adult fish attraction problems
- Energy dissipation may not be adequate in stilling basin for high velocity jets
- Reduces spillway capacity - will need new spill facilities to compensate for loss of capacity, or else accept risk of deficient capacity

5 Raised Stilling Basin

a) Hydraulic Design: This alternative involves lengthening the existing stilling basin, and raising both the primary basin floor elevation and the secondary basin floor elevation. The primary upstream basin of the modified stilling basin would be 83.5 ft long with a floor elevation of 3.3, and the secondary downstream basin would be 232.0 ft long with a floor elevation of 0.40. The purpose of this alternative is to decrease the depth of plunge and increase the time the flow can off-gas to reduce TDG before entering the unmodified spillway exit channel. Maximum spillway discharge capacity of 1,600 kcfs is not compromised with this alternative.

b) *Structural Design & Constructibility*: The raised secondary basin is one of the simplest solutions proposed. This option would fill the entire 18-bay width of the primary and secondary basins to elevation 3.3 and 0.4, respectively, and extend the secondary basin downstream. Reinforced concrete with anchors grouted into the existing stilling basin floor after demolishing the existing surface concrete down to competent and clean subsurface concrete would be used to construct the new basins. It is possible that tremie fill concrete could also be used for this alternative, eliminating the need for dewatering the entire work area. The maximum depth of eroded pools and other depressions within the proposed area of fill for the secondary basin extend to elevation -50.0 in some places. See Plates 21 through 23 of Appendix A for details.

c) *Advantages*:

- Some TDG reduction may be achieved
- Minimal adult fish passage impacts if adult access to ladder entrances not impaired
- If tremie fill concrete can be used, no de-watering or cofferdam needed

d) *Disadvantages*:
- Potentially moderate impact to project operation during construction
- Possibly minimal reduction in TDG, as tailwater depth ranges widely and is not ideal for TDG reduction
- To be effective, it must be combined with filling deep holes spillway exit channel to eliminate plunging of aerated flow to deep depths

6. Raised Tailrace

a) *Hydraulic Design*: The raised tailrace alternative consists of filling the tailrace downstream of the secondary stilling basin to an elevation of about +5.0, providing a fast, shallow, turbulent channel similar to The Dalles Dam spillway exit channel. The shallow, fast moving, turbulent exit channel at the Dalles Dam apparently permits dissolved gases to come out of solution and escape into the atmosphere. The proposed raised tailrace spillway exit channel for Bonneville is designed to provide similar hydraulic conditions to The Dalles Dam spillway exit channel, with no more than about 12 to 15 ft depth for discharges up to about the average annual spring river flow. Deeper channels will be provided along both shorelines through the raised tailrace section to aid adult fish passage to the existing fish ladder entrances. At very high discharges, the raised tailrace channel will be submerged by more than the desired 12 to 15 ft due to backwater effects from the downstream channel. Flow velocity in the raised channel section will vary from about 10 to 15 fps during the average annual spring river flow.

b) *Structural Design and Constructibility*: The raise tailrace alternative is also one of the least complicated solutions presented in this report. No concrete structures are proposed, and no modifications to existing structures will be required with this alternative. The large armor rock proposed as fill material for the tailrace channel will be grouted in place with tremie concrete. This grout will not be designed as a structural element, rather only a means of eliminating voids in the armor rock layer. Stability of the armor rock fill material is expected to be provided primarily by the reduced slope at which the rock is placed, but enhanced by the grout layer. Tremie concrete grout in this case is designed to reduce the surface area of the armor rock stone available to the flow, which should limit the ability of the flow to pluck stones from the armor layer. The construction schedule for this alternative extends over a period of about 2 years. Armor rock will be placed in phases, with the south half of the tailrace filled during the first year of construction and the north half of the tailrace filled during the second year. Grout will be placed by tremie method from a floating plant. Placement quality will be verified by diving inspections during construction. See Plates 11 through 13 for details.

c) *Advantages*:

- TDG reduction similar to that observed at The Dalles may be achieved, provided forebay and stilling basin TDG is very high to start with
- Minimal adult fish passage impacts if adult passage through deepened side channels is successful
- No de-watering or cofferdam needed

d) *Disadvantages*:

- Potentially moderate impact to project operation during construction
- Wide tailwater elevation range may cause this alternative to be less successful than The Dalles Dam at reducing very high TDG levels
- May raise TDG levels above stilling basin level as a result of additional aeration in shallow tailrace channel

7. Additional Spillway

a) *Hydraulic Design:* Additional spillway alternatives for Bonneville Dam were investigated earlier in a previous report produced by Summit Technology and Northwest Hydraulic Consultants. The conclusions of that study report established that an additional spillway at Bonneville Dam would be difficult to develop, given the limited space available for such a large structure. Further investigation herein determined that a limited length, baffled chute spillway could be constructed on Cascade Island, with a large, very deep, concrete lined approach channel passing between the south side of the second powerhouse and the existing north bank spillway fish ladder. The existing adult transportation channel would pass through the spillway approach channel under the proposed bulkhead crane access bridge. Maximum capacity of this additional spillway would be about 239,000 cfs (60% of the 10 year flow minus 44,000 cfs existing spillway capacity to 110% TDG). Five 200 ft long x 75 ft radius x 30 ft high drum type gates pass maximum unit discharge of 240 cfs/ft to a baffled chute spillway with 2.3H to 1V slope (similar to proposed Libby re-regulating dam). Baffled chute spillway discharges into second powerhouse tailrace channel well downstream of powerhouse. Baffled chute spillways have been shown to be quite effective in reducing TDG levels. Crest elevation of baffled chute spillway would be about 45.0, and the approach channel invert elevation would be about 0.0. Minimum width of about 250 feet in the approach channel would occur at the point between the existing second powerhouse and the north bank spillway fish ladder. The channel would expand to as much as 500 feet wide near the drum gates. Three 85 foot wide x 80 feet high bulkheads placed from the crane access bridge at the narrowest point of the approach channel provides for positive closure of the channel and dewatering. This alternative does not compromise existing maximum spillway capacity.

b) *Structural Design:* Several major features that will be developed for the project are listed as follows:

- Establish cofferdam requirements for upstream and downstream construction
- Excavation and removal of significant part of Cascade Island above elevation 0.0 msl

- Establish a concrete cutoff wall and non-overflow/embankment dam around the parameter of the new forebay
- Establish a three-bay bulkhead/closure dam between the second powerhouse and upstream portion of Cascade Island
- Establish a multiple chord five-bay drum gate/baffled chute spillway
- Incorporate trash boom(s) for floating debris
- Forebay drainage conduit and valve

This complete development will require several construction phases and multi-year contracts. See Plates 27 through 30 of Appendix A for details.

c) Constructibility: The new drum gate spillway contains five bays with an operating range between elevation 45.0 msl and elevation 75.0 msl. The drum gates would be 200 ft in width and have a gate radius of 70 ft. The drum gate would lower into a gate recess that extends to elevation 13.0 msl. The projected gate surface would be 32 ft high by 200 ft wide. Each new spillway pier will be 10 ft thick with base length of 85 ft. The downstream pier edge is battered on a 1 horizontal on 3 vertical, with top of pier set at elevation 90.0 msl. The new trunnions are set at elevation 43.0 msl. The baffled chute spillway is set on a fixed slope 2.3 horizontal on 1 vertical and extends from elevation 45.0 msl to elevation -16.0 msl. The new spillway baffles are the same as those proposed for Alternatives 10A and 10B. The baffle base is a polygon; 2.0 ft (w) x 4.41 ft (w) x 4.5 ft (l) x 4.5 ft (h) with a triangular stem extension 2.0 ft (w) x 0.73 ft (d) x 4.5 ft (h). The total height of each baffle is 9.0 ft. The spillway would have 6 rows of baffles and placed on a staggered space of 10 ft. Each row would be 15 ft apart. A total of 138 baffles will be required for each 200-ft wide spillway bay.

The new bulkhead closure dam would consist of 3 - 80 ft wide bays and extend from elevation 0.0 msl to elevation 78.0 ft. Each bulkhead would be segmented and put into place by the existing second powerhouse intake gantry crane. The new service bridge and gantry crane bridge will span the new forebay channel.

d) *Advantages*:

- Good debris passage
- Excellent TDG reduction
- Could be designed into Cascade Island
- Minimal impact to existing adult fish passage facilities

e) *Disadvantages*:

- May impacts project operations
- Significant impact to public access areas on Cascade Island
- High costs
- Complex upstream and downstream de-watering
- Additional adult fish ladder entrances and transportation channels may be required

8. Additional Spillway Bays

a) *Hydraulic Design*: This alternative considers the addition of two spillway bays between the north end of the existing spillway and the north bank adult fish ladder (Washington shore fish ladder). The additional bays would be similar to the existing bays but with an elevated stilling basin. Discharge from the two additional spillway bays would pass under a portion of a reconstructed, elevated portion of the existing north bank spillway fish ladder in a concrete lined channel leading to the spillway exit channel. Very little additional spillway capacity can be provided within the confines of the existing spillway and the area bounded by the fish ladder structures. Limited clearance under the ladder will prevent the passage of any more than about 5,000 cfs through this channel, falling far short of the additional 239,000 cfs required to meet the TDG criteria. This alternative does not require modification of the existing spillway, thus it will not compromise the maximum existing spillway capacity of 1,600 kcfs.

b) *Structural Design and Constructibility*: Two additional 50-ft-wide Bonneville type spillway bays could be added into the right abutment at the end of the existing spillway on Cascade Island. The new stilling basin for the two additional bays would be provided with baffles identical to those used in Alternative 10A and 10B. De-watering requirements for upstream and downstream construction areas are confined but complex. The proposed new bays 19 and 20 would be founded on rock, they would have an ogee crest at elevation 24.0 msl and 2 rows of new baffles at stilling basin elevation -16.0 msl. The discharge from the proposed new spillway bays would pass under the existing fish ladder to the west. The excavation for the new intake would cut through the existing Washington shore fish ladder that is upstream and east of the right abutment of the spillway. All debris created from this development would be hauled off site. The proposed site for this alternative could also accommodate the structures proposed for Alternate 3 or Alternative 17. See Plates 31 through 33 of Appendix A for details.

c) *Advantages*:

- Work area may be isolated by cofferdams

d) *Disadvantages*:

- TDG reduction not significant
- Impacts project operations
- Limited effectiveness in reducing TDG
- Difficult construction adjacent to operational existing project features
- Moderate costs for dewatering work area
- May affect adult fish passage
- Eliminates upstream section of Washington shore fish ladder that is used during emergencies

9. Overshot Spillway Gates

a) *Hydraulic Design*: In this alternative, spillway bays number 5 through 14 are replaced with 5 - 100 ft radius drum gates 110 feet wide. These drum gates discharge into an elevated and contained spillway exit channel about 1400 ft long with an invert slope of 0.0145 ft/ft. The channel will be separated from the existing exit channel by sidewalls extending to about elevation 50. Drum gates provide crest overflow control for a unit discharge range of up to about 470 cfs/ft, or 257 kcfs total, through the contained exit channel. Additional flow (26 kcfs) will pass through the remaining 8 existing spillway bays, providing the total desired spillway flow capacity of 283 kcfs (60% of 10 yr 7-day event) for TDG reduction. The long, shallow gradient drum gate exit channel is designed to form an undular hydraulic jump or a smooth transition to subcritical flow at some point within the channel length for a range of drum gate discharges of from 94 kcfs to 257 kcfs. Theoretically, this channel would have to be very rough in order for an undular jump or smooth transition to occur within the channel length. The very rough channel may prove to be unacceptable for passage of juvenile fish. Although this alternative may meet the TDG goals, it reduces the total maximum spillway capacity to about 880 kcfs, which is about 720 kcfs less than the existing maximum spillway capacity of about 1,600 kcfs. Additional spillway capacity will be required with this alternative.

b) *Structural Design & Constructibility*: This concept would require an extensive modification to the existing spillway and stilling basin. The development would create five new drum gates within existing bays 5 through 14. Each of the new modified bays would be 110 ft wide, with a 100-ft radius drum gate with crest elevation in the full down position of about 24.0 and elevation 80.0 in the full up position. New supporting piers between drum gates would be 7.5 ft thick, and would extend 110 ft downstream of the existing construction base line (CBL). The new spillway apron and exit channel will have an invert slope of 0.0145 ft/ft and will extend downstream for 1400 ft. Each side of this new spillway exit channel would have new 7.5-ft thick training walls. See Plates 34 through 37 of Appendix A for details.

A major portion of the existing spillway concrete ogee and intermediate spillway pier will be removed to accommodate the new drum gates. The remaining existing piers will be extended and new trunnions placed at elevation 24. The new drum gate compartment would be configured to accept the upstream curved radius of the new water tight drum gates. The new filling and emptying system will supply water to the drum gate for normal operation. The mechanical and electrical equipment will be located within the new spillway piers. This alternative will require an extensive stilling basin extension and revision for the affected spillway bays. Roller compacted concrete would be used to construct the sloping spillway apron and exit channel downstream of the drum gates. The spillway exit channel is 1400 ft long, with a slope of 0.0145 ft/ft and upstream and downstream invert elevation of 24.0 and 3.7, respectively. This alternative would take about 4 to 5 years to construct.

c) *Advantages*:

- Good juvenile fish bypass, except for possible excessive exit channel roughness
- Good debris passage

- TDG reduction may be good
- Could be designed into existing spillway
- Moderate adult fish passage impacts

d) *Disadvantages*:

- May impact project operations
- May need to be combined with stilling basin modification to otherwise unaffected bays
- High costs
- Complex upstream and downstream de-watering during construction.

10. Modified Baffles in Stilling Basin (10a - Modified baffles on spillway & stilling basin, 10b - Modified baffles in stilling basin)

Alternative 10A (Modified Baffles on Spillway & Stilling Basin)

a) Hydraulic Design: This alternative consists of raising the stilling basin floor elevation, modification of the existing stilling basin baffles, and addition of spillway chute baffles. Very little design guidance or previous experience is available in the literature for application to stilling basin baffle design specifically for the purpose of reducing TDG levels or of preventing gas from dissolving into the stilling basin flow. However, raising the stilling basin floor elevation will prevent most aerated stilling basin flow from plunging to deep depths, thereby reducing the potential for TDG increases. For the spillway baffled chute, we selected the baffle design from the proposed (but not completed) Libby re-regulating dam spillway (see Libby Dam Reregulating Dam Model Study Report). In the Libby Dam design, this baffle type is about 9 feet high, with a triangular base and wedge-shaped extension. It was originally designed to protrude above the flow profile in the spillway chute application, and can accommodate unit discharges as high as 250 cfs/ft. In this proposed Bonneville Dam spillway, unit discharge will be as high as 260 to 270 cfs/ft. In the Libby re-regulating dam baffled chute spillway model study, excellent energy dissipation was achieved in the spillway chute, and TDG increases above the forebay arising from flow aeration on the spillway chute were very low. Overall, the baffled chute spillway application for this baffle design was highly successful. The stilling basin baffle design is of the characteristic St. Anthony Falls dentate baffle. With the raised stilling basin floor, the need for TDG reduction is met primarily by the elimination of deeply plunging aerated flow, and the baffle design is intended for energy dissipation only. The length of raised stilling basin necessary to accomplish the required de-aeration of stilling basin flow has not been determined. However, further analysis during the following phase of this study would accomplish that requirement. This alternative is not likely to adversely impact the maximum spillway discharge capacity of 1,600 kcfs.

b) Structural Design & Constructibility: This proposal utilizes new spillway and stilling basin baffles. The existing primary at secondary stilling basin floor elevations will be raised to elevation 8, thus eliminating a portion of the deep plunge pool in the spillway tailrace. Two new types of baffles will be used in this alternative. The spillway face baffle has a four side polygon base, tapered sides, and triangular stem that is 9 ft tall, identical to that used in alternative 7 on the baffled chute spillway. In plan, there are five rows of spillway face baffles, with stagger spacing of 5.58 ft and rows 18 ft apart. Counting half baffles on alternate rows, there are a total of 27 baffles on the spillway face per spillway bay. The stilling basin baffles are conventional dentate baffles, arranged in two rows 15 ft apart and staggered at 5 ft apart. This option would require about a multiple 3-year contract for construction. See Plates 38 through 41 of Appendix A for details.

c) Advantages:

- Eliminates plunge pool in secondary stilling basin
- Work areas may be isolated by cofferdams

d) Disadvantages:

Unknown TDG reduction can only be determined with modeling and prototype tests.

- Impacts project operations
- Moderate costs associated with de-watering for construction

Alternative 10B (Modified Baffles in Stilling Basin)

a) *Hydraulic Design:* This alternative consists of simple modification of the existing stilling basin baffles only, with no raise of the stilling basin floor elevation. Very little design guidance or previous experience is available in the literature for application to stilling basin baffle design specifically for the purpose of reducing TDG levels or of preventing gas from dissolving into the stilling basin flow. In lieu of more specific guidance or designs for accomplishing this purpose, we selected the baffle design from the proposed (but not completed) Libby re-regulating dam spillway. In the Libby Dam design, this baffle type is about 9 feet high, with a triangular base and wedge-shaped vertical extension. The baffle was originally designed for use in baffled chute spillways, not necessarily in deep stilling basins. In addition, it was originally designed to protrude above the flow profile in the spillway chute application, and could accommodate unit discharges as high as 250 cfs/ft. In this stilling basin application, it will be fully submerged and the unit discharge will be as high as 260 to 270 cfs/ft. In the Libby re-regulating dam baffled chute spillway model study, excellent energy dissipation was achieved in the spillway chute, and TDG increases above the forebay arising from flow aeration on the spillway chute were very low. However, the TDG reduction effectiveness of the same baffle design as proposed for use in this alternative in the stilling basin is unknown and would require significant model and prototype testing to confirm. This alternative is not likely to compromise maximum spillway discharge capacity.

(b) Structural Design: Alternative 10B differs from Plan 10A in that the stilling basin fill is eliminated, the existing stilling basin baffles are removed, and the new 9-ft-tall baffle discussed for Alt. 10A would be used in the stilling basin. Alternative 10B would have four rows of tall baffles, 15 ft apart, and at 10-ft stagger spacing. A total of 26 new baffles would be placed per stilling basin bay. The configuration would include four rows spaced 15 ft apart and staggered at 10-ft intervals. See Plates 42 through 44 of Appendix A for details.

c) *Advantages*:

- Work area may be isolated by cofferdams

d) *Disadvantages*:

- Unknown TDG reduction, but likely small
- Impacts project operations
- Moderate costs associated with de-watering for construction

11. Downstream End Sill Control Structure

a) *Hydraulic Design*: Alternative 11 includes a raised stilling basin and a new end sill control structure. The existing stilling basin has no end sill and as a result aerated flow from the stilling basin plunges to great depths immediately downstream of the secondary stilling basin. This alternative would raise the entire stilling basin floor to elevation 12.0, and an end sill with crest elevation 19.5 and width of 76 ft would be constructed about 70 ft downstream from the toe of the existing spillway. With this configuration, the hydraulic jump should be fully contained within the stilling basin for the range of discharges of interest in the design criteria (TDG reduction to 110% for spillway discharge equal to 60% of 10 year, 7-day event), and highly aerated flow will have more time to off gas prior to passing over the end sill into deeper sections of the exit channel. The end sill and stilling basin will be designed for the lower range of river flows for which TDG reduction is desired (120 kcfs) and would operate as a submerged weir for flows in excess of that range. For spillway flow of 120 kcfs and corresponding tailwater elevation 20.0, the end sill will not be submerged and critical depth control will be achieved at the sill with about 8.2 ft depth on the sill. The sequent depth (d_2) in the stilling basin at this discharge is about 21 ft. For spillway flow of 283 kcfs and tailwater elevation 35.0, the end sill will act as a submerged broad crested weir. The sequent depth (d_2) in the stilling basin at this discharge is about 32 ft, or about elevation 44.0.

b) *Structural Design & Constructibility*: This option would require extending the existing right and left bank fishway channels downstream beyond the new weir end sill. The projects would be phased to allow continued use of portions of the existing spillway bays during high river flows. The existing deep holes downstream of the stilling basin would be filled with very large rock. New sheet pile cofferdams will be required to form the new north and south fishway channels and phased end sills. New mass RCC will be placed within the stilling basin area to raise the spillway and eliminate the existing plunge pool. This option would require a contract of between 3 to 4 years long. See Plates 45-47 of Appendix A for details.

c) *Advantages*:

- Work areas may be isolated by cofferdams
- Modifications may be required for existing fish ladder entrance location
- Could be designed into existing spillway
- TDG reduction should be fair

d) *Disadvantages*:

- Impacts project operations
- Must be combined with other stilling basin and plunge pool modifications to be successful
- May reduce maximum spillway capacity as a result of artificially high tailwater
- May have to use multiple stilling basin separated by lower weirs to achieve adequate TDG reduction
- Still may have high TDG in each of the multiple stilling basins, if they are necessary
- May require a new auxiliary spillway structure to provide additional spillway capacity

12. New Spillway Gates

a) *Hydraulic Design*: This alternative consists of replacement of existing split leaf vertical spillway gates with large tainter-type gates downstream of the existing gate slots to control spillway discharge. These gates would be supported by trunnions mounted on large downstream extensions to the existing spillway piers. The gate seat would be embedded in the existing spillway ogee surface at about elevation 0.0 ft MSL. Preliminary model study evaluation of this alternative at the Waterways Experiment Station shows that the jet eminating from under the tainter gate is submerged for a range of discharges, provided the gate lip is submerged by at least several feet below the tailwater surface. No aeration of the jet was noted for spillway discharges up to about 10,000 cfs per spillway bay at tailwater elevations as low as 10.0 ft MSL. Lack of aeration indicates that this alternative will pass forebay TDG directly to the tailrace without increase. Although the new spillway gate alternative as proposed in this report consists of radial gates, vertical lift gates could also be employed to control spillway flows. However, vertical gates require large, high capacity hoist systems, and gate handling may cause this alternative to be less practical than the tainter gate design. Conversely, vertical lift gates would significantly reduce the length and size of spillway pier extension required to support gate slots compared to those required for radial gates, and also the size and complexity of construction dewatering structures. Vertical gates have also been shown to be subject to unacceptable vibrations resulting from operation in the submerged condition. Detailed physical model studies of both the radial gate concept and the vertical gate concept will be required to develop potential solutions to the possible vibration problems and to determine gate design criteria.

b) *Structural Design & Constructibility*: The new spillway gate alternative as proposed requires that the spillway piers be extended more than 100 feet downstream of the existing downstream pier face. The new spillway gate structure will require an extensive post-tension anchorage system to ensure stability under the very large loads transferred from the tainter gate trunnions. The 100 ft radius, 50 ft wide tainter gates will also require large structural members to resist the 70 to 80 feet of hydrostatic head applied to the upstream face of the gate. Trunnion bearings and yoke assemblies for these large gates will be quite large, to resist hydrostatic loads of as much as 5000 tons per gate. Hoist loads will be equivalent to approximately the weight of the gate assembly plus bearing and seal friction loads. A new spillway access bridge will also be constructed just downstream of the tainter gate trunnion axis. Construction of tainter type gates as proposed in this report would require cofferdams extending to the downstream end of the existing primary stilling basin floor and covering one spillway bay at a time. This cofferdam structure would be about 56 feet high, extending to elevation 40.0. The construction schedule requires about 3 years to complete the proposed project, with about 6 of the 18 spillway bays completed during each construction season. During high flow periods, portions of the cofferdam structure may have to be removed from the stilling basin to permit increased spillway capacity or to accommodate fish passage requirements. See Plates 14 through 18 for details.

c) *Advantages*:

- Effectively passes forebay TDG level without increase
- Reduces turbulence and aeration in stilling basin
- Construction disrupts operation of only a portion of the spillway at any one time
- Does not adversely affect existing maximum design spillway discharge capacity

d) *Disadvantages*:

- Potentially moderate impact to project operation during construction
- Construction dewatering cofferdam structures are large and extend well out into stilling basin
- Submerged operation of gates may cause unacceptable vibrations
- Downstream fish passage survival unknown
- May adversely affect adult attraction to existing fish ladder entrances

13. Convert Some Turbines to Sluices

a) *Hydraulic Design*: This alternative would consist of removal of four turbine runners, wicket gate assemblies, and scroll cases from the First Powerhouse, and replacement with pressurized sluices with large vertical slide gates at the downstream end to provide positive closure. Each of the existing First Powerhouse turbines has three intake entrance bays and two draft tube outlet bays. Bulkhead slots and large cable lift bulkheads are provided for closure of each of the three existing intake bays and for each of the two existing draft tube bays. In the proposed alternative, flow would enter the three intake bays, combine, and flow out through the two draft tube outlet bays. This alternative would require straightening of the concrete dividing walls between the three intake entrance bays and modification of the two existing draft tube closure bulkhead gates and slots into bonneted vertical slide gates with hydraulic operators. In the proposed alternative, the pressurized sluices and vertical slide gates would be designed to withstand full reservoir head differential. The vertical slide gates would be operated only fully open or fully closed. Theoretical capacity of each of the converted turbines ranges from about 80 kcfs at forebay elevation 75 and tailwater elevation 35, to about 95 kcfs at forebay elevation 75 and tailwater elevation 20. Four converted turbines plus the existing spillway would provide at least 364,000 cfs spillway and sluice capacity, while meeting the TDG goal of 110% for the 10 year 7-day event. Note that the total project capacity loss of four turbines is accounted for in the additional capacity of this alternative Model studies would be required to identify measures necessary for insuring that the large discharge jets exiting the draft tubes from the converted turbine units do not cause such turbulence in the tailrace water surface to cause gas entrainment and to insure that structural damage to unchanged turbine units is minimal.

b) *Structural Design*: This alternative would replace four existing generator bays in the First Powerhouse with sluices. These water passages would be uncontrolled, and positive closure would be provided by a downstream vertical slide gate mounted in the modified draft tube closure bulkhead slots. The hydraulic operator for each gate and the pressure bonnet would be mounted on the tailrace access deck and secured to the existing downstream powerhouse wall. Extensive modifications will be needed within the intake structure and existing turbine area to construct the two sluices as discussed. This option will require extending the existing intake piers (full height) down through the turbine area. This modification is primarily within the skeleton bay additional concrete. A majority of the existing heavily reinforced concrete in the vicinity of the turbine scroll case would have to be removed and the void re-constructed to the new shape of the sluices. A new single discharge pier would be formed upstream of the new vertical slide gates. This intermediate pier would divide the discharge outlet into two 34’ 0”- wide water passages.

The new sluice gates would seat at elevation -45.0 msl and extend past the existing draft tube ceiling (elevation -21.4 msl). The new gates would be 36 ft wide and 25 ft high. The new hydraulic operator with bonnet would be set on the existing tailrace deck (elevation 55.0 msl). The new hydraulic operation would be about 30 ft long. The new hydraulic cylinders would be installed and serviced by a mobile crane.

The monolith joints within the new sluice bays would have new waterstops at all new vertical construction joints. It may be difficult to maintain the existing watertight joints within the skeleton bay during the concrete removal phase. Remedial measure, such as drilling and grouting may be necessary.

This alternative would surplus four existing first powerhouse generators, shafts, turbines, and transformers. There is value associated with this equipment and thus a separate repair/storage building would be required. This concept would require a crawler transporter to move the equipment and a new rail gantry crane to serve the building. See Plates 51 through 54 of Appendix A for more details.

c) *Constructibility:* The upstream and downstream dewatering would be accomplished by using existing bulkheads/stoplogs. The work area is very small and the entire work area would have to be isolated with temporary, but dust proof walls. The downstream powerhouse wall would have to be modified to create a new access door. The existing downstream crane rail girder would be reinforced in order to create the new wide access door. The existing powerhouse bridge cranes would be made available to the contractor for debris removal and for materials placement. There would be a steel liner/watertight bulkhead access door that would allow the removal of concrete forms and access for inspection and maintenance. There will probably be some type of access shaft from the access door to generator floor (elevation 56.0 msl). This alternative would take about three years to construct.

d) *Advantages:*

- Work area may be isolated by existing bulkhead
- Could be designed within the first powerhouse
- May reduce TDG significantly
- Low cost as compared to other alternatives
- Large discharge capacity of converted turbine unit

e) *Disadvantages:*

- Reduces power generation capacity
- Impacts project operations
- Unknown effects on adult fish passage
- May impact structural integrity of remaining turbine units
- Potential juvenile fish impacts

14. Wells Dam Hydrocombine

a) *Hydraulic Design*: This alternative involves rebuilding the first powerhouse as a hydrocombine. Wells Dam on the mid-Columbia provides an example of a hydrocombine with ten turbines located below the spillway bays. The turbines and spill bays each have three intakes, with the exception of Bays 1 and 11 which each have two intakes (Johnson et al, 1992). The Bonneville powerhouse could be rebuilt as a hydrocombine without removing the entire structure. Three spill bay intakes could be constructed above the turbine intake, and the spill bay crest would be located on each side of the turbine generator units. The roof of the turbine intakes would be rebuilt at a lower elevation to provide enough area for the spill bay intakes. This type of structure would provide additional spillway capacity without eliminating any of the existing spill bays. Turbine discharge flows would prevent the spillway flows from plunging to deep depths by supporting the issuing spillway jet near the tailwater surface. The hydrocombine also provides an alternative route for juvenile fish bypass. A hydrocombine structure at Bonneville could provide additional spillway capacity and lower TDG levels in the tailrace, and would not compromise existing maximum existing spillway discharge capacity. The extra spillway and powerhouse capacity of a Wells-type hydrocombine would provide good TDG reduction for this alternative.

b) *Structural Design*: The hydrocombine development was first introduced in Russia in the early 1970s. The Douglas County P.U.D. elected to use this concept for the Wells Dam. The concept incorporates all the concrete features within a single mid-river structure 1000 ft long. The structure requires difficult forming and thus the unit price for concrete is much higher than conventional water control structures. Three turbine intakes per turbine bay are the lowest water passage in the structure. Trash racks are provided for each turbine intake slot. There is a turbine unit cover at the top deck elevations that, when removed, exposes the generator below. The intake structure has bulkhead gate slots for each spillway entrance slot. The spillway bays are on each side of the generator compartment. The spillway bays have a pair of vertical lift gates similar to those on the Bonneville spillway.

The Wells Dam spillway approach deck is located at elevation 704.0 and discharge is at elevation 688.0 msl. There is a maximum of 65.5 ft of head on the spillway crest and spillway bay intakes are 87 ft high at Wells Dam. Spillway bays for a Bonneville hydrocombine development would not have this high head.

The new Bonneville hydrocombine development may be constructed as one of two options. The existing first powerhouse may be rebuilt to accommodate new generators, turbines, and spillway water passages and gates. The other option would be to build a new hydrocombine structure downstream of the existing first powerhouse and tie the ends to the existing structures. The Wells Dam hydrocombine is approximately the same length as the Bonneville first powerhouse. Thus at least nine generator units may be created. There would be at least ten spill passages. This total combined discharge exceeds the existing first powerhouse discharge capacity. The existing structure may be removed to elevation +55.0 msl if the hydrocombine is seated within the first powerhouse channel. See Plates 55 through 60 of Appendix A for more details.

c) *Constructibility*: The hydrocombine is a proven technology. There is at least one prototype that may be tested for the effectiveness of reducing TDG. This alternative would replace aging equipment at the Bonneville First Powerhouse and thus life-cycle costs savings could result. There would be a downstream cofferdam and concrete cutoff walls that would tie to the left river bank and Bradford Island. The major materials could be supplied by barge to the downstream cofferdam. Gantry cranes located on the new tailrace would service the downstream half of the project. New hydrocombine intakes would be serviced from the existing first powerhouse tailrace.

d) *Advantages:*

- Prototype development is operation
- Proven technology to replace aging equipment
- May provide good juvenile fish passage
- Good reduction in TDG
- Could be designed into Cascade Island or first powerhouse
- Minimal impact on adult fish passage, unless new powerhouse is constructed downstream of existing
- Prototype can be tested for TDG reduction
- Replaced power benefits

e) *Disadvantages:*

- Impacts project operations
- High costs
- Complex upstream and downstream de-watering
- Lost power benefits from first powerhouse during construction

15. V-shaped Spillway

a) *Hydraulic Design*: In this alternative, the existing spillway would be replaced with a long V-shaped baffled chute spillway extending about 1000 ft downstream in the existing spillway exit channel. The total length of the proposed spillway would be about 2200 ft. A total of 45 tainter gates with gate seat elevation 38 would operate in submerged position, with flow passing over an ogee crest at elevation 47 and into a baffled chute spillway. The tainter gates would be 50 ft wide by about 40 ft high, with a 45 ft radius. The ogee crest of the baffled chute spillway is located about 55 ft downstream of the gate trunnion, to insure fairly stable and uniform flow delivery to the baffled chute. Energy dissipation for the baffled chute spillway is quite good, and as a result the tailwater discharge flow under TDG reduction discharge of 283 kcfs spillway flow should remain fairly uniform. However, it is not yet known what flow profile will result from the relative confinement of such large discharges along the left and right banks of the existing spillway exit channel. In addition, impacts to adults seeking the existing entrances to the fish ladder, which are located near the toe of the existing spillway, may be significant in this alternative.

Structural Design: This concept would require an extensive modification to the existing spillway and would have to be phased over several construction periods. The new "V" spillway would consist of 45 new bays that have new tainter gates that are 50 ft wide and have a 45-ft radius. The new gates would be hinged by new trunnions within new 10-ft wide spillway piers. The new mass concrete spillway dam would extend from bedrock, elevation -30.0 msl to elevation +38.0 msl to form the spillway approach channel. The spillway piers would extend to elevation +90.0 msl, they would be 10 ft wide and about 100 ft long. The upstream bulkhead slots would be 25 ft upstream of the tainter gate. The spillway crest would be 55 ft downstream of the trunnion and set at elevation +47.0 msl. The spillway chute would be sloped at 2.3 horizontal on 1.0 vertical. The baffled chute spillway would be about 144.9 ft long and extend to elevation -10.0 msl. The new 9-ft tall baffles discussed for Alternative Nos. 8 and 10 would be used for the new sloping "V" shaped spillway chute. See Plates 61 through 64 of Appendix A for more details.

b) *Constructibility*: The "V" spillway would be constructed in several phases. Project operations will set the order and sequence for construction. One plan would be to construct a downstream cofferdam that would divide the channel at mid-river, extend downstream 1500 ft and turn to either shore to tie into the existing bank. This concept would impact adult fish passage and possibly additional fish ladder entrances may have to be considered in the nest phase of this study. In this alternative, a minimum of seven spillway bays will be available for discharge at any one time during construction. The spillway crests and upper baffled chute would be placed during low flow periods. New abutment spillway bays will be operational upon removal of downstream cofferdam tie-ins to existing bank. Existing mid-river spillway bays and dam would be removed after all the new spillway bays become operational. Because of the project complexity, it is assumed that the construction would span six to seven years.

c) *Advantages*:

- Reduces unit discharge over spillway crest
- Good reduction in TDG
- Would eliminate deep plunge pool in existing spillway exit channel

d) Disadvantages:

- High impacts to existing project operations
- High costs
- Complex upstream and downstream de-watering
- Possible high impacts to adult fish passage

16. Relocated Spillway Downstream

a) *Hydraulic Design*: This alternative includes a new spillway structure located downstream of the existing spillway. The purpose of this alternative is to move the spillway downstream of the deep holes located at the base of the existing stilling basin. This concept is similar to Alternative 6 which includes filling in the tailrace downstream of the spillway to about elevation -16.0. Both concepts would prevent the discharge from plunging into the deep holes. As a result, the amount of time that the aerated water would be at a depth that results in increases in TDG would be reduced.

b) *Structural Design*: This option would create a new tainter gated spillway downstream of the existing spillway, near the confluence with the second powerhouse channel. The intent here is to eliminate the existing deep pools that are illustrated in Alternative 6. The new spillway would have 18 bays, with gate openings 50 ft wide, 60 ft high, and the tainter gates would have a 75-foot radius. The tainter gate crests are set at elevation 20.0 msl with top of gate at elevation ± 78.0 msl. New spillway piers are 10 ft thick and 100 ft long. This option would have a conventional ogee-shaped spillway and a stilling basin floor elevation of about -10.0 msl.

This option would require new adult fish passage channels and ladder that would connect to the upper reaches of the existing ladders. The new fish ladders and channels would have to have attraction water supplied from the existing spillway during construction and then changed to forebay supply when the relocated spillway becomes operational.

A new closure dam with non-overflow monoliths, would be located at the south side of the spillway and tie to high ground on Bradford Island. Another closure dam with non-overflow monoliths would be provided on the north bank of the existing spillway channel and would tie to high ground on Cascade Island. Both non-overflow sections would be similar to the one that is at The Dalles Dam between the spillway and powerhouse. Both closure dams would incorporate new adult fish ladder entrances. See Plates 65 and 66 of Appendix A for more details.

c) *Constructibility*: The alternative is difficult to plan and construct since it utilizes the existing spillway channel and construction is limited due to operational limitations. The dewatering scheme would utilize two cofferdams. A northern cofferdam would dewater enough width of the existing exit channel for construction of about ten bays. The concrete stilling basin and spillway piers would be constructed in the dry. These spillway ogees would be left low for second phase diversion. The second cofferdam would encompass the remaining five spillway bays, non-overflow closure dam, and the adult fishway on the south bank. Spillway bays would be completed, including new tainter gates and ogees. The last phase of construction would place the first ten ogee and spillway crest concrete and the remaining ten tainter gates. This work will be performed during low water flows. The next phase would be to remove the remaining cofferdam cells and flood the new forebay. The existing spillway gates and hoist would be surplused. The old spillway bridge may be left spanning the river and act as a means to control trash and debris. This option would take approximately 5 years to construct.

d) *Advantages*:

- Better mixing of flow from Second powerhouse and from spillway
- Elimination of deepest plunge pools in existing spillway exit channel
- Can construct a more effective TDG reduction spillway from the start, instead of having to retrofit an existing structure at high costs.

e) Disadvantages:

- Very high costs
- Possible significant impacts to existing project operations.
- Large cofferdam required to construct new spillway
- Long construction time

17. Sluices Under Existing Spillway

a) *Hydraulic Design*: This alternative consists of modification of all existing spillway bays by embedding sluice conduits through the crest and extending to downstream of the primary stilling basin. Sluice discharge capacity at full open operation would be about 7,400 cfs, or about 14,800 cfs per spillway bay. Maximum exit velocity would be about 30 fps, and maximum velocity through the sluice is about 64 fps. The design as proposed does not permit pressures within the sluice to fall to near atmospheric or below at any point, thereby eliminating potential cavitation. The sluice is designed to operate only full open with or without discharge over the spillway through the existing spillway gates, and the sluice closure gate is opened or closed only when the spillway gate is closed. Preliminary computations indicate that the submergence of the sluice entrance may be sufficient to prevent vortices from forming in the forebay when the existing spillway gate is not operating and the sluice is discharging at full capacity.

c) *Structural Design and Constructibility*: The proposed submerged sluice conduits will be constructed by excavating a portion of the existing spillway crest and primary stilling basin and reconstructing it with conduits embedded in monolithic concrete. Guide slots will be cut into the upstream faces of the spillway intake piers for embedment of steel gate guides for the sluice closure bulkhead. The new sluice closure bulkhead will be a 54-ft-wide by 15-ft-high cable hung tractor gate placed with new hoists mounted on the spillway piers. Maximum loads acting on the closure bulkhead are anticipated to be

equivalent to about 100 ft of hydraulic head. A new spillway gantry crane will be required to provide the necessary reach to lift the closure bulkheads entirely from their slots during gate maintenance. New crane rail girders constructed near the upstream side of the spillway piers will support this crane. Reinforced concrete is to be used to form the sluice conduit throughout. The portion of the sluice conduit extending under the primary stilling basin will be constructed of heavily reinforced concrete to resist large vertical loads imposed in the stilling basin floor above. See Plates 19 through 28 for details.
Construction of the proposed sluice conduits will require a downstream cofferdam extending from the existing spillway downstream to the downstream end of the secondary stilling basin. Upstream dewatering will be accomplished with a floating bulkhead similar to the system developed for spillway gate repair at Folsom Dam in California.

d) *Advantages*:

- Pass forebay TDG to tailrace in/out increase
- Construction confined to existing structures
- Minimal adverse affect on stilling basin capacity
- Operates in conjunction with surface spill

e) *Disadvantages*:

- Extensive dewatering structures required
- Demolition of large portions of existing structure required
- May adversely affect adult fish attraction to existing fish ladder entrance structures
- May entrain juvenile fish into high velocity flow in closed conduit

18. Pressure Conduit Through Old Navigation Lock

a) *Hydraulic Design:* This alternatives requires conversion of the old navigation lock into a pressurized discharge conduit with gated vertical slots at the downstream end and a large bulkhead at the upstream end with slots constructed in the lock walls. The conduit would be about 66 ft high and 80 ft wide inside the existing navigation lock, decreasing to about 40 ft at the existing access bridge deck across the lock exit channel. The flow would discharge through gated vertical slots located about 1000 ft downstream from the end of the navigation lock. The conduit would bend and wrap around the south bank to minimize interference with the powerhouse discharge. At forebay and tailwater elevations of 75.0 ft and 35.0 ft, respectively, (spillway discharge of 283 kcfs), the capacity of the conduit and vertical slots is about 80 kcfs through about 115 vertical slots spaced 10 ft apart. The total length from the entrance of the navigation lock to the end of the conduit would be approximately 2500 ft. This alternative does not provide sufficient discharge capacity to meet the TDG reduction goal for the 10 yr 7-day event.

b) *Structural Design*: This option applies some of the same design features that were previously discussed for alternatives 4A and 4B. The single conduit 76 ft wide by 50 ft deep would start near the upper third of the old navigation lock. The new conduit would follow the old navigation lock downstream approach channel. The new conduit would exit the old navigation lock, pass under the project access road and continue downstream along the left bank of the river some 2,000 ft. The discharge structure would be about 500 ft long, contain 115 gated vertical slots that are 1 ft wide and 20 ft high. The flow for this new conduit would combine with the first powerhouse discharge in a reach approximately 1,500 to 2,500 ft downstream of the project. The existing upstream sill of the old navigation lock would be removed. See Plates 70 through 72 of Appendix A for more details.

c) *Constructibility*: The new submerged gated conduit would be constructed within the old navigation lock chamber. The existing upper sill at elevation 40.0 msl and the upstream miter gate and bulkhead would serve as an upstream cofferdam for construction. The downstream discharge slots would be gated with full on or full off vertical lift gates, and the upstream end of the conduit would be provided with a large bulkhead for positive closure. Both upstream bulkheads and downstream vertical slots would be required to undergo routine inspections and maintenance. The large conduit 76 ft wide by 50 ft deep by 2,000 ft long parallels the left bank of the river. The downstream end of the discharge structure would have a sloped ceiling and invert that converge at the downstream end. The discharge structure could be precast and barged into place and the extended large conduit could be designed as match cast segmented precast elements that are set into place and post-tensioned to the navigation lock approach channel bottom, then tremie fill concrete grouted. The Portland District would have to process with a request to de-commission the old navigation lock prior to any feature-design or construction.

d) *Advantages*:

- Existing spillway would not be affected.
- Submerged intake and outlets
- TDG equivalent to forebay
- Outlet orifices discharge downstream directly into powerhouse flow
- Provides a new mission for the old navigation lock
- Downstream work area may be isolated by cofferdam

e) Disadvantages:

- Conduit is extremely long.
- Cost and time to construct.
- Does not meet target flow for 283,000 cfs condition.
- Impacts project operations
- Possible impacts to adult fish passage
- TDG reduction overall (total project discharge) poor

6. SELECTED ALTERNATIVES

6.1 Alternative 1 - Extended / Stepped Deflectors

6.1.1 Hydraulic Design

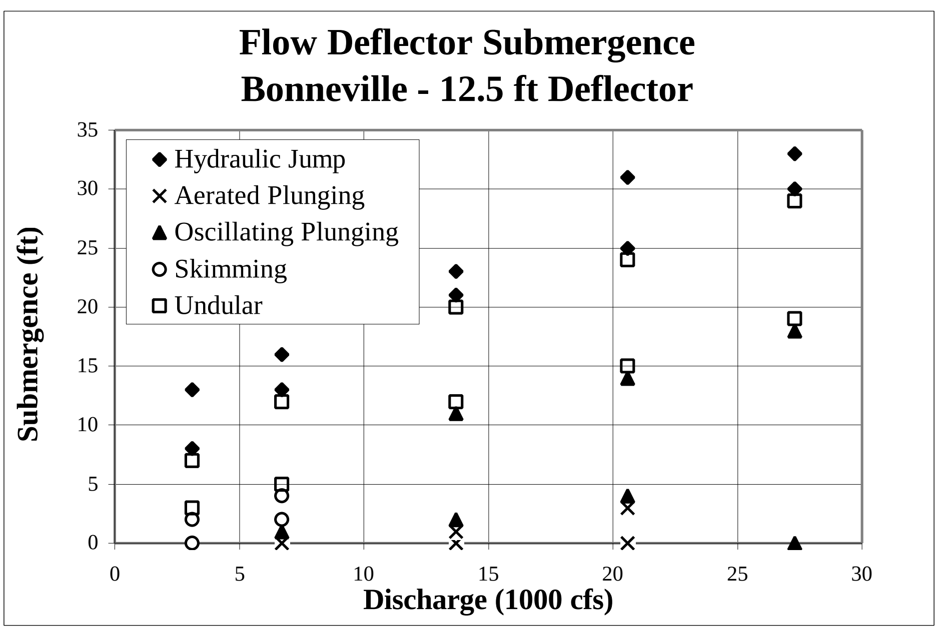
The stepped deflector is expected to be more effective over a wider range of discharges and tailwater submergence than the existing deflectors. Data from the model study report on spillway deflectors for Bonneville Dam (TR 104-1) suggest that extended and lowered deflectors at the Bonneville Dam spillway would provide for more effective reduction in TDG levels over a wider range of discharge and tailwater conditions than the existing deflectors. The stepped deflector was developed to provide the benefits of deflectors at varying elevations to maximize performance throughout a wider range of tailwater elevations. The two-step deflector includes an upper and a lower deflector connected by a parabolic curve.

Goals for this study include the ability to reduce TDG levels for spillway discharges up to 15,700 cfs per bay (283,000 cfs spillway flow). Data from Ice Harbor Dam showed that optimum skimming flow performance was obtained for spill discharges of 2,500 to 8,000 cfs per bay with deflector submergence of 2 to 15 feet. Widely variable tailwater elevations at Bonneville make it difficult to optimize performance with a single deflector at a fixed elevation. Deflector step elevations of El. +4.0 and El. +14.0 were selected to provide this optimum performance over a tailwater range from about El. 7.0 to about El. 35.0. Stilling basin flow stability observations in the 1984 physical model study report for Bonneville (TR 104-1, September 1984) indicate that deflectors at El. 14.0 produced stable stilling basin flow only for discharges greater than 11,500 cfs per bay, and deflectors at El. 17.0 produced stable stilling basin flow only for discharges greater than 18,000 cfs per bay. In general, these data suggest that higher elevation deflectors may reduce TDG effectively only at high flows. Consistent deflector elevation for all spillway bays was proposed in this alternative because desired spill discharge patterns can be more easily achieved than with different deflector elevations between bays.

The effectiveness of the two step spillway deflectors is difficult to predict, although the recent model tests show that aerated flow does not plunge deeply into the stilling basin, rather it skims the surface, which should reduce the amount of gas supersaturation. However, the proposed stepped deflector configuration would require more detailed analysis with a physical model study to verify its performance, with potentially significant changes to the deflector configuration as a result. It may also be necessary to fill the deep holes in the downstream spillway exit channel to the elevation of the stilling basin in order to achieve the desired reduction in TDG at Bonneville Dam. Spillway flow deflectors are not expected to adversely affect the maximum spillway discharge capacity of 1,600 kcfs. However, stilling basin adequacy for the 1,600,000 cfs spillway discharge must be verified in a physical model study with the extended deflectors in place. Deflectors may cause the stilling basin to be unable to contain the hydraulic jump, which may result in entrainment of rock and other sediment and debris into the stilling basin. This entrained rock debris can cause significant erosion damage to stilling basins.

Design criteria provided by the Corps for the stepped/extended deflector alternative specified only to develop a deflector design that results in optimum skimming flow characteristics for the range of normal operating tailwater elevations. Further design of deflectors must include detailed documentation of flow velocity and pressures on the spillway ogee, flow deflector surface and downstream face, stilling basin baffles, and spillway pier walls and downstream nose. This documentation can be obtained from a physical hydraulic sectional model of the spillway with deflectors installed.

WES has recently produced a letter report summarizing results of laboratory evaluation of air entrainment on the Bonneville spillway. The WES physical hydraulic model reproduced a portion of the spillway approach, 3 - 50 foot wide spillway bays, 2 - half spillway bays, the stilling basin, baffle blocks, and the existing deflector configuration. Although gas saturation could not be measured in the model, the processes that cause gas to go into solution were observed and evaluated for different gate discharge and tailwater conditions. Generally, spillway jet deflectors effectively force the aerated discharge jet to skim the surface of the stilling basin. This prevents bubbles entrained in the jet from plunging to deep depths, where hydrostatic pressure forces gas into solution, which raises the TDG level in the tailrace. Characterization of the hydraulic performance of the existing jet deflectors at Bonneville are shown in the performance curves below, from the WES letter report. The stepped deflector is anticipated to produce ideal skimming flow characteristics over a wider range of tailwater elevations by providing multiple elevation deflector surfaces. The performance curves shown below indicate that the spillway flow behavior changes significantly with varying deflector emergence and discharge. For example, the desired skimming flow is achieved with deflector submergence of 2 to 7 ft only throughout a discharge range of about 3,000 to10,000 cfs per spillway bay. At higher discharges for the same deflector submergence, the flow characteristics change to plunging flow.



6.1.2 Structural Design

(1) General

This preliminary concept consists of an extension of the existing deflector in the form of a parabolic curve down to a second deflector step lower on the spillway apron. The existing upper deflector at El. 14.0 ft (MSL) would be connected to the second deflector at El. 4.0 ft (MSL) with a smooth transition curve 47.8 ft long. The second deflector would be 12 ft long and transverse the entire 18-bay spillway width. The lip of the lower deflector would be located approximately 103.8 ft downstream from the existing construction base line (C.B.L.) of the dam. Plates 7 through 10 provide details for alternative 2. The structural design considerations for the new deflectors include the following elements:

- Dewater the work area in three construction phases.
- Extension of the existing spillway deflector.
- Installation of the new lower deflector.
- Installation of the transition curve between steps.
- Special treatment for the existing adult fish ladder entrances.
- Reduced vehicle access on the spillway bridge during construction.

(2) Dewatering of Work Area

The cofferdam construction and work area dewatering plan is shown on plates 4 through 6.

(a) First Phase Cofferdam: The project will require isolating approximately 6 spillway bays during a single in-water work (IWW) period (1 December through 28 February). This will allow maximum discharge through 11 of the 18 existing spillway bays during flood events. The downstream cellular or crib-type cofferdam elevation would be El. 40± ft (MSL). This top elevation prevents overtopping from spillway operations. The new cofferdam would be installed from the right spillway training wall, at spillway Bay 1, and extend to and include spillway Bay 6. This concept leaves eleven full spillway bays available for flood discharge since Bay 7 would be filled with tie-in cells. This provides 90 days, excluding holidays, to install the cellular cofferdam for each 1/3 of the project. All concrete placement for the new deflectors would occur between 7 March and 30 November. A series of pumps will be required to keep the work area dry for the first construction phase. The base elevation of the cofferdam would vary from about -16.0 to -50.0, depending on location. Some sections will rest on the existing stilling basin floor at El. -16.0 while the deeper sections will extend to the downstream concrete cap, which varies from about El. -50.0 to El. -22.0, or to the bottom of the river channel if it falls downstream of the concrete cap material.

(b) Second Phase Cofferdam: The downstream-most cell from first phase construction may be left in place at Bay 7. The second phase construction would

require removal of the first phase cofferdam and reinstallation of the steel cells from the left bank (Bay 18) to Bay 12. As for the first phase, the cofferdam tie or wingwall section would rest on the stilling basin floor at El. -16.0 (MSL) and extend up to +40.0 ft (MSL). The dewatering pumps would be relocated to Bay 13. Flood discharges would be passed through Bays 1 – 6 and 8 - 11 during the second phase construction.

(c) Third Phase Cofferdam: The deep cofferdam section extending from Bay 7 through Bay 12 would be installed during the third construction phase. Tie cells would be moved to Bays 6 and 13. Cofferdam wing walls would be installed on the El. -16.0 ft (MSL) stilling basin floor. The 47.8-ft-long smooth transition curve from El. 4.0 ft to El. +14 ft (MSL) will require two special designed cofferdam sections. The dewatering pumps will probably be located at Bay 12. Removal of the second phase cofferdam and installation of the third phase cofferdam would be completed during the third IWW period: 1 December through 29 February. These work periods may need to be extended for cofferdam installation work in the upstream portion of the stilling basin and adjacent to the existing spillway piers.

(d) Alternative 1, Submersible Dewatering Bulkhead:
An effective alternative to the gravity-type cofferdam dewatering system as discussed above could include a system of floating structural bulkheads that can be submerged to provide dewatering for one or two spillway bays at a time. This system can be deployed in three different configurations depending on location on the spillway stilling basin.

Case 1 - one wing wall over two bays
Case 2 - two wing walls over two bays
Case 3 - no wing walls over one bay

Plate 10 provides a plan, downstream elevations and details for this option. The floating bulkhead would be segmented such that it can be reduced in width to cover just a single bay or increased in width with wing walls to cover more than one bay. Case 1 would attach to an existing extended pier and the outside pier surface on the second bay spanned. This configuration would work on the opposite hand also. Case 2 with two wing walls would span over two bays as a complete unit. Case 3 would use only one-half the bulkhead form. The auxiliary floatation tank within the bay areas would be raised out of the lower work area. The bulkhead would be sunk into position just upstream from the existing stilling basin baffles.

(3) Concrete Design Criteria

The stepped deflectors will use design criteria found in Engineering Manual EM-1110-2-2104 "Strength Design for Reinforced Concrete Hydraulic Structures." The upper three feet of the concrete exposed to high velocity flows will be superior quality, having a water-cement ratio of not more than 0.35. The mass concrete portions of the placements shall have a water-cement ratio of 0.50. The downstream vertical face will extend from the stilling basin apron shown at El. -16 ft (MSL) to the top of the lower deflector surface at El. -4.0 ft (MSL). This formed vertical surface will be faced with superior quality concrete for a zone thickness of 5 ft. The transition curve concrete surface that extends from El. 14.0 ft (MSL) to El. 4.0 ft (MSL) will be designed in accordance with EM-1110-2-1603 "Hydraulic Design of Spillways." Reinforcing steel used in the concrete will be ASTM A615 Grade 60.

6.1.3 Geotechnical Design

Geotechnical design for this alternative is limited to investigation of the strength of the existing stilling basin apron and spillway monolith. Post-tensioning of the extended deflector structure may be required to secure it to the existing spillway.

6.1.4 Mechanical Design

There are no specific mechanical items required for this alternative. The only mechanical work identified is the temporary relocation of existing spillway gate hoists from the contractors work area.

6.1.5 Electrical Design

There are no specific electrical items required for this alternative. The only electrical work identified is the temporary relocation of existing spillway gate hoists from the contractors work area and a temporary power supply for construction.

6.1.6 Constructibility

(1) General

Construction sequence and work phase assumptions are defined below:

- Railroad service will be maintained for the current train schedules on both banks of the river.
- Navigation service will be maintained for the current barge schedule.
- Washington Fish and Game Department, Oregon Department of Fisheries, the U.S. Fish and Wildlife Service, and National Marine Fisheries Service (NMFS) will coordinate fisheries issues.
- Local visitor vehicle access through specified designated contractors work areas or construction corridors will be temporarily prohibited during construction.
- Controlled fishing access will be allowed at existing designated on-water docking locations.

Construction activities for the stepped deflectors within the existing spillway bays may significantly restrict vehicle traffic across the dam during construction. The contractor will have the option to provide ferry and barge service across the river at a designated location, if necessary to complete construction. Barge and ferry service may also be used to access the work area downstream of the cofferdam, and to gain access through the navigation lock to areas upstream of the spillway.

(2) Concrete Surfaces

The new deflector surface will be a reinforced concrete slab that is tied to the existing spillway ogee curve by grouted hooked dowels. Each of the horizontal deflector surfaces would be placed prior to placing the curved section. The smooth transition curve extends over 47.8 ft of length. Mass concrete would be placed in lifts to form stepped progressions and the final cold joint would stage the steps from approximately El. +1.0 ft (MSL) to El. +11.0 ft (MSL). The final structural invert slab would be placed in a two layer step progression that follows the steps provided from the mass concrete. The last layer would be an unformed surface for the flatter reaches. The contract specification should require the final surface to be formed with a temporary holding form that would be removed after the initial set, and then the surface would receive a hand-trowelled finish.

(3) Contractors Logistics

The logistics for the project would require that a majority of the construction activity would be supported by floating plants. Concrete production facilities, including the batch plant, aggregate barges, cranes, construction air supply, and an area for material handling and laydown would be provided on barges. The contractors tug service would ferry materials to the job site from new landings on both the Washington and Oregon shores. The contract would require that an optional on-water staging area be identified for the Washington shore and the Oregon shore. The Washington access may be downstream of the BPA towers with access to Washington State Highway 14. The Oregon shore on-water location should not conflict with the present navigation and have access to I-84. The Oregon shore access dock could be placed on the north shore of Robins Island and downstream of the old navigation lock. A small staging and docking area could be constructed along the existing lock approach wall.

(4) Contractors Spillway Gantry Crane

The contractor would be given the option to erect a temporary gantry crane on the spillway dam. This crane would be placed between the two existing government cranes for maximum flexibility. This would allow the contractor to access each third of the spillway for the three construction phases discussed in Section (2) above. The contractors gantry crane (200-300-ton capacity) would have approximately 175-ft reach from the construction base line (CBL) for light loads, and a maximum lift capacity at 50-ft radius. This crane could be used to move material from barges upstream of the spillway to the work area downstream in the stilling basin. Smaller rubber-tired cranes may be placed in and out of the dewatered work area with the gantry crane. The construction procedure used will be more dependent on the type of equipment that the successful bidder has secured for the work. All work could be performed from floating plants; however, during period of high spillway discharge (typically during spring and early summer), floating plants may not be able to access the work area.

(5) Construction Duration

The dewatering three phase construction would require a contract of between 2 to 3 years long, assuming that 2 IWW periods are required. The current IWW period is 1 December through 28 February.

6.1.7 Construction Sequence

The following items are the work activities for the cofferdam installation, work area, and construction phases necessary for constructing the stepped deflectors. They are provided below in the order in which they are to occur.

- Establish on-water docking and handling areas that are accessible to truck traffic from existing roads.
- Mobilize a floating plant: work barges, cranes, tug service, crane with pile driver, and access craft to the downstream cofferdam area. The cell erection template will be fabricated off site and barged to the job site. Sheet pile and z-pile will be delivered by barge as needed, and downstream floating bulkhead will be delivered as government-furnished property if applicable.
- Construct cofferdam surrounding Bays 1 through 6 and divert spillway flows through spillway Bays 8 through 18. Phase I cofferdam protects the work area in Bays 1 through 6. Cellular or crib cofferdam installed as shown on Plates 4 through 6. The downstream cofferdam leg transverses seven spillway bays and the south cutoff is placed on the existing double row of dentates and conforms to the existing ogee concrete. Piling placement between existing stilling basin dentates may require divers to assist pipe buck crews. Tremie concrete may be necessary at the toe of the cofferdam structure to provide a water-tight seal.
- Complete the stepped deflectors within Bays 1 through 6 for Phase I construction.
- Remove Phase I cofferdam and reinstall in Bays 13 through 18 as Phase II cofferdam. Phase II construction will require additional piles to be available at the start of IWW period 2. Two floating plants will be required for cofferdam cell work; one for removal and another for installation. Divert spillway flows through spillway Bays 1 through 11, except Bay 7.
- Complete the stepped deflectors within Bays 13 through 18 for Phase II construction.
- Remove Phase II cofferdam and reinstall in Bays 6 through 13 as Phase III cofferdam. Note, the north and south legs of the cofferdam will be placed on previously placed stepped deflectors. An embedded a shear key or other anchorage in the previously placed concrete may be required to provide additional

stability for the north and south legs of the cellular or crib structure. Any temporary structural element of this type will be removed prior to operation of the affected bay. Divert spillway flows through spillway Bays 1 - 5 and 14 through 16.

- Complete the stepped deflectors within Bays 7 through 12 for Phase III construction.
- Remove the Phase III cofferdam during the IWW period 4. Remove contractors spillway gantry crane and perform final clean up for the project.

6.1.8 Fisheries Issues

Upstream and downstream migrant anadromous salmonids should not be adversely affected by extended deflectors to any greater degree than the existing deflectors. Attraction to the adult fish ladder entrances may be affected by different flow conditions resulting from implementation of this alternative. The extent of flow pattern changes can be predicted with reasonable success with a general physical hydraulic model study of the spillway and exit channel. A physical model study of the extended deflector alternative would be performed in the feature design phase of this concept. Deflectors do not adversely affect the success of juvenile fish attraction to spillway passage routes. Insufficient data are available form which conclusions regarding juvenile fish passage survive with deflectors can be drawn.

6.2 Alternative 2 - Raised Tailrace

6.2.1 Hydraulic Design

This alternative involves filling the large deep holes in the area downstream of the stilling basin in the exit channel (see Plates 11-13). This area varies in elevation from -60.0 to -16.0 and in this alternative would be filled to an elevation of +5.0. The reason for eliminating the deep holes that presently exist in the tailrace is to prevent the highly aerated spillway flow from plunging to such great depths as in the existing spillway exit channel. This should reduce the TDG production from the spillway; however, at higher tailwater elevations, TDG reduction may be less successful because the depth of aerated flow becomes significant, increasing the depth and the length of time for gas to be absorbed. This alternative is not expected to compromise maximum spillway discharge capacity of 1,600 kcfs. Theoretical computation of stilling basin capacity indicates that the existing basin is adequate provided a minimum length of 200 ft at elevation –16.0 is provided. However, stilling basin adequacy for the maximum spillway discharge capacity must be verified with a physical model study of the filled tailrace condition.

Raised tailrace elevation of +5.0 was selected to simulate the tailrace at The Dalles Dam, which is very shallow. The stilling basin length of 200 ft as shown in the drawings is theoretically adequate without the addition of an end sill. Recent data for the Dalles Dam spillway exit channel, which ranges in depth from 10 to 20 ft during spring discharge events, shows that TDG level remained between 120% and 130%, regardless of spillway discharge. One might infer that with a tailrace channel invert elevation of +5.0 and typical depth of 10 to 30 feet, TDG would likely be between 120% and 130% at Bonneville. The raised tailrace alternative as shown, with channel elevation -16.0, would be expected to produce TDG levels somewhat higher than that. However, it is not likely that a shallower spillway exit channel can produce TDG levels as low as 110%, which is the state water quality standard.

For design of the gradation and placement of fill material, maximum local scour velocity of about 20 fps was assumed at the channel invert. Although the computed average channel velocity throughout the range of expected operations is slightly less than 10 fps, local turbulence would be expected to create zones of high velocity flow much higher than the average channel velocity. The tailrace fill material is designed such that exposure to spillway flow will not cause damages sufficiently serious to require replacement of rock over the project life span of 50 years. Concrete grout infill in the voids is intended to stabilize the armor rock fill and eliminate predator habitat in the exit channel. Grout placement by tremie fill results in a lean, water rich concrete mixture at the water-concrete interface. To accommodate erosion of this weak surface layer, grout will be placed to an average depth of 2 feet above the armor rock. Construction of this extensive placement of tremie concrete will require thorough analysis of environmental issues associated with in-water concrete placement.

6.2.2 Structural Design

This alternative requires over 300,000 cubic yards of fill material, a significant portion of which will be very large rock. The raised tailrace area as proposed covers an extensive distance downstream from the spillway. It may be economical to fill the deepest portions of the affected area with dredge disposal material from downstream reaches of the river then cover with rock. The surface of the entire filled area would require a cover of very large riprap or armor rock to ensure stabilization. Armor rock gradation would be about 10,000 lb to 80,000 lb size class. Tremie-placed concrete grout with at least 5 ft of void penetration would be placed to stabilize the armor rock. A recent bathymetric survey shows that some deep pools extend below El. -60.0. See Plates 11 through 13 for details. Tremie concrete will be used above MSL El. -22.0 to MSL El. -16.0 in the areas downstream of the existing stilling basin.

6.2.3 Mechanical Design

No mechanical elements are required for this alternative.

6.2.4 Electrical Design

No electrical elements are required for this alternative.

6.2.5 Constructibility

The construction phases for the work would include the following:

- Grading for storage area and for access roads.

- Initial stockpiling of required rock and other materials (gradation provided on Plate 13).
- Mobilize floating plant for IWW
- Establish on-water loading facility.
- Establish triangulation system to control material placement during IWW.
- Complete bathymetric survey for pay quantities.
- Transport and deposit materials as required by design.
- Perform global positioning survey (GPS) for material placement.
- Perform final clean up after last construction season.

The work sequence for this alternative is different from others. This is primarily a materials supply and handling operation. It will be extremely important for the required materials to be stockpiled prior to IWW. The contractor will establish a construction grid for the work phases that will keep the operation within the project plan. The work period would be at least a two-shift operation, with rock being placed at night and concrete placed on the day shift. Concrete production and materials stockpiles would likely be positioned on a floating plant. A conveyor system could feed several placement points at once within the designated work grid. Placements of materials will be controlled by a GPS system.

Soundings will be needed during the placement of materials. Divers may be employed to provide video inspection of the completed work or work progress.

Armor rock supply sources will likely be water-accessible, as the design gradation calls for very large rock placed with floating plant equipment. The cost estimate for this alternative assumes rock will be barged from quarries located within 250 navigable river miles of the Bonneville project. The riparian quarry near Little Goose Dam could be used for this project. The haul distance is about 280 river miles to Bonneville Dam.

The construction duration for this alternative would be three and one-half years, utilizing three IWW periods. Extension of the IWW period could reduce total construction time.

6.2.6 Fisheries Issues

This alternative would not impact juvenile passage through the project. However, some minor impact to the adult fish ladder entrances may result from changes in flow patterns in the stilling basin and spillway exit channel.

6.3 Alternative 3 - New Spillway Gates

6.3.1 Hydraulic Design

This alternative includes modification of the existing spillway and piers to include large tainter gates to regulate flow at a location well downstream of the existing vertical spillway gates (see Plates 14-18). The proposed gate seat location at El. 0.0 on the existing spillway crest would effectively submerge the flow jet exiting under the gate during most operations. The jet would also be directed downward into the stilling basin without first becoming aerated. At unit discharge as high as 320 cfs/ft (16,000 cfs per spillway bay), the jet may remain fully submerged. Physical model tests of this alternative showed that the jet remains fully submerged for unit discharges of up to 10,000 cfs per spillway bay (200 cfs/ft) at tailwater elevation of 28.0. The jet is also fully submerged for unit discharge of up to 134 cfs/ft (67,000 cfs per bay) at tailwater elevation of 12.0.

This unit discharge develops a spillway discharge of at least 283 kcfs, which is the required discharge capacity for TDG reduction to 110% for the 10-year 7-day event. This alternative is not necessarily capable of lowering TDG levels to the described 110%, as it will not degas the water but merely pass the ambient forebay gas level through to the tailrace. This alternative would not adversely affect maximum spillway design capacity of 1,600 kcfs, since the large tainter gates could be lifted clear of the spillway flow profile. The control gate would be a large, 78 ft high by 50 ft wide by 100 ft radius tainter gate. Preliminary model studies at Waterways Experiment Station have shown that the jet remains fully submerged at tailwater elevations as low as 10.0 (MSL) with gate discharge as high as 200 cfs/ft (10,000 cfs per spillway bay). The proposed alternative would require very high and large radius tainter gates, larger than any other gates on the Columbia River system, and these gates would be required to operate under partially submerged conditions. Submerged operation of these very large tainter gates could result in unacceptable levels of vibration, a condition that must be fully studied using both numerical and physical modeling techniques before final selection of this alternative can be made.

This alternative was constructed in the WES physical sectional model of the Bonneville spillway, and preliminary observations were made of its performance throughout a range of gate openings and tailwater elevations. The model shows that the discharge jet remains fully submerged throughout a wide range of gate openings and tailwater elevations. Based on the submerged jet hydraulic characteristics observed in the model, we would expect this alternative to be capable of passing forebay gas levels directly to the tailrace without additional air entrainment. In the model, the discharge jet was observed to adhere to the spillway apron and stilling basin floor, whereupon it impacted the baffle blocks. Concerns for fish survival make it necessary to consider removal of the baffle blocks from the existing stilling basin in order to make this concept acceptable. However, stilling basin adequacy with baffle blocks removed must be verified with the physical model.

This alternative could use either a large tainter gate, as proposed, or a large split leaf vertical gate, similar to the existing spillway gates at Bonneville Dam. Tainter gates were selected for this conceptual level design primarily because of the small lifting hoist requirements. Tainter gates have also been shown to be less subject to changing vibration and unbalanced load conditions than vertical lift gates. However, tainter gates are not normally designed for high-energy flow and submerged operation. And the physical size of the large piers required to support these gate trunnions makes this alternative difficult and quite costly to build. Large vertical lift gates could also be used here, without the need for such large pier extensions. The relatively smooth, uniform jet observed issuing from under the large radial gates in the model may not be observed with vertical lift gates. The convex surface of the upstream skin of the radial gate helps to develop initial jet velocity downward, such that the jet adheres to the spillway chute surface and stilling basin floor. A physical model of vertical lift gate operation would be required to verify jet characteristics and gate performance.

6.3.2 Structural Design

This alternative would require extensive modification of the downstream extension of the existing spillway piers. The new piers would retain the present 10-ft thickness and would extend to 140 ft downstream of the construction base line (CBL). The top of the new piers would be at El. 90.0 ft (MSL), with new gate hoists placed near the downstream end of the existing piers. The downstream portion of the existing piers would be modified to receive new radial gate side plates. The spillway ogee would also be modified to receive the new tainter gate on a new gate seat at El. 0.0, flush with the existing ogee shape. The new tainter gate would have a 100-ft radius, with top of gate El. 78.0 ft (MSL) and trunnions set at El. 40.0 ft (MSL). Construction of this alternative will require de-watering of the stilling basin. Additional stilling basin modifications could thus be conveniently combined with construction of the new gates. For example, the existing deep holes in the secondary stilling basin floor could be cleaned, partially excavated, and refilled with concrete anchored to the existing stilling basin floor. The new precast prestressed trunnion bridges would be constructed in three phases. New tainter gate installation will be performed from floating plant and from the new trunnion bridge. The first construction activities would include construction of abutment access to the new trunnion bridge and construction of the new pier corbels for the new gate hoist machinery. This alternative would require a 4 to 5-year construction period. See Plates 14 through 18 for more details.

(1) General

Structural design considerations for the new spillway gate alternative for 18 spillway bays includes the following elements:

- Downstream cofferdam scheme similar to that discussed for alternative 1. This proposed phased dewatering plan would divide the spillway into three areas for phased construction.
- Removal of existing and extended piers and spillway deflectors on 13 bays.
- Spillway pier extensions and new trunnion anchorages.
- New spillway trunnion bridge constructed in three phases
- New pier corbels for gate machinery hoists.
- New gate storage pits for existing vertical spillway gates.

- Install new bottom and side gate seals plates
- Install new tainter gates 50 ft wide, 78 ft high, with 100-ft radius.
- Remove and store existing vertical gates and operating hoists.
- Special treatment for the existing adult fish ladder entrances.
- Reduced vehicle access on spillway bridge during construction.

(2) Downstream Cofferdam Selection

This alternative will use a cellular or crib-type structure similar to that discussed for alternative 1. The first phase cofferdam will isolate approximately 1/3 of the spillway bays on the north side of the river during the initial IWW period. The second phase cofferdam would be placed on the south six spillway bays during the second IWW period. The third phase construction would complete the middle 1/3 spillway bays and the fourth IWW period would remove the third phase cofferdam. A more detailed description of these activities are found in section 6.1.2 (2) above "Dewatering of Work Area". The cellular structure will be designed in accordance with EM 1110-2-2503 Design of Sheet Pile Cellular Structures.

(3) Concrete Design Criteria

The type and grade of reinforcing steel will be limited to ASTM A615 (billet steel), Grade 60. The minimum concrete cover over reinforcement steel should conform to EM 1110-2-2104, which is 4 inches for formed and screened surfaces such as still basin walls, chute spillway slabs or ogee faces. The anchorage, bar development and splice requirements should conform to ACI 318. The minimum clear distance between parallel bars should not be less than 1.5 times the normal diameter of the bars nor less than 1.5 times the maximum size of coarse aggregate. No. 14 and No. 18 bars should not be spaced closer than 6 and 8 inches, respectively, center to center. When parallel reinforcement is placed in two or more layers, the clear distance between layers should not be less than 6 inches. The maximum permissible water-cement ratio for mass concrete containing cementitious materials other than 100% Portland cement should be 0.45 for thin sections and 0.50 for mass sections as recommended in EM 1110-2-2000.

(4) Spillway Trunnion Bridge

A new spillway trunnion bridge will be constructed immediately downstream of the new spillway gate trunnion yokes. This trunnion bridge serves two major functions: 1) expedites the tainter gate construction, and 2) improves project access for maintenance after construction. The new bridge will consist of eight precast prestressed girders 3 ft wide by 2.5 ft high by 59 ft 10 inches long. The bridge will have new parapet walls that are anchored to the exterior girders. The individual girders will be bonded together with an epoxy grouted key at the upper adjacent connecting surfaces. The entire upper girder surface shall receive a new bonded concrete slab that is sloped to drain. Each bridge abutment will require two spans to connect to land. There will be some required civil design for development of road access to the existing road system plus any required relocations of existing utilities.

(5) Structural Modifications

This option would require extensive modification to the existing spillway piers. The new piers would be 10 ft thick and would extend to 160 ft downstream of the construction base line (CBL). The top of the new piers would be at El. 90.0 ft (MSL), with a new pier corbel for gate hoists placed near the downstream end of the existing piers. The downstream portion of the existing piers would be modified to receive new radial gate seal plates. Concrete removal required for the new radial gate side seal plates may cut existing reinforcing steel and thus some type of post-tensioning may be needed in these areas. Any required post-tensioning will be extended to foundation rock as identified in the profile on Plate 18. The spillway ogee would also be modified to receive the new tainter gate on a new gate seat at El. 0.0 ft (MSL). The new tainter gate would have a 100-ft radius, with top of gate at El. 78.0 ft (MSL) in the closed position, and trunnions set at El. 40.0 ft (MSL). If desired, the existing deep holes in the secondary stilling basin floor may be cleaned, partially excavated, and refilled with concrete. New concrete would be anchored to the stilling basin floor. This activity would provide a level area on which to install the downstream cofferdam and would add 1 year to the three-phase construction schedule. An advanced procurement will be needed for the structural steel and Z-piling for the dewatering cofferdam. Alternative 3 would require a 4 to 5-year construction period. See Plates 4 through 6 for more details on dewatering system, and plates 14 through 18 for modification details.

(6) Concrete Removal and Dowel Anchorages

The existing pier reinforcing steel within the downstream area of encasement would be exposed in order to tie the pier extension to the existing structure. The new pier face reinforcement would be tied to the existing pier reinforcing steel. The existing four long-pier extensions in Bays 1 and 18 will require extensive concrete removal. A major portion of these original walls and elevated slabs will be cut away to make space for the new trunnion anchorage assemblies as required for the new tainter gates. The only portion to remain will be the floating wing wall connection for a tie-in for the dewatering cofferdam. The new radial gate side seals to be placed in the existing pier wall surfaces and in the spillway ogee surface at El. 0.0 ft (MSL) will require concrete removal and anchorage embedment. Removal of existing concrete spillway deflectors will also be required for spillway bays 4 through 15 and 18, or a total of 13 bays. Each of the areas discussed above would require new doweled anchorages that conform to ACI 318 Standard Build Code and ACI 355 Anchorage to Concrete.

The spillway ogee concrete will have miscellaneous metals embedded at various depths. The original structure was built during the period of time when it was common practice to grout all vertical contraction joints. This procedure used a series of 1 or 1 1/2-inch diameter galvanized pipes embedded in concrete to deliver Portland cement grout under pressure to the contraction joint locations with 1/2-inch risers or vent pipes. Each spillway monolith consists of one pier and thus each spillway by has a formed contraction joint at the transverse centerline of the spillway bay. The existing spillway was originally constructed in two phases. The northern half of the spillway was constructed with full height spillway ogee sections to El. +24.0 for Bays 1 through 7 and one half of Bay 8. The southern bays (one-half of Bay 8 and Bays 9 through 18) were constructed as low bays with a sloping cold joint for first step construction and river diversion. A longitudinal profile section that illustrates this is shown on Plate No. 18. The spillway dam foundation is deeper on the south abutment, El. -77.0, than on the north abutment (El. -45.0). A more detailed drawing appears in the original Contract Drawing File "Bonneville Power Navigation Project, 14th Contract, Spillway Dam, Grouting Layout, Original Contract Drawing File." Another known obstacle is the layout of piezometers on the ogee centerline of Bay 13. This instrumentation system will be removed during construction and replaced following completion. The present read out location and manifold is in the drainage gallery at Monolith 13.

(7) Bulkhead Gate Storage Pits

Several of the existing spillway vertical gates will be saved as bulkheads for maintenance of the new tainter gates. These existing gates will require a minimum of 3 new gate storage pits that are located on either Cascade Island or Bradford Island. Both the existing 50.75-ft high and 60.0-ft high vertical gates should be considered when designing these storage pits. Gantry crane rail alignment may be modified to enable transport of vertical gates to storage pits. Precast concrete deck slabs will be used to cover the storage pits. These storage pits will have all utilities, such as air supply, wash water, electricity, and phone service. Care will be taken to site these pits in areas in which public access is restricted.

6.3.3 Mechanical Design

(1) General Mechanical Design

Considerations for the new spillway gates include the following elements:

- Tainter gates
- Lifting cables and assemblies
- Hoists and cable drums
- Gear boxes
- Bearings
- Trunnion anchorages
- Yokes
- Lubricating systems
- Radial gate seat sills and seal plates
- Air and wash water supply lines

(2) Tainter Gates

The new 100-ft radius, radial tainter gate will consist of a steel skin plate and supporting frame that transfer the water load to the trunnion yokes. Each of the 18 gates are sized to fit a water passage that is 50 ft wide and 78 ft high, extending from a bottom sill at El. 0.0 ft (MSL) to the top of the gate at El. 78.0 ft (MSL). Gate configuration and details are shown on Plates 15 through 18. Normal forebay elevation at Bonneville Dam is El. 71.5 ft (MSL) (minimum) to El. 74.5 ft (MSL) (maximum).

There will be an embedded metal gate sill beam on the ogee chute and a radial gate side seal plate in each pier face. Each tainter gate will have a bottom bar seal and side "J" seals to seat against the sill beam and against each pier face. The trunnion anchorage assemblies will be post-tensioned to the concrete spillway piers. A mechanical hydraulic lubrication system will be provided for 18 bay/36 yoke locations.

(3) Tainter Gate Hoists and Assemblies

The tainter gate hoists are placed on the spillway piers. The hoists consist of an electric drive motor (20 HP assumed), a gear reduction box, a shaft, a cable drum, and six or more lifting cables per drum. The lifting cables will be of galvanized wire rope. Cables will have premolded bolted cable eyes for the connection to the tainter gate skin plate. The new tainter gate, hoists, and assemblies will extend the state-of-the-art for spillway design.

The hoist design is usually performed by both mechanical and electrical engineers. The electrical engineers will be responsible for motor specifications, power supply, lighting, and the control systems.

6.3.4 Electrical Design

(1) General

Electrical design considerations for the new spillway gates include the following elements:

- Power source
- Electric hoist motors
- Power supply for hand tools and lighting circuits
- Communication lines for telephone, project code call, and security cameras

A new electrical equipment room will be formed in either the north or south abutments depending on the design of the electrical system and the location of the control room for operations. The electrical conduits will be carried by the existing spillway access bridge. New conduit alignments across Cascade Island and Bradford Island will consist of buried utility vaults and conduits.

The following paragraphs provide an outline of some of the systems that will be incorporated in the new development.

(2) Power Source

The main power source will be from an existing bus at the powerhouse No. 1 or No. 2 locations. The distance, if sourced from the existing bus at powerhouse No. 1 is approximately 3800 ft; if sourced from the powerhouse No. 2 it is approximately 4,500 ft.

The power source will be 480V, 3-phase, with a transformer located at the spillway. Suggested wire size is 4/0- conductor by 4, to accommodate 3-phase plus ground. The power source will service the electric hoist motors, the lighting, and the power circuits.

A total motor control center will be connected to three combination motor starters. A programmable logic control (PLC) center will be used to operate the tainter gates from the powerhouse control room. The lighting and hand tool power source will be fed from a 480-12/240V transformer to a 200A panelboard.

(3) Lighting

The spillway structure will be illuminated to provide adequate visibility for miscellaneous equipment and periodic maintenance of the intake gate hoists and mechanical gearboxes as required at any time during day or night operations. Two light standards will be required for each of 19 pier locations, spillway trunnion bridge and trunnions at each pier, and new bulkhead gate storage pits, for a total requirement of [19+(2x19)+6]=63 light standards.

There will also be lighting in the new electrical room and in the bulkhead storage pits. This lighting will be controlled from the powerhouse control room.

(4) Communications

The new facilities on the spillway structure will be serviced by telephone, project code call, and a security system with cameras. In addition, a 12-pair, fiber-optic, digital control cable will link the powerhouse control room to the new spillway gate structure.

All of the above communication systems will be linked to the new spillway gate structure. The digital control system will be used to remotely operate each gate from the powerhouse control room, with readouts for tainter gate position. Alarm systems will be provided to alert project staff when spill volume or characteristics violate design criteria for gas abatement.

(5) New Conduits

A new conduit system will be provided, consisting of nine 3-inch-diameter polyvinyl chloride (PVC) pipes extending from either of the two existing powerhouse control rooms to the new spillway structure. It will run parallel to, and be buried in, the existing roadway shoulder on either Cascade or Bradford Island.

Five pull boxes, or vaults, will be placed throughout the 3,800 or 4,500-ft run on a 250-ft spacing. The conduits will change to steel for the reach that spans the existing spillway access bridge and the new spillway trunnion bridge. The new bridge box girders interior yard may be used for the new conduits or conductor cable routing for trunnion lighting. These nine new conduits will be fastened to the existing concrete bridge and terminate at the electrical room.

The pull boxes, 4 ft by 4 ft by 4 ft, will incorporate a locking cover hatch. Conduit runs will be installed in a 2-ft-deep trench and backfilled with select material. A second set of eight 3-inch-diameter conduits will start at the electrical room and extend over the existing bridge area. A third set of two 3-inch-diameter conduits will extend to the bulkhead gate storage pits.

6.3.5 Constructibility

(1) General

Construction sequence and work phase assumptions are defined below:

- Navigation service will be maintained for the current barge schedule
- Washington Department of Fish and Wildlife, Oregon Department of Fish and Game and/or U.S. Fish and Wildlife Service will provide criteria for in-water restricted areas during construction
- Reservoir control and discharge requirements in accordance with Northwestern Division Reservoir Control Center

(2) Downstream Cofferdam Selection

The most feasible method for dewatering the spillway pier and stilling basin area is to provide a Z-pile crib cofferdam wall. The proposed plan for phased construction is shown in Plates 4 through 6. A detailed discussion for a three-phase construction sequence is provided in Section 6.1.2 (2), "Dewatering of Work Area". This scheme divides the spillway into thirds and requires a minimum of three IWW periods to complete construction. A fourth year may be needed if the secondary stilling basin must be filled prior to placing the downstream cofferdam.

(3) Upstream Cofferdam

The existing vertical spillway gates will be used as bulkheads for the work areas during each construction phase.

(4) Construction Sequence

The following items of work are common to each construction phase:

- Remove existing spillway gate hoists from work area.
- Mobilize floating plant and install Z-pile downstream cofferdam during the IWW period.
- Install dewatering pumps and dewater work area.
- Install post-tensioned pier-to-foundation anchorages.
- Install contractors' 350-ton spillway gantry crane with a 250-ft boom between existing government spillway gantry cranes.
- Remove spillway pier, ogee gate sill and spillway deflector concrete.
- Place new reinforcing steel.
- Place new concrete pier extensions in six spillway bays per phase from floating plant.
- Install new spillway trunnion bridge.
- Remove downstream cofferdam and reinstall for next phase.
- Install new spillway gates from floating plant crane and contractors spillway gantry crane from barges located in the forebay.
- Install mechanical items.
- Install electrical items.
- Construct bulkhead gate storage pits and modify existing spillway gantry crane rail system to provide access to pits.

The contractor will probably use a floating plant to gain access to the work area and to perform a majority of the construction activities. This will require at least one on-water loading facility. The floating plant will include work barges, cranes, tug service, cranes with pile driver, and access craft to the downstream cofferdam area. The cofferdam cell erection template will be fabricated off site and barged to the job site. Z-pile will be delivered by barge as needed. Cofferdam template will be pulled following z-pile placement and each crib cell will be filled with granular material. At the time of cofferdam removal, the previously completed work area will be flooded and downstream cofferdam removal will take place in reverse order. A majority of cofferdam fill granular material will be removed by clam shell buckets and placed on a material barge for the next phase cofferdam construction.

(5) Concrete Structural Modifications

One of the first construction activities will be installation of the new pier hoist corbels on Bays 1 through 18. Spillway pier extensions will require post-tensioned anchorages to provide adequate stability for the large radial gate loads. Formed voids will be cast within the new pier extensions over the predrilled foundation anchorage location to provide for post-tension tendons. Concrete production will be performed from a floating plant that is secured to the downstream cofferdam. The floating concrete plant will have aggregate barges, batching and mixing plant, and some type of delivery/conveyance system. Since a majority of the new concrete placements are at the pier extensions, a conveyor system may be used to feed buckets or movable hoppers. Replacement concrete for the deflector locations and radial gate seal plates will most likely be placed by crane and bucket. Reinforcement steel cages and curtains may be constructed off site and be transferred by floating plant. Work on the post-tensioned concrete trunnion anchorage will follow the pier placement. There will probably be some type of repair for existing spillway baffles while the stilling basin is dewatered. The post-tensioned pier anchorages will be completed prior to loading the new spillway gates.

(6) New Tainter Gate Installation

The new tainter gates will probably be delivered to the project by barge in large segments. Shop fabrication will save time and money and only a minimum amount of welding will be required in the field. It is anticipated that the new tainter gates would be installed after the downstream cofferdam is removed and thus the mechanical and electrical work would lag the gate placement. Gate installation may be dependent on certain tailwater conditions conducive to large-mounted placement and erection equipment.

(7) Bulkhead Gate Storage Pits

This activity is not dependent on any work within the new spillway gate modification. The desired location would be on either Cascade Island or Bradford Island. Electrical service for maintenance will be provided at the storage pit locations.

(8) Final Cleanup

This phase of the work will include the stockpiling of all cofferdam steel at a designated storage area. The contractors spillway gantry crane will be dismantled and removed as well as all logistical support facilities. There will also be a requirement for an underwater inspection of the entire spillway stilling basin and all debris will be removed before acceptance of the completed project. In-water disposal for filling deep holes in the tailrace may be an option if permitted. On-water transfer dock may be considered for future government use and left in place.

6.3.6 Fisheries Issues

Downstream juvenile and adult fish impacts with this alternative are unclear. Although the new gates are capable of passing high discharges of unaerated flow, the jet issuing from the gate into the stilling basin may cause fish to impact the stilling basin floor and baffles. The overall effects, including benefits from gas reduction and disbenefits from impact and abrasion injuries, are not clear at present. Modification of or removal of existing baffles may be required to mitigate these impacts. Adult fish ladder entrances may require modification to avoid interference with the extended spillway piers on the two outer bays. Existing side entrances to the ladder will no longer be operational when the spillway pier extensions are complete. New side entrances will likely be provided either through the new pier extensions or through the existing ladder entrance walls immediately downstream of the new pier extensions.

6.4 Alternative 4 - Sluices Under Existing Spillway

6.4.1 Hydraulic Design

This alternative includes modification of all existing spillway bays to incorporate embedded sluice conduits located underneath the existing spillway crest and stilling basin (see Plates 19-28). By drawing from deep within the forebay and discharging through an enclosed conduit with a submerged outlet, air has no opportunity for entrainment. The submerged sluice alternative is not necessarily capable of lowering TDG levels to the desired 110%, as it will not degas the water but merely pass the ambient forebay gas level through to the tailrace. The sluice entrance floor would be horizontal, while the ceiling and sidewalls would be flared in a bellmouthed shape. Floor elevation would be -12.0, and the tangent point of the upper point of the bellmouth with the gate slot would be at El. 1.4. The 12.5 ft wide by 9.2 ft high sluice conduit would be inclined at about a 33^{o} angle with the horizontal at the entrance. A 60 ft radius vertical bend brings the conduit back to horizontal under the spillway crest, with invert elevation about -36.2. A gradual expansion at the downstream end from 9.2 ft high by 12.5 ft wide to 11.3 ft high by 19.0 ft wide exits into the secondary stilling basin. Total length of the proposed sluice conduit is about 190 ft; an 85 ft long expansion section, and a 105-ft long uniform dimension section. See Plates 19 through 23 for sluice details.

Each sluice conduit is designed to pass a maximum of about 7,400 cfs, with a maximum exit velocity of about 34 fps and maximum velocity in the conduit of about 64 fps. Entrance geometry is designed to minimize form loss and reduce turbulence. The schematic figure below shows the computed energy and pressure grade lines for the proposed sluice design.

Bonneville Dam Submerged Sluice Outlet (not to scale)

The existing primary stilling basin floor elevation is -16.0, while the secondary stilling basin varies in elevation across the spillway from about -22.0 to about -50.0. A vertical lift tractor gate is provided at the sluice conduit entrance, capable of closing both sluice entrances at once. Downstream closure will be accomplished with a caisson bulkhead that can be floated into place and sunk into guide at the sluice exit section, possibly with diver assistance. The top of the caisson will be at El. 30.0 (MSL) when in place. The sluice can be dewatered by opening the closure valve in the caisson allowing water to flow from the sluice into the caisson, then pumping from the caisson chamber until dry. Man access will be provided through a watertight door at the base of the caisson chamber.

This alternative would require removal of part of the secondary stilling basin floor down to approximately El. -40.0 to accommodate the sluice outlets. Removal of the lower portion of the stilling basin should not adversely affect stilling basin performance. The upper spillway discharge jet should remain supported by the sluice jet, preventing it from plunging to the great depths of the existing channel floor. The proposed sluice location under the existing spillway would minimize interference with the existing spillway operation, and would not compromise the existing spillway discharge capacity. The sluices would be designed to operate only fully open, with the closure gate lifted clear of the forebay water surface, and could be operated concurrently with the existing spillway gates. However, opening or closure of the sluice conduits could only be made when the existing spillway gates were closed in that particular spillway bay. Maximum capacity of the sluices would be about 240 kcfs, and the combined spillway and sluice discharge for the 10 year 7-day event would be about 283 kcfs, which meets the required TDG goals for forebay TDG levels at 110% or less.

The spillway discharge jet should dissipate its energy in the El. -16.0 primary stilling basin, upstream of the sluice outlet portals. Preliminary observations from the Ice Harbor Dam sectional spillway model at WES show that when the sluice exit portal is located upstream of the hydraulic jump formed by the spillway gate discharge jet, aerated flow from the spillway is entrained by sluice discharge and pulled to deep depths. The sluices in this alternative are designed to discharge into the tailrace downstream of the primary stilling basin. The Ice Harbor Dam model also showed evidence of vortex generation by the submerged sluices when operated alone, without discharge through the existing spillway gates. This problem will require significant modification to the sluice entrance configuration. Various configurations of entrance shapes must be evaluated in the physical model study to confirm the severity of this vortex problem and to develop modifications to eliminate vortices if necessary.

6.4.2 Structural Design

The deeply submerged sluices for Bonneville would require new upstream gate slots cut into the existing spillway piers and extending from the existing El. 90.0 spillway bridge deck to El. -12.0. The two new sluice intakes in each spillway bay are about 21 ft wide, 13.5 ft high each, separated by a large pier. A new vertical lift gate about 54 ft wide by 15 ft high would provide closure for the two new sluiceways in each bay. The closure gate would fit into a new recessed bulkhead slot and lifting cables would extend to the new hoists located on the existing spillway bridge (El. 90.0 ft (MSL)). The new sluiceways would have a smooth, inclined invert, starting upstream at El. -12.0 MSL and dropping through a smooth curve to El. -36.2 ft (MSL) about midway through the spillway crest section. The existing spillway ogee crest will be removed and reconstructed in order to form the new submerged sluiceways. See Plates 19 through 27 for details. The new proposed spillway gantry crane is shown on Plate 2B. A new spillway gantry crane will be required to operate the new sluice closure gates, since the existing cranes are not capable of lifting the gate from the existing crane rail alignment.

(1) General

Structural design considerations for the modification to add sluices underneath existing spillway for eighteen bays include the following:

- Remove existing upstream parapet wall by diamond saw cut.
- Install new gantry crane corbels on upstream faces of all piers.
- Install new gantry crane girders and crane rail.
- Install new 110-ton spillway gantry crane.
- Dredge upstream impervious fill to set floating bulkhead.
- Install downstream cofferdam scheme similar to that previously discussed for Alternatives 1 and 3.
- Install three upstream floating bulkhead frames and stoplog assemblies that will be utilized to dewater at least three alternate bays at a time.
- Remove existing spillway vertical gate operating hoists to provide spillway crest access as work progresses.
- The existing spillway ogee and stilling basin concrete will be removed to about El. -40.0 for construction of the new sluices.
- In water or land disposal of excavated material.
- Modify the existing upstream spillway parapet wall as necessary for new upstream sluice closure gates.
- Establish new upstream closure gate slots for all spillway bays.
- Install post-tension tendons at new bulkhead gate slots in existing piers.
- Re-establish the stilling basin drainage system in the new sluice piers and connect drainage to existing spillway drainage and grouting gallery.
- Form and place reinforced concrete for two new sluices per spillway bay.
- Form and place reinforced concrete for new stilling basin and baffles.

- Form and place reinforced concrete ogee section with new vertical gate sill beams.
- Install new sluice gate hoists to service new upstream sluice closure gates.
- Construct new downstream bulkhead storage pits on Cascade Island or Bradford Island.
- Move upstream floating bulkhead frame and stoplog assembly to alternate bays as work on the first three is completed.
- Remove and reinstall downstream cofferdam during next IWW period as discussed for Alternatives 1 and 3.
- Reduce vehicle access on spillway bridge during construction. Make night hours and Friday through Sunday available to contractor, except for emergencies.
- Replace existing spillway vertical gate hoists as work is completed for each phase.

(2) Downstream Cofferdam Selection

This alternative will use a cellular or crib-type structure of the type that was discussed for Alternatives 1 and 3. The positioning of the north-south segment will be located somewhat downstream in order to provide additional area for concrete removal on the primary stilling basin floor. Floating connecting wing walls will be used to stabilize the first full cell in the stilling basin. See plates 4 through 6 for downstream cofferdam details.

(3) Upstream Dewatering Selection

None of the previously discussed alternatives required complete dewatering of the area upstream of the existing vertical spillway gates. Plates 24 through 27 illustrate the proposed concept for dewatering for this alternative. This method has been used successfully for an emergency spillway gate repair at Folsom Dam by the Sacramento District of the Corps of Engineers. The bulkhead would be floated to the location and submerged to seat against the existing spillway structure. This is an item that could be secured as a supply procurement before the main construction contract is advertised. Dredging will be required upstream and adjacent to the spillway dam prior to setting the upstream floating bulkhead.

Upstream Floating Bulkhead Frame and Stoplogs

The bulkhead assembly will generally consist of a flotation tank, stoplog frame and slot structure, steel stoplogs, and a lower skin plate truss structure. The full bulkhead assembly is floated into position for placement in front of the spillway. The steel stoplogs are then installed prior to removal of the ogee crest and construction of the new submerged sluices. A separate stoplog lifting frame (see Plate 27) will be required to place the steel stoplogs into the bulkhead frame assembly.

The flotation tank is connected to the bulkhead assembly and is located at the top of the bulkhead assembly frame. The flotation tanks have provisions to allow flooding of the tanks after the bulkhead assembly is floated into position.
The bulkhead assembly frame structure is constructed with slots on each side to accept steel stoplogs to isolate the work area on the spillway crest. After the bulkhead frame assembly has been floated into position, the stoplogs are set in place with a separate stoplog lifting frame.

A skinplate truss structure, below the removable stoplog portion of the bulkhead assembly, will prevent flow through the portion of the spillway where the existing ogee crest will be removed and replaced by a new ogee crest and submerged sluices.

The upstream concrete corbels, crane girder, and crane rail installation will be one of the initial items of work. The new 110-ton capacity spillway gantry crane will be installed for the first phase construction. These items of work are shown on Plates 20 and 28, respectively.

(4) Concrete Design Criteria

The strength design for reinforced concrete hydraulic structures is detailed in EM 1110-2-2104. The quality of concrete based used for the various areas is defined in EM 1110-2-2000 Standard Practice for Concrete. Other concrete design criteria is the same as previously stated for alternative 3, section 6.3.2 Structure Design.

(5) Structural Modifications

Spillway Deck/Corbel and Crane Girder

During the first year of construction, work will be completed for the required modifications to the spillway upper deck, piers, locations for new post-tensioning assemblies, constructing new corbel and crane girders. A detailed design will be required prior to cutting the new vertical sluice gate slots. The existing spillway piers contain the steel bridge piers that were used for initial construction. The zone upstream of the trestle would be the logical location for the supplemental post-tensioning.

Ogee, Sluice and Stilling Basin

The complex system for constructing this alternative was outlined in section 6.4.2 “Structural Design, (1) General” for this alternative. The invert of the new sluice intake entrance is at El. -12.0 ft (MSL), and the tangent point of the bellmouth entrance ceiling is located at El. 1.4 ft (MSL) at the upstream face, 20 ft upstream of the CBL. There are two new sluices per spillway bay. Each water passage is 12.5 ft wide and 9.2 ft high, as measured perpendicular to the axis of the new sluice. The invert of the horizontal portions of the sluices are set at El. -36.2 ft (MSL), while the downstream exit portal ceiling is set at El. -24.9 ft (MSL). The stilling basin invert will be reconstructed at El. -16.0 ft (MSL) in accordance with the original design of the Bonneville spillway. A pair of new vertical closure gate slots per bay (3 ft wide and 1 ft deep) will be established in the upstream portion of the existing spillway piers. The new stilling basin footing drain system will be connected to the existing stilling basin drainage conduit and routed to the existing upstream drainage and grouting gallery. This extensive modification is shown on Plates 21 through 23.

(6) Concrete Removal

The initial concrete removal work will include demolition of the upstream parapet wall of the spilling bridge structure. The wall is approximately 1,080 ft long, and could be segmented into 12-ft lengths, drilled for cable connections and held in place by a mobile crane on the roadway deck. As the segments are cut, they may be loaded and hauled to disposal or salvage. Other items of concrete to be removed include demolition of the existing upstream pier nose and preparation for placement of the new upstream corbel and also the core drilling for the post-tensioning units.

Prior to concrete removal activity, a thorough stability analysis will be performed for the crest monolith sections. If it is determined by this analysis that the monolith will be subject to destabilization due to unresisted uplift forces during concrete removal during construction or following construction, relief wells will be drilled into the foundation prior to demolition. These wells will be pumped as necessary during construction and permanently drained following construction to ensure stability of the modified crest monoliths. The monoliths may be provided with grouted foundation post-tension anchorage if drainage is not feasible.

The next work for each spillway bay will be concrete removal to a net line 2 ft below the invert of the new sluices. A majority of this work will be performed by controlled blasting. The first phase will include removal of a 10 to 15-ft bottom width V-shaped excavation out of the middle of each monolith down to the desired grade. This excavation is designed to provide relief for the outer areas. Controlled blasting may be the selected procedure; however, the blast areas will be covered with a blasting mat to prevent flying debris. The second phase will include removal of the side portions and extending the excavation to El. -38.2 ft (MSL). There is an existing cold joint between the piers and ogee section for the south half of Bay 9 and all bays 10 through 18. This cold joint extends down to the first step diversion surface which is sloped upstream from MSL El. -6.0 to MSL El. -12.0±. There will be miscellaneous embedded metals associated with the contractions joint grouting system in these areas that must be removed. Concrete removal for the sluices below the first step diversion surface will require line drilling for pre-splitting. Plate 18 provides a downstream elevation and a partial longitudinal section through the dam that illustrates the monolith depths and construction details. Spillway bays 1 through the north half of bay 9 will require core drilling to form a pre-split line. Any type of concrete removal may cause micro-fracturing of structural members in the embedded steel framework. Thorough review of the original construction drawings will be required to determine the best methods for approved concrete removal to avoid damage to existing reinforcement. Existing steel reinforcement will be flame cut as necessary and disposed of or salvaged for recycling. The contractor should be given the option to salvage and recycle the demolished concrete and crush the material into processed granular fill.

The new upstream corbels will require some concrete removal to expose the existing steel reinforcement and dowel to the existing pier for load transfer. This area will also receive concrete core drilling for the vertical post-tensioning units. The new corbels will be a heavily reinforced section in order to transfer the loads from the new gantry crane and girder bridge. It is assumed that at least two post-tensioning units will be needed at the upstream zone of each pier.

The new vertical upstream bulkhead slots will be cut into the existing concrete piers. The desired finished slot dimension will be 3 ft wide and 1 ft deep. The concrete removal will be about 7 ft wide and 18 inches deep. Care will be taken to add the necessary supplemental steel reinforcement and/or post-tensioning required. The existing piers are 10 ft thick and a total of 3 ft of concrete will be removed to accommodate the new gate slots on each side. The width of each gate slot will be cut vertically with a diamond blade rail saw to outline the excavated portion. The concrete within the gate slot will be removed and the existing steel reinforcement will be flame cut away and recycled as it is exposed. The new gate slots will extend from the service deck at El. 97± ft (MSL) down to El. -12.0 ft (MSL) as shown on the Plates 19 through 23.

(7) Bulkhead and Spare Gate Storage Pits

New downstream bulkheads will be stored in some type of new facility on either Cascade Island or Bradford Island. The caissons are about 56 ft high, 60 ft wide, and about 30 ft thick. The project will require a minimum of one caisson. There will also have to be one spare upstream closure gate in addition to the eighteen provided for all of the spillway bays. This spare upstream closure gate is 54 ft wide, 15 ft high, and 3 ft thick, and will require a dedicated gate storage pit in which to house it.

(8) Under drainage System

Excess leakage in the existing spillway and stilling basin joint system is currently drained to the upstream drainage and grouting gallery. The excavation for the new sluices will cut this system within the central 40-ft width of each spillway bay. There will be a new collector conduit formed in the reconstructed stilling basin slab. Any stilling basin joint leakage collected would be dropped into the existing collectors beneath the existing stilling basin floor and immediately downstream of the existing spillway piers. The present drainage system within the piers will transfer the new drainage to the existing drainage in the grouting gallery. Dam safety criteria may require additional waterproof doors to isolate the existing drainage sump and pumps. Construction of the new sluices will remove a substantial portion of the mass of the existing monolith and, as a result, it may be necessary to install footing drainage wells along the new sluices to relieve uplift pressure on the stilling basin footing and spillway monolith. This relief well system would be connected to the new collector drain and existing drainage and grouting gallery.

(9) Instrumentation

The existing piezometers in Bay 13 will be completely removed during the construction of the new sluices. Pore pressure meters and strain meters may be used in the concrete to determine the physical loads to the structure and/or gates during operations. Instruments may also be required throughout the sluices and within the stilling basin. The read-out locations for the instrumentation program may be either in the drainage gallery or at the new upstream spillway pier corbel(s).

6.4.3 Mechanical Design

(1) General

The mechanical design considerations for this alternative include the following elements:

- Replace one existing spillway gantry crane, booms, cables, and hoists in order to lift, position, and store the 18 new upstream sluice closure gates and assist in placing the upstream floating bulkheads.
- Eighteen, plus a spare, sluice closure gates; 54’ W x 12’ H x 3’ T cables and controls.
- Lifting beam for new upstream sluice closure gates.
- One new downstream caisson bulkhead.
- Permanent on-water dock to handle and install the new downstream caisson bulkhead.
- Portable submersible pumping system for upstream floating bulkheads.
- Portable submersible pumping system for dewatering new sluices; to be lowered into the downstream caisson bulkheads once they are in place.
- New vertical gate guides for sluice gate closure slot.
- New stilling basin under drainage system with drops within new sluice walls to feed existing drainage system.
- New spillway vertical gate sill beams in new ogee crest concrete.
- New “J” seals for existing spillway vertical lift gates for use as dewatering bulkheads in the existing upstream bulkhead slots.

(2) Replace or Modify Spillway Gantry Cranes

The existing spillway gantry cranes do not have sufficient lifting capacity to handle the new upstream sluice closure gates. Either a new gantry crane will be constructed or one of the existing cranes will be modified to provide the required 100-ton lifting capacity at the new sluice closure gate slots. The replacement of or required modifications of one of the existing spillway gantry cranes is the largest single mechanical item. The new unit will operate on the existing downstream crane rail and a new crane girder and rail located on a new upstream concrete corbel. The new crane will have the following features:

- Upgraded power supply and transfer towers
- Trucks spaced at 60 ft to transfer maximum load directly to piers
- Gage distance 50 ft and a clearance height on main hoists of 62 ft
- Sluice service hoist

Rated capacity:	110 tons	
Hoisting speed:	Full load	8 fpm
	32 tons	18-24 fpm
	No load	24 fpm
Hook travel:	173 ft	
	high El. 161	
	low El. -12	
Trolley speed:	16 fpm	

- Main hoist - all specifications same as above for sluice service hoist, except for hook travel: 137 ft
  high El. 161
  low El. 24
- Actuating hoist

Rated capacity:	2 hooks @ 15 tons each	
Hoisting speed:	Full load	20 fpm
	No load	40 fpm
Hook travel:	168 ft	
	high El. 124	
	low El. -39	
Trolley travel:	42 ft	
Trolley speed:	16 fpm	

- Gantry Travel

Travel speed:	100 fpm
Length of travel:	Approx. 1,100 ft

- Monorail Hoist

Rated capacity:	2 tons
Hoisting speed:	24/5 fpm
Hook travel:	40 ft
Trolley travel:	65 ft
Trolley speed:	100 fpm

The performance specifications shown above provide the guidelines for the new gantry crane. This is a major improvement to the spillway operations. The area of existing parapet wall to be removed will have a new handrail and include the area of the new upstream corbels. A new power source, including power poles and bus bars, will be required across the spillway. Additional concrete standard bases may be needed at intermediate bay and pier locations. The proposed new lifting beam for the upstream dewatering bulkhead and stoplog lifting beam is shown on Plate 27.

This replacement gantry crane will be procured by supply contract and should be operational prior to the time at which the sluices are put into service.

(3) Gates and Bulkheads

The 18 new vertical sluice closure gates (54'W x 12'H x 3'T) will have "J" seals around the perimeter to minimize leakage during sluice dewatering operations. A new lifting beam will be required for the gates. As discussed above, a floating caisson bulkhead will provide for closure of the downstream exit portal of the sluices. These caissons will be floated into position and sunk into place in the guides provided at the exit portal. Divers will be required to assist in the installation of the downstream caisson bulkhead. Any maintenance in the sluices will probably occur during non-spilling season. A portable submersible pumping system will be required for dewatering the new sluices.

(4) Sluice Gate Hoist Machinery

Gate hoist machinery will be required for all 18 spillway bays. The new hoist drum capacity will be sufficient to lift the sluice closure gates from MSL El. -16.0 to MSL El. +90.0. The gate guide assemblies will have provisions to dog off the new sluice gates in order for them to be changed out with the new gantry crane.

(5) Other Items

Other minor mechanical items will be the design of the new stilling basin under-drainage system and "J" seal replacement and/or reconditioning for the existing spillway vertical lift gates.

6.4.4 Electrical Design

(1) General

Electrical design considerations for this alternative include the following:

- Power sources for new gantry crane, including towers
- Power sources for sluice gate machinery
- Spillway gantry crane driver and hoist motors
- Power supply for hand tools and lighting circuits
- Communication lines for telephone, project code calls, and security cameras

(2) Power Source, Lighting, Communications and New Conduits

All these items will be the same as required for Alternative 3, with at least one additional light mounting to illuminate the upstream gate slot area for sluice gate operations and any additional electrical requirements for the new spillway gantry crane.

6.4.5 Constructibility

(1) General

A new upstream cofferdam system would be required to isolate several spillway bays at a time. A similar cofferdam system will be required for the stilling basin work area. The deep holes downstream of the existing stilling basin slab could be filled with concrete debris and a top layer of large armor rock. Further study would be needed to determine the cost effectiveness of mining the two new 12.5-ft wide by 9.2-ft high sluiceways versus removing the entire spillway ogee concrete. It appears that the lower portion of the sluices would require excavation into the rock foundation of the stilling basin. This alternative would require five to six years for construction with present in-water work window limitations, or somewhat less if work windows can be modified. Construction sequence and work phase performance will be coordinated as discussed below:

- Navigation service will be maintained for the current barge schedule.
- Washington Department of Fish and Wildlife, Oregon Department of Fish and Game, and/or U.S. Fish and Wildlife Service will provide criteria for restricted areas during construction.
- Reservoir control and discharge requirements in accordance with Northwestern Division Reservoir Control Center.

(2) Downstream Cofferdam Selection

The most feasible method for dewatering the spillway ogee and stilling basin area is to provide a Z-pile crib or cellular-type cofferdam. The proposed plan for phased construction is similar to that for alternatives 1 and 3, and is shown in plates 4 through 6. A detailed discussion for the three-phase construction sequence is provided in section 6.1.2 (2) “Dewatering of Work Area”. This scheme divides the spillway into thirds, thus requiring a minimum of three IWW periods. A fourth year may be needed if tailrace leveling is needed prior to placing the downstream cofferdam crib.

(3) Upstream Floating Bulkhead for Dewatering

The concept shown on Plate 24 combines a stoplog gate frame and a bulkhead truss structure as a floating and submersible unit that is secured to the existing spillway piers. The bulkhead will be shop fabricated and delivered to upstream of the spillway by barge. Installation will require diver assistance. A diver inspection with video camera will be required at the start of design to confirm the lower protruding concrete lift configuration at the upstream side of the spillway crest. The installation of the stoplog portion of the bulkhead is shown on Plates 25 and 26. The proposed lifting beam for stoplog handling is shown as Plate 27. The installation of the stoplogs would best be accomplished if the new spillway gantry crane was procured prior to the award of the main construction contract. This would improve confined job site logistics at the spillway bridge and may reduce total project costs.

(4) Construction Sequence

The following items or work are common to each construction phase:

- Construct upstream pier corbels and crane girder bridge.
- Install new spillway gantry crane.
- Remove existing spillway gate hoists within work area.
- Mobilize floating plant and install Z-pile downstream cofferdam during the IWW period.
- Install upstream dewatering bulkheads
- Install dewatering pumps and dry work area
- Install contractors spillway gantry crane, boom with jib between government spillway gantry cranes.
- Remove existing spillway ogee concrete and gate seat beam, stilling basin concrete, and some bedrock.
- Remove spillway pier concrete for upstream vertical sluice bulkhead slots.
- In-water disposal of concrete debris, if allowable.
- Place new reinforcing steel.
- Place new concrete sluice and spillway concrete in 6 spillway bays from floating plant.
- Replace spillway gate hoists
- Replace spillway gates
- Move upstream dewatering bulkhead to successive bays as work is completed.
- Remove downstream cofferdam crib and reinstall for next phase.
- Repeat steps above for remaining 12 bays in two phases as described.
- Dredge remaining granular material from stilling basin.
- Install mechanical items.
- Install electrical items.
- Construct bulkhead gate storage pits.

The contractor will probably use a floating plant to gain access to the work area and perform a majority of the construction activities. This will require at least one on-water loading facility. The floating plant will include work barges, cranes, tug service, cranes with pile driver, and access craft to the downstream cofferdam area. The cofferdam cell erection template will be fabricated off site and barged to the job site. Z-pile will be delivered by barge as needed. Cofferdam template will be pulled and each crib cell will be filled with granular material. At the time of cofferdam removal, the previously completed work area will be flooded and downstream cofferdam removal will take place in reverse order. A majority of granular material will be removed by clam shell bucket and placed on a material barge for the next phase cofferdam construction.

(5) Concrete Structural Modifications

The concrete production will be performed from a floating plant that is secured to the downstream cofferdam. The floating concrete plant will have aggregate barges, batching and mixing plant, and some type of deliver/conveyance system. Since a majority of the new concrete placements are at the stilling basin, sluices and spillway ogees, a conveyor system may be used to feed buckets or belt conveyors. Replacement concrete for the bulkhead slot locations and seal plates will most likely be placed by crane and bucket. All resteel cages and curtains will probably be constructed off site and be transferred by floating plant.

(6) In-Water Concrete Disposal

The option for in-water concrete in the deep holes downstream in the tailrace should be evaluated in the next design phase. This may be accomplished using hopper dredge-type equipment and global positioning surveys. The required concrete removal will be accomplished throughout the entire year and thus upstream deep water disposal in midstream locations could be utilized as well as tailrace locations. Another economical means of effectively handling the great volume of concrete debris would be to crush and recycle it for use in new aggregate for spillway crest reconstruction. Additional evaluation is needed to effectively weigh the advantages and disadvantages and costs associated with the respective options.

(7) Bulkhead Gate Storage Pits

This activity is not dependent on any work within the new spillway sluice gate modification. The desired location would be on either Cascade Island or Bradford Island. Electrical service will be provided for maintenance at the storage pit locations.

(8) Floating Dewatering Caisson Bulkhead Storage

The floating dewatering caisson bulkhead will be stored either in a deep water area or on some type of ramp. A rail-mounted carrier may be needed to retrieve the caisson bulkhead from the river.

(9) Final Cleanup

This phase of the work will include the stockpiling of all cofferdam steel at a designated storage area. The contractors spillway gantry crane will be dismantled and removed as well as all logistical support facilities. There will also be a requirement for an underwater inspection of the entire spillway stilling basin and all debris will be removed before acceptance of the completed project. In-water disposal for filling deep holes in the tailrace may be an option if permitted. On-water transfer dock may be considered for future government use and left in place. The three upstream dewatering bulkheads will be either mothballed and/or recycled.

6.4.6 Fisheries Issues

This alternative may cause entrainment of juvenile fish into the submerged conduits. However, maximum velocities inside the sluice conduits is not greater than that currently endured by juveniles in passage through the existing spillway. The deep submergence of the sluice entrances, combined with surface withdrawal through the existing spillway gates directly above, will minimize opportunity for entrainment of fish. Adult fish passage may be adversely impacted by the flow exiting from the sluices near the existing ladder entrances. However, operational changes could be made to minimize operation of the outer sluices during adult migration periods.

7.0 RELOCATIONS

The physical impact of these four selected Alternatives differ widely. The following paragraphs will briefly discuss each of the four plans.

(1) Alternative 1 - Stepped / Extended Deflectors

Construction of this alternative will cause minimal impact to the structure and the present infrastructure. The construction will be confined to the zone within the spillway bays and immediately downstream of the existing piers.

(2) Alternative 2 - Raised Tailrace

This option has perhaps the least impact to the present structures. There will be selected corridors and stockpile areas identified for construction use. The contractor will remove some existing fences in order to gain access to the river bank on the north shore. This project may also require the removal of existing post and beam guardrail. A new on-shore dock will be required for transfer of concrete aggregates and rock. After construction of this option, the on-shore dock will become property of the government, and can be used for future maintenance activities.

(3) Alternative 3 - New Spillway Gates

The concept of extending the existing spillway piers and installing new spillway tainter gates has little negative impact to the existing structure. This alternative will require the construction of a new trunnion bridge in three phases. After the new spillway piers are placed, the new precast pre-stressed concrete bridge will be set into place. The trunnion bridge will be constructed in the same phases as shown on Plate 4, Temporary Cofferdam Dewatering Plan. Existing mechanical and electrical services will be upgraded or replaced as required to provide service to the new spillway gate hoists. There will be some on-shore work on each bridge abutment to set new piers and complete construction of connecting roads, curbs, and new utilities. Lighting will be required for each new spillway gate trunnion and for the bridge approaches. The new trunnion bridge approaches will be connected to the existing road system. Concrete removed from the structure may be recycled as road materials or placed in disposal areas. Temporary roads for construction on each abutment may be required.

(4) Alternative 4 - Sluices Under Existing Spillway

This alternative is the most complex of the four selected for further study. The major relocations are listed below:

- New upstream spillway gantry crane and upstream crane rail
- New mechanical and electrical services to upstream crane rail
- New upgraded power supply for gate hoists
- New and relocated underdrainage system
- New power supply and feed towers for new gantry crane
- Upstream floating dewatering bulkhead storage area

Removal of the upstream parapet wall of the existing spillway bridge will probably affect the existing spillway bridge utilities. If so, temporary services will be needed during construction. The new upstream crane rail corbels will require foundation post-tensioning prior to construction of the corbels. New electrical ducts, control systems, and other essential utilities will be supplied to the new crane rail support corbels and the new sluice closure gate lifting hoists. The new gantry crane will require a complete new power supply consisting of new power supply towers and feed conduits. During the construction of the new sluices, a new underdrainage system will convey seepage to the existing downstream longitudinal tunnel at each pier location. This is shown on Plate 21. A new deep water storage facility or access ramp will be provided for the upstream floating dewatering bulkhead.

8. ASSUMPTIONS AND UNKNOWNS

8.1 Alternative 1 - Stepped / Extended Deflectors

This option has the least amount of work and thus the least amount of unknowns before the final design is completed. The design schedule for Alternative 1 identifies the need for a hydraulic model and a bathymetry survey. A careful review of the existing drawings should be made to identify the items of conflict prior to construction. The detailed bathymetry survey is required to define the actual conditions in which the bulkhead will make seals for dewatering. A diving inspection may be necessary to supplement the bathymetry survey findings if considerable erosion is found in the seal areas of the piers and stilling basin. The only information found for this document was drawing M-2-61/7 entitled “Spillway Dam, Apron and Baffle Repair, Bay 13, Showing Scour as of December 1952”.

A detailed physical hydraulic model study will be required to further define the configuration of the new stepped deflectors. The elevation of the two steps of the deflector can not be established for certain until such configuration studies can be completed and evaluated in the physical model. Final step configuration will be evaluated in the model to determine pressure distribution along the step surface and downstream face, and along the pier face and downstream nose. Velocities along the spillway ogee, the deflector surface, and in the stilling basin must be measured in the model as well. Stilling basin performance must also be evaluated in the model with the stepped deflector in place.

The other item of interest is to study the potential for bank erosion of the north and south downstream spillway channel revetment when all spillway bays have stepped/extended deflectors. A drawing review shows that previous work had been performed in 1951, Drawing M-1-59 entitled “Spillway-Downstream, Revetment Reconstruction Plan and Section for the South Shore of the Spillway Channel.” The last item of consideration would be the need to review the existing layout and details of piezometers in Bay 13. The original drawing is entitled “Bonneville Project, Contract 698, Eng. 575 and dated 6/30/37.” The condition of these piezometers is unknown, and it is not certain whether additional instrumentation will be needed for the new stepped/extended deflectors.

8.2 Alternative 2 - Raised Tailrace

This alternative is presented as a non-structural modification but will generate the same initial concerns as identified in paragraph 8.1. The detailed hydraulic model study and bathymetry survey are essential for successful implementation of this alternative. In particular, several different elevations of the raised portion of the exit channel should be evaluated to determine which provides the most successful reduction of air entrainment to deep depths. In addition, the model must be used to determine whether an end sill will be required to contain the hydraulic jump within the stilling basin and to prevent entrainment of rock into the stilling basin floor. As discussed in the fisheries issues section, this alternative may eliminate a large area of potential sturgeon habitat. Mitigation for this loss is not included in the cost estimate, and may require significant effort to identify and develop mitigation measures. A new habitat area may need to be created away from the salmon and steelhead juvenile and adult bypass systems. Habitat restoration is beyond the scope of this document.

8.3 Alternative 3 - New Spillway Gates

The WES model study show very encouraging results with regard to reduction of air entrainment in the gate discharge jet. However, hydraulic model evaluation will be required to verify the adequacy of the stilling basin with and without the baffle blocks, and to determine if vibration problems are likely to arise with submerged tainter gate operation. The model will also be used to verify that the trunnion location well below the PMF flood event tailwater elevation does not cause adverse impacts to the gate structure or to the spillway discharge capacity.

Since this is a structural modification, there are a number of assumptions and unknowns associated with the proposal. A complete review of the spillway drawings will be needed to identify all the existing systems to be relocated. The new extended piers will require post-tension anchorages to the foundation rock. Geotechnical explorations will be needed to re-evaluate the competence of the Eagle Creek formation. This tuffaceous formation may require benefaction by intrusion grouting at the anchorage locations, and grout holes may need to be drilled deeper to the underlying intrusive and esztic lava. The design schedule also calls for detailed downstream cofferdam design and work schedules for IWW periods and spillway gate design and anchorages. The required concrete removal for the existing extended piers will have to be scheduled in order to be ready for the new trunnion anchorages. The location of the original steel construction trestle should be researched to minimize the conflicts and expense for installing new post-tensioning and required concrete removal. The new trunnion bridge will facilitate gate construction and modernize the operations of the spillway and provide improved traffic patterns. Research should also be conducted to set the required freeboard for the downstream cofferdam structures. Any new instrumentation criteria will be incorporated into the final design. All relocations will be identified in future designs.

8.4 Alternative 4 – Sluices Under Existing Spillway

Hydraulic model studies of the submerged sluice concept as applied to the Bonneville spillway will be required to verify sluice geometry and stilling basin performance. It will be necessary to modify configuration of the sluice entrance and approach in the model to eliminate vortex generation. Pressures and velocities must be measured in the model throughout the length of the sluice conduit and modifications must be made to eliminate areas of unacceptably low pressure or excessive velocity. Performance of the stilling basin must be evaluated for a range of sluice and spillway gate discharge conditions. In particular, if the sluice exit jet tends to entrain air into the deeper portions of the tailrace, then it may be necessary to extend the conduit downstream well beyond the hydraulic jump in the stilling basin and the associated entrained air.

This concept for TDG reduction is the most complex to design and construct. The downstream dewatering plan would be the same as that used for Alternative 3. The upstream dewatering plan uses the same bulkhead / stoplog beam system that was used to make spillway repairs at Folsom Dam on the American River in California. A complete design of the closure system, including connections, will be needed for this alternative. The assumption to use a new spillway 110-ton gantry crane to help install the upstream dewatering bulkhead will require advance planning, funding, and installation prior to any spillway modifications and associated concrete removal. Research should also be conducted as to the best alternatives for concrete removal for the existing roadway railings, vertical gate slots, concrete spillway ogees, and stilling basin areas. Phasing the concrete removal is beyond the scope of this document. Hydraulic model testing will be required for new sluices and to protect potential downstream erosion. The geotechnical concerns expressed for Alternative 3 hold true for this option. Foundation explorations will be required to re-evaluate the Eagle Creek formation. Any new instrumentation criteria will be incorporated into the final design. All relocations will be identified in future designs.

9.0 COST ESTIMATES

Detailed cost estimates for each of the four alternatives are provided in Appendix B.

9.1 Alternative 1 - Stepped / Extended Deflectors

The total project cost for the stepped/extended deflector alternative is $21,416,058. The cost per spillway bay would be $1,189,781. These costs reflect a 25% construction contingency, an 18% engineering and design contingency, and a 10% supervision and administration contingency. This cost estimate assumes progression of construction would be similar to that which occurred during construction of existing deflectors. The cost estimate also includes an 8.125% interest rate on construction cost during construction.

9.2 Alternative 2 - Raised Tailrace

Most of the cost of the raised tailrace alternative is captured in the materials supply and placement costs. The bathymetric survey shows that it will take approximately 730,000 cy of armor stone and 133,000 cy of concrete and grout to stabilize the tailrace. The total project cost for this work is $82,988,442. The cost estimate also includes an 8.125% interest rate on construction cost during construction. This cost estimate assumes that no rock is lost downstream during the break between In-Water work periods. This is the second to least cost alternative studied. To compare with the other alternatives, the cost per spillway bay is about $4,610,469. These costs reflect a 25% construction contingency, an 18% engineering and design contingency, and a 10% supervision and administration contingency. This cost estimate assumes progression of construction would be similar to that which occurred during construction of existing deflectors.

9.3 Alternative 3 - New Spillway Gates

The anticipated project costs, excluding interest during construction are $196,527,630. This is a preliminary estimate containing a 25% construction cost contingency plus 18% for engineering and design and 10% for supervision and administration during construction. This is a very complex project and deals with construction of very large tainter gates and associated equipment that will extend the state-of-the-art. The cost per bay is about $10,918,202. The cost estimate also includes an 8.125% interest rate on construction cost during construction. This cost estimate assumes that large radial gates of this type will operate successfully. The cost of split leaf vertical lift gates instead of radial gates may be lower.

9.4 Alternative 4 Sluices Under Existing Spillway

This is the most complex alternative evaluated in this study. The project costs, excluding interest during construction, are $253,315,905. To compare with the other alternatives, the cost per bay is about $14,073,106. This option is about 29% more costly than Alternative 3. These costs are preliminary and contain 25% construction cost contingency plus 18% for engineering and design and 10% for supervision and administration during construction. The cost estimate also includes an 8.125% interest rate on construction cost during construction. This cost estimate assumes that upstream dewatering can be successfully achieved with the floating bulkhead. Although the bulkhead system is similar to that used to successfully dewater failed spillway gates at Folsom Dam, it may not be possible to apply the concept to Bonneville Dam. If an upstream cellular-type cofferdam is required, the cost of construction would be significantly increased.

10.0 DESIGN AND CONSTRUCTION SCHEDULES

Detailed design and construction schedules for all four alternatives are provided in Appendix C.

10.1 Alternative 1 - Stepped / Extended Deflectors

10.1.1 Design Schedule

The accuracy of the design schedule for the stepped / extended deflectors is dependent on funds available and time in which the authority and the appropriation is obtained in the Portland District. The schedule is written to reflect the need for architect-engineering support and to incorporate the following major items:

- Precept of authority and funding
- Coordination activities
- Draft economic report
- Feasibility report with hydraulic model testing and downstream cofferdam design
- Northwestern Division comments and USACE review
- Submit to H.R. Committee and testify to Congress
- Receive authorized funds for planning and engineering
- Receive funds for advanced procurement (GFP)
- Prepare plans and specifications

The design phase should be used to provide documentation to lengthen the in-water work (IWW) period. One suggestion would be to perform all work closest to shoreline within the present IWW window. However, the work in mid channel and close to the structure may be performed during the expanded in-water work period. The total allotted time for design is about 24 months, assuming that adequate funding is available each fiscal year.

10.1.2 Construction Schedule

The stepped / extended deflectors will be placed on all 18 spillway bays. It should be noted that there are existing smaller (first generation) deflectors on bays 4-15 and 18, or 13 bays. These were placed by previous contracts. The construction shown in this report reflects the new multi-bay floating cofferdam structure for constructing the stepped / extended deflectors. The procurement of this floating cofferdam would be a supply contract issued once the project is authorized by the Feature Design Memo 1. The total construction contract can be compressed to about 27 months, assuming the floating cofferdam would be supplied as Government Furnished Property (GFP) at the start of the first IWW period.

10.2 Alternative 2 - Raised Tailrace

10.2.1 Design Schedule

Alternative 2 is of relatively uncomplicated design; however, implementation is more difficult. Design of the fill material and placement method would be completed within no more than one year. Detailed physical hydraulic model testing and evaluation would be required to verify the elevation to which the tailrace channel would be raised, and the configuration of fill placement. Extensive coordination with fisheries agency staff would be required to develop the fill surface material gradation and placement, and to develop the final grade that best suits the needs of anadromous and resident fish species utilizing the spillway exit channel area. Since it is anticipated that construction will likely be executed from floating plants without dewatering, some design effort will be expended on placement control survey systems, including triangulation markers and grid layout.

The schedule for design of Alternative 2 as shown in the following pages reflects the necessary steps toward acquiring funding support and implementation of the project from design through final construction. The schedule also assumes that funding will be obtained without delay within the year of project request in the Congressional budget agreement. Major features of the design schedule are summarized below.

- Precept of authorization and funding for final design and plans and specifications
- Coordination activities
- Draft economic report
- Letter design report, with physical hydraulic model testing
- Northwestern Division review
- USACE Headquarters review
- Submit to H.R. Committee and testify to Congress
- Receive authorized funds for planning and engineering
- Prepare plans and specifications

During the design phase, coordination efforts with fishery agency staff should include negotiation of extended in-water work periods. Construction schedule for this project would be severely impacted and lengthened considerably if no room for expansion of the in-water work period could be made. The design schedule as shown indicates a period of about 26 months would be required for design and preparation of plans and specifications.

10.2.2 Construction Schedule

The spillway exit channel invert would be raised during two phases of construction. It consists of primarily a material supply contract, thus considerable attention will be paid to providing sufficient on-site area available for material stockpiles. A significant amount of time will be allowed for the contractor’s procurement of materials. Materials handling facilities will include construction of an on-water dock and miscellaneous material transfer equipment. Construction will also include the triangulation system and buoy grid markers for material placement control. Approximately 26 months will be required for construction of Alternative 2. The construction schedule reflects a very optimistic view, with no weather or adverse river conditions delays, and depends upon the approval for expansion of the in-water work period.

The major raised tailrace construction activities are listed below:

- Mobilization and preparatory work
- Develop quarry or purchase rock form supplier
- On-shore dock; storage area and material handling
- Bathymetry survey and install GPS
- Barge and deposit armor rock and tremie concrete
- Diving inspections and bathymetry surveys
- Conduct spillway TDG tests

The proposed schedule reflects two IWW periods to accomplish the work over 18 months. An additional 40 weeks was set to conduct the TDG tests which would be dependent on high flows in the river. The work schedule is short and will require careful planning and sufficient floating plant to place the materials accurately. The proposed plan utilizes final contract payment to be made from bathymetric surveys. Global positioning surveys will be used for placing materials. Underwater soundings will be coordinated with depositing work activities.

10.3 Alternative 3 - New Spillway Gates

10.3.1 Design Schedule

The proposed design schedule covers about 25 months, which is optimistic and will require that authority, approval of design, and sufficient funds are available throughout the schedule. The design schedule assumes some architect-engineer support and illustrates the respective steps for requests and proposals (RFP), reviews, awards, and milestone revisions. The major new spillway gate design activities are listed below:

- Draft economic report
- Model testing and foundation explorations
- Downstream cofferdam design
- Feasibility for spillway design
- Design review and approval
- Submit to committee and testify to Congress
- Receive funds for planning, engineering, and cofferdam, and floating wing wall procurements
- Plans and specifications

The design phase should document the areas of work that may be performed during an expanded IWW period. The design for spillway pier extensions and the new trunnion bridge represents a major modernization program for the project.

10.3.2 Construction Schedule

The construction schedule for the new spillway gate alternative shows an optimistic construction period of 33 months. This schedule is based on an advanced procurement of cofferdam steel and floating wing walls, which would be available to the main contractor at the beginning of the first IWW. This schedule may be extended by lack of funds, high river flows, availability of materials, labor strikes, weather delays, contractor's ability to organize and perform the work, or all the above. The major construction activities for each phase are listed below:

- Concrete removal and pier hoist corbel construction
- Dewater downstream work area
- Spillway pier extensions
- Install trunnion bridge
- Install spillway gate and equipment
- Remove and reinstall downstream cofferdam
- Repeat above for three phases
- Install and test electrical and mechanical systems
- Diving inspection of stilling basin
- Conduct spillway TDG tests

The construction schedule provides a more detailed description of the work activities and assigns a duration of time to accomplish the work. The schedule assumes a three-shift operation and some overtime. The time duration for each activity are dependent on some of the variables and uncertainties discussed earlier. The contractor will be expected to plan the work items in an effective manner.

10.4 Alternative 4 - Sluices Under Existing Spillway

10.4.1 Design Schedule

The design schedule for sluices under existing spillways is optimistic at 26 months, but includes all the required items of work. This schedule mirrors that for Alternative 3 design and includes the advanced procurement of the items listed below:

- Cofferdam steel for downstream dewatering
- Upstream dewatering bulkhead
- New 110-ton spillway gantry crane

The design phase will include the documentation and negotiations with regulatory agency staff to ensure that the required work can be performed in a pre-approved order with built-in options to pre-established design criteria.

10.4.2 Construction Schedule

The new sluices under the existing spillway requires the most complex and demanding construction of any of these four alternatives. The design schedule has four months of float before the construction schedule commences. This was to insure that government furnished materials would be available on time. This same float may be given to the construction contractor for preliminary work if authority and funds are received. The proposed construction schedule provides 49.5 months to do the total job. This is an optimistic schedule but time is money and the project should be driven by some amount of pressure (milestones and liquidated damages) to accomplish the required work. The new sluices under existing spillway construction schedule is dependent on government furnished materials for dewatering systems and the new spillway gantry crane. If these items are placed in the main construction contract, an additional 12 months would be added to the schedule. The major construction activities are listed below for each phase:

- Concrete removal and crane corbels
- Dewatering downstream work area
- Install upstream gantry crane girders and rails
- Install upstream gantry crane
- Install upstream floating bulkheads
- Concrete removal and post-tensioning
- Concrete removal at ogees and stilling basin
- Concrete placement for ogees and stilling basin
- Remove and replace upstream bulkheads
- Repeat the above for each phase
- Install gates, mechanical and electrical systems
- Remove all dewatering systems.

The construction schedule provides a more detailed description of the work activities. Installation of the upstream spillway crane girders and new spillway gantry crane will lead the upstream bulkhead placement. The schedule assumes a standard three-shift operation with some overtime. Most forming activities for concrete placement will be on the day shifts and concrete placements on the night shifts. The time duration of each activity is dependent on some of the variables and uncertainties described earlier. The contractor will be expected to plan and execute the work items in an efficient manner.

11.0 OPERATION AND MAINTENANCE

11.1 Alternative 1 – Stepped/Extended Deflectors

Operation of the extended deflectors is not expected to be any different than operation of the existing deflectors at the Bonneville Dam project. Operation considerations for the existing deflectors consist of managing spillway gate operation to optimize skimming flow characteristics of spillway discharge over the deflectors into the stilling basin. Spillway gate operation is also regulated by the preferred spill pattern developed by regional agencies. The preferred spill patterns were developed to optimize adult attraction to the fish ladder entrances by varying the discharge volume passed through adjacent spill bays. The preferred spill patterns and ideal skimming flow operation are not necessarily compatible at all times. The proposed stepped/extended deflector configuration is anticipated to permit the spillway to operate with the optimal skimming flow characteristics over a wider range of tailwater elevations and spill pattern configuration than the existing deflectors.

Deflectors are of monolithic concrete construction with no moving parts or machinery. Maintenance will be limited to periodic inspection of the deflector surface and downstream face, and repair or reconstruction of damaged concrete surfaces. The deflector surface may be damaged by cavitation or erosion caused by high velocity flow. Deterioration of the concrete surfaces by freeze/thaw action or poor construction may also result in periodic maintenance repair. Overall, this alternative requires very little maintenance when compared with the other three discussed in this report.

11.2 Alternative 2 – Raised Tailrace

Operation of the raised tailrace does not modify existing spillway operation. The raised tailrace alternative as proposed elevates the existing channel floor downstream of the stilling basin to approximately +5.0 ft MSL, or about 25 to 50 ft higher than the very deep present channel. The hydraulic characteristics of the raised tailrace are anticipated to resemble that of The Dalles Dam spillway exit channel, with fast moving, turbulent, shallow, aerated flow downstream of the stilling basin. At The Dalles Dam, this shallow flow tends to off-gas dissolved gases from the spillway flow prior to combining with powerhouse discharge. At Bonneville Dam, this shallow spillway tailrace channel as proposed will accomplish similar goals throughout the lower range of tailwater elevations. However, at tailwater elevations above about 20.0 (total river flow of about 200,000 cfs), the tailrace channel will become increasingly submerged such that the benefits of the raised tailrace are no longer apparent. At lower tailwater elevations, the raised tailrace will cause some backwater effects to extend to the stilling basin, which may affect the position of the hydraulic jump. At higher tailwater elevations this effect will be less significant.

Maintenance of the raised tailrace will consist of periodic diving inspections, in which erosion or damage to the grouted armor rock will be assessed and mapped. Repairs, consisting of armor rock replacement and tremie concrete placement, will be required if damages threaten to cause instability of the rock fill. Cost estimates for this alternative assume no rock replacement is required over the life of the grouted rockfill. Additional maintenance of the channel bank riprap may be required with this alternative. The increase in tailrace velocity resulting from the shallower channel section may cause erosion and failure of portions of the existing riprap blanket protecting the shorelines. Periodic repairs may also be required to stabilize the fish ladder foundation and appurtenant structures.

11.3 Alternative 3 – New Spillway Gates

Operation of the new spillway gates is not expected to be any different from operation of the existing spillway gates, except that the new gates may be large radial gates instead of vertical gates as in the existing spillway. Radial gates require considerably less hoist capacity, as the water load is transferred to the trunnion rather than to high friction guide slots. Hoist capacity would be expected to be similar to that for large spillway tainter gates at other Columbia River projects. Regular operation would include adjustment of the gate setting as required to provide the desired discharge capacity. Gate operation would require monitoring of gate movement, oscillation, and vibration very carefully to ensure integrity of the new spillway gates and supporting piers.

Maintenance of the new spillway gates is expected to be no different from that of the existing large spillway tainter gates at other Columbia River Dam projects. Regular lubrication of the trunnion bearings and connections would be required. Periodic inspection of various features of the new spillway gate system would include inspection of structural members of the gate, trunnion, yoke, and all connections for structural adequacy. Paint and other protective coatings would be inspected for continuous and uniform coverage with no rust or corrosion. Seals and sealing surfaces would be inspected for tears and gouges or evidence of binding. Hoist cables would be inspected for damaged strands or lack of lubrication, hoists would be inspected for damage and operated through at least a partial spill range. Concrete surfaces would be inspected for erosion and wear and evidence of corrosion of steel reinforcement.

11.4 Alternative 4 – Sluices Under Existing Spillway

Operations considerations for alternative 4 are more complex than that for any other alternative evaluated in this report. The large vertical closure gate at the entrances to the sluices is designed to be removed fully from the forebay when the sluices are operating in that particular spillway bay. To commence sluice operation, the existing spillway gate must be fully closed in that particular bay before the sluice closure gate can be opened. Movement of such a large gate will require a significant amount of time to lift it from its closed position to the forebay surface. Once the gate is fully removed from the forebay and locked in position, the existing spillway gate would be opened as necessary to provide the desired spillway discharge capacity. Closure of the sluice gate would be accomplished in reverse order to the opening sequence. The existing spillway gate would first be closed fully, then the large sluice gate would be lowered into place. Then the existing spillway gate would be opened as necessary to provide the desired spillway discharge capacity.

Maintenance of the sluices and associated equipment is likely to be more labor intensive and more time consuming than for any other of the alternatives presented in this report. Inspection of the sluice conduit requires complete dewatering to well below the tailwater elevation, a task that takes considerable planning and equipment. Regular maintenance would include lubrication of hoist machinery, painting of the upstream closure gate as necessary to prevent corrosion, and removal of debris from the guide slots. Periodic inspections of the sluice conduits and all operating equipment would be required at regular intervals throughout the life of the project. Inspections would include assessment of concrete erosion or cavitation damage and repair recommendations, inspection of operating hoist machinery and hoist cables for proper lubrication and maintenance, and inspection of the upstream entrance gate for corrosion damage, seal damage, and proper alignment in the guide slot. Inspection of the sluice conduits would be accomplished by dewatering the sluice. Dewatering would be accomplished by fully closing the upstream sluice closure gate and placing a caisson structure at the exit section of the sluice. A drain valve in the base of the caisson structure would be opened to permit flow from the sluice conduit into the caisson, Then the caisson would be pumped dry until the sluice was fully dewatered. An alternate method of dewatering could be provided by placement of the upstream floating bulkhead on the pier noses and dewatering the sluice downstream of the bulkhead prior to removal of the upstream control gate. The floating bulkhead, which would be used for construction, would be stored on site and maintained as necessary to keep all equipment in working order.

12.0 SUMMARY AND RECOMMENDATIONS

This report evaluates 18 different conceptual structural alternatives for abating Total Dissolved Gas (TDG) production by the existing Bonneville Dam spillway. At high spillway discharges, the existing spillway causes TDG levels in the downstream channel to rise well above the maximum allowable limit set by state and federal water quality standards. High TDG levels can cause injury to fish inhabiting or migrating through affected waters. The 18 alternatives developed in this study ranged in complexity and cost from concepts as simple as modification of existing spillway flow deflectors to replacement of one of the powerhouse structures with a hydrocombine design powerhouse. The number of feasible alternatives was reduced significantly by matrix evaluation in which individual alternatives were independently scored on their effectiveness in meeting seven different criteria. The four highest scoring alternatives in the matrix evaluation were developed to a greater level of detail in this study. The more detailed analysis provided determination of feasibility and developed total construction cost, as well as operation and maintenance considerations for each of the four selected alternatives.

The four selected alternatives include Alternative 1 - extended spillway flow deflectors, Alternative 2 – raised tailrace, Alternative 3 – new spillway gates, and Alternative 4 – submerged sluices through existing spillway monoliths. Alternative 1 consists of extending the existing spillway flow deflectors downstream a total of about 60 feet, with one upstream horizontal deflector surface at elevation 14.0 ft MSL, and a downstream horizontal deflector surface at elevation 4.0 ft MSL, and the two surfaces connected by a smooth curved surface. The purpose of the extended, or stepped, deflector is to widen the range of tailwater elevations over which the deflector will produce desirable skimming flow characteristics in the stilling basin. Alternative 2 consists of filling a portion of the length of the spillway exit channel with large, grouted armor rock to about elevation 5.0 ft MSL. The desired effect will be to cause shallow, fast moving flow over the raised channel section. Similar conditions at The Dalles Dam spillway exit channel can successfully reduce high TDG content in the flow after it exits from the stilling basin. Alternative 3 consists of replacement of existing split leaf vertical spillway crest gates with very large radial tainter gates. The existing sill beams for the crest gates is at about elevation 24.0 ft MSL, and the proposed new radial gate sill beam will be located on the existing spillway chute surface at about elevation 0.0 ft MSL. The desired effect will be to fully submerge the spillway discharge jet below the tailwater surface, affording no opportunity for aeration prior to entering the stilling basin. Alternative 4 consists of excavation and replacement of each of the existing spillway crest monoliths and primary stilling basin with new monoliths into which sluice conduits have been cast. The upstream entrances of these sluice conduits will be submerged well below the forebay water surface, and the exit portal will be submerged well below the tailwater surface downstream of the primary stilling basin floor. The desired effect will be to pass forebay TDG levels directly to the stilling basin without increase.

Model study results from testing at Waterways Experiment Station has shown that Alternative 3 (New Spillway Gates) and Alternative 4 (Sluices Under Existing Spillway) have perhaps the most promising opportunity for significant gas reduction at Bonneville Dam. Alternatives 1 (Stepped / Extended Deflectors) and 2 (Raised Tailrace) were both evaluated in the Bonneville sectional model, and both showed fair results with respect to limiting the depth to which entrained air plunges in the stilling basin compared to the existing condition. However, large amounts of air are still entrained with both alternatives. Alternative 3 was evaluated in the Bonneville sectional model, and it showed no air entrainment with discharges up to 10,000 cfs per spillway bay. Alternative 4 was evaluated in the Ice Harbor Dam physical model, since no representation of it was available in the Bonneville sectional model. In the Ice Harbor sectional model, alternative 4 showed significant air entrainment when the existing surface spillway gates pass flow at the same time as the submerged sluices. Air entrainment does not occur with discharge passing through the submerged sluices only.

12.1 Alternative 1 – Stepped / Extended Deflectors

Alternative 1 was expected to significantly improve performance of the deflector concept at Bonneville over a wider range of tailwater levels than the existing deflectors. However, the hydraulic characteristics of flow over the extended deflector are such that at low tailwater elevations, the lip of the deflector causes the thin jet trajectory to arc above the stilling basin, then plunge to fairly deep depths. Air entrainment occurs to about the same degree as with the existing deflectors. At higher tailwater levels, the jet trajectory causes significant amounts of aerated flow to be drawn up into the area below the deflector, where the turbulent back roller re-entrains air multiple times. At the highest tailwater levels, the back roller entrains air in the same way, with underflow pulling air from the skimming jet to the depths of the stilling basin and back under the deflector.

We recommend more evaluation of the extended/stepped deflector in the physical model. Additional investigation should consider several different shapes for the step transition between the high and low deflector lip surfaces. We believe better performance may be obtained by reassessing the design of the deflector in the hydraulic model. Overall, however, the performance of extended deflectors is not likely to provide the desired reduction of gas saturation to 110% TDG level, based on observed performance of existing deflectors at other projects.

12.2 Alternative 2 – Raised Tailrace

Alternative 2 was also evaluated in the Bonneville sectional model. The raised tailrace eliminated the plunge of aerated flow into the deep holes downstream of the stilling basin. It also appeared to reduce the total amount of time that aeration bubbles remain in the tailwater. Aerated flow did not extend downstream as far with the raised tailrace as it does under the existing condition. However, alternative 2 did not eliminate the aerated spillway discharge, which causes high gas saturation levels. Expected improvement over the existing condition is not likely to be sufficient to reduce TDG level to the desired 110% for the 10 year, 7 day river flow.

12.3 Alternative 3 – New Spillway Gates

Alternative 3 was evaluated in the Bonneville sectional model also. Surprisingly, this alternative showed excellent results with regard to elimination of aerated discharge. Flows of up to 10,000 cfs per spillway bay (prototype) were passed through the large tainter gates with gate seat submergence of as little as 10 ft without any significant indication of aeration of the jet. In addition, there appeared to be very little turbulence immediately downstream of the gate. Initial concerns for gate vibration resulting from highly turbulent conditions immediately downstream of the gate were alleviated significantly upon observation of the model in operation. The discharge jet appeared to adhere closely to the spillway apron and stilling basin floor in a mostly cohesive stream up to the point of impact on the stilling basin baffles. No significant back roller was evident within the near vicinity of the gate itself.

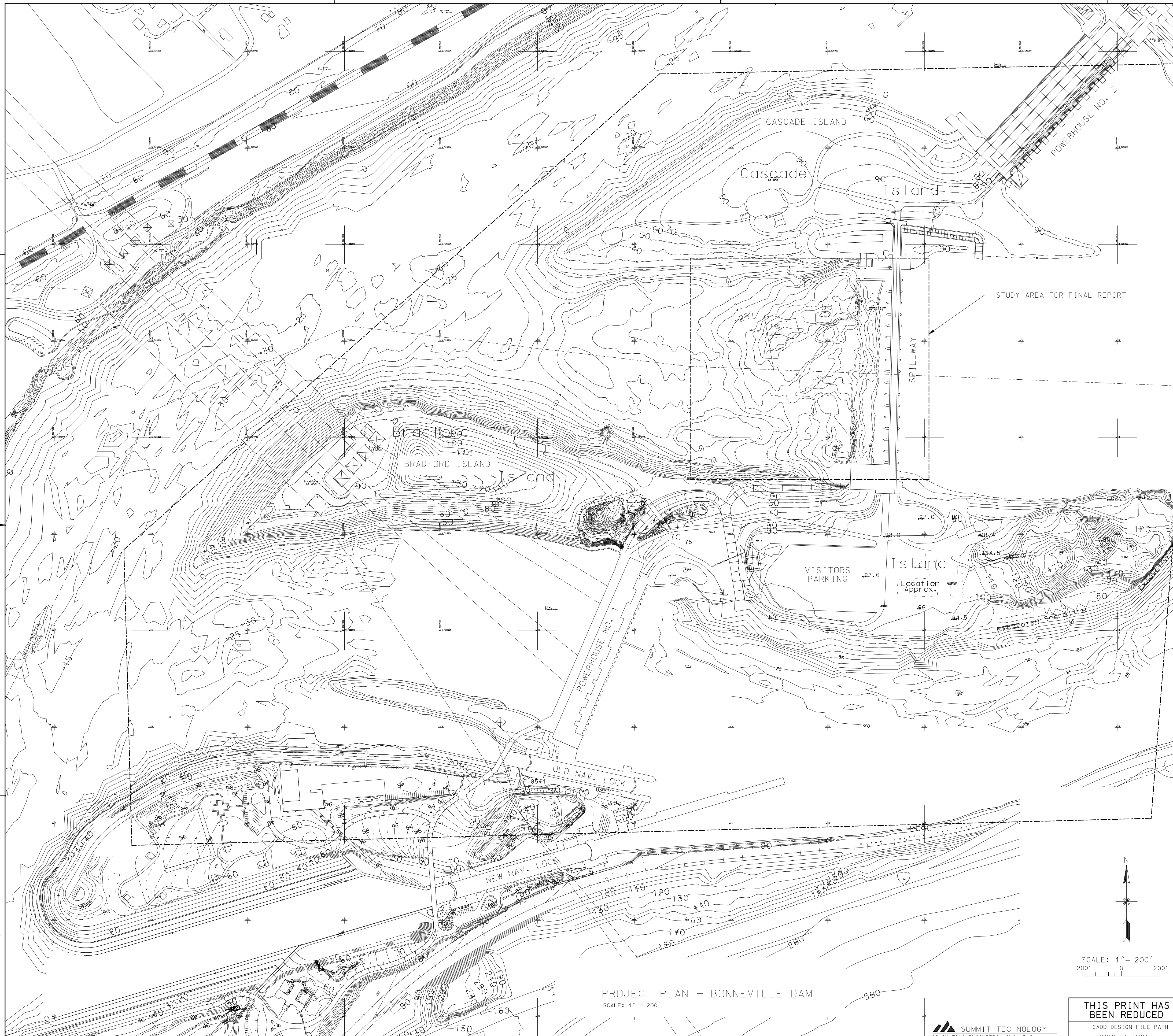
In spite of the encouraging hydraulic results, some significant biological questions remain with alternative 3. The cohesive jet, which adheres to the stilling basin floor, impacts the baffles at high velocity, a condition that surely would be undesirable for fish survival. This condition could likely be eliminated by removing the stilling basin baffles altogether. The original stilling basin design does not appear to rely upon the baffles for sufficient energy dissipation. Upon first examination, the baffles could be removed without jeopardizing the performance of the stilling basin. In addition to the baffle impact issue, the cohesiveness of the jet may force fish to remain very near the roughened spillway apron and stilling basin surface for a longer period of time than in the existing condition. The existing aerated spillway flow jet may loft the fish toward the surface of the stilling basin soon after passing under the gate itself, separating them from the concrete surface. On the other hand, the existing stilling basin conditions may subject the fish to severe shear conditions in the highly turbulent back roller downstream of the gate.

More investigation of this alternative is highly recommended. Specifically, removal of the baffles should be considered, and the elevation of the gate seat should be verified. The proposed elevation of 0.0 at the gate sill beam was selected with very little supporting information. This elevation could be raised to a slightly higher elevation without significantly modifying the performance of the discharge jet. In addition, this concept should be evaluated in the model with new gates installed in adjacent spillway bays, in order that the combined gate discharge flow circulation patterns can be verified. Additional investigation into the structural feasibility of such a large tainter gate must also be made.

12.4 Alternative 4 – Sluices Under Existing Spillway

Alternative 4 was evaluated in the Ice Harbor sectional model rather than the Bonneville sectional model, thus the results may not be directly applicable to Bonneville Dam. In general, the concept proved to be fairly successful in significantly reducing the aerated flow conditions in the stilling basin. However, as mentioned above, when surface spill through the existing spillway gates is combined with submerged sluice flow, aeration created by the existing gate discharge is entrained to deep depths by the high energy jet exiting from the submerged sluice. Re-circulation of this aerated flow also appears to occur within the near portions of the stilling basin. In addition, low pressures observed in the submerged sluices while under operation must be verified. The condition may be a result of inaccurate model construction due to the small scale, or it may be a result of poorly designed conduit entrance configuration.

We recommend the submerged sluice concept be redesigned and evaluated in a larger scale physical model of sufficient accuracy in construction as to represent the prototype as well as possible. Instrumentation systems should be carefully designed to accurately depict the correct pressure distribution throughout the entire sluice.



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BONNEVILLE DAM

COLUMBIA RIVER — OREGON - WASHINGTON

GAS ABATEMENT STUDY

ALTERNATIVE LOCATIONS
PROJECT PLAN

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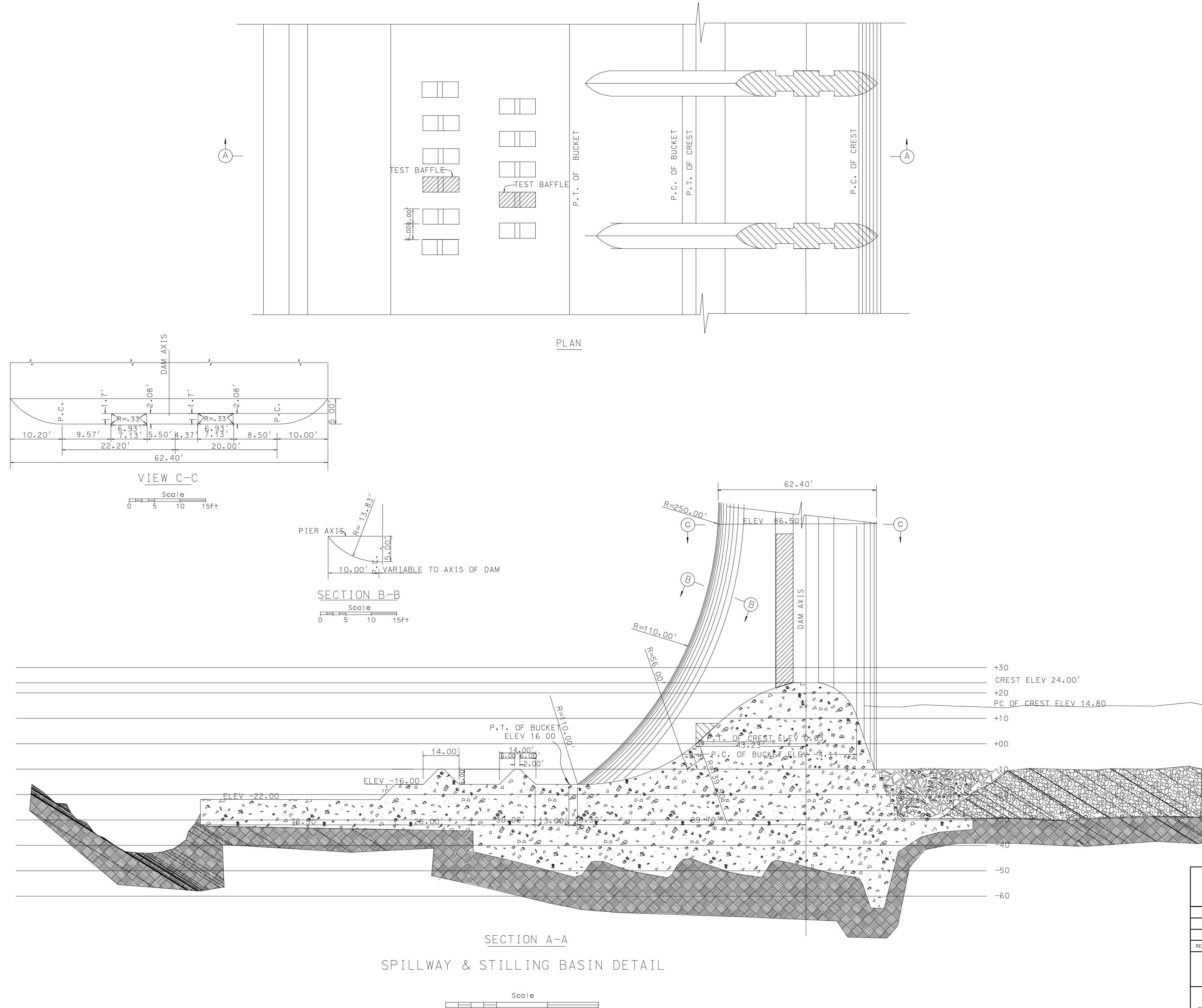

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GAS ABATEMENT STUDY
EXISTING SPILLWAY
TYPICAL CROSS-SECTION

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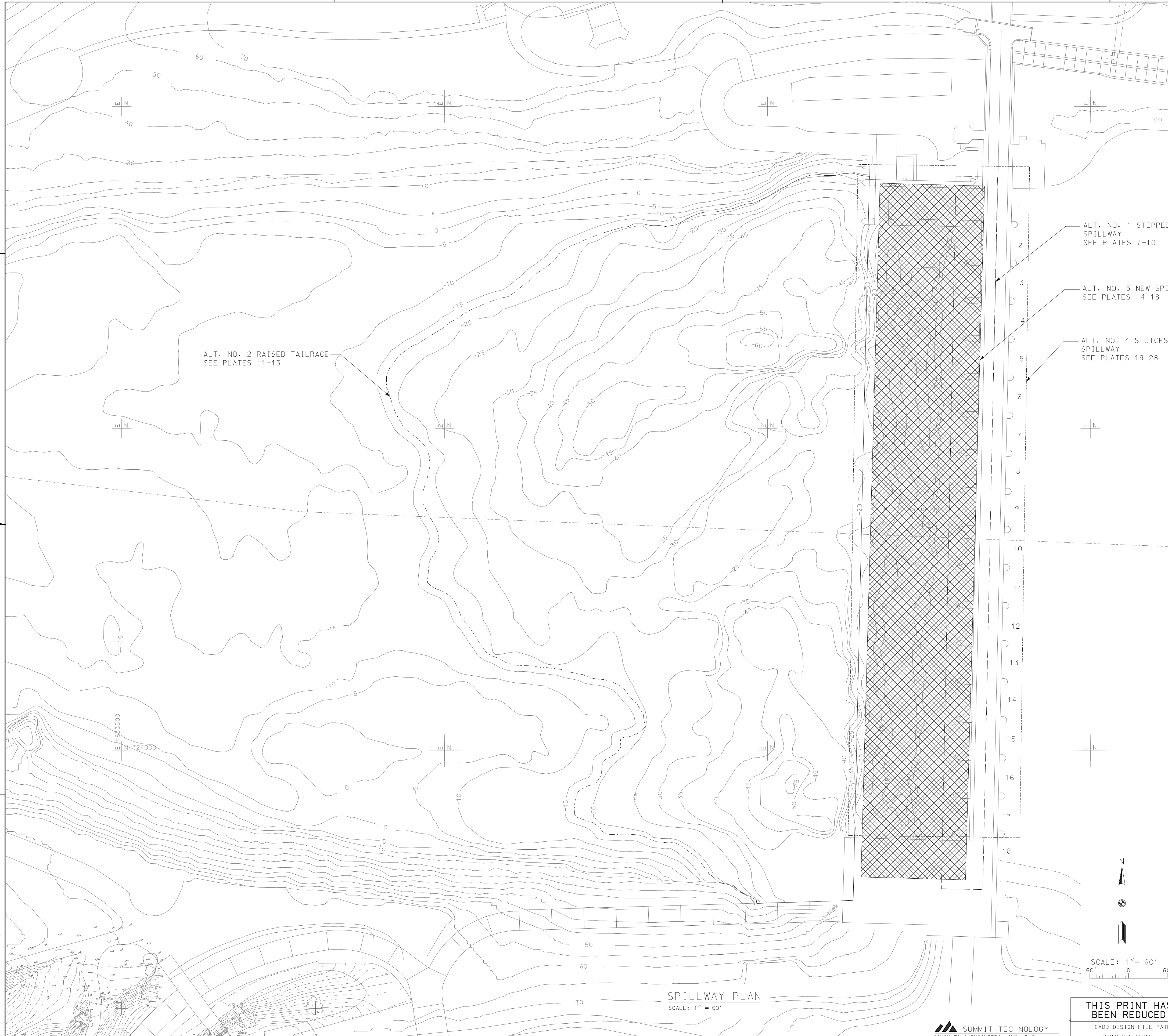

NOTES:

1. COMMON DEWATERING PLANS ARE SHOWN AS PLATES 4-6.

2. ORIGINAL TOP OF ROCK AND GEOLOGICAL SECTIONS ARE SHOWN ON PLATE 29.

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GAS ABATEMENT STUDY
ALTERNATIVE LOCATIONS
SPILLWAY PLAN

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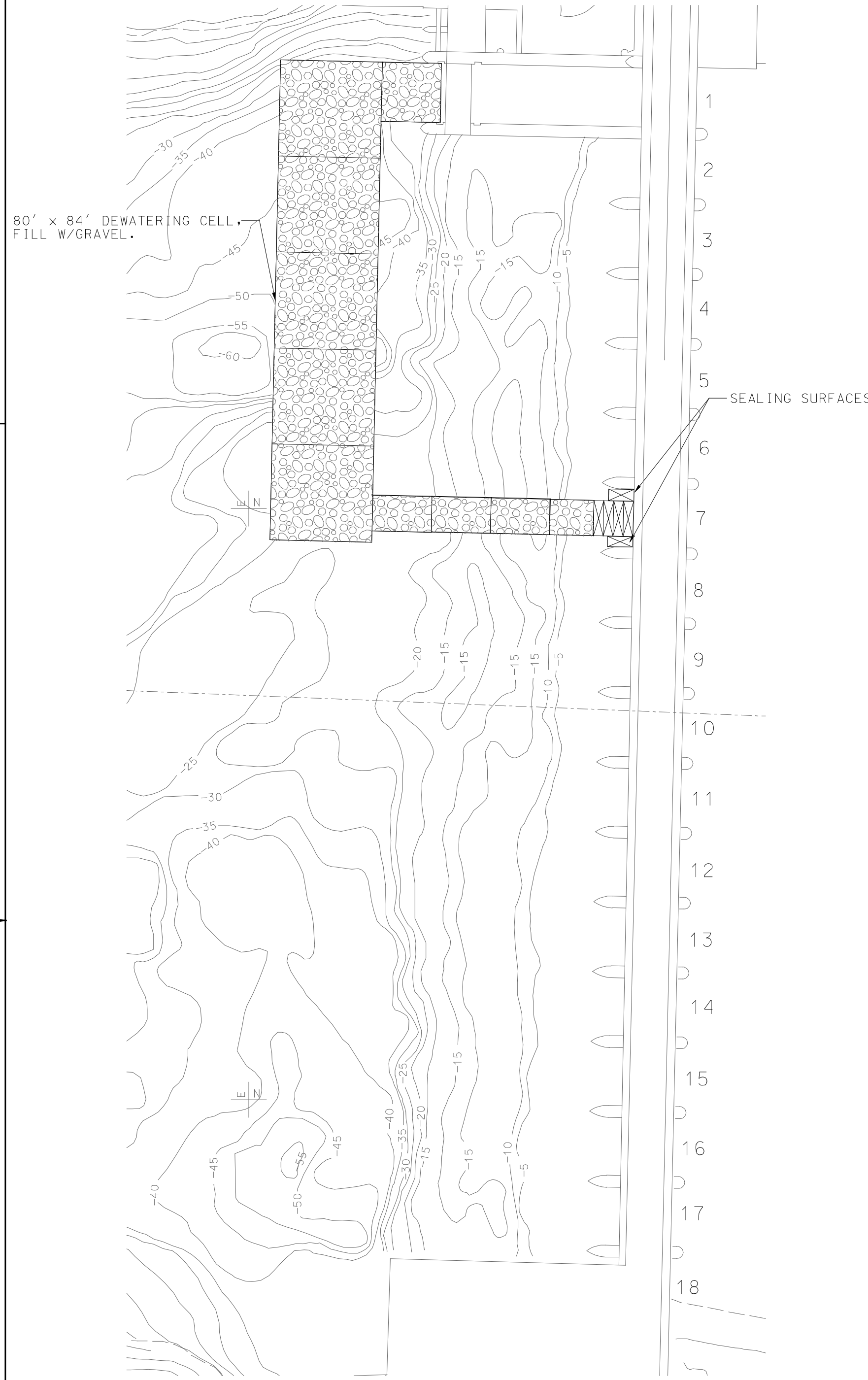
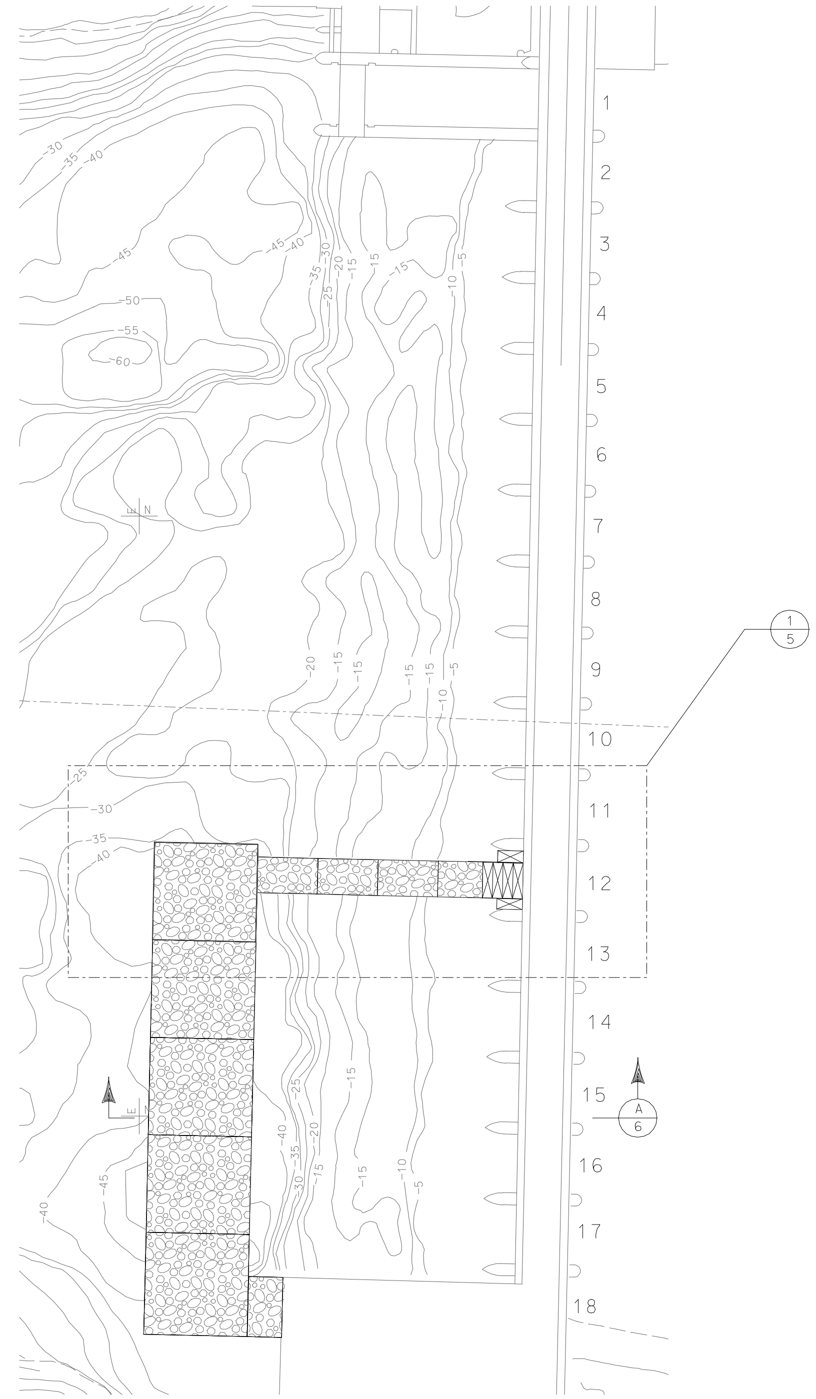
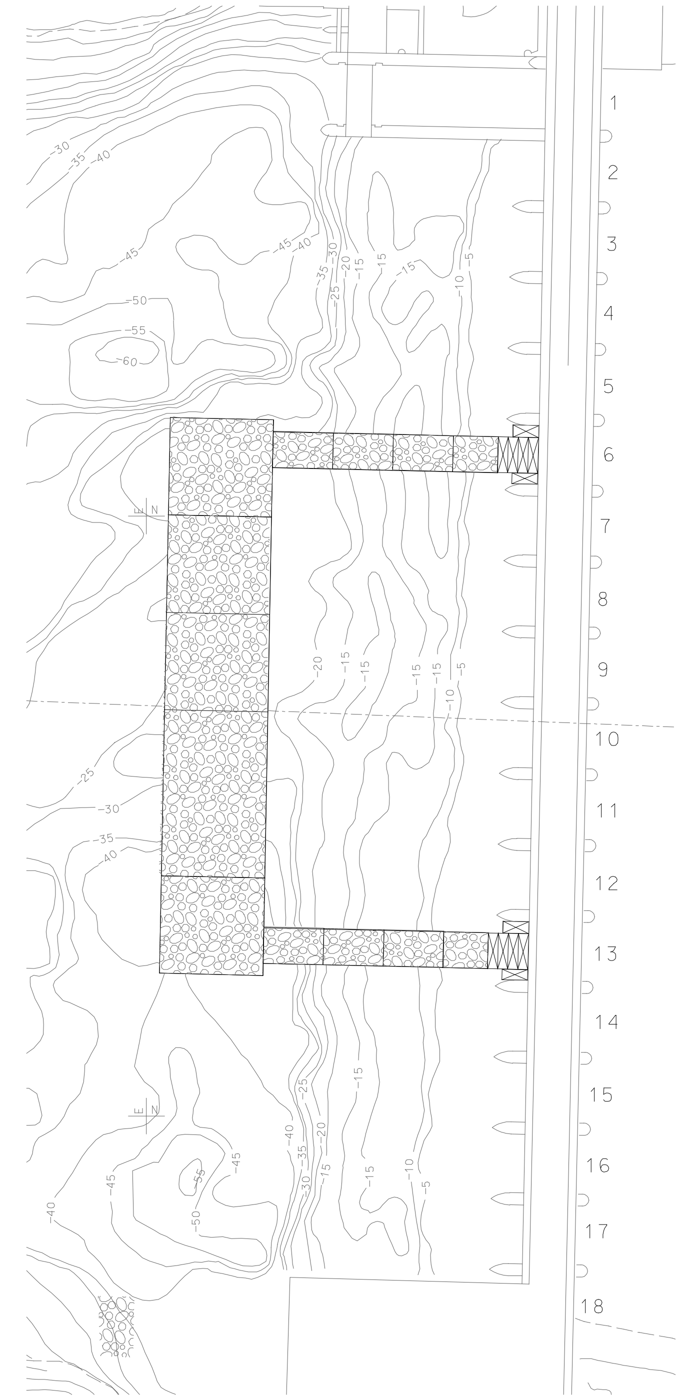
PLATE 03



PHASE I DEWATERING PLAN
SCALE: 1" = 60'



PHASE II DEWATERING PLAN
SCALE: 1" = 60'



PHASE III DEWATERING PLAN
SCALE: 1" = 60'

SCALE: 1"= 60'

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COLUMBIA RIVER
BONNEVILLE DAM
OREGON - WASHINGTON
GAS ABATEMENT STUDY
ALT. 3 & 4 DOWNSTREAM DEWATERING
TEMPORARY COFFERDAM
DEWATERING PLAN

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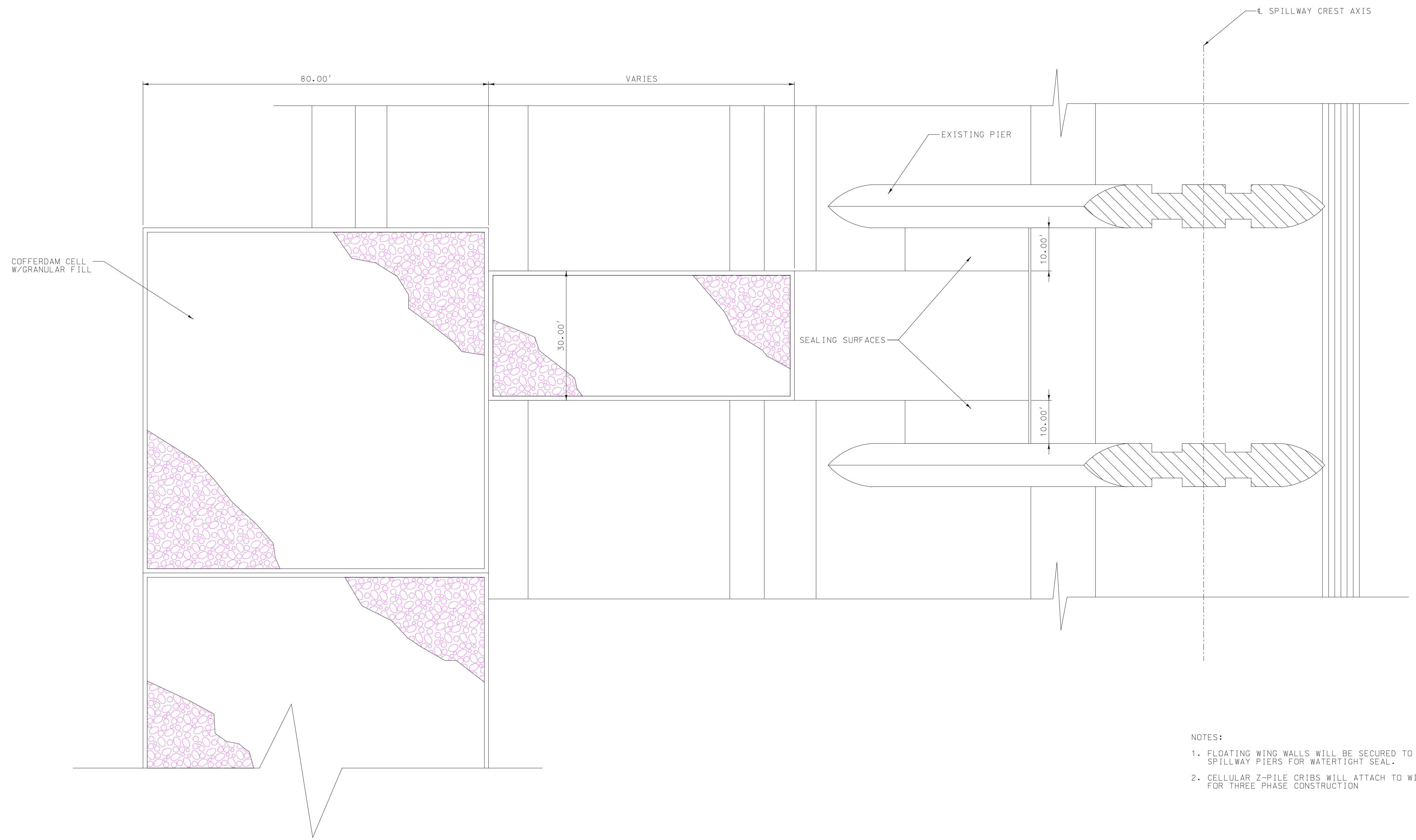

NOTES:

1. FLOATING WING WALLS WILL BE SECURED TO EXISTING SPILLWAY PIERS FOR WATERTIGHT SEAL.
2. CELLULAR Z-PILE CRIBS WILL ATTACH TO WING WALLS FOR THREE PHASE CONSTRUCTION

COFFERDAM LAYOUT (1/4)
SCALE: 1" = 10'

SCALE: 1"= 10'
10' 0 10'

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GAS ABATEMENT STUDY
ALT. 3 & 4 DOWNSTREAM DEWATERING
TEMPORARY COFFERDAM
LAYOUT PLAN

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PLATE 05

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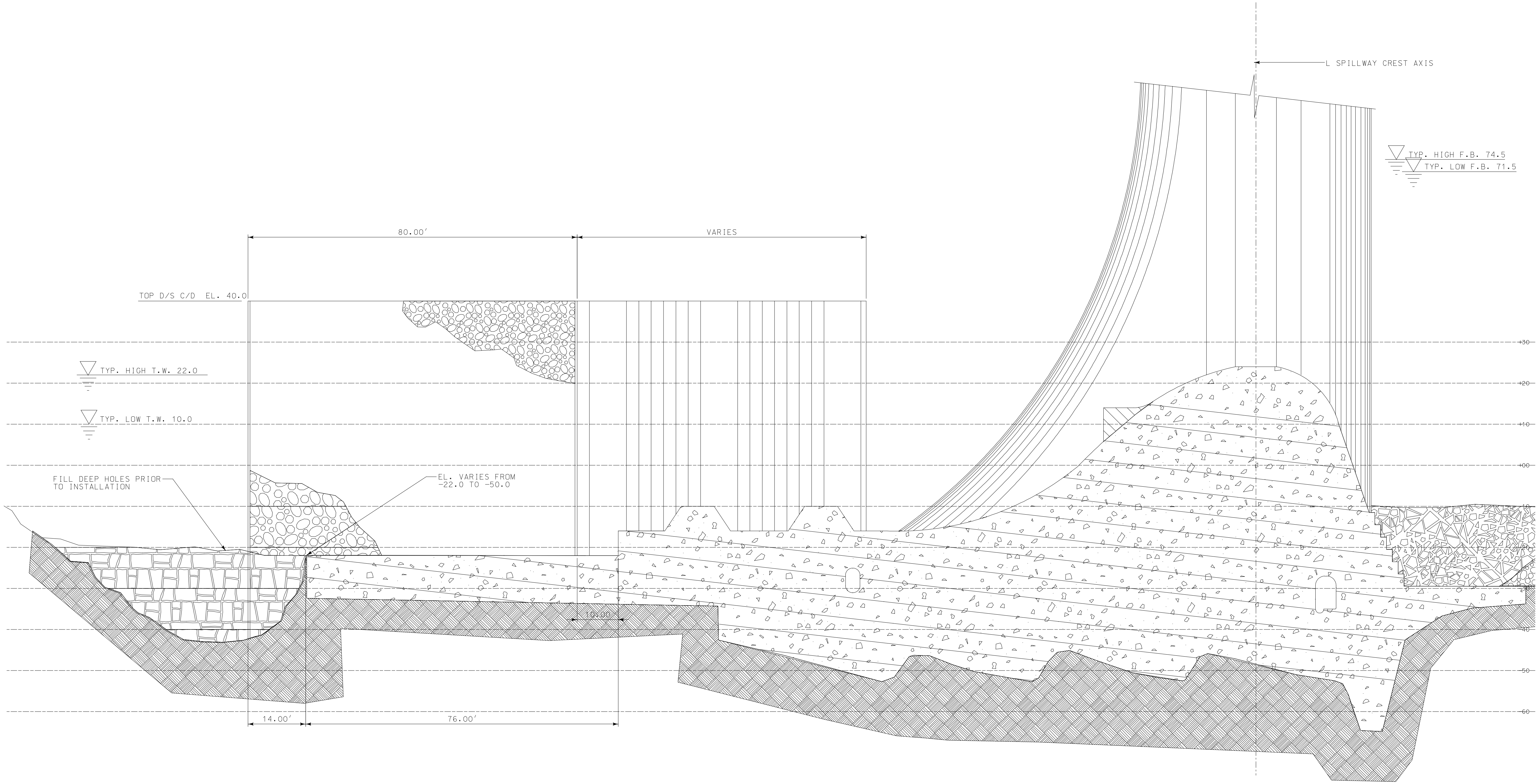

SECTION A/4
SCALE: 1" = 10'

SCALE: 1"= 10'
10' 0 10'

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COLUMBIA RIVER — OREGON - WASHINGTON
GAS ABATEMENT STUDY
DOWNSTREAM DEWATERING
TEMPORARY COFFERDAM
SECTION

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GENERAL PLAN - ALT. 1

SCALE: 1" = 60'

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GAS ABATEMENT STUDY
ALTERNATE NO. 1
STEPPED/EXTENDED DEFLECTORS
GENERAL PLAN

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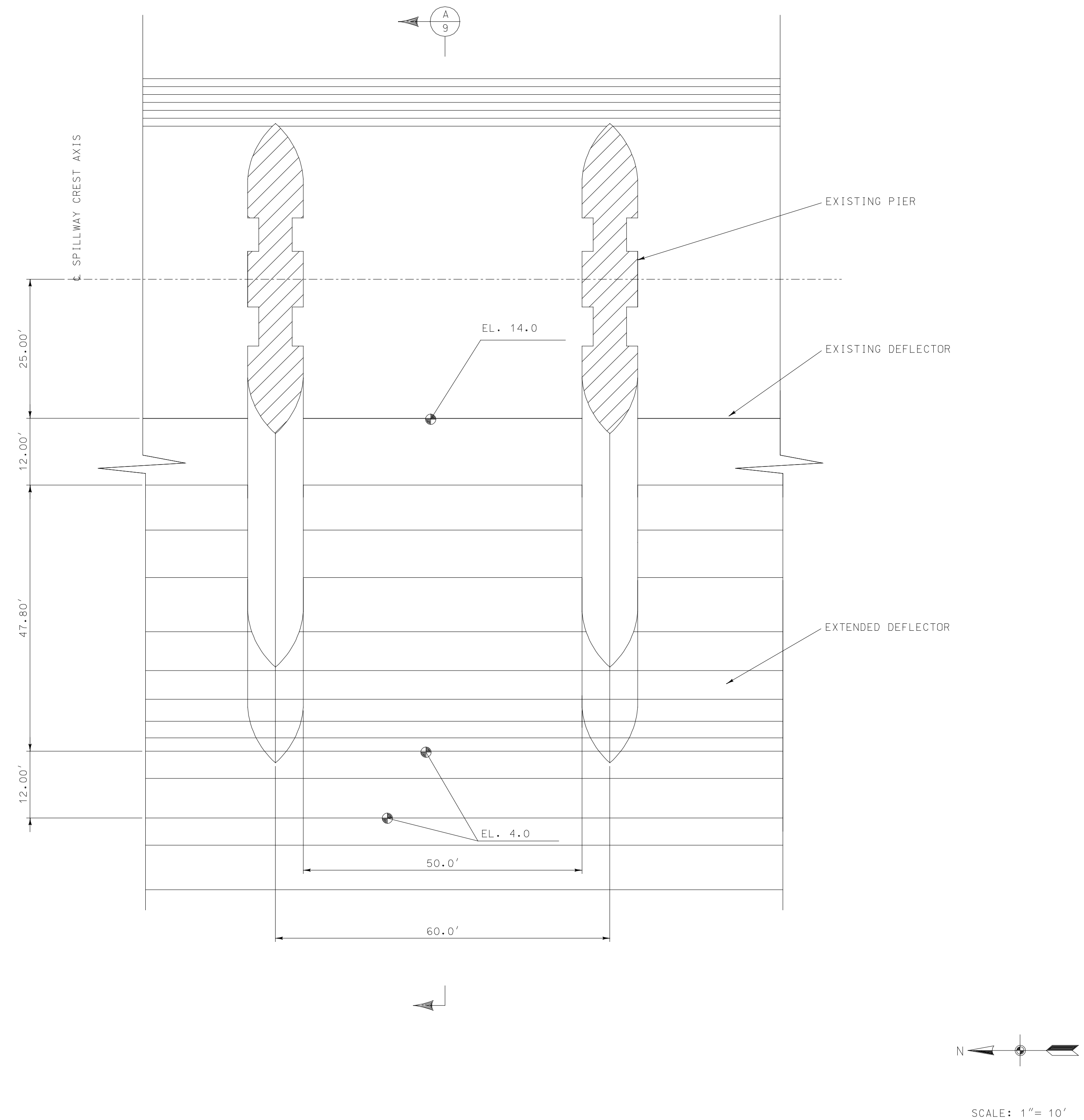

PARTIAL PLAN @ SPILLWAY 1/7
SCALE: 1" = 10'

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GAS ABATEMENT STUDY
ALTERNATE NO. 1
STEPPED/EXTENDED DEFLECTORS
PARTIAL PLAN @ SPILLWAY

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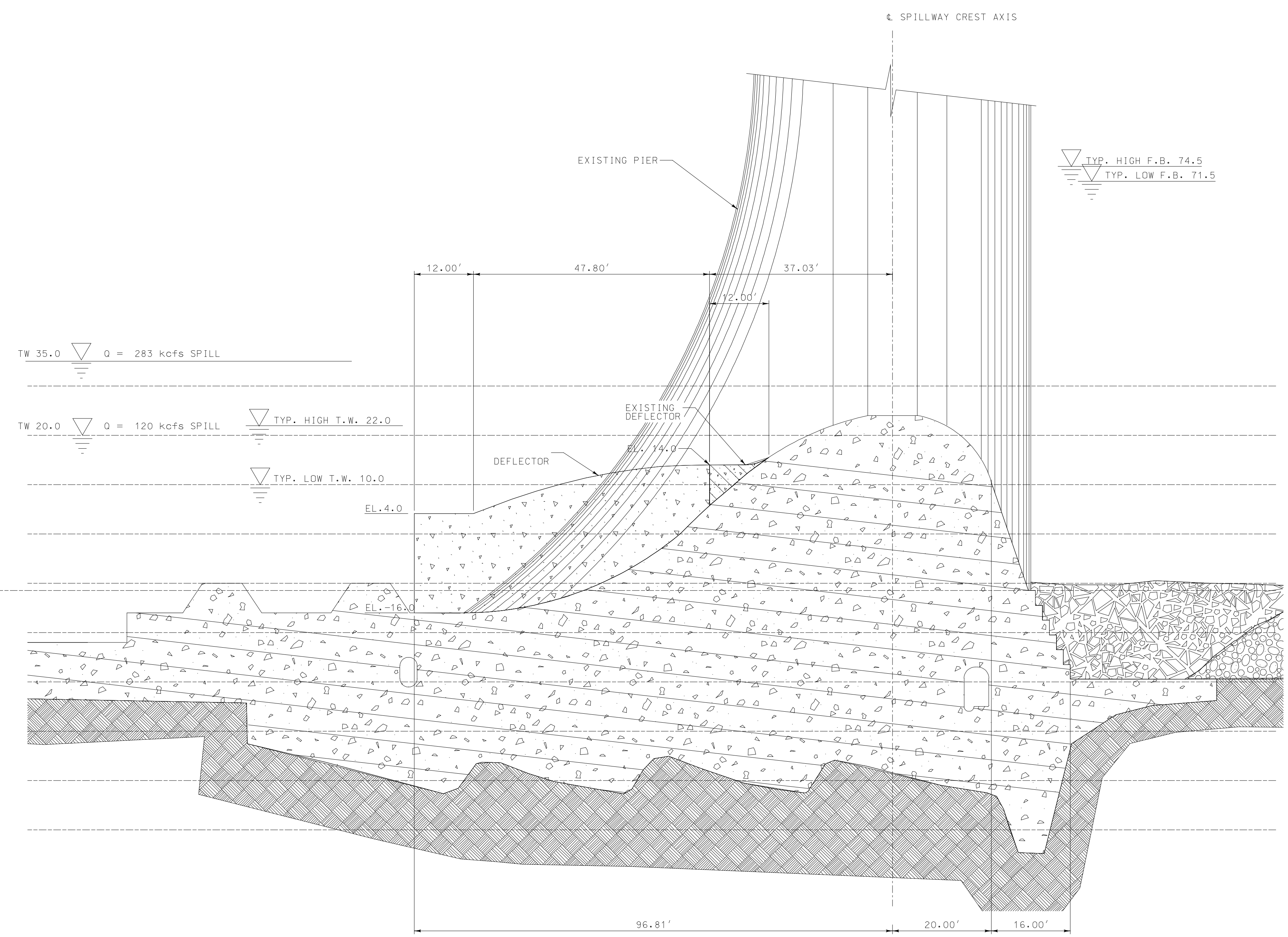
PLATE 08



SECTION A/5
SCALE: 1" = 10'

SCALE: 1"= 10'

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GAS ABATEMENT STUDY
ALTERNATE NO. 1
STEPPED/EXTENDED DEFLECTORS
SECTION

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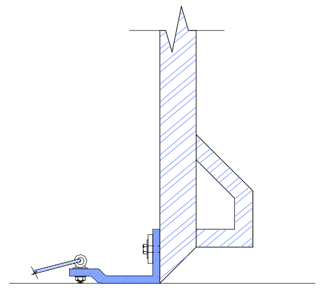
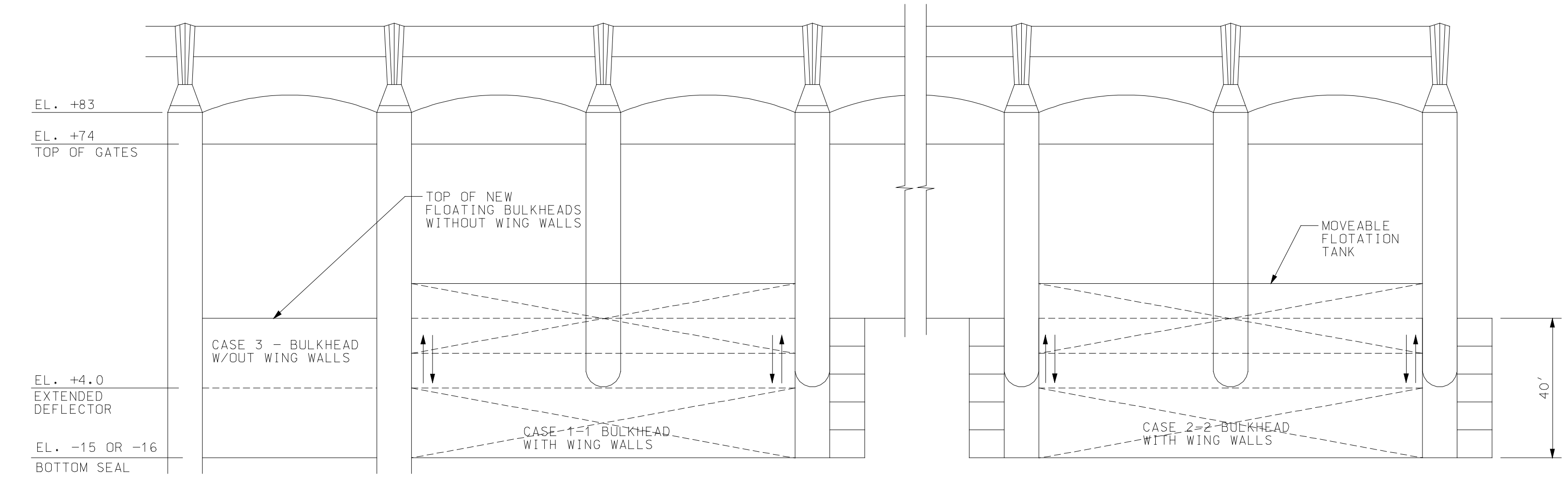
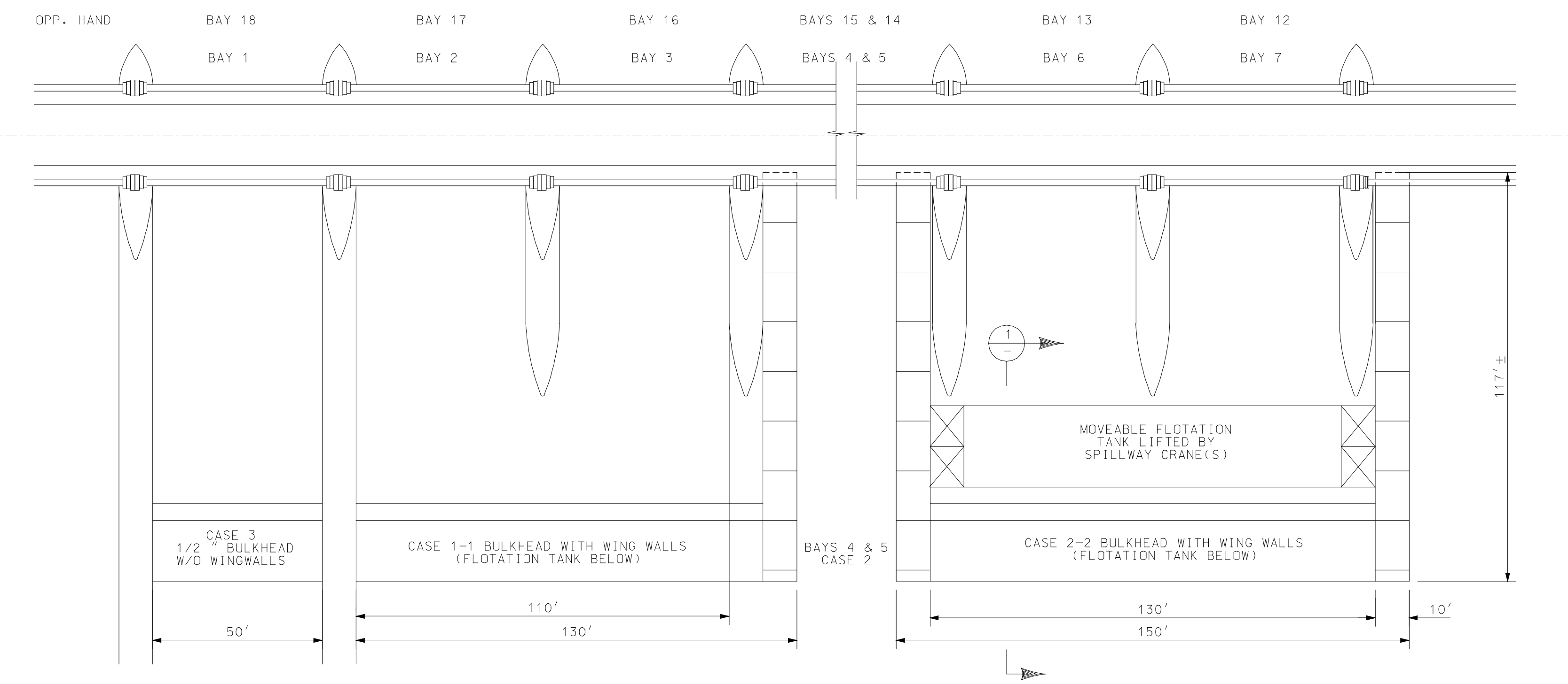


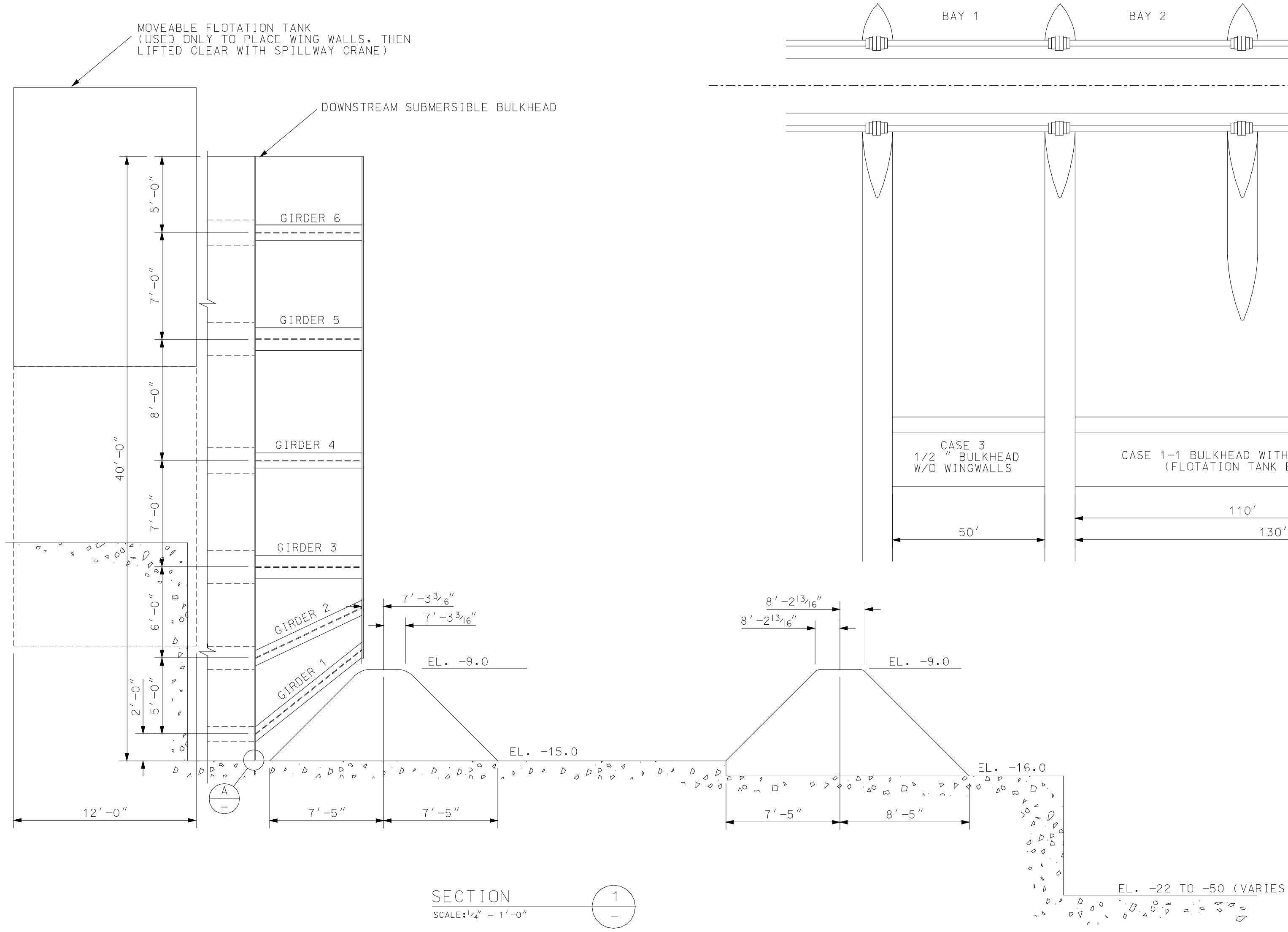
DETAIL (A)
SCALE: 1/4" = 1'-0"



DOWNSTREAM ELEVATION (CASE 1, 2 & 3)
SCALE: 1" = 20'



PLAN (CASE 1, 2 & 3)
SCALE: 1" = 20'



SECTION (1)
SCALE: 1/4" = 1'-0"

NOTES:

1. DOWNSTREAM FLOATING BULKHEAD FOR DOWNSTREAM DEWATERING STEPPED/EXTENDED DEFLECTOR WORK AREAS
   - CASE 1-1 WING WALL
   - CASE 2-2 WING WALLS
   - CASE 3 1/2 BULKHEAD, NO WING WALLS
2. MOVEABLE WING WALL FLOTATION TANK TO BE LIFTED OUT OF WORK AREA AFTER WING WALLS ARE PLACED
3. SOUTH HALF OF SPILLWAY, OPPOSITE HAND

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GAS ABATEMENT STUDY
ALT. NO.1 STEPPED/EXTENDED DEFLECTOR
DOWNSTREAM DEWATERING BULKHEAD
PLAN AND ELEVATION

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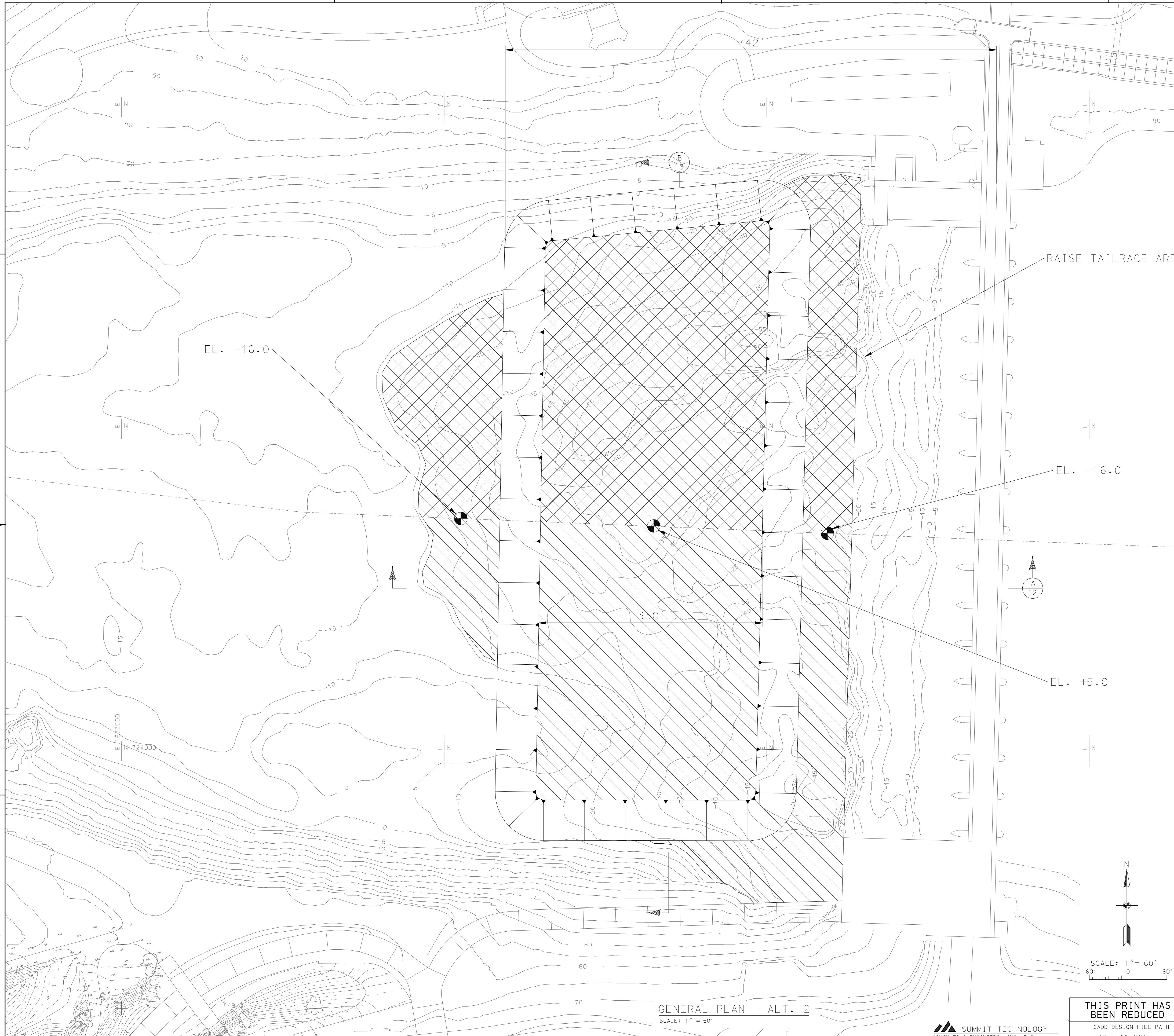

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GAS ABATEMENT STUDY
ALTERNATE NO. 2
RAISED TAILRACE
GENERAL PLAN

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PLATE 11

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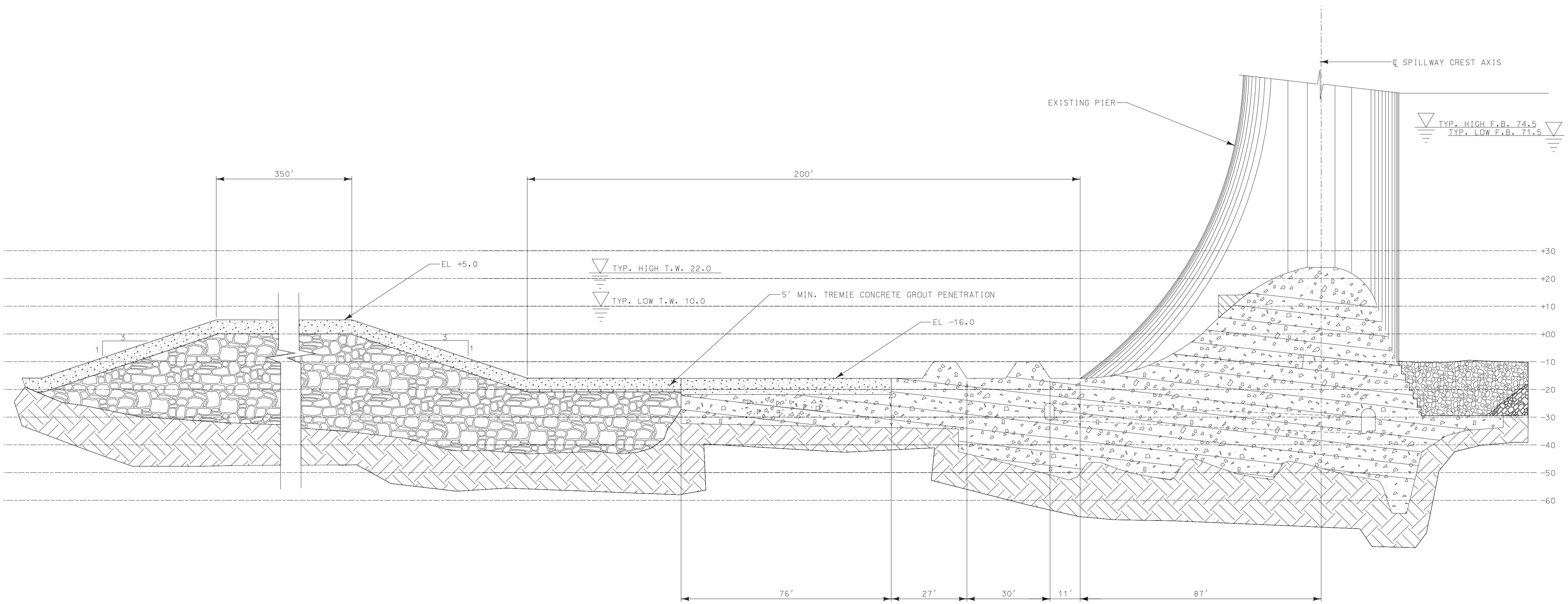

NOTE: SEE PLATE 13 FOR CLASSES AND DEPTHS OF MATERIALS

SECTION A/11
SCALE: 1" = 10'

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GAS ABATEMENT STUDY
ALTERNATE NO. 2
RAISED TAILRACE
TRANSVERSE SECTION

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PLATE 12

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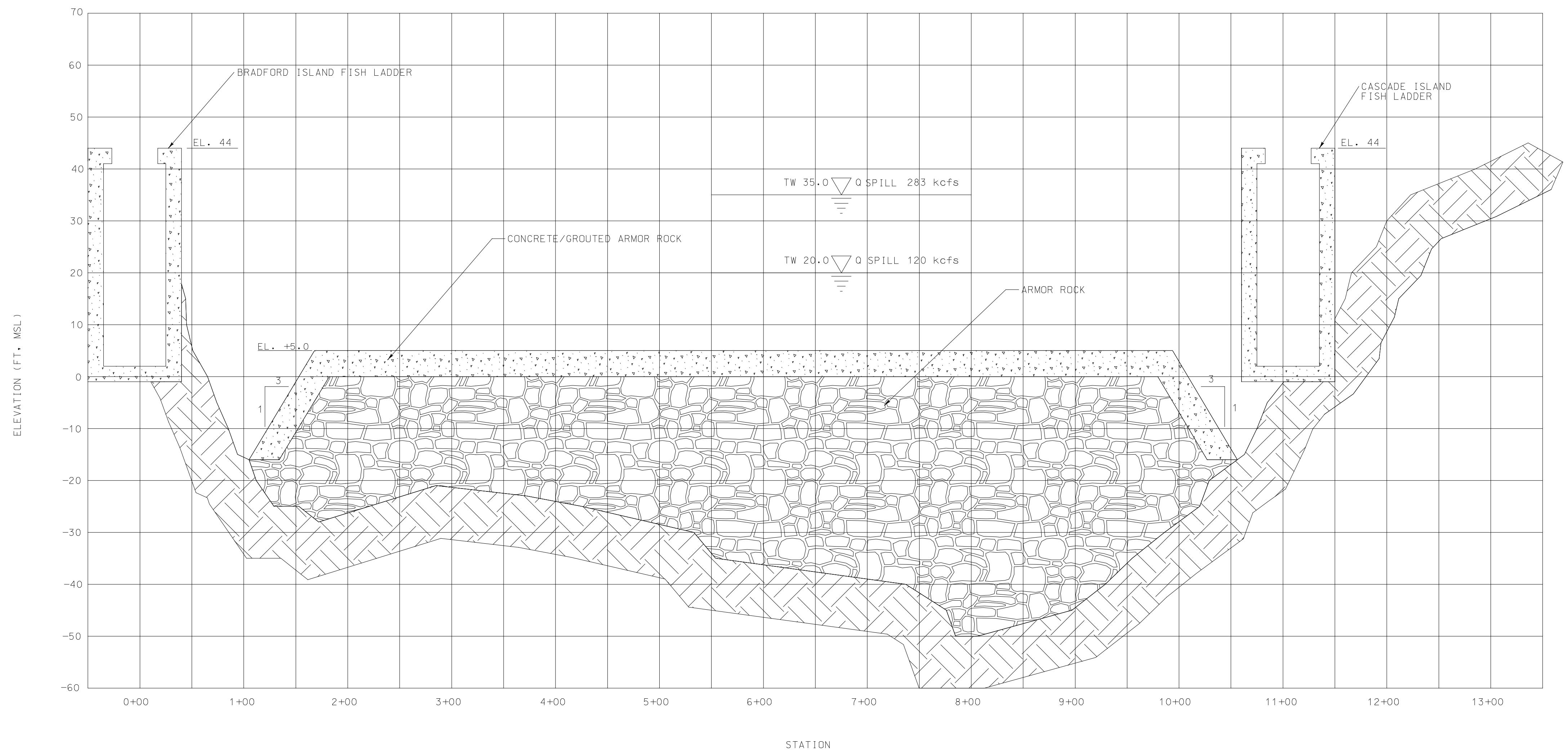
D C B A



ARMOR ROCK GRADATION: W_{100} = 32,000 lb to 80,000 lb
W_{50} = 16,000 lb to 50,000 lb
W_{15} = 5,000 lb to 16,000 lb

SECTION B/11
SCALE: 1" = 10'

NOTES:

1. PLACE TREMIE CONCRETE IN SPILLWAY APRON AREA BELOW EL. -16.
2. PLACE TREMIE CONCRETE / GROUT IN ARMOR ROCK. ASSUME 5' PENETRATION.
3. PERFORM ALL PHASES OF WORK ADJACENT TO FISH ENTRANCES DURING IWW PERIODS.
4. EXTENDED IWW PERIODS WILL BE USED FOR MID-STREAM WORK.

SCALE: 1" = 10'
10' 0 10'

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GAS ABATEMENT STUDY
ALTERNATE NO. 2
RAISED TAILRACE
LONGITUDINAL SECTION

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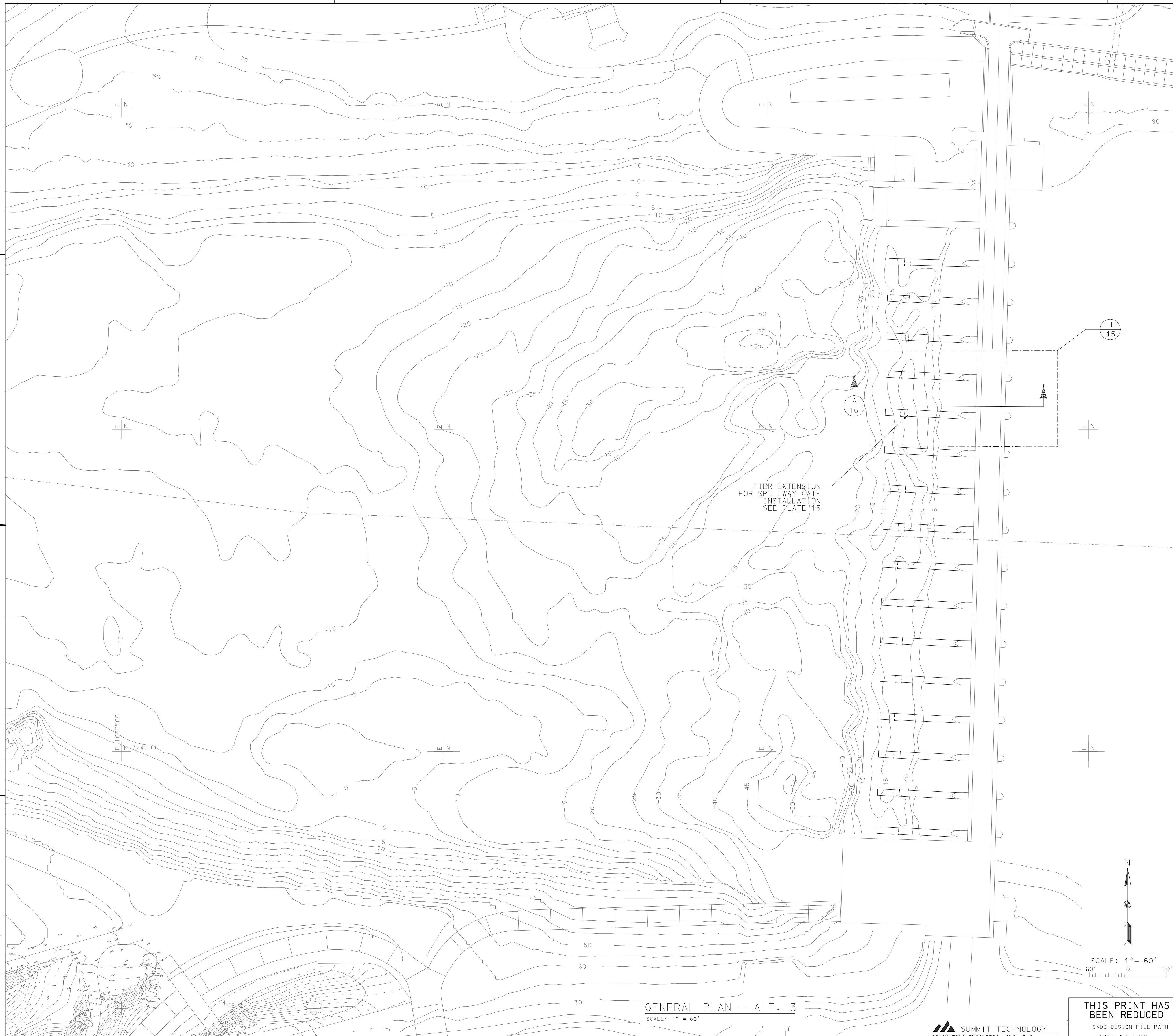

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GAS ABATEMENT STUDY
ALTERNATE NO. 3
NEW SPILLWAY GATES
GENERAL PLAN

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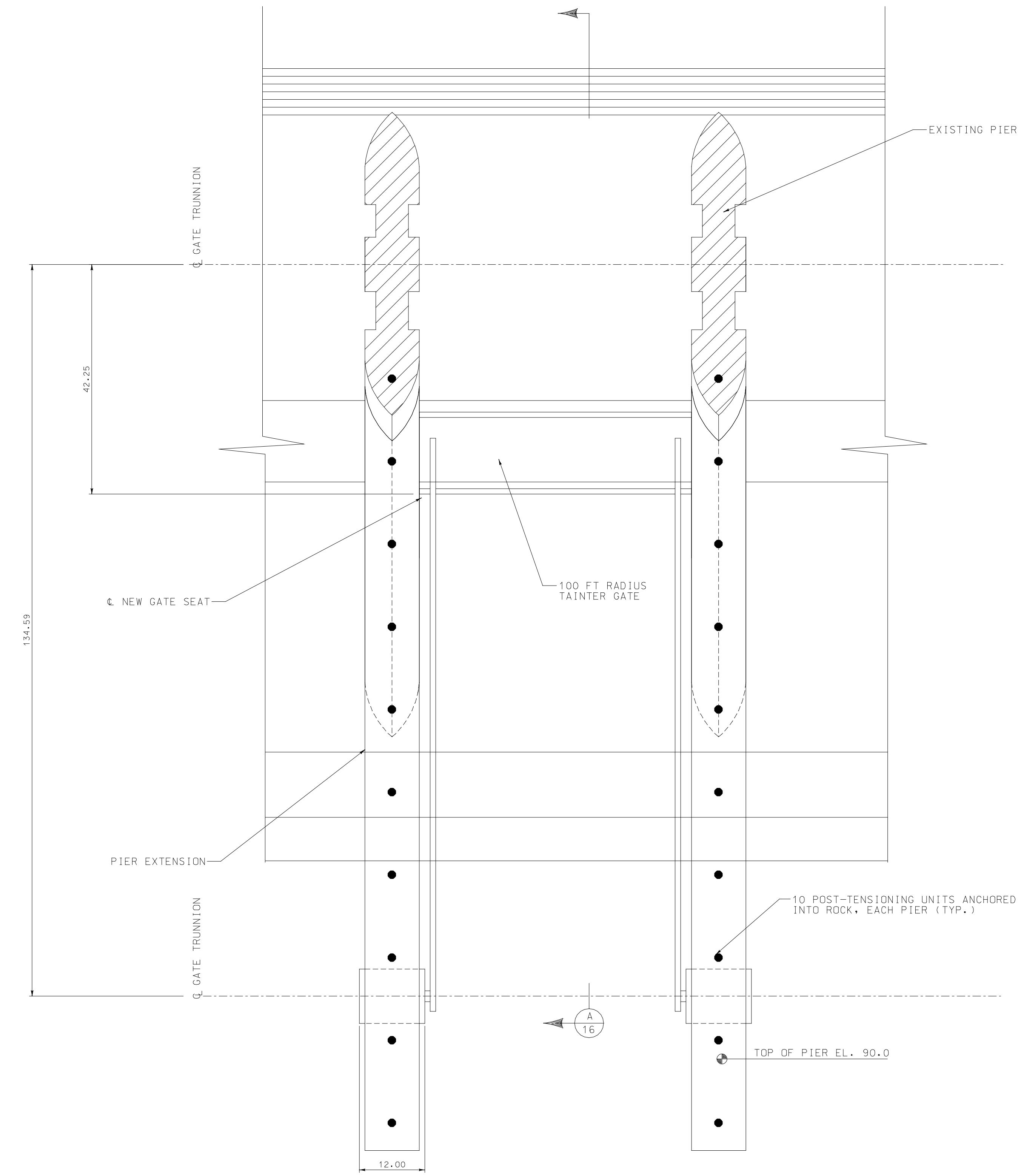

PARTIAL PLAN @ SPILLWAY (1/14)
SCALE: 1" = 10'

SCALE: 1"= 10'
10' 0 10'

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COLUMBIA RIVER

BONNEVILLE DAM

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GAS ABATEMENT STUDY
ALTERNATE NO. 3
NEW SPILLWAY GATES
PARTIAL PLAN @ SPILLWAY

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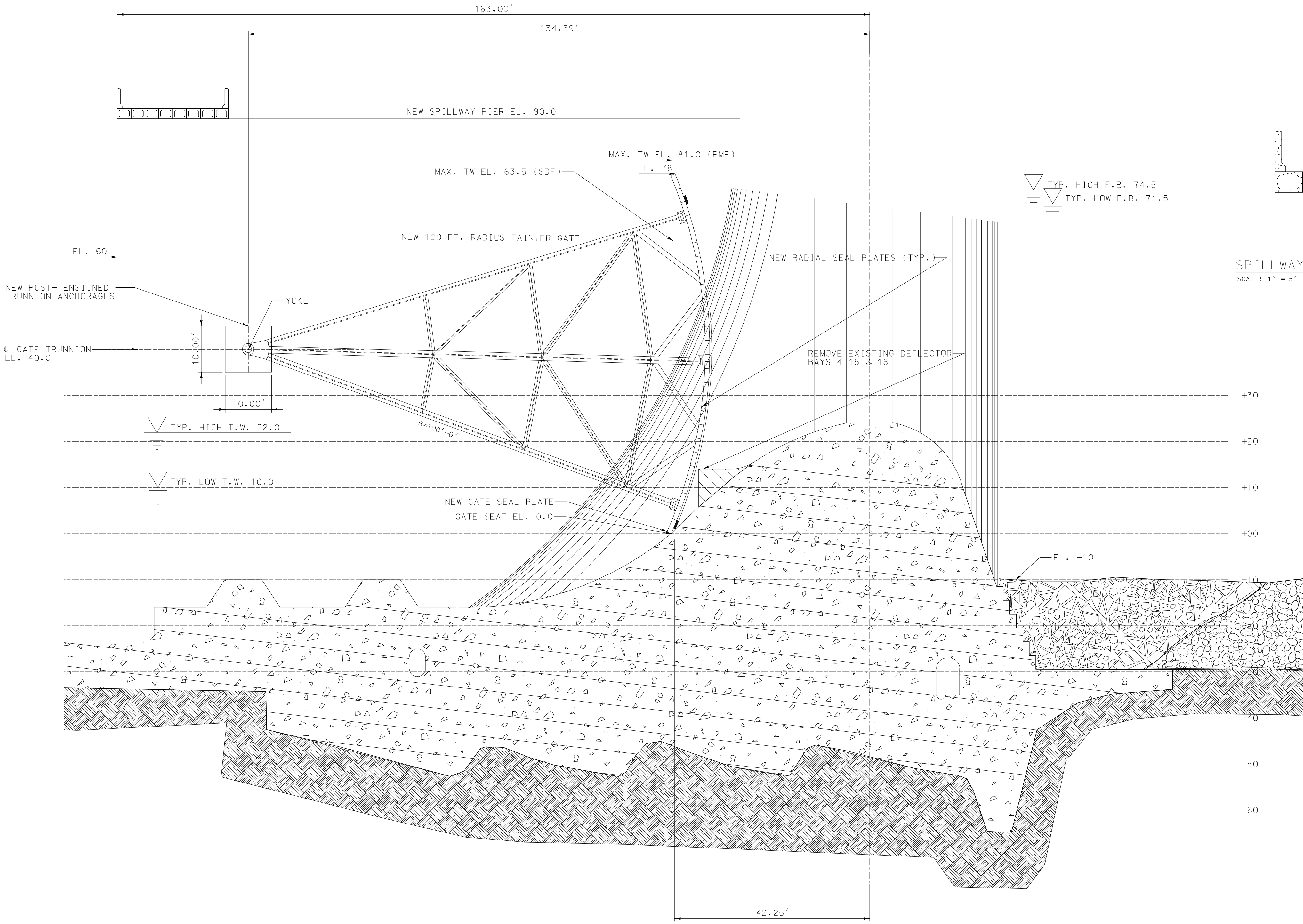
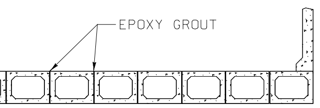
DATE: 1998 APRIL 23 SHEET: PLATE 15



SECTION A/14
SCALE: 1" = 10'



SPILLWAY TRUNNION BRIDGE SECTION B/–
SCALE: 1" = 5'

SCALE: 1"= 10'
10' 0 10'

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BONNEVILLE DAM
OREGON – WASHINGTON
GAS ABATEMENT STUDY
ALTERNATE NO. 3
NEW SPILLWAY GATES
SECTIONS

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DESIGNED: RAK
DRAWN: JMP
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DATE: 1998 APRIL 23
SHEET:
PLATE 16

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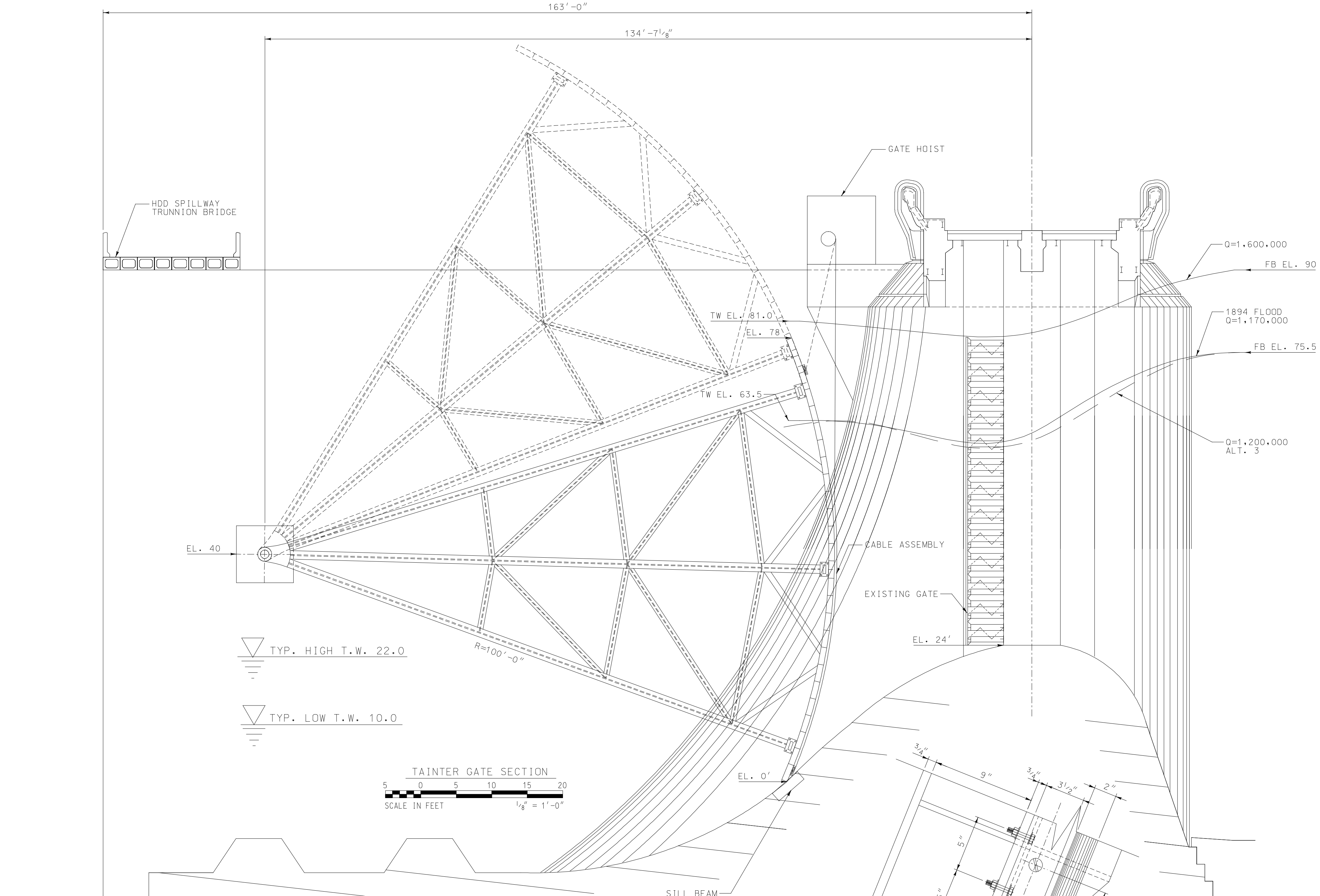
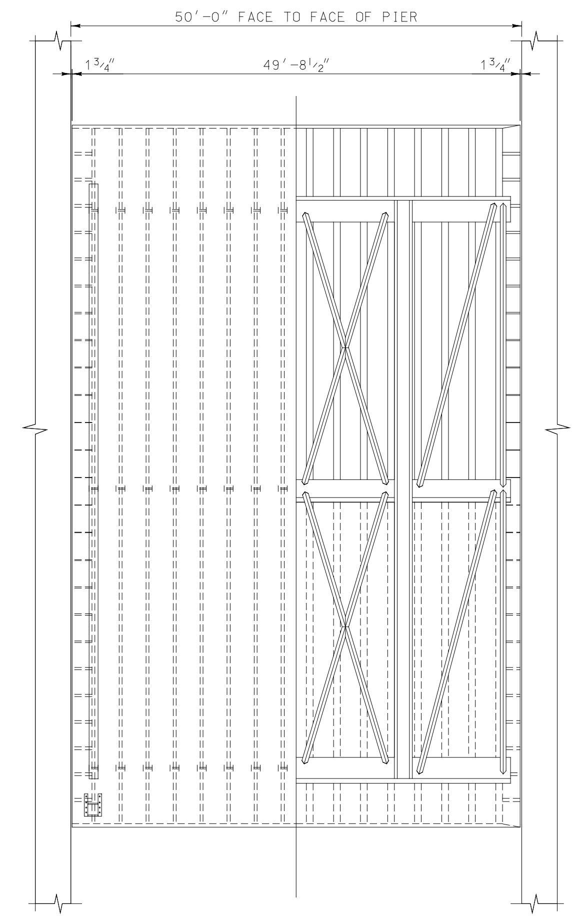


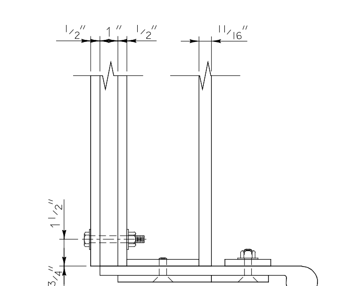
TAINTER GATE SECTION

SCALE IN FEET 1/8" = 1'-0"



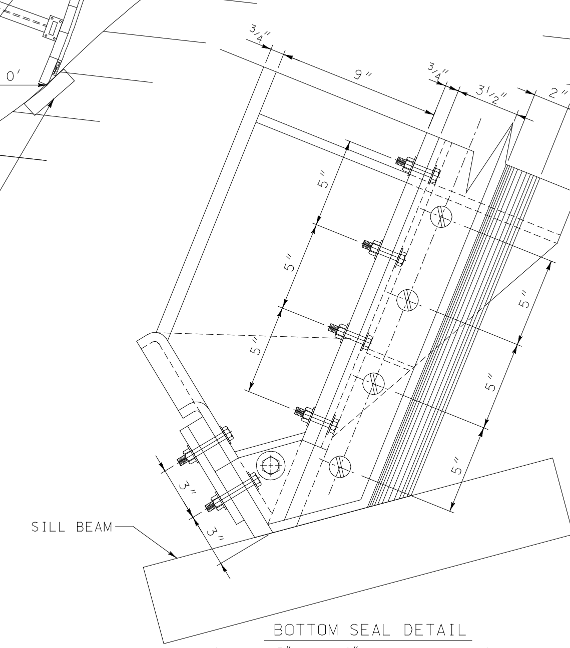
HALF UPSTREAM ELEVATION | HALF DOWNSTREAM ELEVATION

SCALE IN FEET 1/8" = 1'-0"



SIDE SEAL DETAIL

SCALE IN FEET 3" = 1'-0"



BOTTOM SEAL DETAIL

SCALE IN FEET 3" = 1'-0"

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COLUMBIA RIVER

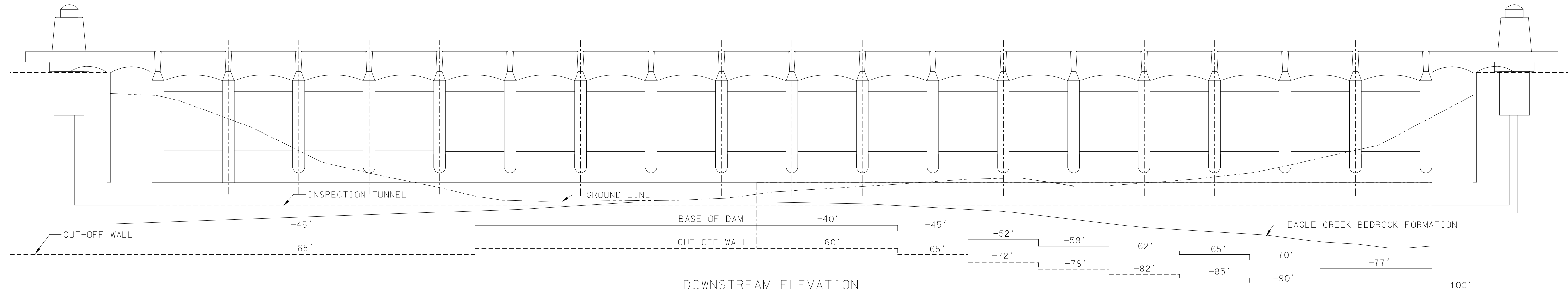
BONNEVILLE DAM

OREGON - WASHINGTON

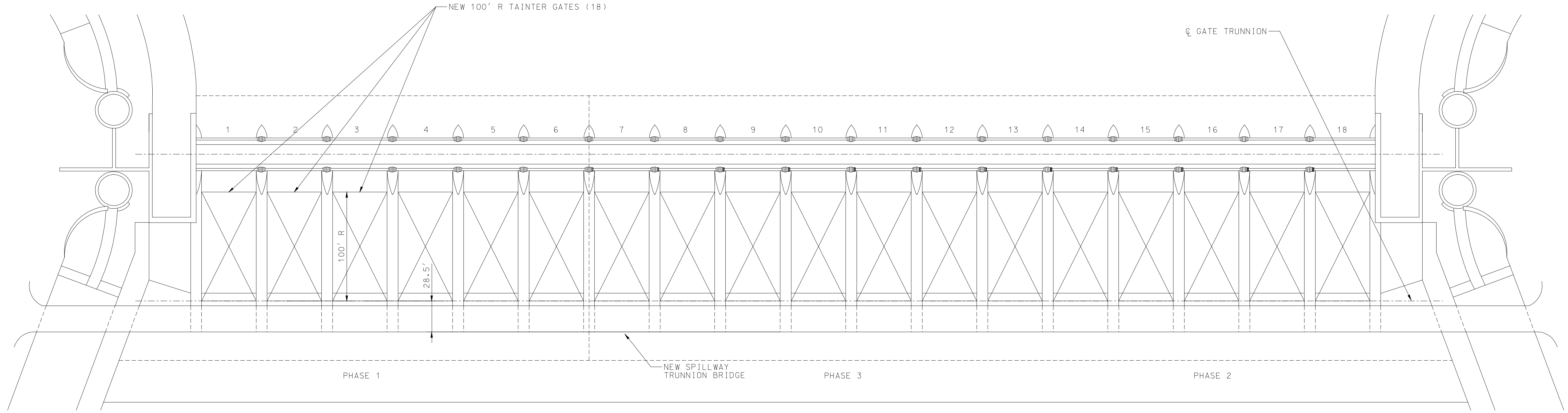
GAS ABATEMENT STUDY
ALTERNATE NO. 3
NEW SPILLWAY GATES
PARTIAL PLAN @ SPILLWAY

SUBMITTED:	DESIGNED:	DRAWN:	CHECKED:
DALE S. MAZAR, CHIEF, DESIGN BRANCH	RAK	JMP	ETZ

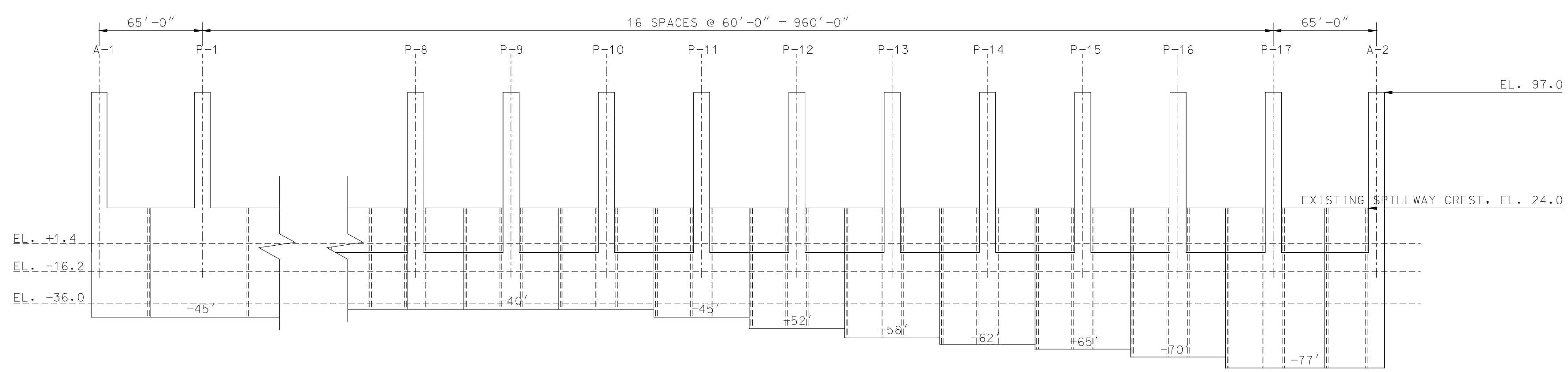
DATE: 1998 APRIL 23 | SHEET: | PLATE 17



DOWNSTREAM ELEVATION
SCALE: 1" = 40'



PLAN
SCALE: 1" = 40'



LONGITUDINAL SECTION THRU DAM
SCALE: 1" = 40'

SCALE IN FEET 1" = 40'

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BONNEVILLE DAM

OREGON - WASHINGTON

GAS ABATEMENT STUDY
ALT. NO. 3, NEW SPILLWAY GATES
SPILLWAY TRUNNION BRIDGE
PLAN AND ELEVATION

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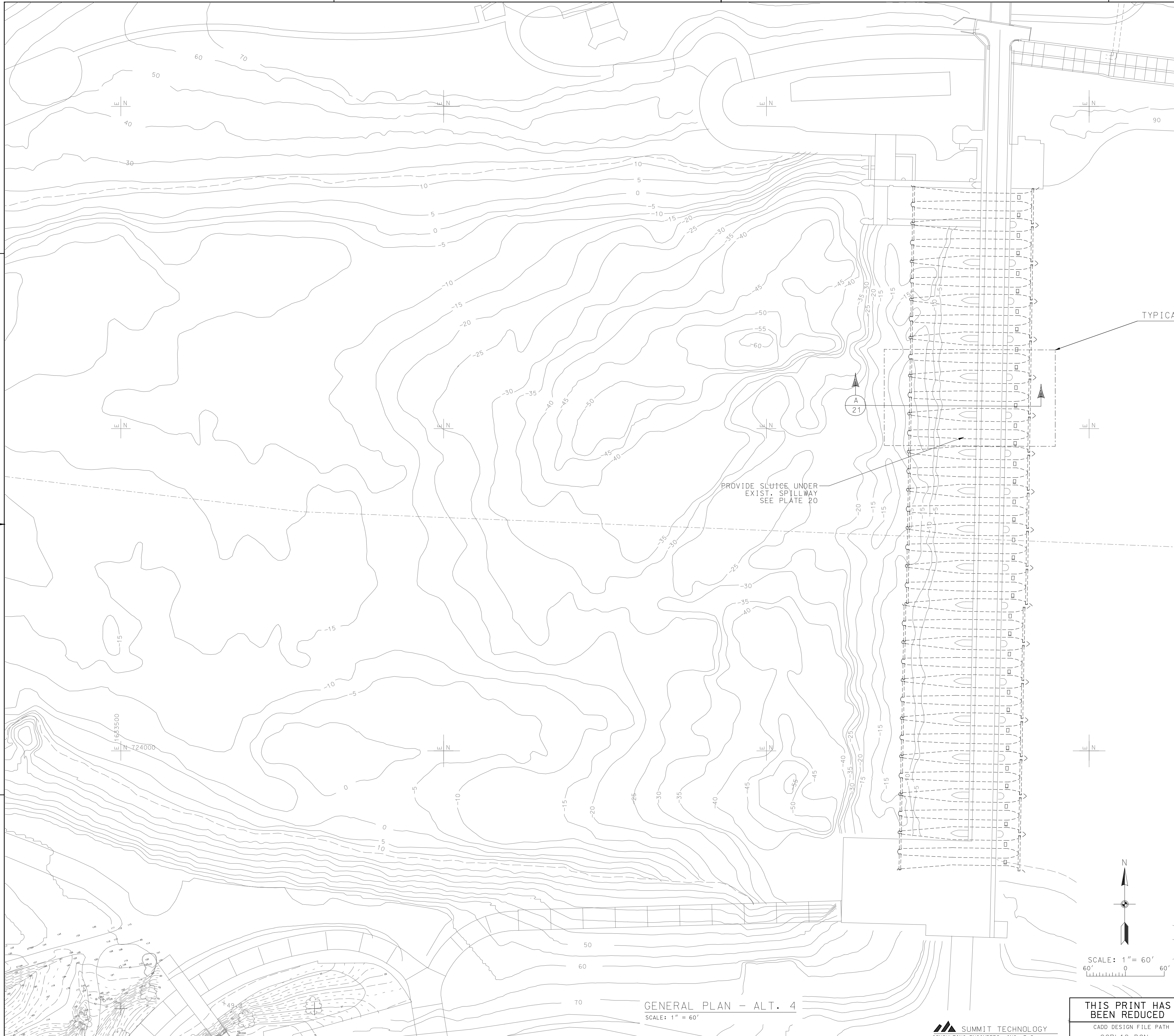
PLATE 18



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BONNEVILLE DAM
COLUMBIA RIVER — OREGON - WASHINGTON

GAS ABATEMENT STUDY
ALTERNATE NO. 4
SLUICES UNDER EXISTING SPILLWAY
GENERAL PLAN

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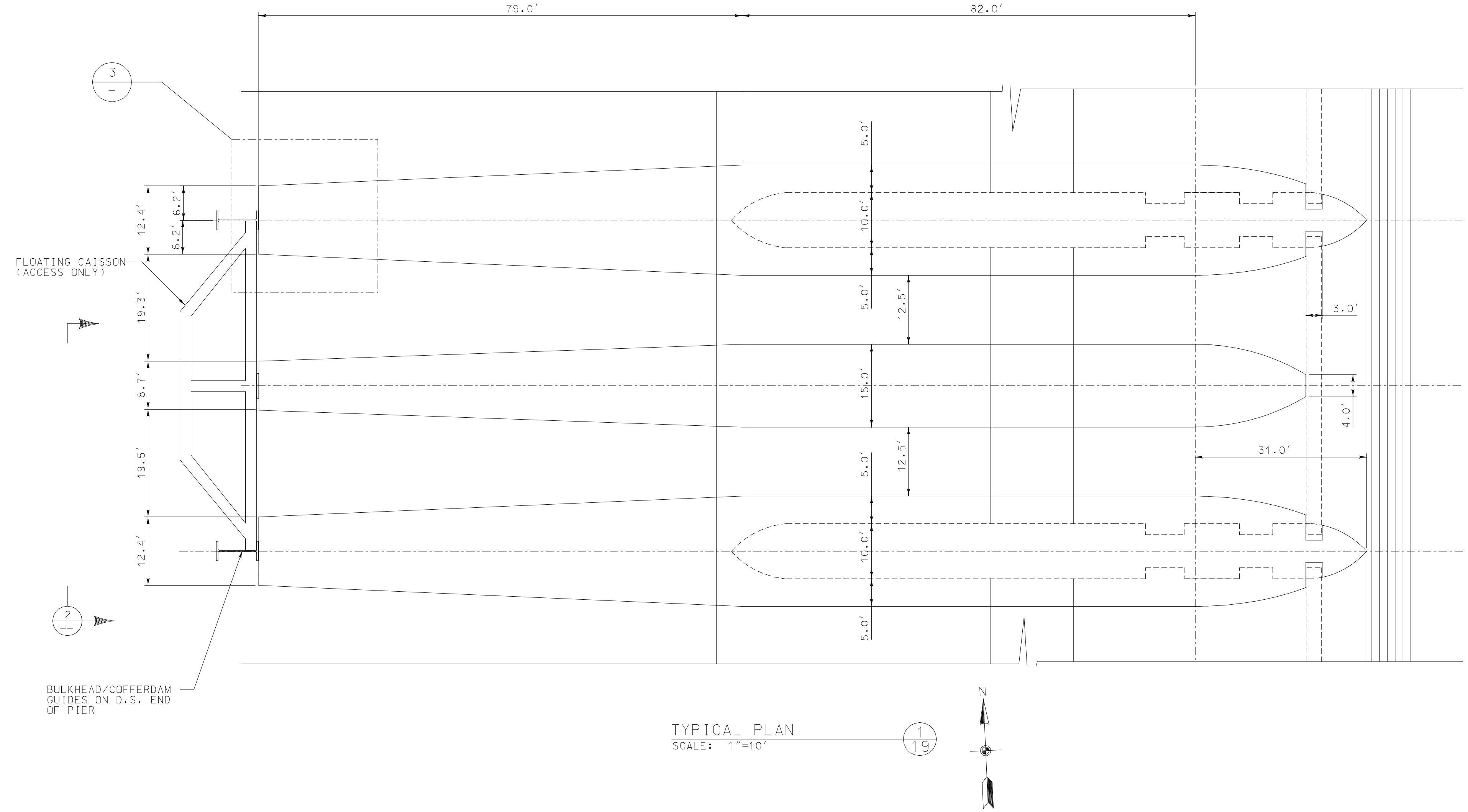
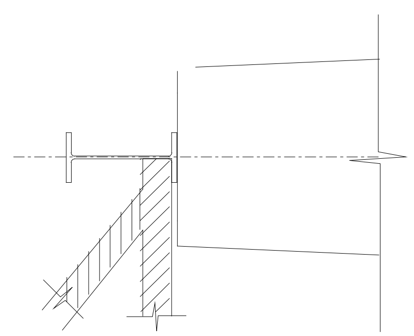
DATE: 1998 APRIL 23 SHEET: PLATE 19

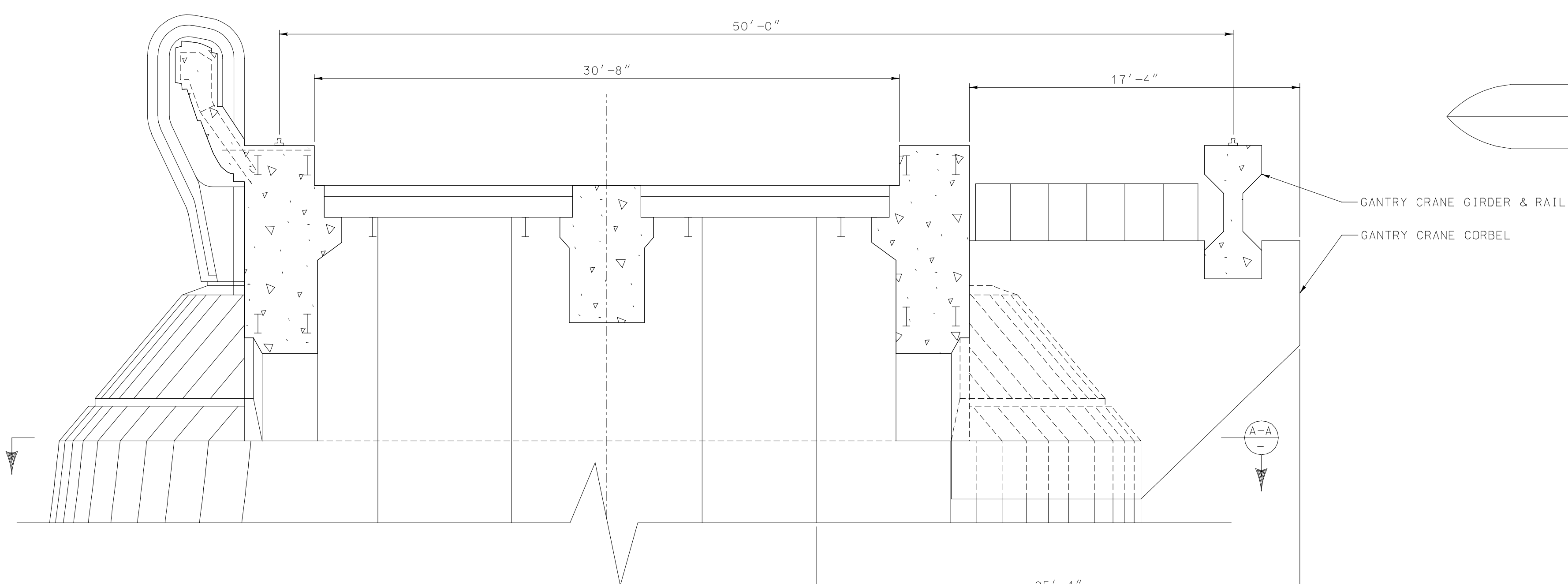
CORPS OF ENGINEERS 4 3 2 1 U.S. ARMY



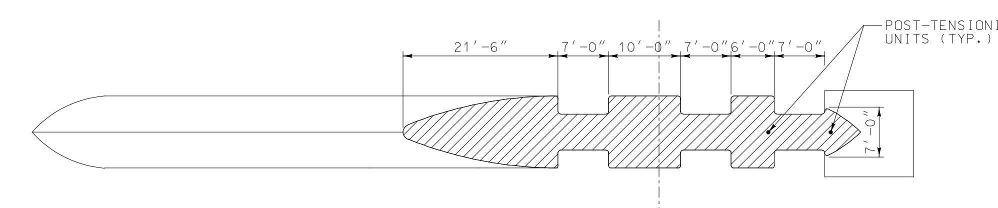
TYPICAL PLAN (1/19)
SCALE: 1"=10'



DETAIL (3)
SCALE: 1"=5'



DETAIL
SCALE: 1"=5'



SECTION A-A

SCALE: 1" = 5'
5' 0 5'

SCALE: 1"= 10'
10' 0 10'

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BONNEVILLE DAM
OREGON - WASHINGTON
GAS ABATEMENT STUDY
ALTERNATE NO. 4
SLUICES UNDER EXISTING SPILLWAY
TYPICAL PLAN & DETAILS

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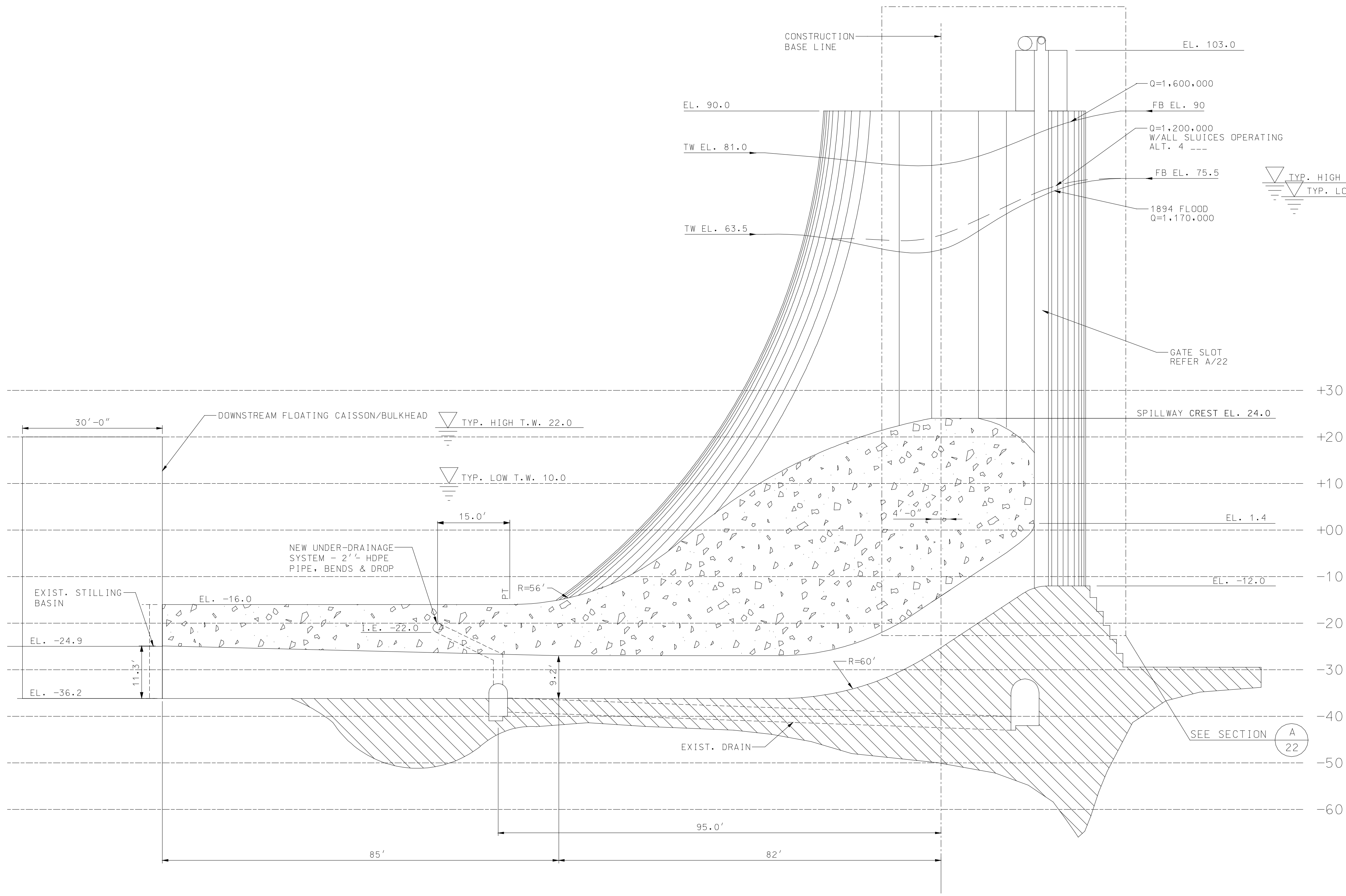
4 3 2 1

CORPS OF ENGINEERS U.S. ARMY



NOTES:

1. DOWNSTREAM CAISSON/BULKHEAD REQUIRED FOR DEWATERING SLUICES (POSITIONED FROM FLOATING PLANT WITH DIVER ASSISTANCE)

SECTION A/19
SCALE: 1"=10'

SCALE: 1"= 10'
10' 0 10'

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GAS ABATEMENT STUDY
ALTERNATE NO. 4
SLUICES UNDER EXISTING SPILLWAY
SECTION

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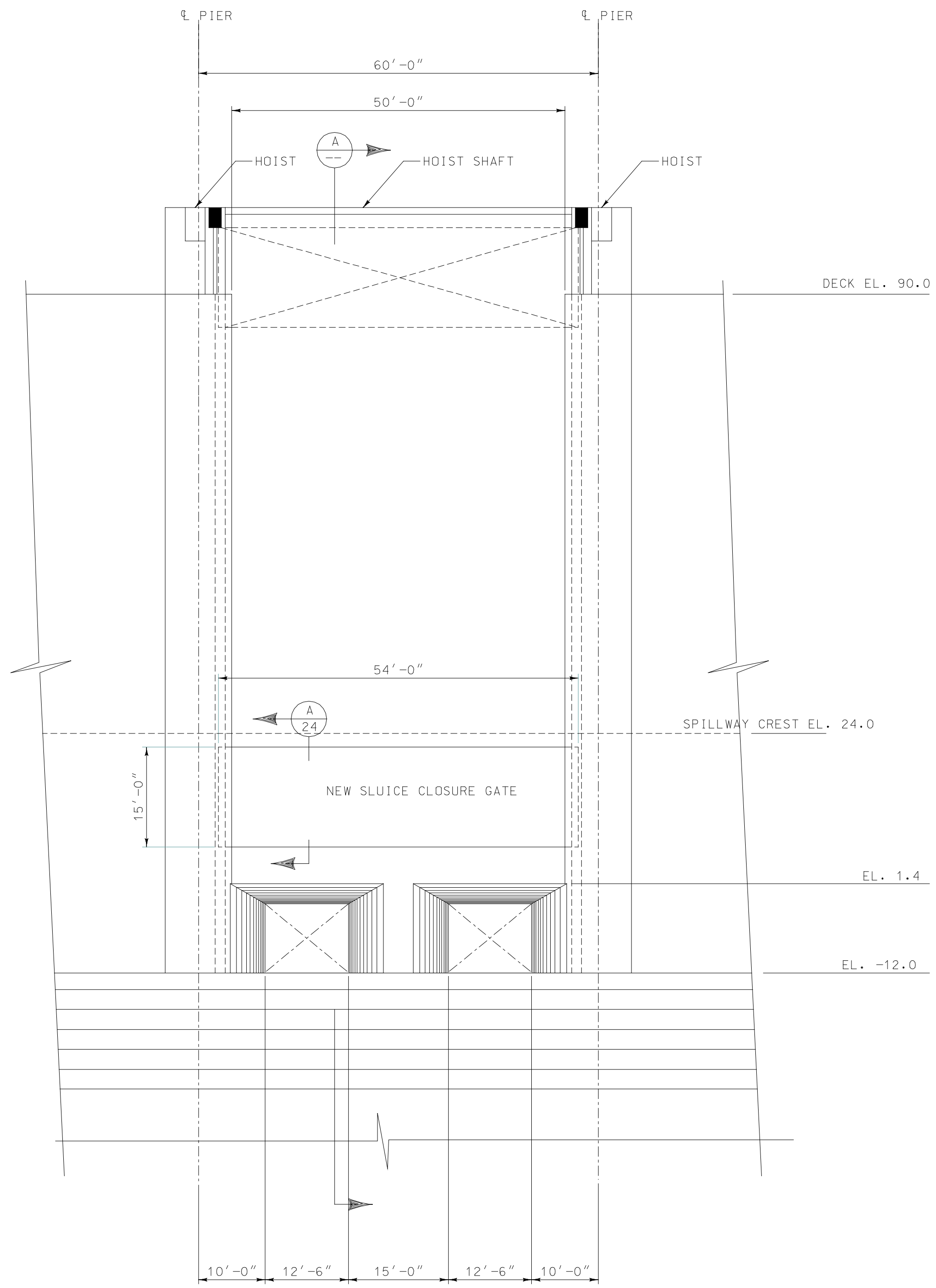
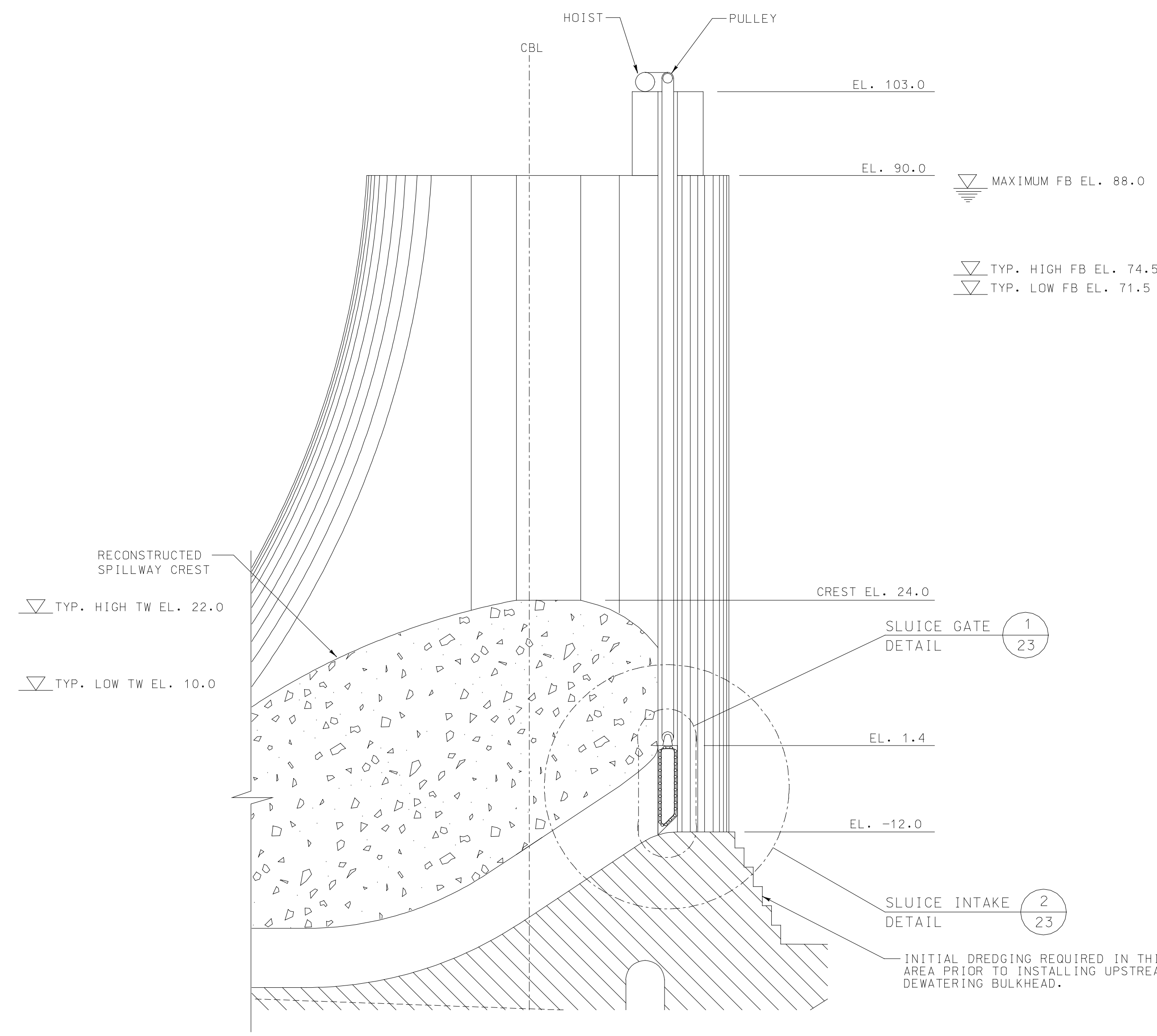


TYPICAL ELEVATION
SCALE: 1:10



SECTION A
SCALE: 1" = 10'

SCALE: 1"= 10'
10' 0 10'

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COLUMBIA RIVER — BONNEVILLE DAM — OREGON - WASHINGTON

GAS ABATEMENT STUDY
ALTERNATE NO. 4
SLUICES UNDER EXISTING SPILLWAY
SECTIONS & DETAILS

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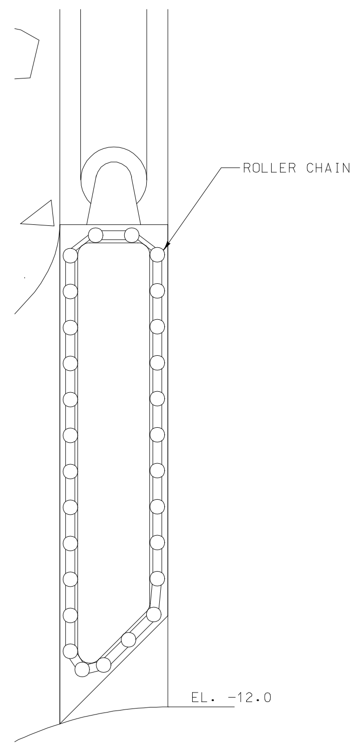
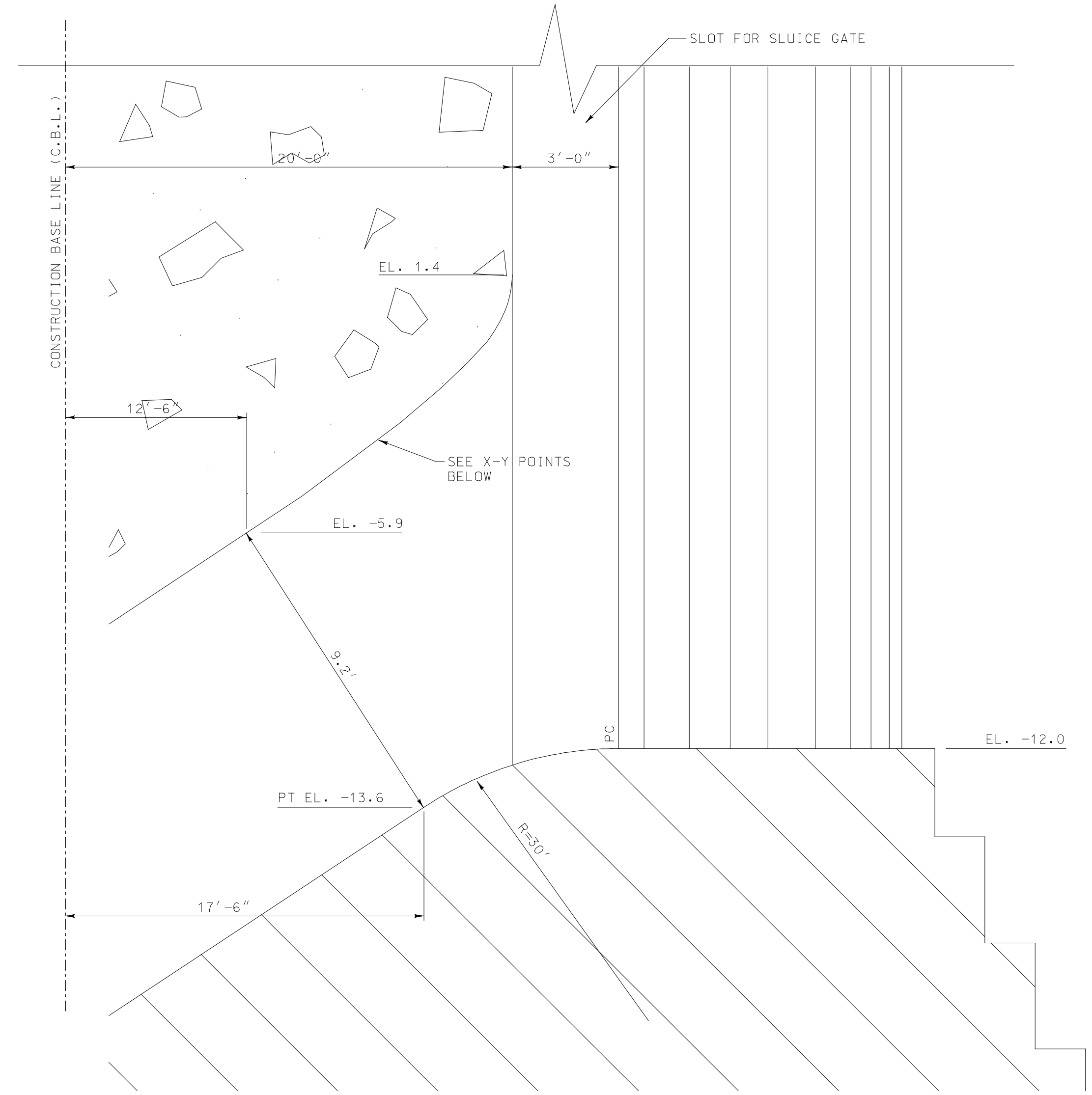
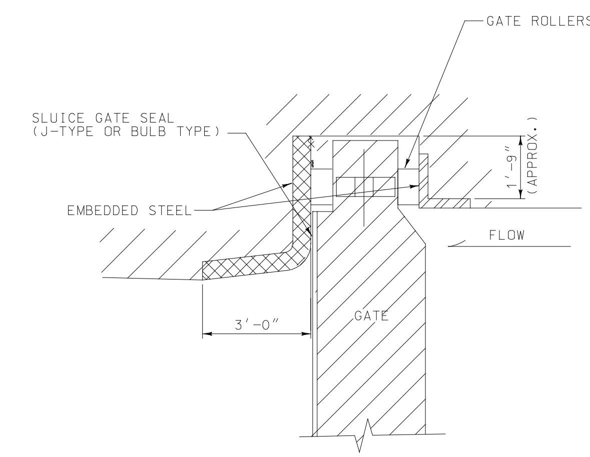


SECTION 1/22
SCALE: 1/2" = 1'-0"



INTAKE DISTANCE FROM CBL	CURVE ELEV.
12.5	-5.9
14.2	-4.8
15.9	-3.5
17.5	-2.1
19.2	-0.6
20.0	1.4

SLUICE INTAKE DETAIL 2/22
SCALE: 1/2" = 1'-0"



GATE DETAIL - SIDEWALL SLOT 3/22
SCALE: 1/2" = 1'-0"

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BONNEVILLE DAM
OREGON - WASHINGTON
GAS ABATEMENT STUDY
ALTERNATE NO. 4
SLUICES UNDER EXISTING SPILLWAY
SECTIONS & DETAILS

SCALE: 1/2" = 1'-0"
12" 0 1' 2' 3' 4'

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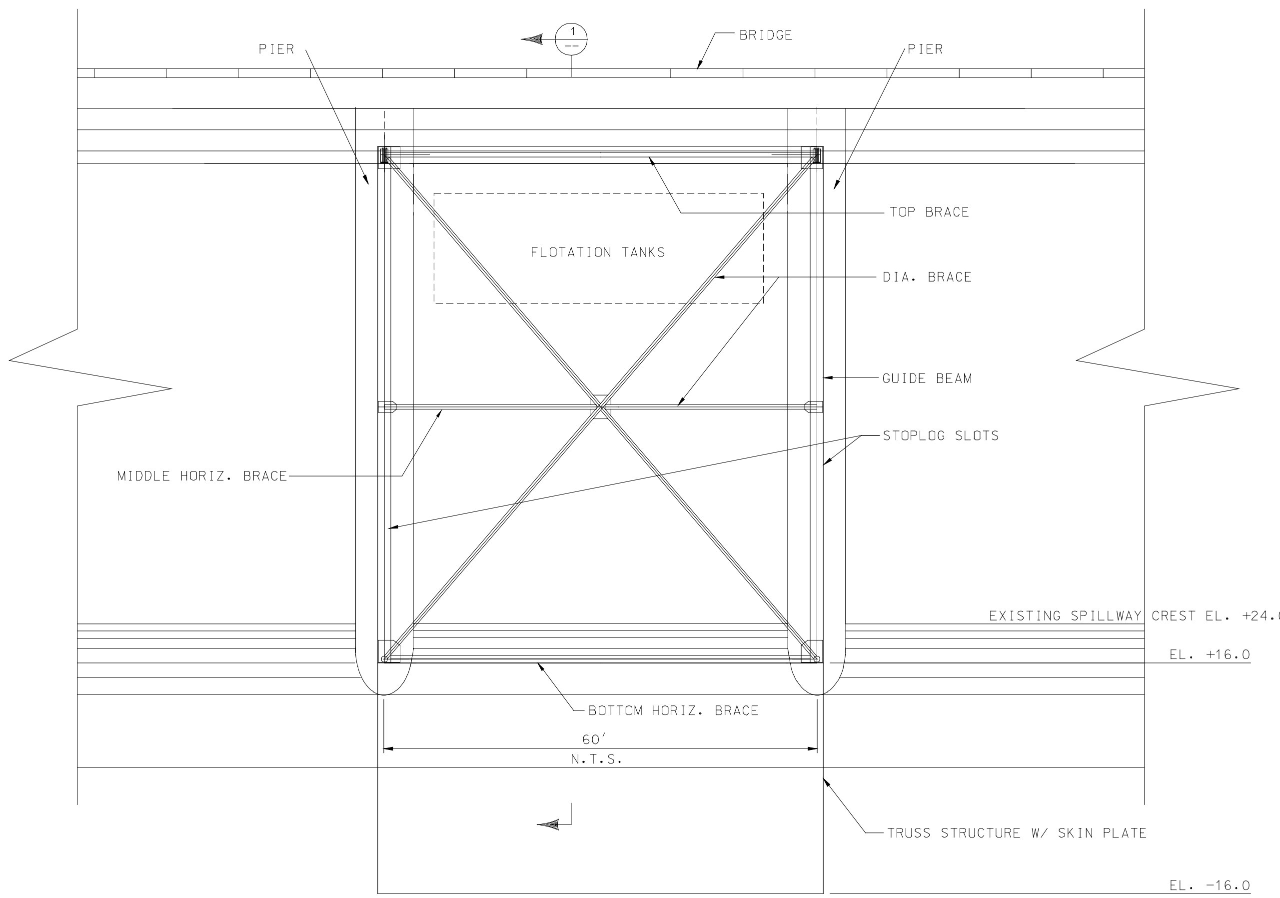
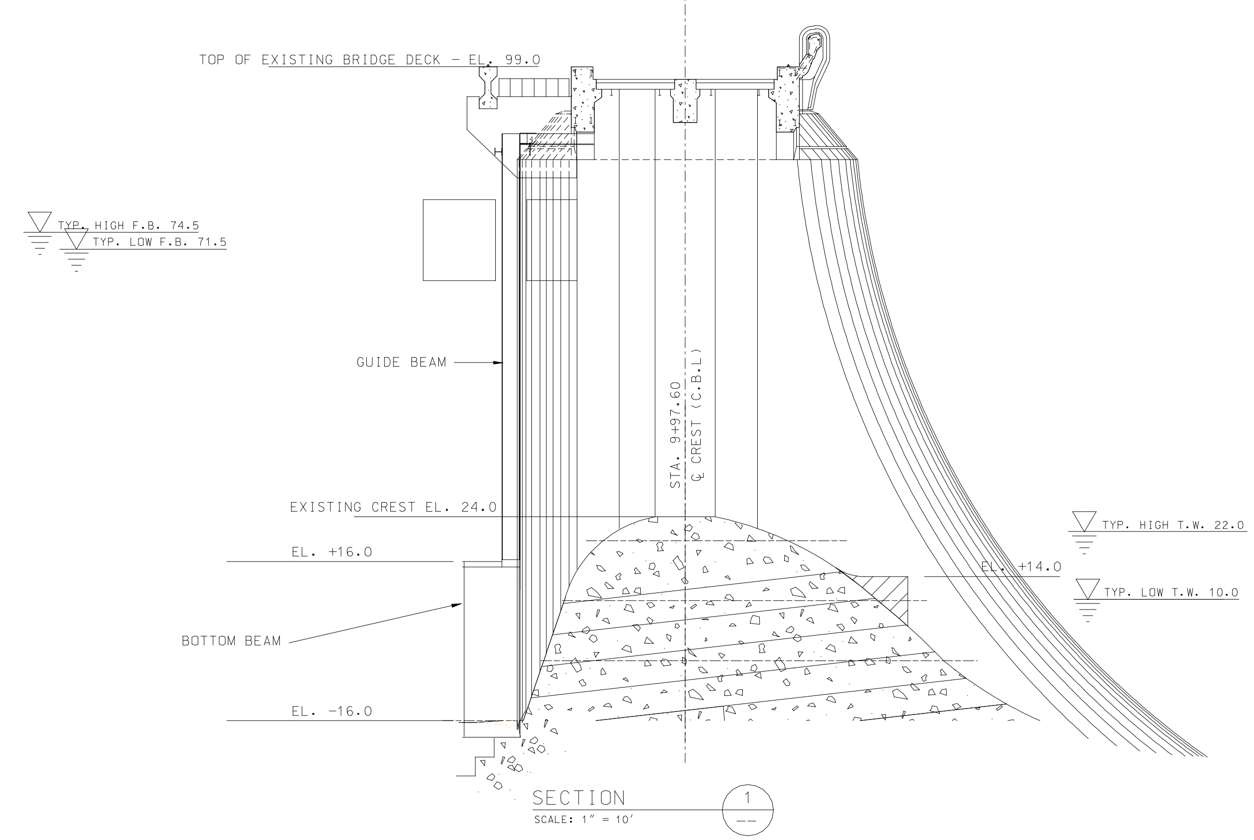
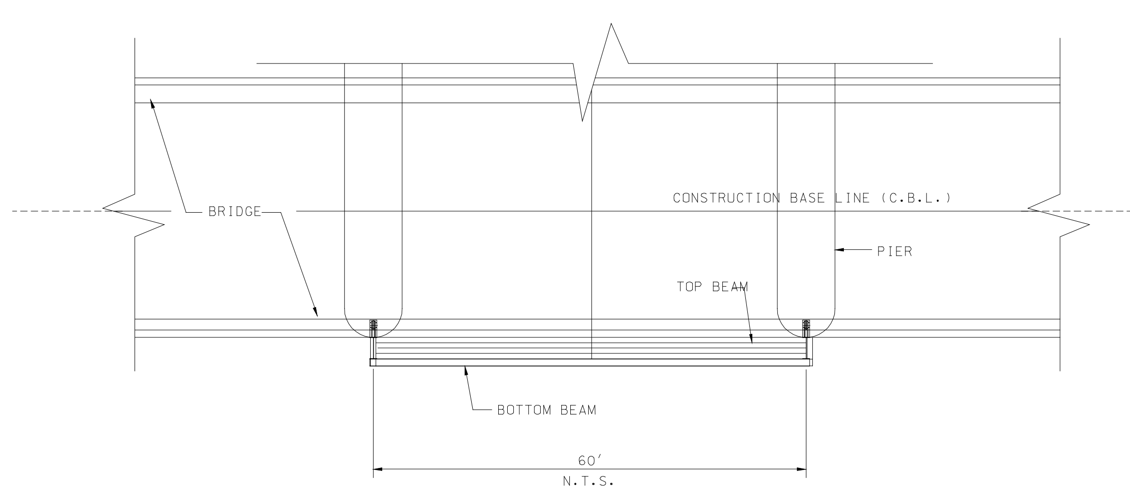
DATE: 1998 APRIL 23 SHEET: PLATE 23



ELEVATION
SCALE: 1" = 10'



SECTION 1
SCALE: 1" = 10'



TYPICAL U/S DEWATERING PLAN
SCALE: 1" = 10'

NOTES:

1. UPSTREAM DEWATERING BULKHEAD WILL BE RETAINED FOR FUTURE MAINTENANCE.
2. NEW SPILLWAY GANTRY CRANE WILL BE USED TO ASSIST IN SETTING THE UPSTREAM BULKHEAD STOPLOG FRAME. SEE PLATE 28.

SCALE: 1"= 10'
10' 0 10'

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BONNEVILLE DAM
OREGON - WASHINGTON

GAS ABATEMENT STUDY
ALTERNATIVE NO. 4
UPSTREAM DEWATERING CONCEPT
PLAN, ELEVATION & SECTION

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90PL24.DGN

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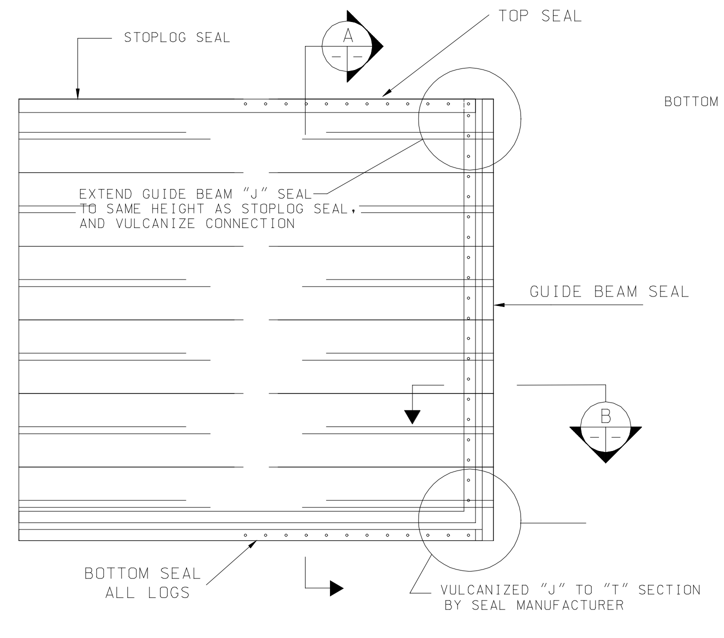
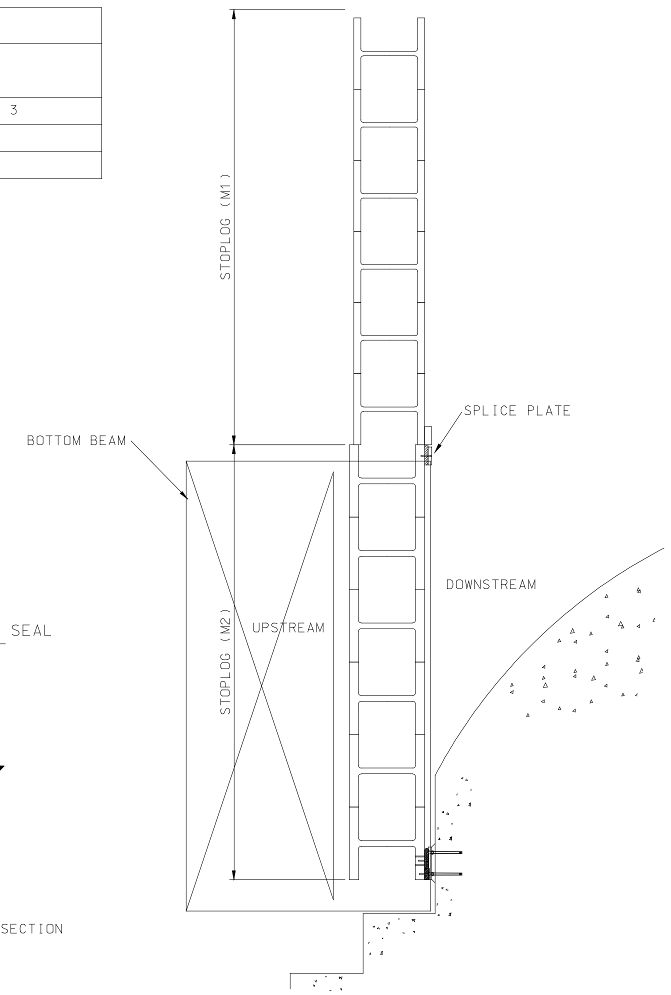
STOPLOG SCHEDULE				
TYPE	NO. STOPLOGS	SECTION SIZE	NO. BEAMS (*)	NOTES
L1	2	W14 X 193	7	USED 5 - 159'S AND 2 - 176'S AT BAY 3
M1	3	W14 X 283	6	
M2	1	W14 X 370	6	

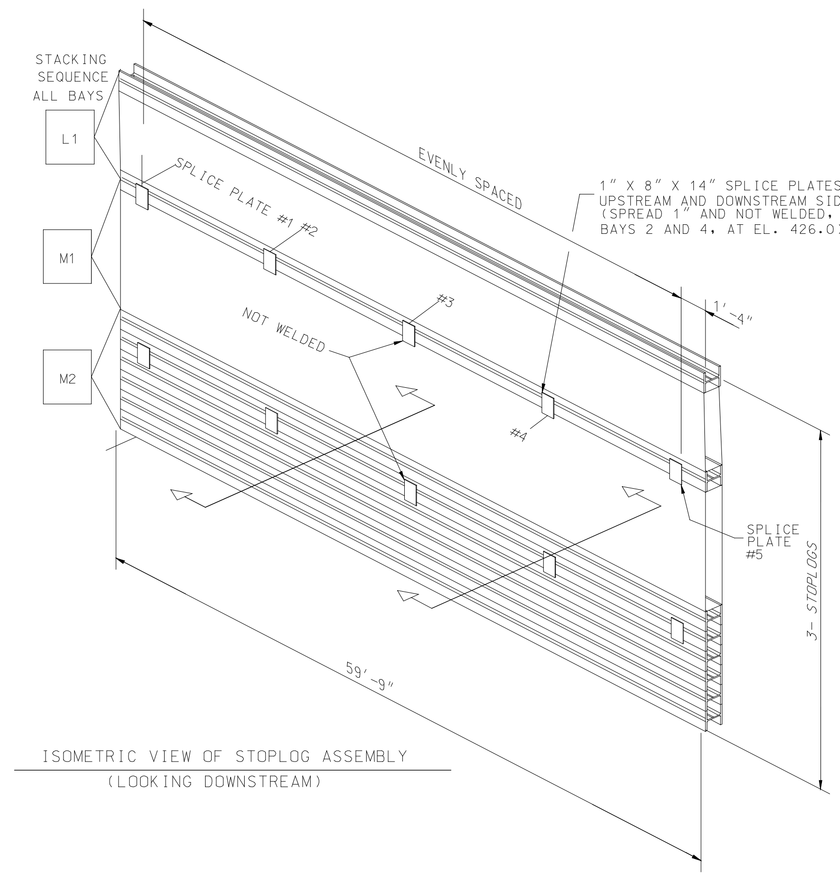
* NUMBER OF BEAMS PER STOPLOG



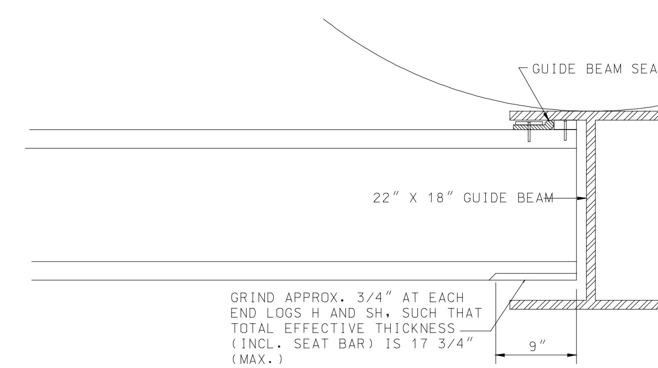
TYPICAL STOPLOG ELEVATION (LOOKING UPSTREAM)
SCALE: 3/4" = 1'-0"



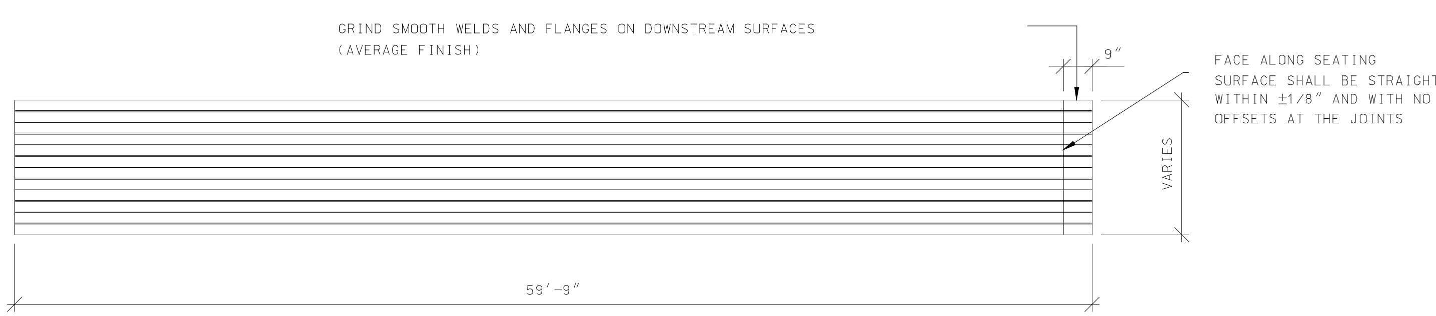
SECTION A
SCALE: 3/4" = 1'-0"



ISOMETRIC VIEW OF STOPLOG ASSEMBLY
(LOOKING DOWNSTREAM)



SECTION B
SCALE: 3/4" = 1'-0"



TYPICAL STOPLOG ELEVATION (LOOKING DOWNSTREAM)
SCALE: 3/4" = 1'-0"

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COLUMBIA RIVER — BONNEVILLE DAM — OREGON - WASHINGTON

GAS ABATEMENT STUDY
ALTERNATE NO. 4
UPSTREAM DEWATERING BULKHEAD
ELEVATIONS AND SECTIONS

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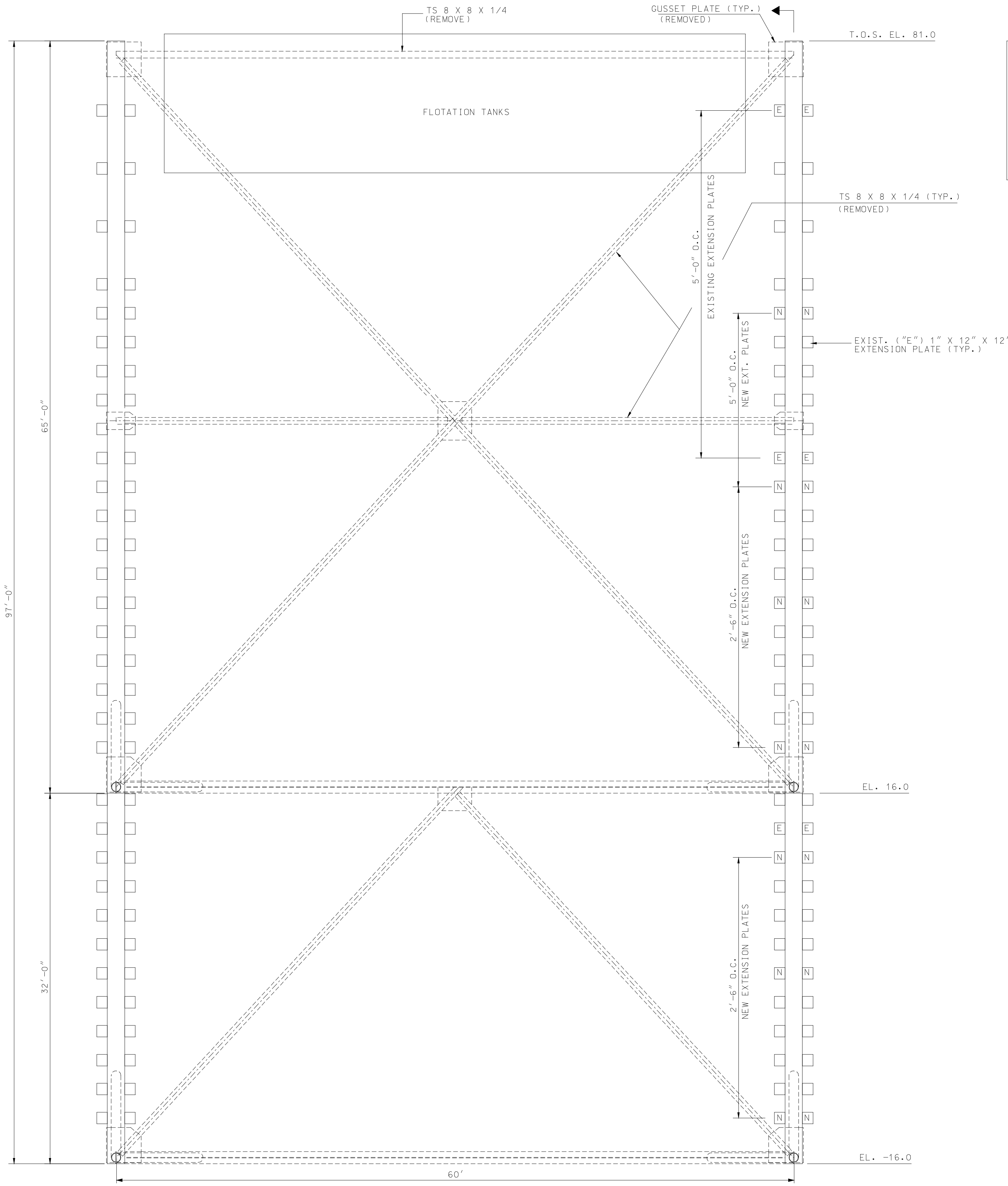
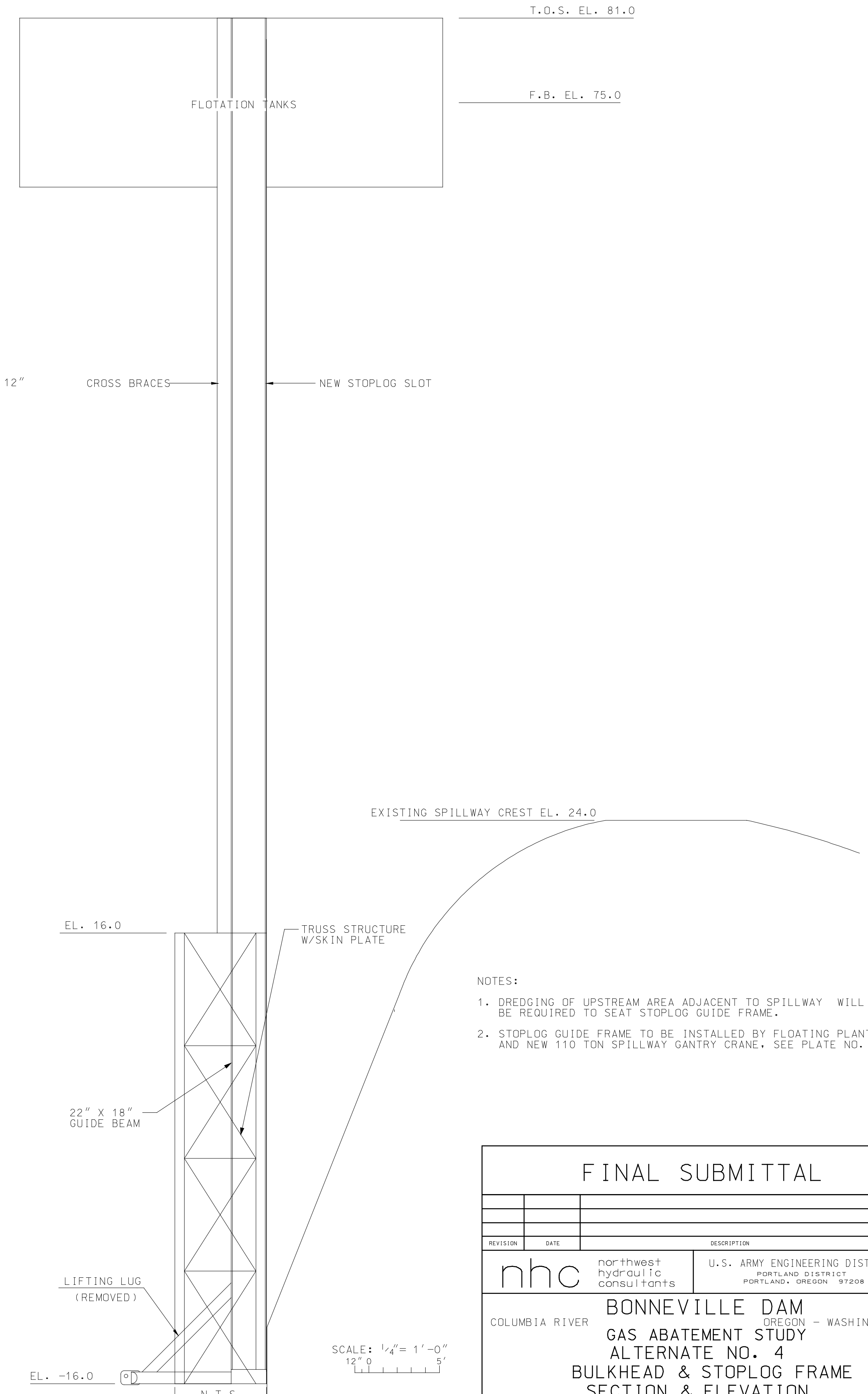
PLATE 25



TYPICAL STOPLOG GUIDE FRAME ELEVATION
SCALE: 1/4" = 1'-0"



NOTES:

1. DREDGING OF UPSTREAM AREA ADJACENT TO SPILLWAY WILL BE REQUIRED TO SEAT STOPLOG GUIDE FRAME.
2. STOPLOG GUIDE FRAME TO BE INSTALLED BY FLOATING PLANT AND NEW 110 TON SPILLWAY GANTRY CRANE. SEE PLATE NO. 28.

SCALE: 1/4" = 1'-0"
12" 0 5'

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COLUMBIA RIVER

BONNEVILLE DAM
OREGON - WASHINGTON

GAS ABATEMENT STUDY
ALTERNATE NO. 4
BULKHEAD & STOPLOG FRAME
SECTION & ELEVATION

SUBMITTED:	DESIGNED:	DRAWN:	CHECKED:
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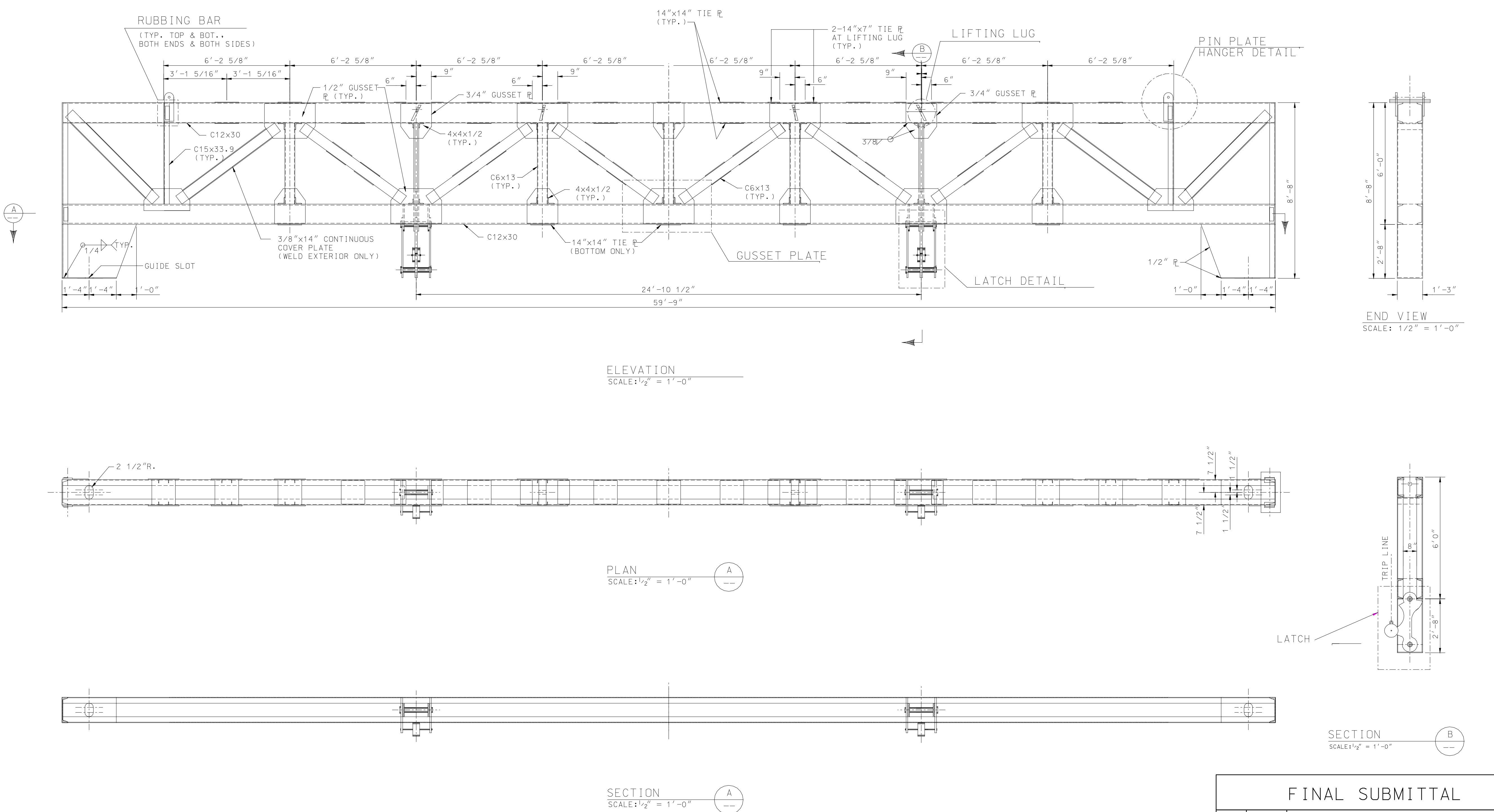
DATE: 1998 APRIL 23 | SHEET: | PLATE 26



NOTE:

BULKHEAD STOPLOG LIFTING BEAM WILL BE USED DURING STOPLOG FRAME INSTALLATION AND FOR POSITIONING AND REMOVAL OF UPSTREAM BULKHEAD STOPLOGS.

SCALE: 1/2" = 1'-0"

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PORTLAND DISTRICT
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BONNEVILLE DAM

COLUMBIA RIVER — OREGON - WASHINGTON

GAS ABATEMENT STUDY
ALTERNATE NO. 4
BULKHEAD STOPLOG LIFTING BEAM
PLAN, ELEVATION & SECTIONS

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DESIGNED: RAK — DRAWN: JMP — CHECKED: ETZ
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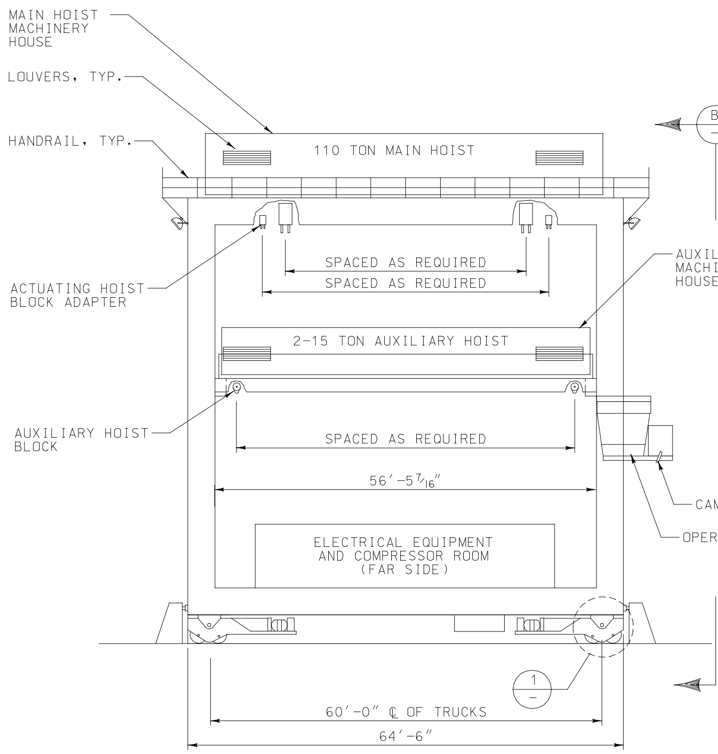
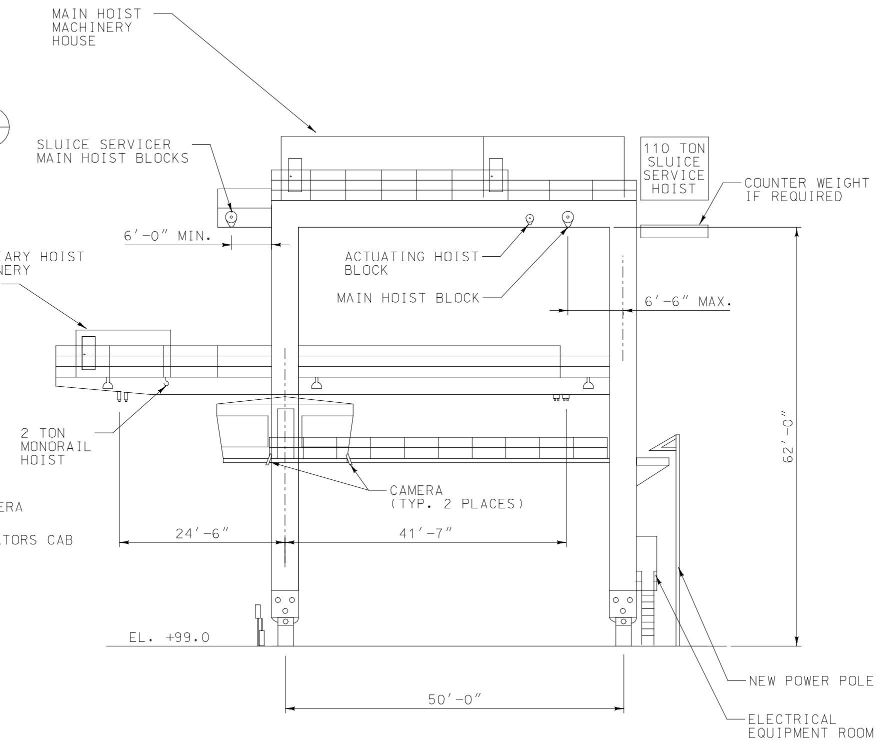
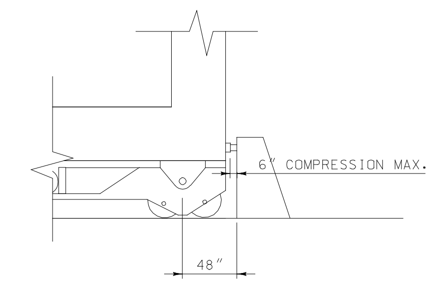


UPSTREAM ELEVATION A
SCALE: 3/32" = 1'-0"



ELEVATION B
SCALE: 3/32" = 1'-0"



DETAIL 1 A
SCALE: 3/16" = 1'-0"

DESIGN DATA

SLUICE SERVICE HOIST

RATED CAPACITY: 110 TOMS
HOISTING SPEED: FULL LOAD 8 FPM
32 TON 18-24 FPM
NO LOAD 24 FPM

HOOK TRAVEL: 173 FT
HIGH EL. 161
LOW EL. -12

MAIN HOIST

RATED CAPACITY: 110 TON

HOISTING SPEED: FULL LOAD 8 FPM
32 TON 18-24 FPM
NO LOAD 24 FPM
HOOK TRAVEL: 137 FT
HIGH EL. 161
LOW EL. 24
TROLLEY SPEED: 16 FPM

ACTUATING HOISTS

RATED CAPACITY: 2 @ 15 TONS
HOISTING SPEED: FULL LOAD 20 FPM
NO LOAD 40 FPM
HOOK TRAVEL: 168 FT
HIGH EL. 129
LOW EL. -39
TROLLEY TRAVEL: 42 FT
TROLLEY SPEED: 16 FPM

GANTRY TRAVEL

TRAVEL SPEED: 100 FPM
LENGTH OF TRAVEL: APPROX. 1100 FT

MONORAIL HOIST

RATED CAPACITY: 2 TON
HOISTING SPEED: 24/8 FPM
HOOK TRAVEL: 40 FT
TROLLEY TRAVEL: 65 FT
TROLLEY SPEED: 100 FPM

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BONNEVILLE DAM
COLUMBIA RIVER OREGON - WASHINGTON
GAS ABATEMENT STUDY
ALT. NO. 4 SPILLWAY CRANE
110 TON GANTRY CRANE
ELEVATION, SECTION & DETAIL

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SUBMITTED: DALE S. MAZAR, CHIEF, DESIGN BRANCH
DESIGNED: RAK
DRAWN: WSY
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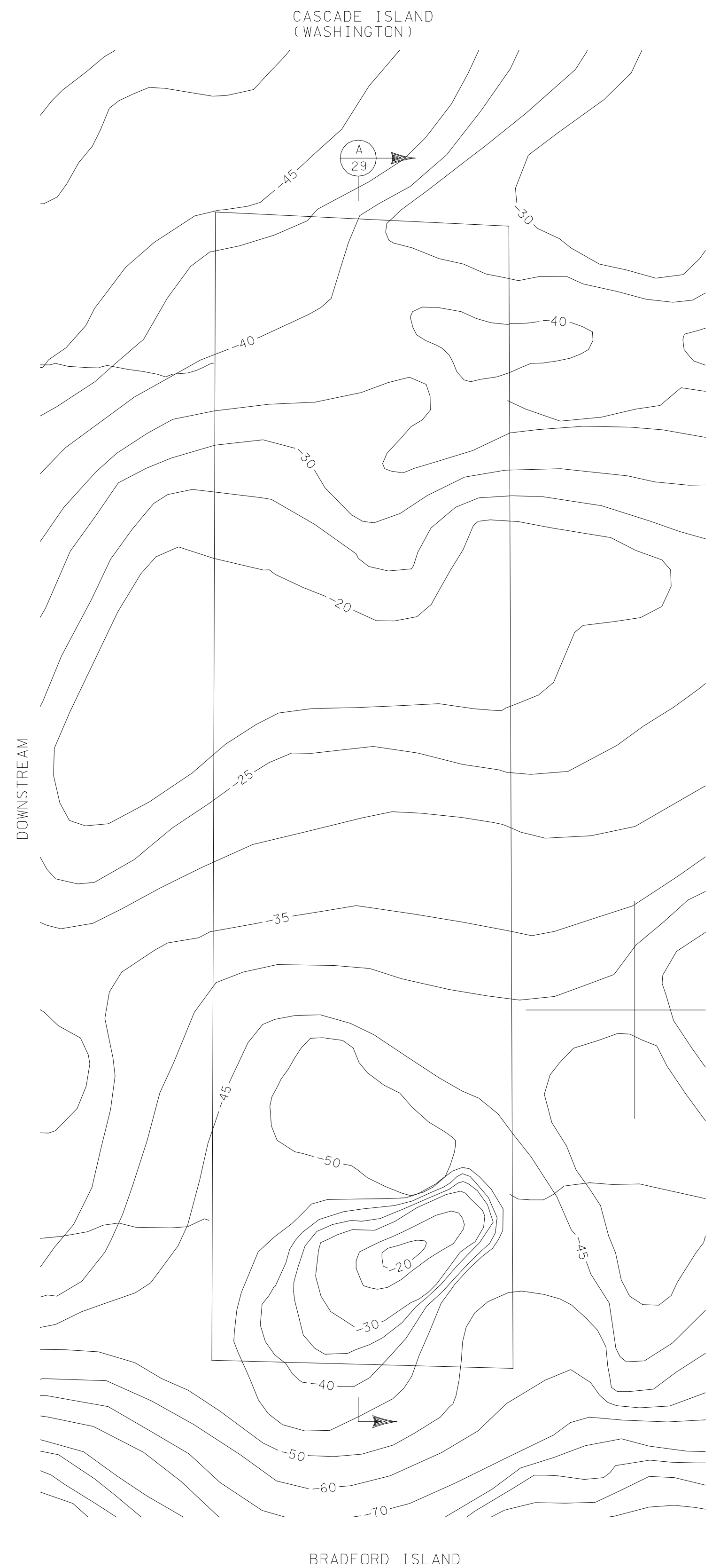
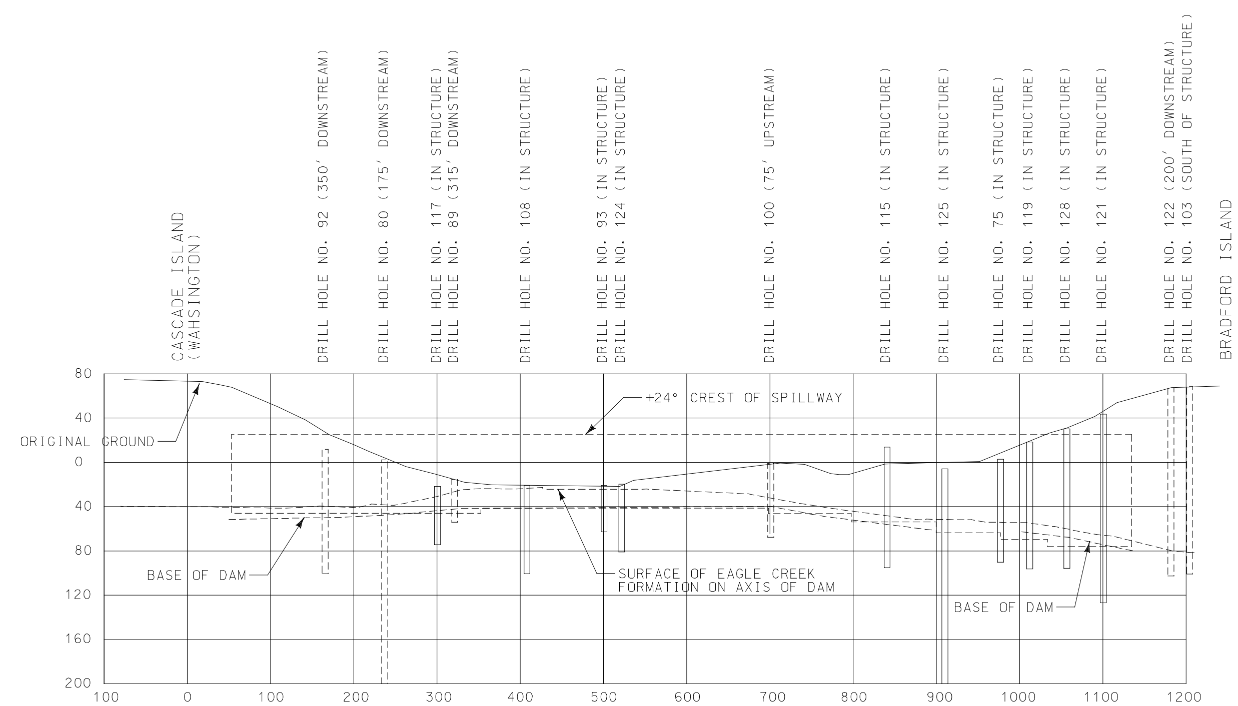
DATE: 1998 APRIL 23
SHEET:
PLATE 28





SECTION ALONG AXIS OF DAM (A/29)
SCALE: NONE

DRILL HOLES							
NO.	S	W.	DEPTH OF HOLE	ELEV. BOTTOM	ELEV. GROUND	ELEV. OF ROCK	MATERIAL
75	10172	12216	92.8	-50.4	+2.4	-52.7	EAGLE CREEK
80	9386	12285	103.6	-98.9	+7.2	-38.3	EAGLE CREEK -34' B.R.
89	9561	12438	56.6	-71.1	+14.5	-21.5	EAGLE CREEK
92	9205	12473	143.8	-71.7	+72.1	-42.2	EAGLE CREEK
93	9719	121.77	47.5	-65.4	-17.9	-19.7	EAGLE CREEK -127' B.R.
100	9929	12051	66.1	-67.9	-1.8	-34.7	EAGLE CREEK
103	10418	12219	170.1	-100.3	+69.8	-80.0	EAGLE CREEK
108	9614	12219	80.4	-100.2	-19.8	-21.9	EAGLE CREEK
110	9513	12251	60.0	-74.9	-14.9	-34.2	EAGLE CREEK
115	10048	12201	83.4	-94.0	-10.6	-42.8	EAGLE CREEK
117	9444	12145	203.3	-200.1	+3.2	-37.5	EAGLE CREEK
119	10231	12166	112.5	-94.0	+18.5	-53.0	EAGLE CREEK
121	10303	12171	172.3	-126.0	+46.3	-60.5	EAGLE CREEK B.R.
122	10370	12330	168.2	-100.1	+68.1	-61.7	EAGLE CREEK
123	9552	12148	57.7	-69.4	-11.7	-20.1	EAGLE CREEKI
124	9739	12144	62.7	-80.5	-17.5	-22.5	EAGLE CREEK
125	10131	12181	193.6	-199.5	-5.9	-50.9	EAGLE CREEK
128	10275	12133	128.7	-95.5	+33.2	-64.0	EAGLE CREEK

FINAL SUBMITTAL

REVISION	DATE	DESCRIPTION	BY

nhc northwest hydraulic consultants

U.S. ARMY ENGINEERING DISTRICT
PORTLAND DISTRICT
PORTLAND, OREGON 97208

BONNEVILLE DAM

COLUMBIA RIVER — OREGON - WASHINGTON

GAS ABATEMENT STUDY
ALTERNATE NO'S. 1-4 SPILLWAY
ORIGINAL TOP OF ROCK
GEOLOGICAL SECTION

SUMMIT TECHNOLOGY
CONSULTING ENGINEERS, INC. P.S.

THIS PRINT HAS BEEN REDUCED

CADD DESIGN FILE PATH: 90PL29.DGN

SUBMITTED:	DESIGNED:	DRAWN:	CHECKED:
DALE S. MAZAR, CHIEF, DESIGN BRANCH	X	X	X

DATE:	SHEET:		PLATE
1998 APRIL 23	X	X	29

APPENDIX A

30% Alternatives

APPENDIX B

Cost Estimates

- Alternative 1 - Stepped / Extended Deflectors
- Alternative 2 - Raised Tailrace
- Alternative 3 - New Spillway Gates
- Alternative 4 - Sluices Under Existing Spillway

Summit Technology, Inc.

Bonneville Dam Alternative 1 - Stepped / Extended Deflectors

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Dams								
	Mobilization and Preparatory Work	1	JOB				$3,000,000.00	$3,000,000	
	Floating Bulkhead	1	JOB				$1,000,000.00	$1,000,000	
	Subtotal Mobilization, Preparatory, and F / B							*$4,000,000*	
	Floating Bulkhead Removal								
	Phase I Bulkhead Removal / High Flows	1	JOB				$30,000.00	$30,000	means 024-820
	Phase II - Bulkhead Removal / High Flows	1	JOB				$30,000.00	$30,000	means 024-821
	Phase III - Bulkhead Removal / High Flows	1	JOB				$30,000.00	$30,000	means 024-822
	Subtotal F / B Removal for High Flow							*$90,000*	
	Dewatering								
	Install 1/2 Floating Bulkhead (2)	1	JOB				$110,000.00	$110,000	
	Install Full Bulkhead (8)	1	JOB				$480,000.00	$480,000	
	Pumping (Dewatering) (10)	1	JOB				$100,000.00	$100,000	
	Subtotal Dewatering							*$690,000*	
	Concrete Removal								
	Spillway Bays	4600	CY		$38.50	$52.00	$90.50	$416,300	
	Subtotal Concrete Removal							*$416,300*	
	Concrete								
	Deflectors	42000	CY	$56.00	$66.65	$9.40	$132.05	$5,546,100	4000psi&crane
	Subtotal Concrete							*$5,546,100*	
	Steel Reinforcement	436.23	Ton	$535.00	$349.50	$15.20	$899.70	$392,476	
	Subtotal Steel Reinforcement							*$392,476*	
	Portland Cement	210000	Cwt	$3.64			$3.64	$764,400	means 033 100
	Pozzolan, Class N or F	84000	Cwt	$3.64			$3.64	$305,760	
	Subtotal Cementitious Materials							*$1,070,160*	
	Diving Inspection								
	Stilling Basin	1	JOB				$25,000.00	$25,000	
	Fishway Entrances	1	JOB				$5,000.00	$5,000	
	Conduct Tests for Dissolved Gas	1	JOB				$500,000.00	$500,000	
	Subtotal Diving Inspection and Tests							*$530,000*	
	Buildings, Grounds, and Utilities								

Summit Technology, Inc.

Bonneville Dam Alternative 1 - Stepped / Extended Deflectors

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Utilities	2	YR				$250,000.00	$500,000	
	Construction Facilities	1	JOB				$150,000.00	$150,000	
	Subtotal Buildings, Grounds, and Utilities							*$650,000*	
	Total							**$13,385,036**	
	Construction Cost Contingency (25%)							$3,346,259	
	Engineering and Design (18%)							$3,011,633	
	Supervision and Administration (10%)							$1,673,130	
	Project Cost							***$21,416,058***	
	Interest During Construction (8.125%)							$1,740,055	
	Investment Cost							***$23,156,113***	

Summit Technology, Inc.

Bonneville Dam Alternative 2 - Raised Tailrace

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Lands and Damages								
	Misc. Real Estate for Gravel Borrow	1	JOB				$400,000.00	$400,000	
	Subtotal Lands and Damages							*$400,000*	
	Fish and Wildlife								
	Raised Tailrace								
	Mobilization and Preparatory Work	1	JOB				$3,000,000	$3,000,000	
	Install Triangulation System	1	JOB				$100,000.00	$100,000	
	Subtotal Raised Tailrace							*$3,100,000*	
	Develop Quarry								
	Produce Rock	1725000	Ton				$11.00	$18,975,000	
	Floating Batch Plant	1	JOB				$500,000.00	$500,000	
	On-Shore Dock and Work Area								
	Remove Guardrails, Fences, and Rip-Rap	1	JOB				$100,000.00	$100,000	
	Install Shore Piling for Dock	1	JOB				$200,000.00	$200,000	
	Develop Rock Storage Area	1	JOB				$200,000.00	$200,000	
	Install Material Handling	1	JOB				$1,000,000	$1,000,000	
	Haul & Stockpile (Large Rock)	1725000	Ton				$7.40	$12,765,000	
	Barge Aggregates to Dam	1	JOB				$1,577,000.00	$1,577,000	
	Barge Cementitious Materials to Dam	1	JOB				$1,577,000.00	$1,577,000	
	Subtotal On-Shore Dock and Work Area							*$17,919,000*	
	Complete Bathymetric Survey	1	JOB				$30,000.00	$30,000	
	IWW Construction (Phases I & 2)								
	Load & Barge Armor Rock	1	JOB				$3,580,927	$3,580,927	
	Place Grout in Armor Rock	84400	CY	$56.00	$66.65	$9.40	$132.05	$11,145,020	
	Place Tremie Concrete	48800	CY	$56.00	$66.65	$9.40	$132.05	$6,444,040	
	Subtotal IWW Construction (Phases I & 2)							*$21,169,987*	
	Portland Cement	881040	Cwt	$3.64			$3.64	$3,206,986	means 033 100
	Pozzolan, Class N or F	467540	Cwt	$3.64			$3.64	$1,701,846	
	Subtotal Cementitious Materials							*$4,908,831*	
	Diving Inspection								

Summit Technology, Inc.

Bonneville Dam Alternative 2 - Raised Tailrace

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Stilling Basin	1	JOB				$25,000.00	$25,000	
	Fishway Entrances	1	JOB				$5,000.00	$5,000	
	Subtotal Diving Inspection and Tests							*$30,000*	
	Control Surveys (GPS)	1	JOB				$1,594,000	$1,594,000	
	Complete Bathymetric Survey	1	JOB				$30,000.00	$30,000	
	Demobilization	1	JOB				$30,000.00	$30,000	
	Conduct Spillway Tests for Gas	1	JOB				$500,000.00	$500,000	
	Buildings, Grounds, and Utilities								
	Utilities	3	YR				$250,000.00	$750,000	
	Construction Facilities	1	JOB				$150,000.00	$150,000	
	Subtotal Buildings, Grounds, and Utilities							*$900,000*	
	Total							**$69,586,818**	
	Construction Cost Contingency (25%)							$17,396,705	
	Engineering and Design (18%)							$15,657,034	
	Supervision and Administration (10%)							$8,698,352	
	Project Cost							***$111,338,909***	
	Interest During Construction (8.125%)							$9,046,286	
	Investment Cost							***$120,385,195***	

Summit Technology, Inc.

Bonneville Dam Alternative 3 - New Spillway Gates

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Lands and Damages								
	Misc. Real Estate for Gravel Borrow	1	JOB				$300,000.00	$300,000	
	Subtotal Lands and Damages							*$300,000*	
	Dams								
	New Spillway Gates								
	Mobilization and Preparatory Work	1	JOB				$9,000,000.00	$9,000,000	
	Dredging/Filling Deep Holes @ Apron								
	Phase I	67000	CY	$1.83	$1.79	$3.62	$7.24	$484,946	means 024-820
	Phase II	67000	CY	$1.83	$1.79	$3.62	$7.24	$484,946	means 024-821
	Phase III	81000	CY	$1.83	$1.79	$3.62	$7.24	$586,278	means 024-822
	Subtotal Dredging/Filling Deep Holes							*$10,556,170*	
	Dewatering, Downstream Cofferdam								
	Floating Wing Walls(2)(FWW)	1	JOB				$250,000.00	$250,000	
	Hydrographic Sounding (5 Times)	1	JOB				$50,000.00	$50,000	
	Diving Assistance (14 Times)	1	JOB				$350,000.00	$350,000	
	Cofferdam Steel Phase III	1425.6	Ton	$205.00	$118.00	$135.00	$458.00	$652,925	
	Install 2 FWW	1	JOB				$200,000.00	$200,000	
	Install Phase I Cells	1201	Ton	$205.00	$118.00	$135.00	$458.00	$550,058	
	Gravel Fill	114000	CY	$8.50	$4.69	$0.65	$13.84	$1,577,760	means 022-262
	Weep Holes	420	EA				$50.00	$21,000	
	Install 2 FWW Phase II	1	JOB				$200,000.00	$200,000	
	Remove Phase I Cells	1201	Ton						included w/install
	Remove Gravel Fill	114000	CY	$3.38	$4.58	$7.96	$15.92	$1,814,880	means 022-250
	Install Phase II Cells	1201	Ton	$205.00	$118.00	$135.00	$458.00	$550,058	
	Gravel Fill	114000	CY	$8.50	$4.69	$0.65	$13.84	$1,577,760	means 022-262
	Weep Holes	420	EA				$50.00	$21,000	
	Install 2 FWW Phase III	1	JOB				$200,000.00	$200,000	
	Remove Phase II Cells	1201	Ton						included w/install
	Remove Gravel Fill	114000	CY	$3.38	$4.58	$7.96	$15.92	$1,814,880	means 022-250
	Install Phase III Cells	1425.5	Ton	$205.00	$118.00	$135.00	$458.00	$652,879	

Summit Technology, Inc.

Bonneville Dam Alternative 3 - New Spillway Gates

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Gravel Fill	137000	CY	$8.50	$4.69	$0.65	$13.84	$1,896,080	means 022-262
	Weep Holes	420	EA				$50.00	$21,000	
	Remove Phase III Cells	1201	Ton						included w/install
	Remove Gravel Fill	137000	CY	$3.38	$4.58	$7.96	$15.92	$2,181,040	means 022-250
	Subtotal Dewatering, Downstream Cofferdam							*$14,581,320*	
	Concrete Removal								
	Remove Deflectors	1800	CY		$38.50	$52.00	$90.50	$162,900	means 020-554
	Remove Deflector Resteel	142.29	Ton		$4,000		$4,000.00	$569,160	
	Expose Pier Resteel on D/S	2000	CY		$33.00	$22.00	$55.00	$110,000	means 020-554
	Remove Pier Extensions (4)	13760	CY		$38.50	$52.00	$90.50	$1,245,280	means 020-554
	Remove Elevated Slabs (4)	350	CY		$38.50	$52.00	$90.50	$31,675	means 020-554
	Remove Ogee Concrete	300	CY		$200.00	$52.00	$252.00	$75,600	means 020-554
	Remove Baffles	530	CY		$38.50	$52.00	$90.50	$47,965	means 020-554
	Pier Foundations	640	CY		$38.50	$52.00	$90.50	$57,920	means 020-554
	Subtotal Concrete Removal							*$2,300,500*	
	Concrete Placement								
	Hoist Corbel	1520	CY	$56.00	$66.65	$9.40	$132.05	$200,716	
	Piers	81000	CY	$56.00	$66.65	$9.40	$132.05	$10,696,050	4000psi&crane
	Pier Foundations	640	CY	$56.00	$16.65	$9.40	$82.05	$52,512	
	Pier Excavation	2000	CY	$56.00	$16.65	$9.40	$82.05	$164,100	
	Gate Seats	100	CY	$56.00	$16.65	$9.40	$82.05	$8,205	
	Gate Storage Pits	2500	CY	$56.00	$16.65	$9.40	$82.05	$205,125	
	Spillway Ogee	1760	CY	$56.00	$16.65	$9.40	$82.05	$144,408	
	Subtotal Concrete Placement							*$11,471,116*	
	Steel Reinforcement								
	Piers	10224.945	Tons	$535.00	$349.50	$15.20	$899.70	$9,199,383	crane added
	Hoist Corbel	54	Tons	$535.00	$349.50	$15.20	$899.70	$48,584	
	Spillway Ogee	22	Tons	$535.00	$349.50	$15.20	$899.70	$19,793	
	Pier Post-Tensioning	1	JOB				$4,630,680.00	$4,630,680	
	#14 Bar Splices and Testing	1	JOB				$5,763,840.00	$5,763,840	
	Subtotal Steel Reinforcement							*$19,662,280*	
	Portland Cement	575000	CWT	$3.64			$3.64	$2,093,000	means 033 100

Summit Technology, Inc.

Bonneville Dam Alternative 3 - New Spillway Gates

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Pozzolan, Class N or F	95900	CWT	$3.64			$3.64	$349,076	
	Subtotal Cementitious Materials							*$2,442,076*	
	Embedded Items								
	End Pier Trunnion Girders	1	JOB				$66,080.00	$66,080	
	Intermediate Pier Trunnion Girders	1	JOB				$702,100.00	$702,100	
	Longitudinal Anchorage Assembly (Lg)	1	JOB				$4,460,400.00	$4,460,400	
	Longitudinal Anchorage Assembly (Sm)	1	JOB				$90,860.00	$90,860	
	Transverse Anchorage, End Piers	1	JOB				$198,240.00	$198,240	
	Transverse Anchorage, Intermediate Piers	1	JOB				$1,685,040.00	$1,685,040	
	Gate Side Seal Heaters	1	JOB				$2,079,000.00	$2,079,000	
	Gate Sill Beam Heaters	1	JOB				$594,720.00	$594,720	
	Subtotal Embedded Items							*$9,876,440*	
	Spillway Tainter Gates	1	JOB				$21,735,000.00	$21,735,000	
	Spillway Gate Stop Beams	1	JOB				$44,600.00	$44,600	
	Gate Opening Calibration	1	JOB				$37,170.00	$37,170	
	Subtotal Spillway Gates							*$21,816,770*	
	Mechanical / Electrical Equipment								
	Gate Seal Heaters	1	JOB				$637,870.00	$637,870	
	Pressure Sensing Equipment	1	JOB				$173,140.00	$173,140	
	Dewatering Pumps	1	JOB				$324,000.00	$324,000	
	Oil Transfer Pumps	1	JOB				$21,060.00	$21,060	
	Air Lines and Equipment	1	JOB				$210,600.00	$210,600	
	Lubricating System	1	JOB				$230,850.00	$230,850	
	Water Strainers and Filters	1	JOB				$76,950.00	$76,950	
	Manholes	1	JOB				$27,540.00	$27,540	
	Elevators (North and South Towers)	1	JOB				$324,000.00	$324,000	
	Cathodic Protection	1	JOB				$81,000.00	$81,000	
	Instrumentation Uplift Pressure	1	JOB				$4,050,000.00	$4,050,000	
	Spillway Gate Machinery	1	JOB				$12,643,600.00	$12,643,600	
	Domestic Water Supply (Mod)	1	JOB				$40,500.00	$40,500	
	Cast Iron Drains and Gates	1	JOB				$42,530.00	$42,530	
	Misc. Valves and Gages	1	JOB				$68,850.00	$68,850	

Summit Technology, Inc.

Bonneville Dam Alternative 3 - New Spillway Gates

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Subtotal Mechanical / Electrical Equipment							*$18,952,490*	
	Electrical Items and Controls								
	Power Source from PH2	1	JOB				$113,400.00	$113,400	
	Panel Boards, 480V Installed	1	JOB				$36,450.00	$36,450	
	Panel Boards, 110V Installed	1	JOB				$20,250.00	$20,250	
	Electrical Conduit Installed	1	JOB				$702,270.00	$702,270	
	Electrical Cable (3c No. 12)	1	JOB				$82,620.00	$82,620	
	Lighting System	1	JOB				$607,500.00	$607,500	
	Transformers	1	JOB				$12,150.00	$12,150	
	Power Receptacles 30 Amp, 480V	1	JOB				$12,960.00	$12,960	
	Gate Heaters	1	JOB				$115,430.00	$115,430	
	Code Call System	1	JOB				$24,300.00	$24,300	
	Equipment Cabinets	1	JOB				$16,200.00	$16,200	
	Control Stand Electrical	1	JOB				$52,650.00	$52,650	
	Cable Trays / Conduits	1	JOB				$121,500.00	$121,500	
	Intake Crane Mod.	1	JOB				$283,500.00	$283,500	
	Embedded Inserts	1	JOB				$48,600.00	$48,600	
	Pull Boxes	1	JOB				$162,000.00	$162,000	
	Fiber Optic / Digital Control	1	JOB				$269,890.00	$269,890	
	Metal Enclosures	1	JOB				$35,640.00	$35,640	
	Electrical Cable #12	1	JOB				$60,750.00	$60,750	
	Subtotal Electrical Items and Controls							*$2,778,060*	
	Diving Inspection								
	Stilling Basin	1	JOB				$25,000.00	$25,000	
	Fishway Entrances	1	JOB				$5,000.00	$5,000	
	Subtotal Diving Inspection							*$30,000*	
	Conduct Tests for Dissolved Gas	1	JOB				$500,000.00	$500,000	
	Roads and Bridges								
	New Spillway Bridge								
	Spillway Box Girders	1	JOB				$1,665,220.00	$1,665,220	
	Pier Extension (20 ft)	1	JOB				$3,264,000.00	$3,264,000	
	Parapet Walls and Slabs	1	JOB				$795,170.00	$795,170	

Summit Technology, Inc.

Bonneville Dam Alternative 3 - New Spillway Gates

Line	Item	Estimated Quantity	Unit	Unit Cost *Mat.*	*Lab.*	*Equ.*	*Total*	Total Cost	Notes
	Approach Piers and Footings	1820	CY	$56.00	$16.65	$9.40	$82.05	$149,331	
	Common Fill	890	CY	$3.89	$0.53	$1.43	$5.85	$5,207	means 022-282
	Base Course	1350	SY	$10.95	$0.40	$0.49	$11.84	$15,984	means 022-308, 12"
	Top Course	450	SY	$10.95	$0.40	$0.49	$11.84	$5,328	means 022-308, 12"
	A.C. Pavement	150	CY	$56.00	$16.65	$9.40	$82.05	$12,308	
	Subtotal Roads and Bridges							*$5,912,547*	
	Buildings, Grounds, and Utilities								
	Utilities	6	YR				$250,000.00	$1,500,000	
	Construction Facilities	1	JOB				$150,000.00	$150,000	
	Subtotal Buildings, Grounds, and Utilities							*$1,650,000*	
	Total							**$122,829,769**	
	Construction Cost Contingency (25%)							$30,707,442.25	
	Engineering and Design (18%)							$27,636,698	
	Supervision and Administration (10%)							$15,353,721	
	Project Cost							***$196,527,630***	
	Interest During Construction (8.125%)							$15,967,870	
	Investment Cost							***$212,495,500***	

Summit Technology, Inc.

Bonneville Dam Alternative 4 - Sluices Under Existing Spillway

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Lands and Damages								
	Misc. Real Estate for Gravel Borrow	1	JOB				$400,000.00	$400,000	
	Subtotal Lands and Damages							*$400,000*	
	Dams								
	Sluices Under Existing Spillway								
	Mobilization and Preparatory Work	1	JOB				$11,000,000.00	$11,000,000	
	Spillway Gantry Crane	1	JOB				$3,702,581.00	$3,702,581	
	Crane Girder Corbel Resteel	112.25	Ton	$535.00	$349.50	$15.20	$899.70	$100,991	
	Crane Girder Concrete Corbels	862	CY	$56.00	$66.65	$9.40	$132.05	$113,827	
	Crane Girder Pads	1	JOB				$96,650.00	$96,650	
	Crane Girder Precast Concrete	1	JOB				$490,650.00	$490,650	
	Crane Rails	1	JOB				$162,000.00	$162,000	
	Drill and Install Resteel	1	JOB				$844,510.00	$844,510	
	Subtotal Spillway Gantry Crane							*$16,511,209*	
	Sluices Under Existing Spillway	1	JOB						
	Dredging/Filling Deep Holes								
	Phase I	67000	CY	$1.83	$1.79	$3.62	$7.24	$484,946	means 024-820
	Phase II	67000	CY	$1.83	$1.79	$3.62	$7.24	$484,946	means 024-821
	Phase III	81000	CY	$1.83	$1.79	$3.62	$7.24	$586,278	means 024-822
	Subtotal Dredging/Filling Deep Holes							*$1,556,170*	
	Dewatering, Downstream Cofferdam								
	Hydrograph Soundings (5 Times)	1	JOB				$50,000.00	$50,000	
	Floating Wing Walls(2)(FWW)	1	JOB						
	Cofferdam Steel Phase III	1425.6	Ton	$205.00	$118.00	$135.00	$458.00	$652,925	
	Install 2 FWW	1	JOB				$200,000.00	$200,000	
	Install Phase I Cells	1201	Ton	$205.00	$118.00	$135.00	$458.00	$550,058	
	Gravel Fill	114000	CY	$8.50	$4.69	$0.65	$13.84	$1,577,760	means 022-262
	Weep Holes	420	EA				$50.00	$21,000	
	Install 2 FWW Phase II	1	JOB				$200,000.00	$200,000	

Summit Technology, Inc.

Bonneville Dam Alternative 4 - Sluices Under Existing Spillway

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Remove Phase I Cells	1201	Ton						included w/install
	Remove Gravel Fill	114000	CY	$3.38	$4.58	$7.96	$15.92	$1,814,880	means 022-250
	Install Phase II Cells	1201	Ton	$205.00	$118.00	$135.00	$458.00	$550,058	
	Gravel Fill	111000	CY	$8.50	$4.69	$0.65	$13.84	$1,536,240	means 022-262
	Weep Holes	420	EA				$50.00	$21,000	
	Install 2 FWW Phase III	1	JOB				$200,000.00	$200,000	
	Remove Phase II Cells	1201	Ton						included w/install
	Remove Gravel Fill	114000	CY	$3.38	$4.58	$7.96	$15.92	$1,814,880	means 022-250
	Install Phase III Cells	1425.5	Ton	$205.00	$118.00	$135.00	$458.00	$652,879	
	Gravel Fill	137000	CY	$8.50	$4.69	$0.65	$13.84	$1,896,080	means 022-262
	Weep Holes	420	EA				$50.00	$21,000	
	Remove Phase III Cells	1201	Ton						included w/install
	Remove Gravel Fill	137000	CY	$3.38	$4.58	$7.96	$15.92	$2,181,040	means 022-250
	Subtotal Dewatering, Downstream Cofferdam							*$13,939,800*	
	Upstream Floating Bulkhead								
	Floating Tanks	1	JOB				$200,000.00	$200,000	
	Bulkhead Protection El.-16.0 to El.+16.0	272.65	Ton	$1,725.00	$640.00	$233.00	$2,598.00	$708,345	means 051-255
	Stoplogs Protection Rl. +16.0 to El.81.0	299.25	Ton	$1,725.00	$640.00	$233.00	$2,598.00	$777,452	means 051-256
	Guideframe (Verts)	20.2	Ton	$1,725.00	$640.00	$233.00	$2,598.00	$52,480	means 051-257
	Guideframe (Horiz. and Diag)	51.435	Ton	$1,725.00	$640.00	$233.00	$2,598.00	$133,628	means 051-258
	Extention Plates and Misc.	2.75	Ton	$1,725.00	$640.00	$233.00	$2,598.00	$7,145	means 051-259
	Lifting Beam	1	JOB				$123,900.00	$123,900	
	Dewatering Pumps / Valves	1	JOB				$150,000.00	$150,000	
	Stoplog Seal Assemblies	1	JOB				$144,550.00	$144,550	
	Subtotal U/S F/B Costs (2 Required) X 2							*$4,594,997*	
	Bulkhead Installation (17 Items)	1	JOB				$3,400,000.00	$3,400,000	
	Bulkhead Diving / Dredging (17 Items)	1	JOB				$850,000.00	$850,000	
	Concrete Removal								
	Spillway Bays	251770	CY		$38.50	$52.00	$90.50	$22,785,185	
	Gate Slots	1040	CY		$38.50	$52.00	$90.50	$94,120	
	Diamond Cut 2' Deep	1646	LF				$50.00	$82,300	
	Remove & Dispose	1	JOB				$21,930.00	$21,930	

Summit Technology, Inc.

Bonneville Dam Alternative 4 - Sluices Under Existing Spillway

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Baffles	5320	CY		$38.50	$52.00	$90.50	$481,460	
	Subtotal Concrete Removal							*$23,464,995*	
	Concrete								
	Pier Corbel	862	CY	$56.00	$66.65	$9.40	$132.05	$113,827	
	Invert Slab	15470	CY	$56.00	$16.65	$9.40	$82.05	$1,269,314	4000psi&crane
	Sluice Piers	30923	CY	$56.00	$184.00	$9.40	$249.40	$7,712,196	
	Stilling Basin	32300	CY	$56.00	$184.00	$9.40	$249.40	$8,055,620	
	Spillway Ogee	142120	CY	$56.00	$16.65	$9.40	$82.05	$11,660,946	
	Access Shafts & Hatches	1	JOB				$128,930.00	$128,930	
	Subtotal Concrete							*$28,940,833*	
	Steel Reinforcement	5666.15	Ton	$535.00	$349.50	$15.20	$899.70	$5,097,835	
	Prestress / Post-Tension Existing S/W Piers	1	JOB				$2,441,500.00	$2,441,500	
	Cementitious Material								
	Portland Cement	1330050	Cwt	$3.64			$3.64	$4,841,382	means 033 100
	Pozzulan, Class N or F	445074	Cwt	$3.64			$3.64	$1,620,069	
	Subtotal Cementitious Material							*$6,461,451*	
	Embedded Items								
	End Pier Reinforcement	1	JOB				$144,500.00	$144,500	
	Intermediate Pier Reinforcement	1	JOB				$1,895,670.00	$1,895,670	
	Drill and Install Anchorages	1	JOB				$8,659,900.00	$8,659,900	
	Drill and Install Corbel Resteel	1	JOB				$844,510.00	$844,510	
	Subtotal Embedded Items							*$11,544,580*	
	Under Drainage System	1	JOB				$110,210.00	$110,210	
	Spillway Bulkheads	1	JOB				$3,717,900.00	$3,717,900	
	Side Plates and Guides	1	JOB				$5,783,400.00	$5,783,400	
	Spillway Lifting Beam	1	JOB				$30,780.00	$30,780	
	Gate Opening Calibration	1	JOB				$510,000.00	$510,000	
	Mechanical / Electrical Equipment								
	Gate Seal Heaters	1	JOB				$662,440.00	$662,440	
	Pressure Sensing Equipment	1	JOB				$163,520.00	$163,520	
	Dewatering Pumps	1	JOB				$324,000.00	$324,000	
	Oil Transfer Pumps	1	JOB				$21,060.00	$21,060	

Summit Technology, Inc.

Bonneville Dam Alternative 4 - Sluices Under Existing Spillway

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Air Lines and Equipment	1	JOB				$210,600.00	$210,600	
	Lubricating System	1	JOB				$218,700.00	$218,700	
	Water Strainers and Filters	1	JOB				$76,950.00	$76,950	
	Manholes	1	JOB				$27,540.00	$27,540	
	Elevators (North and South Towers)	1	JOB				$324,000.00	$324,000	
	Cathodic Protection	1	JOB				$81,000.00	$81,000	
	Instrumentation Uplift Pressure	1	JOB				$4,050,000.00	$4,050,000	
	Spillway Gate Machinery	1	JOB				$12,643,600	$12,643,600	
	Domestic Water Supply (Mod)	1	JOB				$40,500.00	$40,500	
	Cast Iron Drains and Gates	1	JOB				$42,525.00	$42,525	
	Misc. Valves and Gages	1	JOB				$68,850.00	$68,850	
	Subtotal Mechanical / Electrical Equipment							*$16,845,475*	
	Electrical Items and Controls								
	Power Source from PH2	1	JOB				$113,400.00	$113,400	
	Panel Boards, 480V Installed	1	JOB				$36,450.00	$36,450	
	Panel Boards, 110V Installed	1	JOB				$20,250.00	$20,250	
	Electrical Conduit Installed	1	JOB				$702,270.00	$702,270	
	Electrical Cable (3c No. 12)	1	JOB				$82,620.00	$82,620	
	Lighting System	1	JOB				$607,500.00	$607,500	
	Transformers	1	JOB				$12,150.00	$12,150	
	Power Receptacles 30 Amp, 480V	1	JOB				$12,960.00	$12,960	
	Gate Heaters	1	JOB				$115,430.00	$115,430	
	Code Call System	1	JOB				$24,300.00	$24,300	
	Equipment Cabinets	1	JOB				$16,200.00	$16,200	
	Control Stand Electrical	1	JOB				$52,650.00	$52,650	
	Cable Trays / Conduits	1	JOB				$121,500.00	$121,500	
	Intake Crane Mod.	1	JOB				$283,500.00	$283,500	
	Embedded Inserts	1	JOB				$48,600.00	$48,600	
	Pull Boxes	1	JOB				$162,000.00	$162,000	
	Fiber Optic / Digital Control	1	JOB				$269,890.00	$269,890	
	Metal Enclosures	1	JOB				$35,640.00	$35,640	
	Electrical Cable #12	1	JOB				$60,750.00	$60,750	

Summit Technology, Inc.

Bonneville Dam Alternative 4 - Sluices Under Existing Spillway

Line	Item	Estimated Quantity	Unit	Unit Cost Mat.	Unit Cost Lab.	Unit Cost Equ.	Unit Cost Total	Total Cost	Notes
	Subtotal Electrical Items and Controls							*$2,778,060*	
	Diving Inspection								
	Stilling Basin	1	JOB				$25,000.00	$25,000	
	Fishway Entrances	1	JOB				$5,000.00	$5,000	
	Subtotal Diving Inspection							*$30,000*	
	Conduct Tests for Dissolved Gas	1	JOB				$500,000.00	$500,000	
	Buildings, Grounds, and Utilities								
	Utilities	6	YR				$250,000.00	$1,500,000	
	Construction Facilities	1	JOB				$150,000.00	$150,000	
	Subtotal Buildings, Grounds, and Utilities							*$1,650,000*	
	Total							**$158,322,441**	
	Construction Cost Contingency (25%)							$39,580,610.31	
	Engineering and Design (18%)							$35,622,549	
	Supervision and Administration (10%)							$19,790,305	
	Project Cost							***$253,315,906***	
	Interest During Construction (8.125%)							$20,581,917	
	Investment Cost							***$273,897,823***	

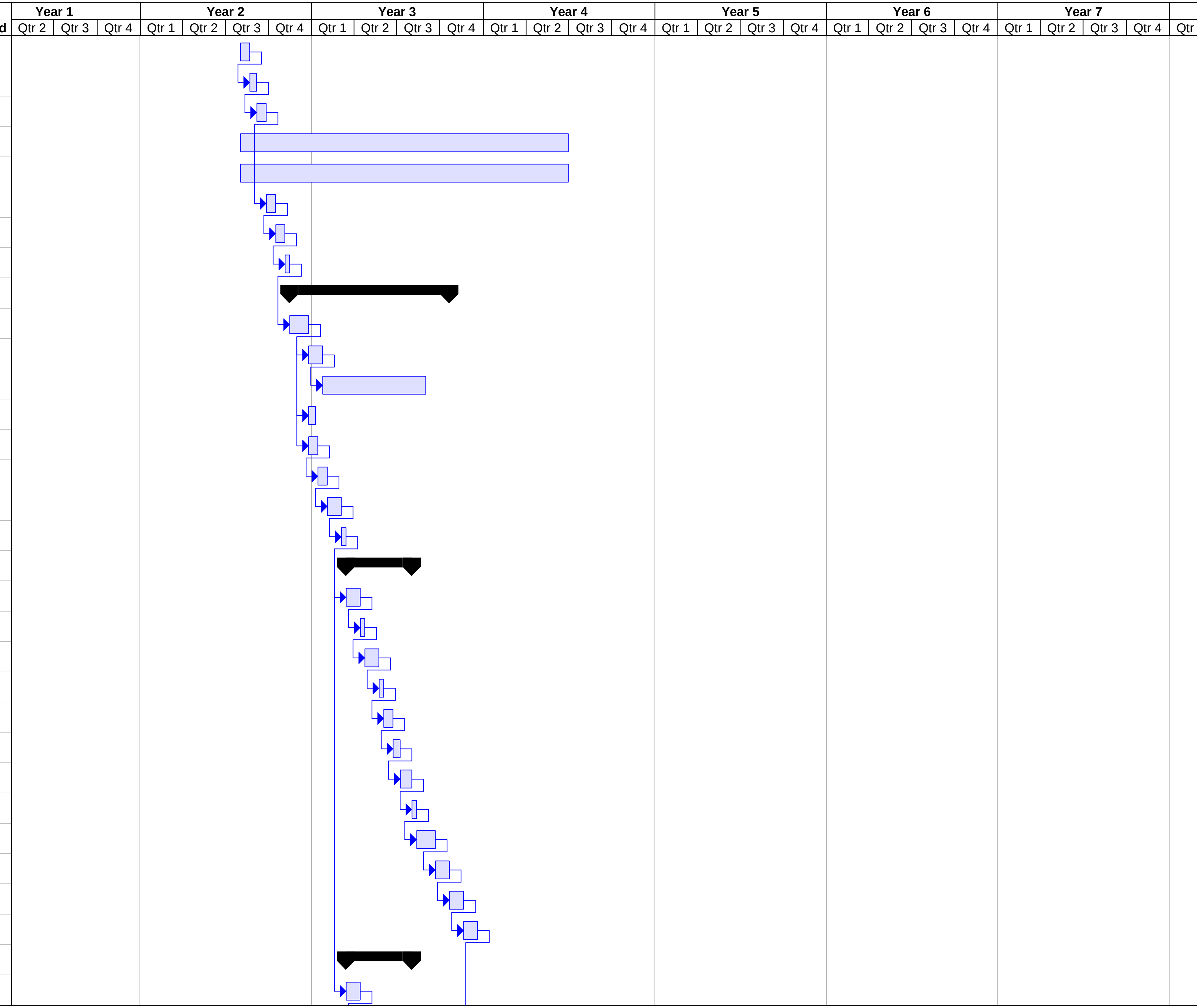
APPENDIX C

Schedules

- Alternative 1 - Stepped / Extended Deflectors, Design
- Alternative 1 - Stepped / Extended Deflectors, Construction
- Alternative 2 - Raised Tailrace, Design
- Alternative 2 - Raised Tailrace, Construction
- Alternative 3 - New Spillway Gates, Design
- Alternative 3 - New Spillway Gates, Construction
- Alternative 4 - Sluices Under Existing Spillway, Design
- Alternative 4 - Sluices Under Existing Spillway, Construction

Schedule: Dissolved Gas Abatement Study Alternative 1: Stepped / Extended Deflectors Design Bonneville Dam

ID	Task Name	Duration	Start	Finish	Pred
1	Spillway Deflector Design/Rec'd Funding	4w	8/3/98	8/22/98	
2	Scope - Feature Design Memo No. 1	3w	8/23/98	9/6/98	1
3	Issue Notice to CBD - FDM No. 1	4w	9/7/98	9/26/98	2
4	Coordination w/Navigation & Power Interest	698d	8/3/98	6/30/00	
5	Coordinate w/USF&WS & Wash. F & G	698d	8/3/98	6/30/00	
6	Issue Request for Proposal - FDM No.1	4w	9/27/98	10/16/98	3
7	Receive Proposals, Select & Issue NTP	4w	10/17/98	11/5/98	6
8	Project Site Visits & Collect Data	2w	11/6/98	11/15/98	7
9	**Draft Report - Feature DM**	**340d**	**11/16/98**	**10/21/99**	
10	Draft Economic Report	8w	11/16/98	12/25/98	8
11	Complete Final Model Construction	6w	12/26/98	1/24/99	10
12	Complete Model Testing	44w	1/25/99	9/1/99	11
13	Complete Bathymetry Survey	3w	12/26/98	1/9/99	10
14	Issue Notice to CBD for Feasability Report	4w	12/26/98	1/14/99	10
15	Issue Request for Proposal	4w	1/15/99	2/3/99	14
16	Receive Proposals, Select & Issue NTP	6w	2/4/99	3/5/99	15
17	Project Site Visits & Collect Data	2w	3/6/99	3/15/99	16
18	**Feature DM Report**	**140d**	**3/16/99**	**8/2/99**	
19	30% Draft Report	6w	3/16/99	4/14/99	17
20	30% Draft Review Meeting	2w	4/15/99	4/24/99	19
21	60% Draft Report w/Explorations	6w	4/25/99	5/24/99	20
22	60% Draft Review Meeting	2w	5/25/99	6/3/99	21
23	90% Draft Report	4w	6/4/99	6/23/99	22
24	90% Review Meeting	3w	6/24/99	7/8/99	23
25	Final Report & Submit to Division	5w	7/9/99	8/2/99	24
26	Incorporate Division Comments	2w	8/3/99	8/12/99	25
27	Submit Feature Report to USACE	8w	8/13/99	9/21/99	26
28	Receive Approval	6w	9/22/99	10/21/99	27
29	Submit to Committee & Testify to Congress	6w	10/22/99	11/20/99	28
30	Receive Authorized Funds for Planning & Engineers	6w	11/21/99	12/20/99	29
31	**Floating Bulkhead P&S**	**140d**	**3/16/99**	**8/2/99**	
32	30% Draft Report	6w	3/16/99	4/14/99	17



Project:
Date: 11/16/98

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress

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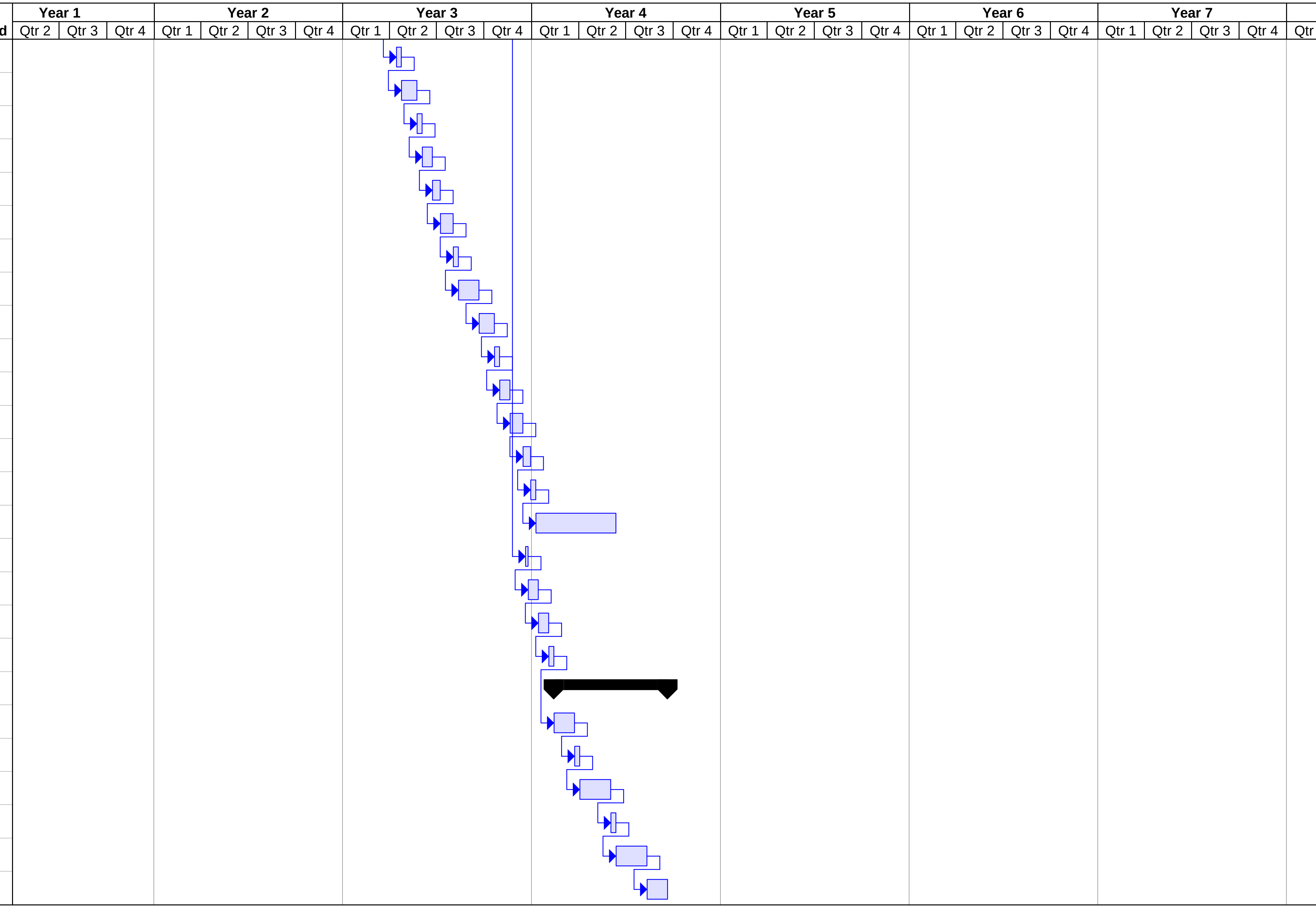
Schedule: Dissolved Gas Abatement Study Alternative 1: Stepped / Extended Deflectors Design Bonneville Dam

ID	Task Name	Duration	Start	Finish	Pred
33	30% Draft Review Meeting	2w	4/15/99	4/24/99	32
34	60% Draft Report w/Explorations	6w	4/25/99	5/24/99	33
35	60% Draft Review Meeting	2w	5/25/99	6/3/99	34
36	90% Draft Report	4w	6/4/99	6/23/99	35
37	90% Review Meeting	3w	6/24/99	7/8/99	36
38	Final Report & Submit to Division	5w	7/9/99	8/2/99	37
39	Incorporate Division Comments	2w	8/3/99	8/12/99	38
40	Submit Feature Report to USACE	8w	8/13/99	9/21/99	39
41	Receive Approval	6w	9/22/99	10/21/99	40
42	Receive Funds for Steel Bulkhead & FW Walls	2w	10/22/99	10/31/99	41
43	Issue Notice to CBD for Steel BUlkhead & FW Walls	4w	11/1/99	11/20/99	42
44	Issue IFB for Steel Bulkhead & FW Walls	5w	11/21/99	12/15/99	43
45	Open Bids and Award Bulkhead & FW Walls	3w	12/16/99	12/30/99	44
46	Issue NTP for Supply Contract for Bulkhead & FW Walls	2w	12/31/99	1/9/00	45
47	Fabricate Bulkhead & FW Walls	31w	1/10/00	6/12/00	46
48	Issue Notice to CBD - Stepped / Extended Deflectors	1w	12/21/99	12/25/99	30
49	Issue Request for Proposal P & S	4w	12/26/99	1/14/00	48
50	Receive Proposals, Select & Issue NTP	4w	1/15/00	2/3/00	49
51	Project Site Visits & Collect Data	2w	2/4/00	2/13/00	50
52	**Plans & Specifications**	**220d**	**2/14/00**	**9/20/00**	
53	30% Plans & Specifications Submittal	8w	2/14/00	3/24/00	51
54	30% Plans & Specifications Review Meeting	2w	3/25/00	4/3/00	53
55	60% Plans & Specifications Submittal	12w	4/4/00	6/2/00	54
56	60% Plans & Specifications Review Meeting	2w	6/3/00	6/12/00	55
57	90% Plans & Specifications Submittal	12w	6/13/00	8/11/00	56
58	Final Plans & Specifications	8w	8/12/00	9/20/00	57

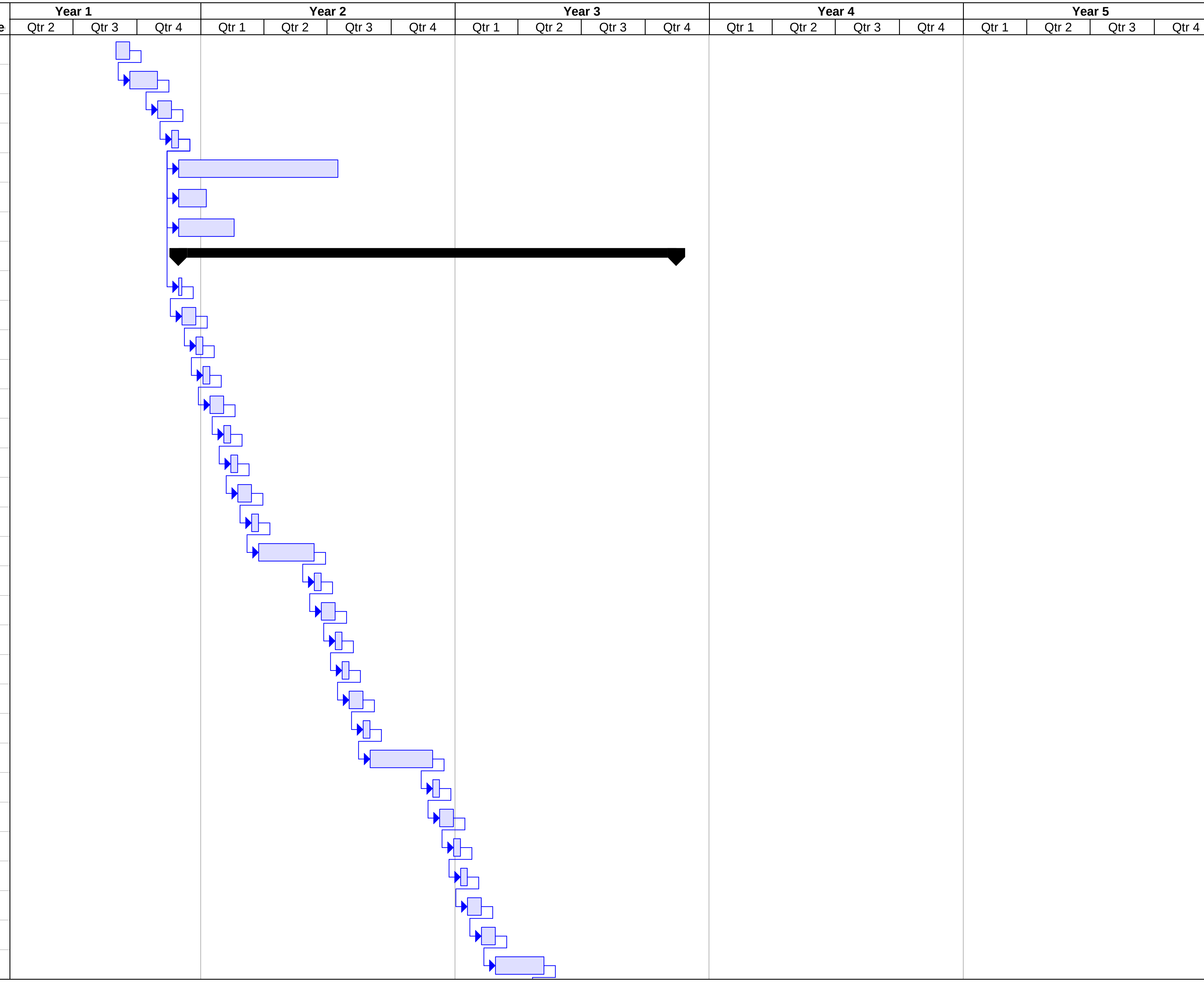


Project:
Date: 11/16/98

Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

Schedule: Dissolved Gas Abatement Study Alternative 1: Stepped / Extended Deflectors with Floating Bulkhead Construction Bonneville Dam

ID	Task Name	Duration	Start	Finish	Pre
1	Issue Notice to CBD for Construction	4w	9/1/00	9/20/00	
2	Issue IFB for Construction	8w	9/21/00	10/30/00	1
3	Open Bids & Award Contract	4w	10/31/00	11/19/00	2
4	Issue Notice to Proceed	2w	11/20/00	11/29/00	3
5	Mobilization	229d	11/30/00	7/16/01	4
6	Preparatory Site Work with Spillway Crane	8w	11/30/00	1/8/01	4
7	Floating Batch Plant & Move Equipment	16w	11/30/00	2/17/01	4
8	**Floating Bulkhead Cofferdam**	**715d**	**11/30/00**	**11/14/02**	
9	Install 1/2 F/B C/D Bays 1 & 18	1w	11/30/00	12/4/00	4
10	Concrete Removal	4w	12/5/00	12/24/00	9
11	Place Resteel & Concrete	2w	12/25/00	1/3/01	10
12	Re-install Full (1) F/B C/D Bays 2 & 3	2w	1/4/01	1/13/01	11
13	Concrete Removal	4w	1/14/01	2/2/01	12
14	Place Resteel & Concrete	2w	2/3/01	2/12/01	13
15	Re-install Full (2) F/B C/D Bays 4 & 5	2w	2/13/01	2/22/01	14
16	Concrete Removal	4w	2/23/01	3/14/01	15
17	Place Resteel & Concrete	2w	3/15/01	3/24/01	16
18	Remove F/B C/D From Spillway	16w	3/25/01	6/12/01	17
19	Re-install Full (2) F/B C/D Bays 8 & 9	2w	6/13/01	6/22/01	18
20	Concrete Removal	4w	6/23/01	7/12/01	19
21	Place Resteel & Concrete	2w	7/13/01	7/22/01	20
22	Re-install Full (2) F/B C/D Bays 10 & 11	2w	7/23/01	8/1/01	21
23	Concrete Removal	4w	8/2/01	8/21/01	22
24	Place Resteel & Concrete	2w	8/22/01	8/31/01	23
25	Remove F/B C/D From Spillway	18w	9/1/01	11/29/01	24
26	Re-install Full (2) F/B C/D Bays 12 &13	2w	11/30/01	12/9/01	25
27	Concrete Removal	4w	12/10/01	12/29/01	26
28	Place Resteel & Concrete	2w	12/30/01	1/8/02	27
29	Re-install Full (2) F/B C/D Bays 14 &15	2w	1/9/02	1/18/02	28
30	Concrete Removal	4w	1/19/02	2/7/02	29
31	Place Resteel & Concrete	4w	2/8/02	2/27/02	30
32	Remove F/B C/D From Spillway	14w	2/28/02	5/8/02	31



Project:
Date: 11/16/98

Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

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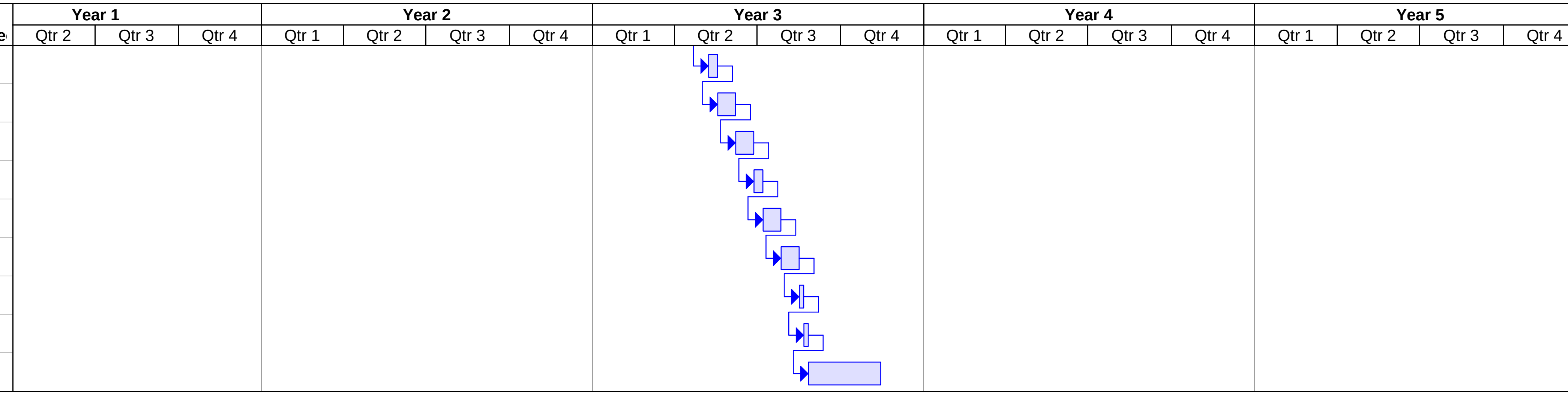
Schedule: Dissolved Gas Abatement Study Alternative 1: Stepped / Extended Deflectors with Floating Bulkhead Construction Bonneville Dam

ID	Task Name	Duration	Start	Finish	Pre
33	Re-install Full (2) F/B C/D Bays 6 & 7	2w	5/9/02	5/18/02	32
34	Concrete Removal	4w	5/19/02	6/7/02	33
35	Place Resteel & Concrete	4w	6/8/02	6/27/02	34
36	Re-install Full (1) F/B C/D Bays 16 &17	2w	6/28/02	7/7/02	35
37	Concrete Removal	4w	7/8/02	7/27/02	36
38	Place Resteel & Concrete	4w	7/28/02	8/16/02	37
39	Remove F/B C/D & Store	1w	8/17/02	8/21/02	38
40	Diving Inspection of Stilling Basin	1w	8/22/02	8/26/02	39
41	Conduct Spillway Tests for Dissolved Gas	16w	8/27/02	11/14/02	40



Project:
Date: 11/16/98

Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

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Schedule: Dissolved Gas Abatement Study Alternative 2: Raised Tailrace Design Bonneville Dam

ID	Task Name	Duration	Start	Finish	Pred
1	Raised Tailrace Design/Rec'd Funding	4w	8/3/98	8/22/98	
2	Scope - Letter Report	3w	8/23/98	9/6/98	1
3	Issue Notice to CBD - Letter Report No. 1	4w	9/7/98	9/26/98	2
4	Coordination w/Navigation & Power Interest	730d	8/3/98	8/1/00	
5	Coordinate w/USF&WS & Wash. F & G	730d	8/3/98	8/1/00	
6	Issue Request for Proposal - Letter Report No.1	4w	9/27/98	10/16/98	3
7	Receive Proposals, Select & Issue NTP	4w	10/17/98	11/5/98	6
8	Project Site Visits & Collect Data	2w	11/6/98	11/15/98	7
9	**Draft Letter Report**	**340d**	**11/16/98**	**10/21/99**	
10	Draft Economic Report	8w	11/16/98	12/25/98	8
11	Complete Final Model Construction	6w	12/26/98	1/24/99	10
12	Complete Model Testing	44w	1/25/99	9/1/99	11
13	Complete Bathymetry Survey	3w	12/26/98	1/9/99	10
14	Issue Notice to CBD for Letter Report	4w	12/26/98	1/14/99	10
15	Issue Request for Proposal	4w	1/15/99	2/3/99	14
16	Receive Proposals, Select & Issue NTP	6w	2/4/99	3/5/99	15
17	Project Site Visits & Collect Data	2w	3/6/99	3/15/99	16
18	**Letter Report**	**140d**	**3/16/99**	**8/2/99**	
19	30% Draft Report	6w	3/16/99	4/14/99	17
20	30% Draft Review Meeting	2w	4/15/99	4/24/99	19
21	60% Draft Report w/Explorations	6w	4/25/99	5/24/99	20
22	60% Draft Review Meeting	2w	5/25/99	6/3/99	21
23	90% Draft Report	4w	6/4/99	6/23/99	22
24	90% Review Meeting	3w	6/24/99	7/8/99	23
25	Final Report & Submit to Division	5w	7/9/99	8/2/99	24
26	Incorporate Division Comments	2w	8/3/99	8/12/99	25
27	Submit Letter Report to USACE	8w	8/13/99	9/21/99	26
28	Receive Approval	6w	9/22/99	10/21/99	27
29	Submit to Committee & Testify to Congress	6w	10/22/99	11/20/99	28
30	Receive Authorized Funds for Planning & Engineer	6w	11/21/99	12/20/99	29
31	Issue Notice to CBD - Raised Tailrace P & S	4w	12/21/99	1/9/00	30
32	Issue Request for Proposal P & S	4w	1/10/00	1/29/00	31

Project:
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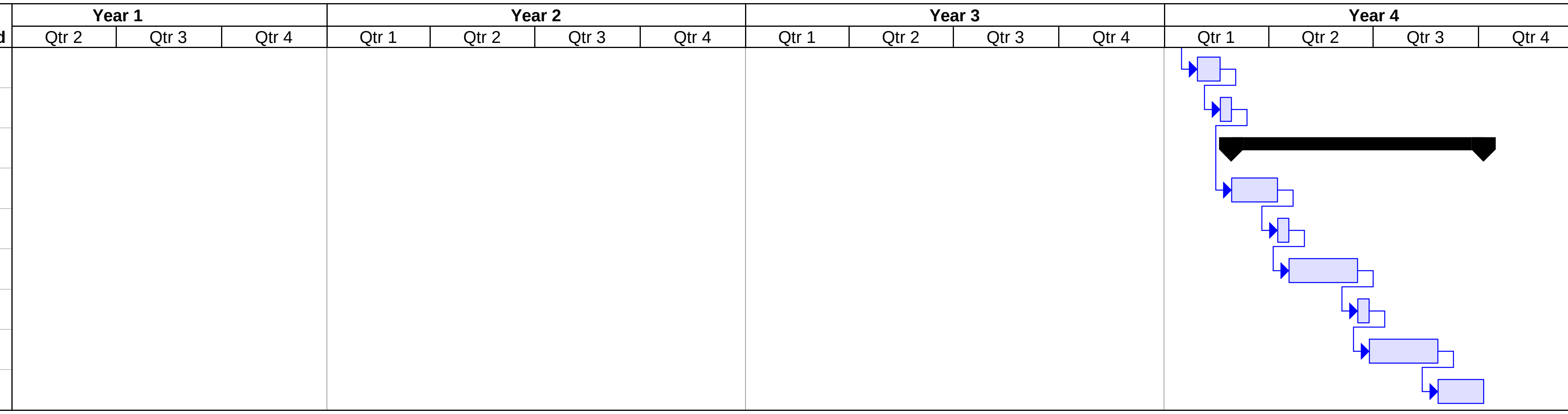
Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

Schedule: Dissolved Gas Abatement Study Alternative 2: Raised Tailrace Design Bonneville Dam

ID	Task Name	Duration	Start	Finish	Pred
33	Receive Proposals, Select & Issue NTP	4w	1/30/00	2/18/00	32
34	Project Site Visits & Collect Data	2w	2/19/00	2/28/00	33
35	**Plans & Specifications**	**220d**	**2/29/00**	**10/5/00**	
36	30% Plans & Specifications Submittal	8w	2/29/00	4/8/00	34
37	30% Plans & Specifications Review Meeting	2w	4/9/00	4/18/00	36
38	60% Plans & Specifications Submittal	12w	4/19/00	6/17/00	37
39	60% Plans & Specifications Review Meeting	2w	6/18/00	6/27/00	38
40	90% Plans & Specifications Submittal	12w	6/28/00	8/26/00	39
41	Final Plans & Specifications	8w	8/27/00	10/5/00	40

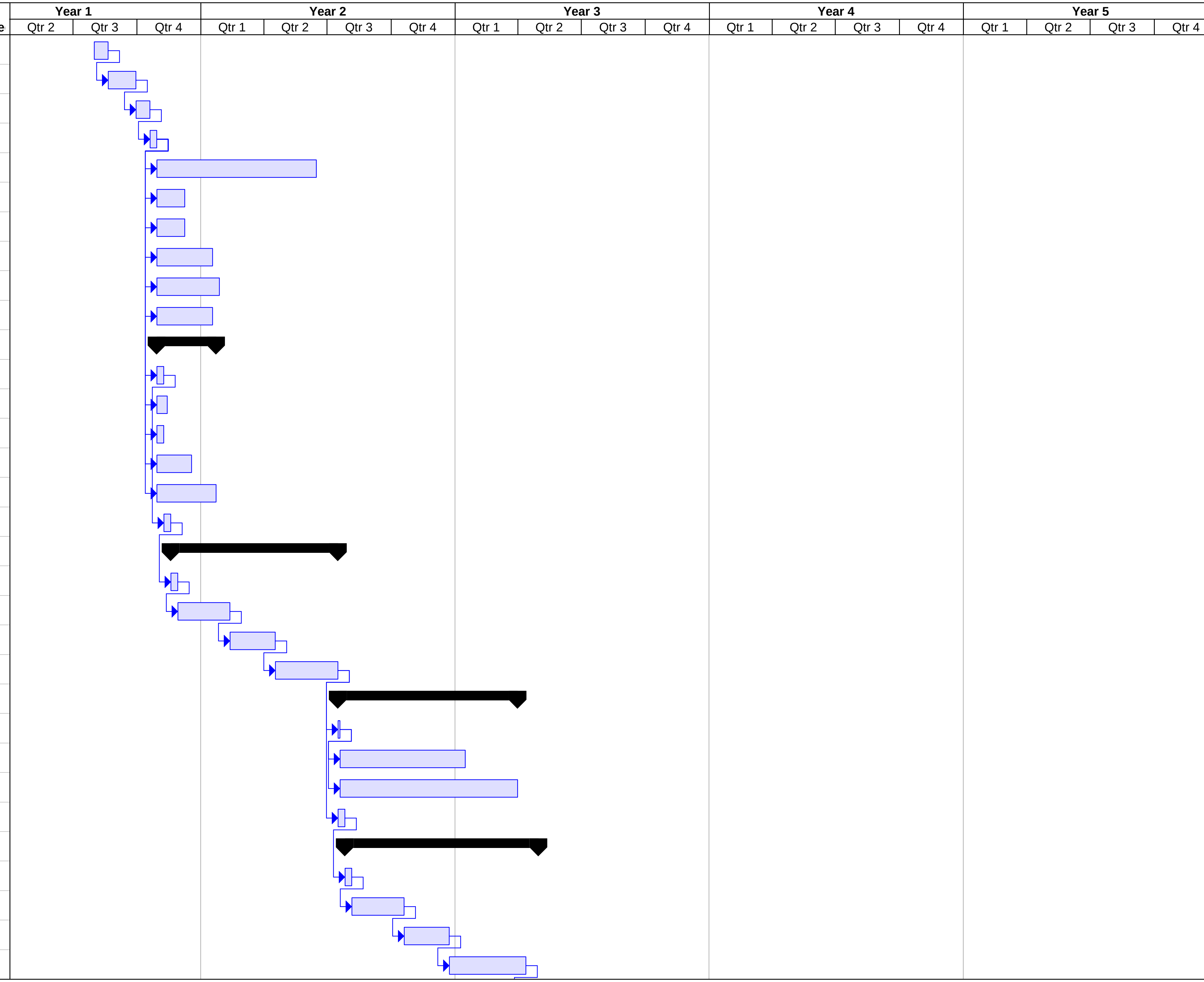


Project:
Date: 11/16/98

Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

Schedule: Dissolved Gas Abatement Study Alternative 2: Raised Tailrace Construction Bonneville Dam

ID	Task Name	Duratior	Start	Finish	Pre
1	Issue Notice to CBD for IFB Construction	4w	8/1/00	8/20/00	
2	Issue IFB for Raised Tailrace Construction	8w	8/21/00	9/29/00	1
3	Open Bids & Award Contract	4w	9/30/00	10/19/00	2
4	Issue Notice to Proceed	2w	10/20/00	10/29/00	3
5	Mobilization	229d	10/30/00	6/15/01	4
6	Install Triangulation System	8w	10/30/00	12/8/00	4
7	Preparatory Site Work	8w	10/30/00	12/8/00	4
8	Develop Quarry	16w	10/30/00	1/17/01	4
9	Produce Rock	18w	10/30/00	1/27/01	4
10	Floating Batch Plant & Move Equipment	16w	10/30/00	1/17/01	4
11	**On-shore Dock**	**85d**	**10/30/00**	**1/22/01**	
12	Remove Guardrails, Fences & Rip Rap	2w	10/30/00	11/8/00	4
13	Install Shore Piling for Dock	3w	10/30/00	11/13/00	4
14	Develop Rock Storage Area	2w	10/30/00	11/8/00	4
15	Install Material Handling	10w	10/30/00	12/18/00	4
16	Haul & Stockpile (Aggregate & Large Rock)	17w	10/30/00	1/22/01	4
17	Complete Bathymetry Survey	2w	11/9/00	11/18/00	12
18	**IWW Construction Phase I**	**240d**	**11/19/00**	**7/16/01**	
19	Install GPS	2w	11/19/00	11/28/00	17
20	Barge Large Armor Rock	15w	11/29/00	2/11/01	19
21	Place Grout in Armor Rock	13w	2/12/01	4/17/01	20
22	Place Tremmie Concrete	18w	4/18/01	7/16/01	21
23	**IWW Preliminary Work Phase II**	**258d**	**7/17/01**	**3/31/02**	
24	Diving Inspection	3d	7/17/01	7/19/01	22
25	Produce Rock	36w	7/20/01	1/15/02	24
26	Haul & Stockpile Agreegate & Rock	51w	7/20/01	3/31/02	24
27	Complete Bathymetry Survey	2w	7/17/01	7/26/01	22
28	**IWW Construction Phase II**	**278d**	**7/27/01**	**4/30/02**	
29	Install GPS	2w	7/27/01	8/5/01	27
30	Barge Large Armor Rock	15w	8/6/01	10/19/01	29
31	Place Grout in Armor Rock	13w	10/20/01	12/23/01	30
32	Place Tremmie Concrete	22w	12/24/01	4/12/02	31



Project:
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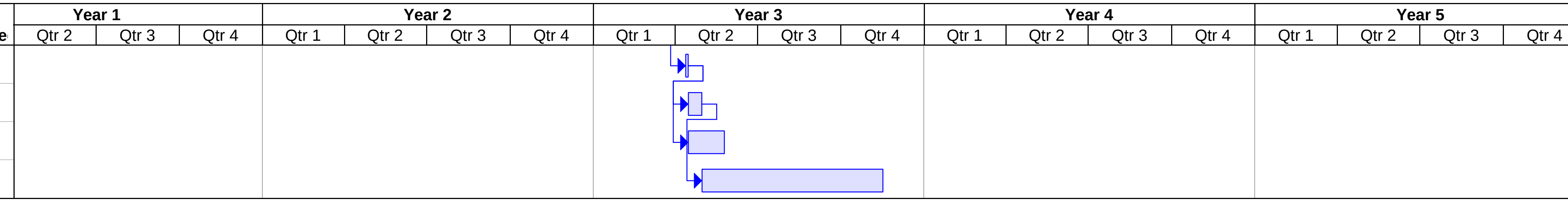
Task	Milestone	Rolled Up Task	Rolled Up Progress
Progress	Summary	Rolled Up Milestone	

Schedule: Dissolved Gas Abatement Study Alternative 2: Raised Tailrace Construction Bonneville Dam

ID	Task Name	Duratior	Start	Finish	Pre
33	Diving Inspection	3d	4/13/02	4/15/02	32
34	Complete Bathymetry Survey	3w	4/16/02	4/30/02	33
35	Demobilization	8w	4/16/02	5/25/02	33
36	Conduct Spillway Tests for Gas	40w	5/1/02	11/16/02	34



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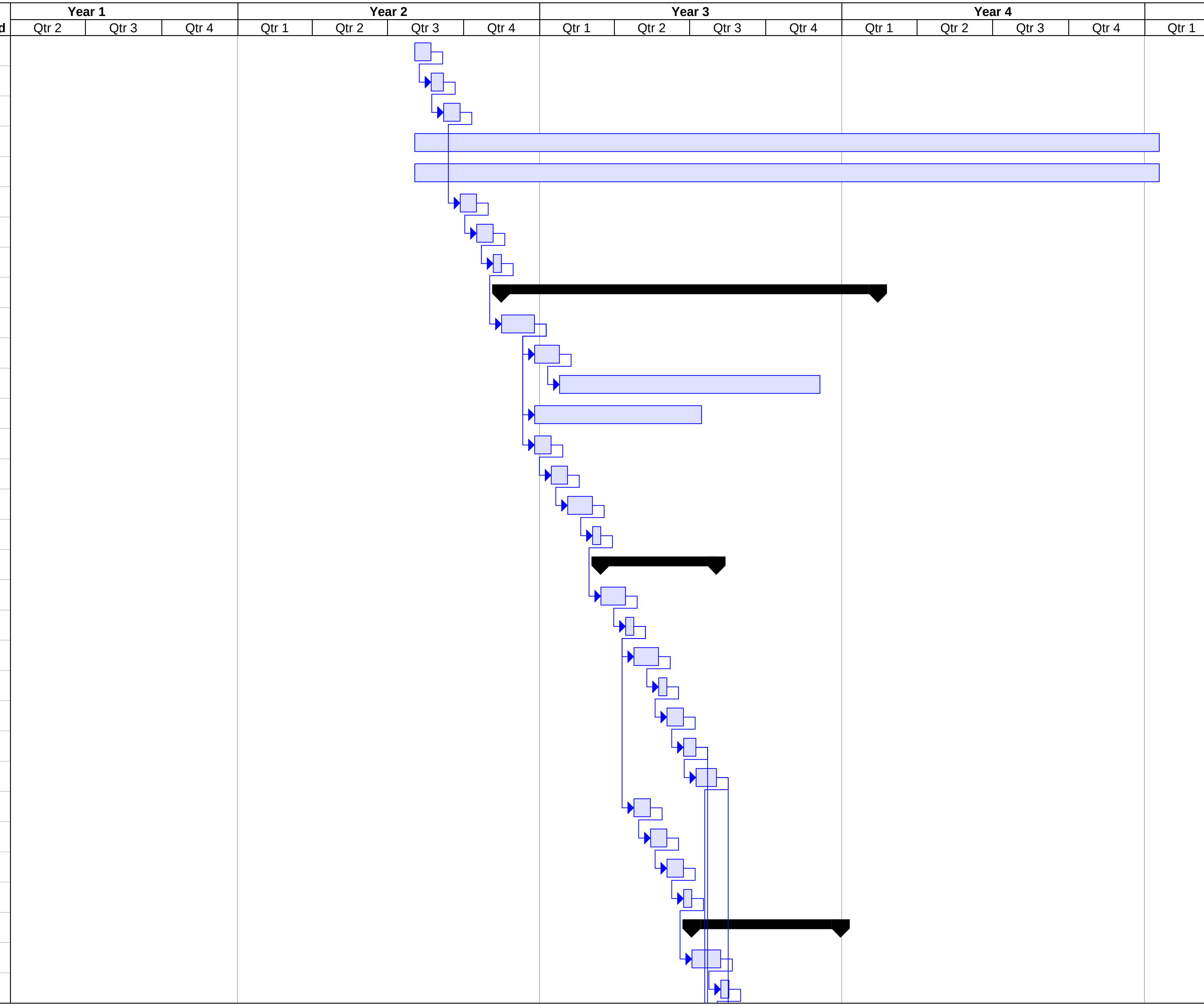
Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

Schedule: Dissolved Gas Abatement Study Alternative 3: New Spillway Gates Design Bonneville Dam

ID	Task Name	Duratior	Start	Finish	Pred
1	Side Channel Spillway Design/Rec'd Funding	4w	8/3/98	8/22/98	
2	Scope - General Design Memo No. 1	3w	8/23/98	9/6/98	1
3	Issue Notice to CBD - FDM No. 1	4w	9/7/98	9/26/98	2
4	Coordination w/Navigation & Power Interest	900d	8/3/98	1/18/01	
5	Coordinate w/USF&WS & Wash. F & G	900d	8/3/98	1/18/01	
6	Issue Request for Proposal - FDM No.1	4w	9/27/98	10/16/98	3
7	Receive Proposals, Select & Issue NTP	4w	10/17/98	11/5/98	6
8	Project Site Visits & Collect Data	2w	11/6/98	11/15/98	7
9	**Draft Report - Feasibility**	**455d**	**11/16/98**	**2/13/00**	
10	Draft Economic Report	8w	11/16/98	12/25/98	8
11	Complete Final Model Construction	6w	12/26/98	1/24/99	10
12	Complete Model Testing	63w	1/25/99	12/5/99	11
13	Complete Explorations	202d	12/26/98	7/15/99	10
14	Issue Notice to CBD for Cofferdam Design	4w	12/26/98	1/14/99	10
15	Issue Request for Proposal	4w	1/15/99	2/3/99	14
16	Receive Proposals, Select & Issue NTP	6w	2/4/99	3/5/99	15
17	Project Site Visits & Collect Data	2w	3/6/99	3/15/99	16
18	**Report Cofferdam Design EM1110-2-2503**	**140d**	**3/16/99**	**8/2/99**	
19	30% Draft Report (EM1110-2-2503)	6w	3/16/99	4/14/99	17
20	30% Draft Review Meeting	2w	4/15/99	4/24/99	19
21	60% Draft Report w/Explorations	6w	4/25/99	5/24/99	20
22	60% Draft Review Meeting	2w	5/25/99	6/3/99	21
23	90% Draft Report	4w	6/4/99	6/23/99	22
24	90% Review Meeting	3w	6/24/99	7/8/99	23
25	Final Report & Submit to Division	5w	7/9/99	8/2/99	24
26	Issue Notice to CBD for Spillway Design	4w	4/25/99	5/14/99	20
27	Issue Request for Proposal Spillway Design	4w	5/15/99	6/3/99	26
28	Receive Proposals, Select & Issue NTP	4w	6/4/99	6/23/99	27
29	Project Site Visits & Collect Data	2w	6/24/99	7/3/99	28
30	**Report Spillway Design EM1110-2-1603**	**180d**	**7/4/99**	**12/30/99**	
31	30% Draft Report for EM1110-2-1603	7w	7/4/99	8/7/99	29
32	30% Draft Review Meeting	2w	8/8/99	8/17/99	31



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Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

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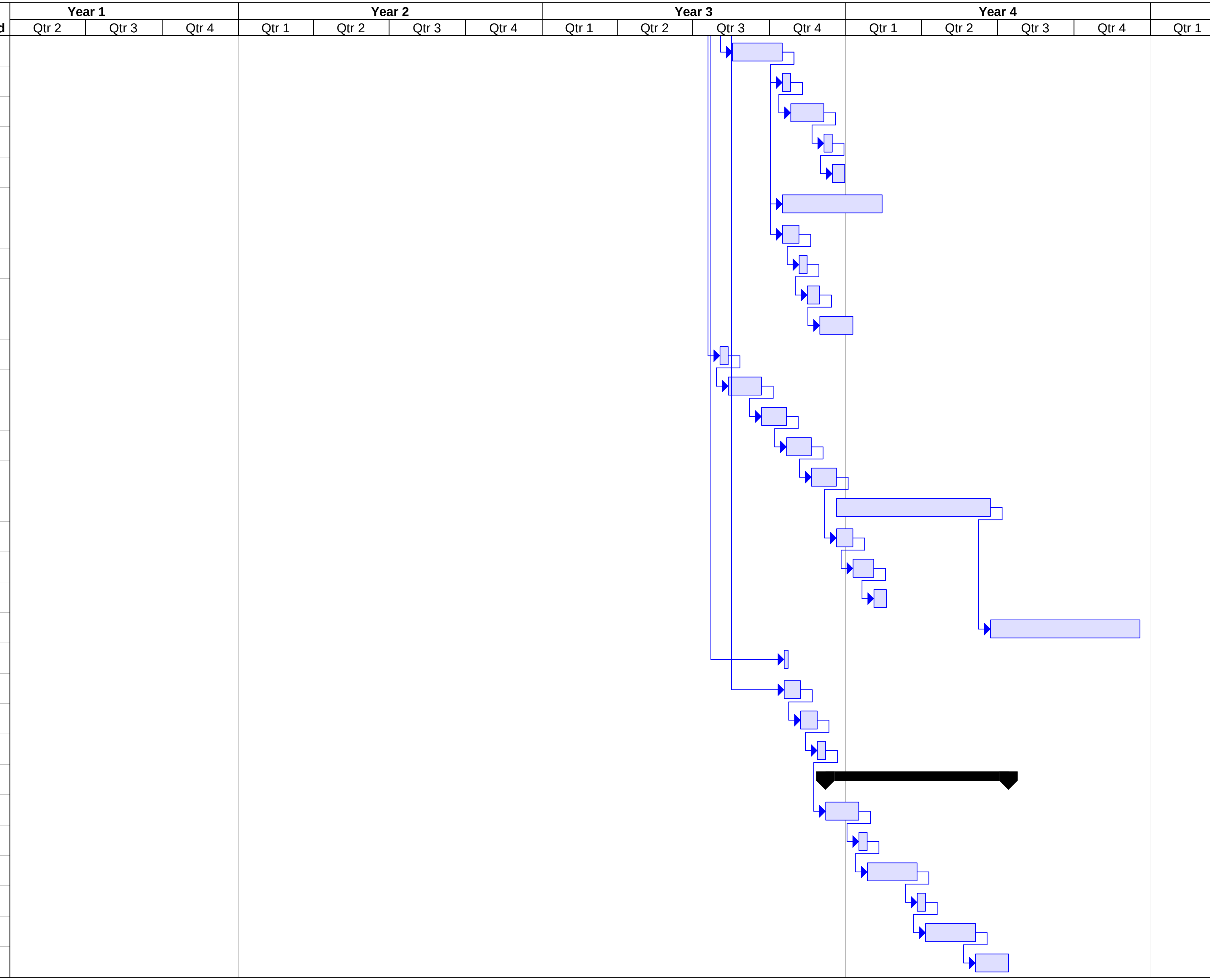
Schedule: Dissolved Gas Abatement Study Alternative 3: New Spillway Gates Design Bonneville Dam

ID	Task Name	Duration	Start	Finish	Pred
33	60% Draft Report w/Model Study	12w	8/18/99	10/16/99	32
34	60% Draft Review Meeting	2w	10/17/99	10/26/99	33
35	90% Draft Report	8w	10/27/99	12/5/99	34
36	90% Review Meeting	2w	12/6/99	12/15/99	35
37	Final Report & Submit to Division	3w	12/16/99	12/30/99	36
38	Apply, Review & Issue 404 Permits	24w	10/17/99	2/13/00	33
39	90% Draft Feasibility Report	4w	10/17/99	11/5/99	33
40	90% Review Meeting	2w	11/6/99	11/15/99	39
41	Final Feasibility Report	3w	11/16/99	11/30/99	40
42	Submit Feasibility Report to Division	8w	12/1/99	1/9/00	41
43	Incorporate Division Comments	2w	8/3/99	8/12/99	25
44	Submit Feasibility Report to USACE	8w	8/13/99	9/21/99	43
45	Receive Approval	6w	9/22/99	10/21/99	44
46	Submit to Committee & Testify to Congress	6w	10/22/99	11/20/99	45
47	Receive Authorized Funds for Planning & Engineers	6w	11/21/99	12/20/99	46
48	Receive Funds for Steel Cofferdam & FW Walls	37w	12/21/99	6/22/00	
49	Issue Notice to CBD for Cofferdam Steel & FW Walls	4w	12/21/99	1/9/00	47
50	Issue IFB for Cofferdam Steel & FW Walls	5w	1/10/00	2/3/00	49
51	Open Bids and Award C/D Steel & FW Walls	3w	2/4/00	2/18/00	50
52	Issue NTP for Supply Contract for C/D Steel & FW Walls	36w	6/23/00	12/19/00	48
53	Issue Notice to CBD - New Spillway Gates	1w	10/19/99	10/23/99	24
54	Issue Request for Proposal P & S	4w	10/19/99	11/7/99	25
55	Receive Proposals, Select & Issue NTP	4w	11/8/99	11/27/99	54
56	Project Site Visits & Collect Data	2w	11/28/99	12/7/99	55
57	**Plans & Specifications**	**220d**	**12/8/99**	**7/14/00**	
58	30% Plans & Specifications Submittal	8w	12/8/99	1/16/00	56
59	30% Plans & Specifications Review Meeting	2w	1/17/00	1/26/00	58
60	60% Plans & Specifications Submittal	12w	1/27/00	3/26/00	59
61	60% Plans & Specifications Review Meeting	2w	3/27/00	4/5/00	60
62	90% Plans & Specifications Submittal	12w	4/6/00	6/4/00	61
63	Final Plans & Specifications	8w	6/5/00	7/14/00	62



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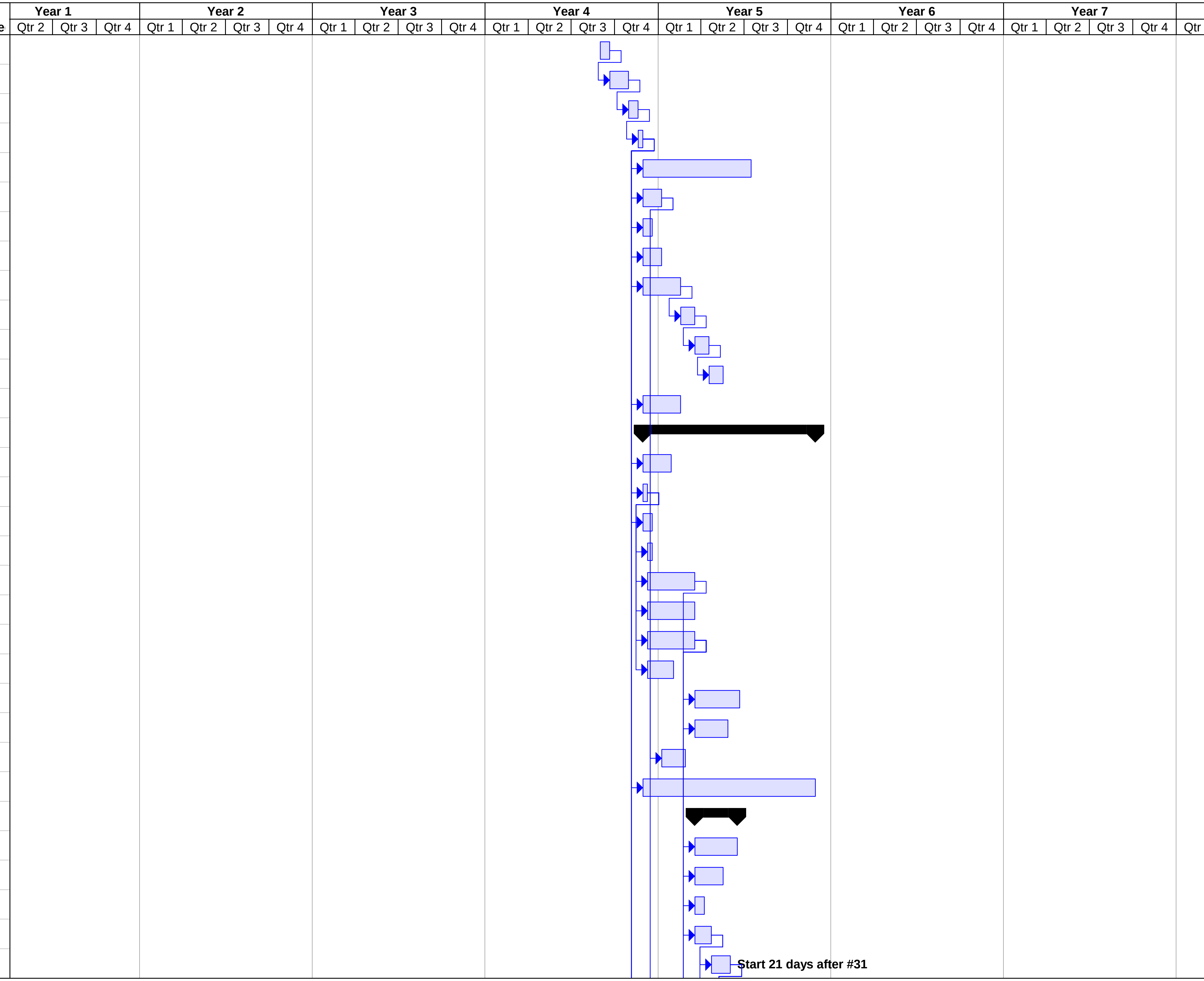
Task	Milestone	Rolled Up Task	Rolled Up Progress
Progress	Summary	Rolled Up Milestone	

Schedule: Dissolved Gas Abatement Study Alternative 3: New Spillway Gates Construction Bonneville Dam

ID	Task Name	Duratior	Start	Finish	Pre
1	Issue Notice to CBD for Construction	4w	9/1/00	9/20/00	
2	Issue IFB for Construction	8w	9/21/00	10/30/00	1
3	Open Bids & Award Contract	4w	10/31/00	11/19/00	2
4	Issue Notice to Proceed	2w	11/20/00	11/29/00	3
5	Mobilization	229d	11/30/00	7/16/01	4
6	Preparatory Site Work Bays 1-6	8w	11/30/00	1/8/01	4
7	Concrete Removal Upper Piers	4w	11/30/00	12/19/00	4
8	Trunnion Bridge Abutments / Grading	8w	11/30/00	1/8/01	4
9	Trunnion Bridge Land Piers	16w	11/30/00	2/17/01	4
10	Pier Hoist Corbels Bays 1-6	6w	2/18/01	3/19/01	9
11	Pier Hoist Corbels Bays 13-18	6w	3/20/01	4/18/01	10
12	Pier Hoist Corbels Bays 7-12	6w	4/19/01	5/18/01	11
13	Floating Batch Plant & Move Equipment	16w	11/30/00	2/17/01	4
14	**Downstream Cellular Cofferdam Bays 1-6**	**365d**	**11/30/00**	**11/29/01**	
15	Mobilize Barges & Floating Plant	12w	11/30/00	1/28/01	4
16	Dredging / Filling Deep Holes	2w	11/30/00	12/9/00	4
17	Install Floating Wing Walls	4w	11/30/00	12/19/00	4
18	Install Cell Template	2w	12/10/00	12/19/00	16
19	Install C/D Cells & Found Blanket	20w	12/10/00	3/19/01	16
20	Remove Cell Template	20w	12/10/00	3/19/01	16
21	Fill Cells with Gravel	20w	12/10/00	3/19/01	16
22	Place Foundation Blankets	11w	12/10/00	2/2/01	16
23	Dewatering, Phase I	95d	3/20/01	6/22/01	21
24	Concrete Removal Stilling Basin & Exterior Walls	14w	3/20/01	5/28/01	19
25	Order Prestressed S/W Girders	10w	1/9/01	2/27/01	6
26	Order Mechanical Metal Items	365d	11/30/00	11/29/01	4
27	**Spillway Pier Concrete Bays 1-6**	**90d**	**3/20/01**	**6/17/01**	
28	Pier Walls (22 placements / pier) (154)	18w	3/20/01	6/17/01	21
29	Ogee w/in Pier Area (2 placements) (12)	12w	3/20/01	5/18/01	21
30	Invert D/S Slab Area (4 placements) (24)	4w	3/20/01	4/8/01	21
31	Set Trunnions for S/W Gates (5 days) (7)	7w	3/20/01	4/23/01	21
32	Post-tensioning Trunnion	8w	4/24/01	6/2/01	31

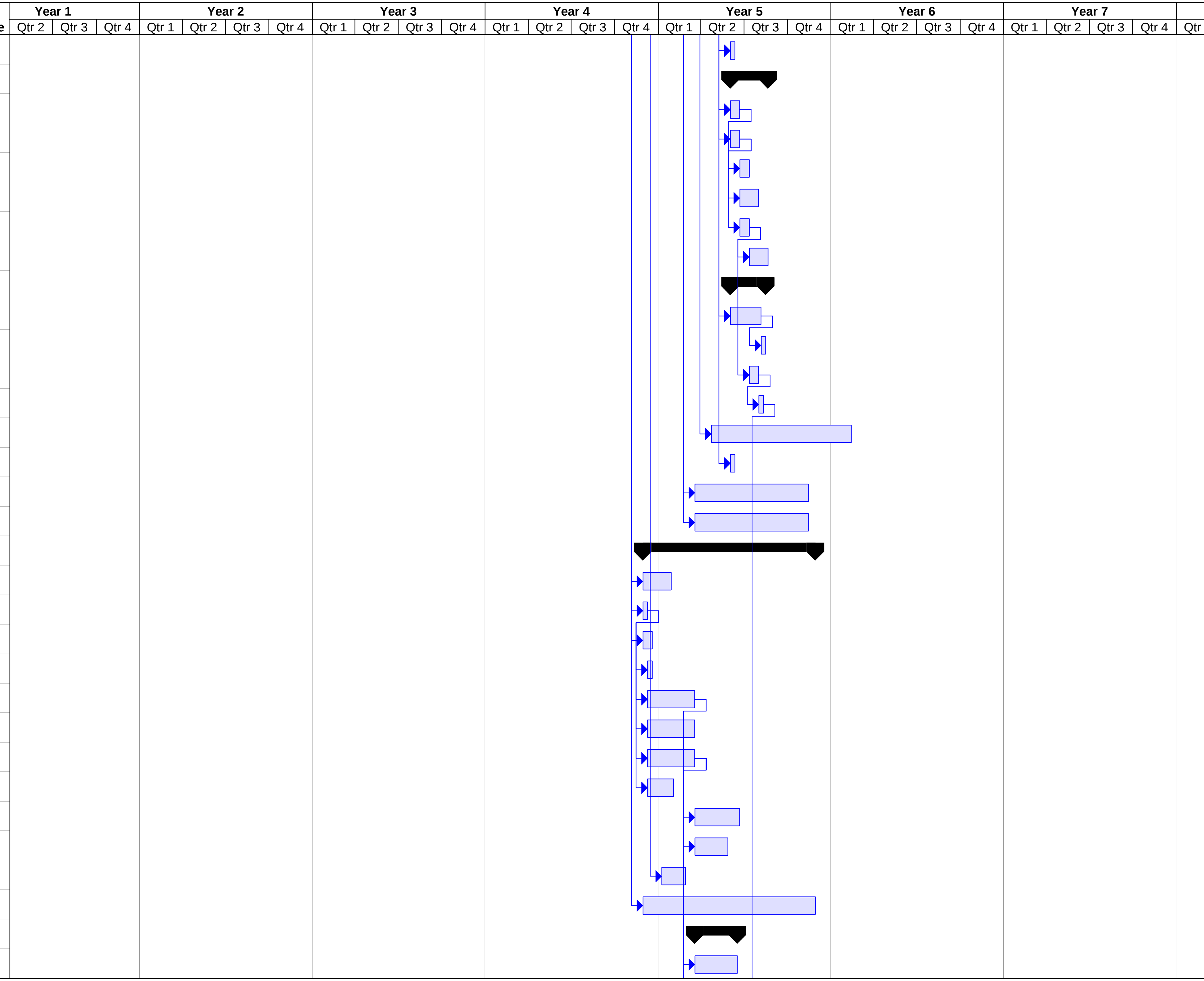


Project:
Date: 11/16/98

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress

Schedule: Dissolved Gas Abatement Study Alternative 3: New Spillway Gates Construction Bonneville Dam

ID	Task Name	Duratior	Start	Finish	Pre
33	Cure Slabs	2w	6/3/01	6/12/01	32
34	**Spillway Bridge Right Abutment to Bay 6**	**80d**	**6/3/01**	**8/21/01**	
35	Install Box Girders (42 members) @ S/W Bay	4w	6/3/01	6/22/01	32
36	Place Cast-in-Place Connection	4w	6/3/01	6/22/01	32
37	Epoxy Girders Together (3 days/span)	4w	6/23/01	7/12/01	35
38	Place Electrical Conduits	8w	6/23/01	8/1/01	36
39	Place Roadway Slab	4w	6/23/01	7/12/01	36
40	Place Concrete Parapets	8w	7/13/01	8/21/01	39
41	**Downstream Cellular Cofferdam Bays 13-18**	**75d**	**6/3/01**	**8/16/01**	
42	Remove Cells (Phase 2)	13w	6/3/01	8/6/01	32
43	Dredging / Filling Deep Holes	2w	8/7/01	8/16/01	42
44	Install Floating Wing Walls	4w	7/13/01	8/1/01	39
45	Install Cell Template	2w	8/2/01	8/11/01	44
46	Install Spillway Gates Bays 1-6	296d	4/24/01	2/13/02	31
47	Finishing Paint Gates	2w	6/3/01	6/12/01	32
48	**Install S/W Mechanical Equipment**	48w	3/20/01	11/14/01	21
49	**Install S/W Electrical**	48w	3/20/01	11/14/01	21
50	**Downstream Cellular Cofferdam Bays 13-18**	**365d**	**11/30/00**	**11/29/01**	
51	Mobilize Barges & Floating Plant	12w	11/30/00	1/28/01	4
52	Dredging / Filling Deep Holes	2w	11/30/00	12/9/00	4
53	Install Floating Wing Walls	4w	11/30/00	12/19/00	4
54	Install Cell Template	2w	12/10/00	12/19/00	52
55	Install C/D Cells & Found Blanket	20w	12/10/00	3/19/01	52
56	Remove Cell Template	20w	12/10/00	3/19/01	52
57	Fill Cells with Gravel	20w	12/10/00	3/19/01	52
58	Place Foundation Blankets	11w	12/10/00	2/2/01	52
59	Dewatering, Phase I	95d	3/20/01	6/22/01	57
60	Concrete Removal Stilling Basin & Exterior Walls	14w	3/20/01	5/28/01	55
61	Order Prestressed S/W Girders	10w	1/9/01	2/27/01	6
62	Order Mechanical Metal Items	365d	11/30/00	11/29/01	4
63	**Spillway Pier Concrete Bays 13-18**	**90d**	**3/20/01**	**6/17/01**	
64	Pier Walls (22 placements / pier) (154)	18w	3/20/01	6/17/01	57



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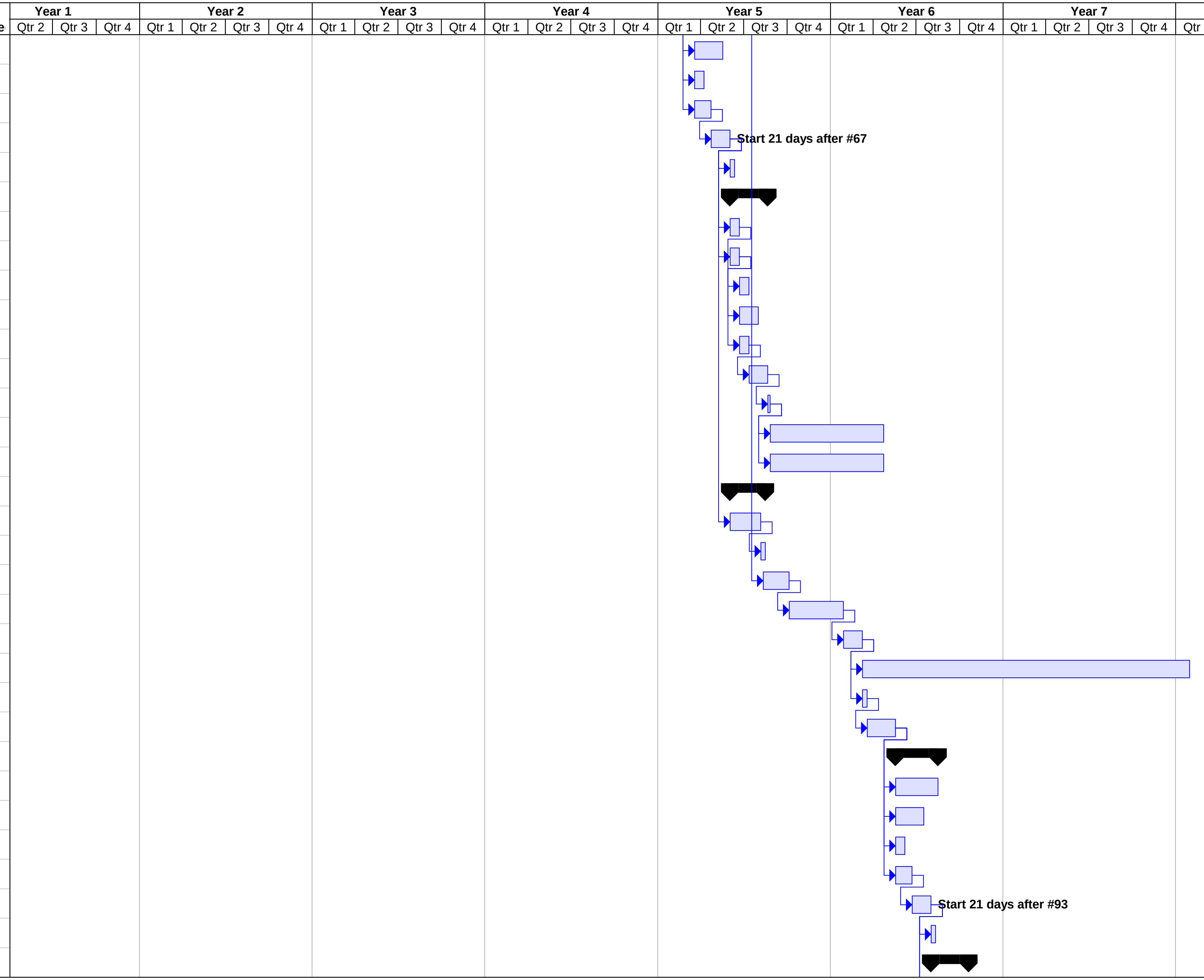
Task		Milestone	◆	Rolled Up Task	
Progress		Summary		Rolled Up Milestone ◇	Rolled Up Progress

Schedule: Dissolved Gas Abatement Study Alternative 3: New Spillway Gates Construction Bonneville Dam

ID	Task Name	Duration	Start	Finish	Pre
65	Ogee w/in Pier Area (2 placements) (12)	12w	3/20/01	5/18/01	57
66	Invert D/S Slab Area (4 placements) (24)	4w	3/20/01	4/8/01	57
67	Set Trunnions for S/W Gates (5 days) (7)	7w	3/20/01	4/23/01	57
68	Post-tensioning Trunnion	8w	4/24/01	6/2/01	67
69	Cure Slabs	2w	6/3/01	6/12/01	68
70	**Spillway Bridge Left Abutment to Bay 13**	**80d**	**6/3/01**	**8/21/01**	
71	Install Box Girders (42 members) @ S/W Bay	4w	6/3/01	6/22/01	68
72	Place Cast-in-Place Connection	4w	6/3/01	6/22/01	68
73	Epoxy Girders Together (3 days/span)	4w	6/23/01	7/12/01	71
74	Place Electrical Conduits	8w	6/23/01	8/1/01	72
75	Place Roadway Slab	4w	6/23/01	7/12/01	72
76	Place Concrete Parapets	8w	7/13/01	8/21/01	75
77	Install Spillway Gates Bay 13-19	1w	8/22/01	8/26/01	76
78	Install S/W Mechanical Equipment	48w	8/27/01	4/23/02	77
79	Install S/W Electrical	48w	8/27/01	4/23/02	77
80	**Downstream Cellular Cofferdam Bays 7-12**	**75d**	**6/3/01**	**8/16/01**	
81	Remove Cells (Phase 2)	13w	6/3/01	8/6/01	68
82	Dredging / Filling Deep Holes	2w	8/7/01	8/16/01	81
83	Install C/D Cells & Found Blanket	11w	8/12/01	10/5/01	45
84	Fill Cells with Gravel	23w	10/6/01	1/28/02	83
85	Install Dewater Pumps	8w	1/29/02	3/9/02	84
86	Dewatering, Phase II	692d	3/10/02	1/30/04	85
87	Concrete Removal Upper Pier	2w	3/10/02	3/19/02	85
88	Concrete Removal	12w	3/20/02	5/18/02	87
89	**Spillway Pier Concrete Bays 7-12**	**90d**	**5/19/02**	**8/16/02**	
90	Pier Walls (22 placements / pier) (154)	18w	5/19/02	8/16/02	88
91	Ogee w/in Pier Area (2 placements) (12)	12w	5/19/02	7/17/02	88
92	Invert D/S Slab Area (4 placements) (24)	4w	5/19/02	6/7/02	88
93	Set Trunnions for S/W Gates (5 days) (7)	7w	5/19/02	6/22/02	88
94	Post-tensioning Trunnion	8w	6/23/02	8/1/02	93
95	Cure Slabs	2w	8/2/02	8/11/02	94
96	**Spillway Bridge Bay 7-12**	**80d**	**8/2/02**	**10/20/02**	



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Task		Milestone		Rolled Up Task		Rolled Up Progress	
Progress		Summary		Rolled Up Milestone			

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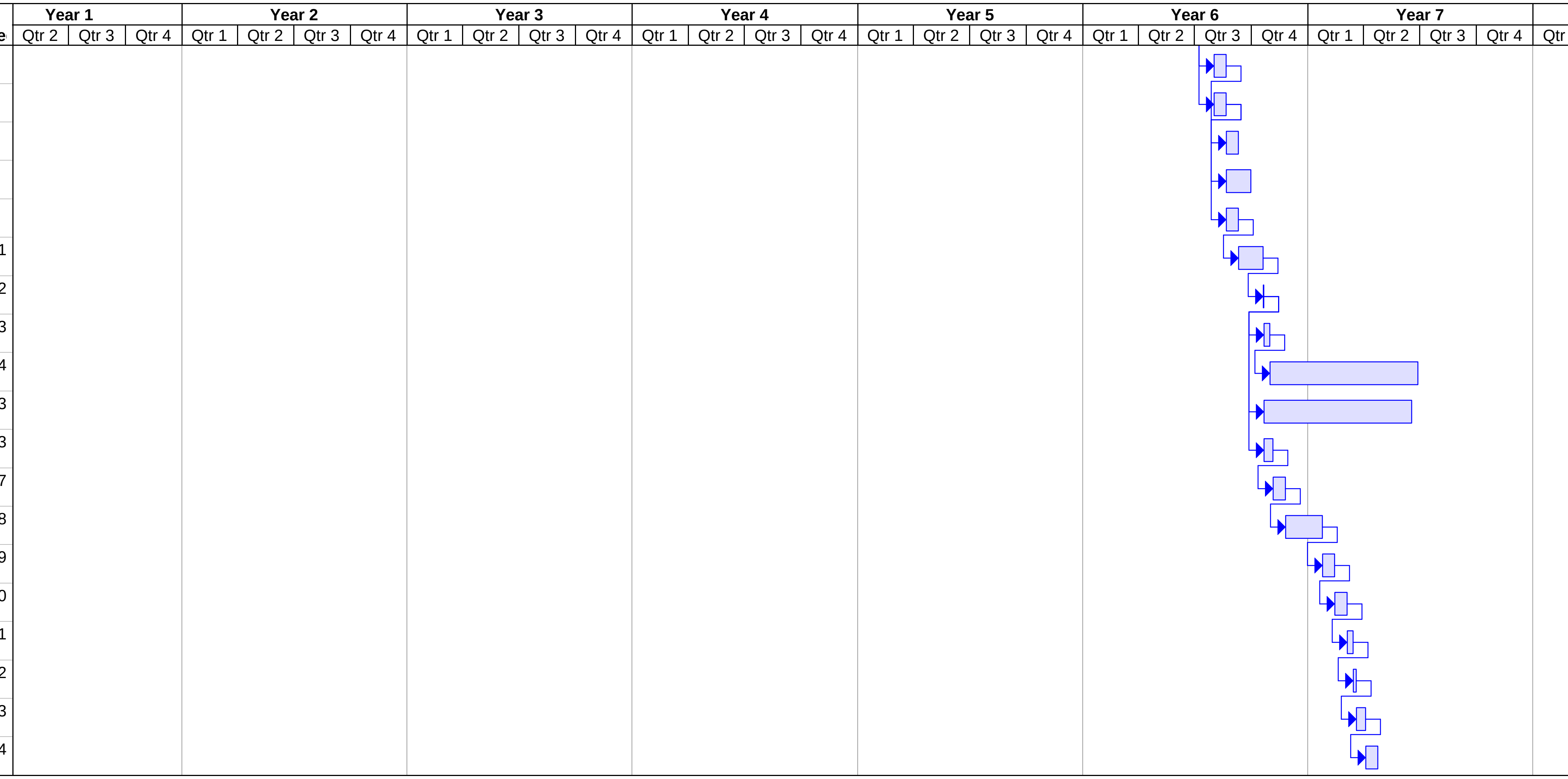
Schedule: Dissolved Gas Abatement Study Alternative 3: New Spillway Gates Construction Bonneville Dam

ID	Task Name	Duratior	Start	Finish	Pre
97	Install Box Girders (42 members) @ S/W Bay	4w	8/2/02	8/21/02	94
98	Place Cast-in-Place Connection	4w	8/2/02	8/21/02	94
99	Epoxy Girders Together (3 days/span)	4w	8/22/02	9/10/02	97
100	Place Electrical Conduits	8w	8/22/02	9/30/02	98
101	Place Roadway Slab	4w	8/22/02	9/10/02	98
102	Place Concrete Parapets	8w	9/11/02	10/20/02	101
103	Install Spillway Gates Bays 7-12	1d	10/21/02	10/21/02	102
104	Finishing Paint Gates	2w	10/22/02	10/31/02	103
105	Install S/W Mechanical Equipment	48w	11/1/02	6/28/03	104
106	Install S/W Electrical	48w	10/22/02	6/18/03	103
107	Install Electrical Pullboxes & Conduits	3w	10/22/02	11/5/02	103
108	Install Permanent Power Supply & Controls to PH	4w	11/6/02	11/25/02	107
109	Remove Required Sheet Pile	12w	11/26/02	1/24/03	108
110	Pave Bridge Approaches	4w	1/25/03	2/13/03	109
111	Install Guardrail, Security Fence, & Gates	4w	2/14/03	3/5/03	110
112	Reestablish Pavement and Striping	2w	3/6/03	3/15/03	111
113	Diving Inspection of Stilling Basin	1w	3/16/03	3/20/03	112
114	Test Electrical/Mechanical Systems	3w	3/21/03	4/4/03	113
115	Conduct Spillway Tests for Dissolved Gas	4w	4/5/03	4/24/03	114

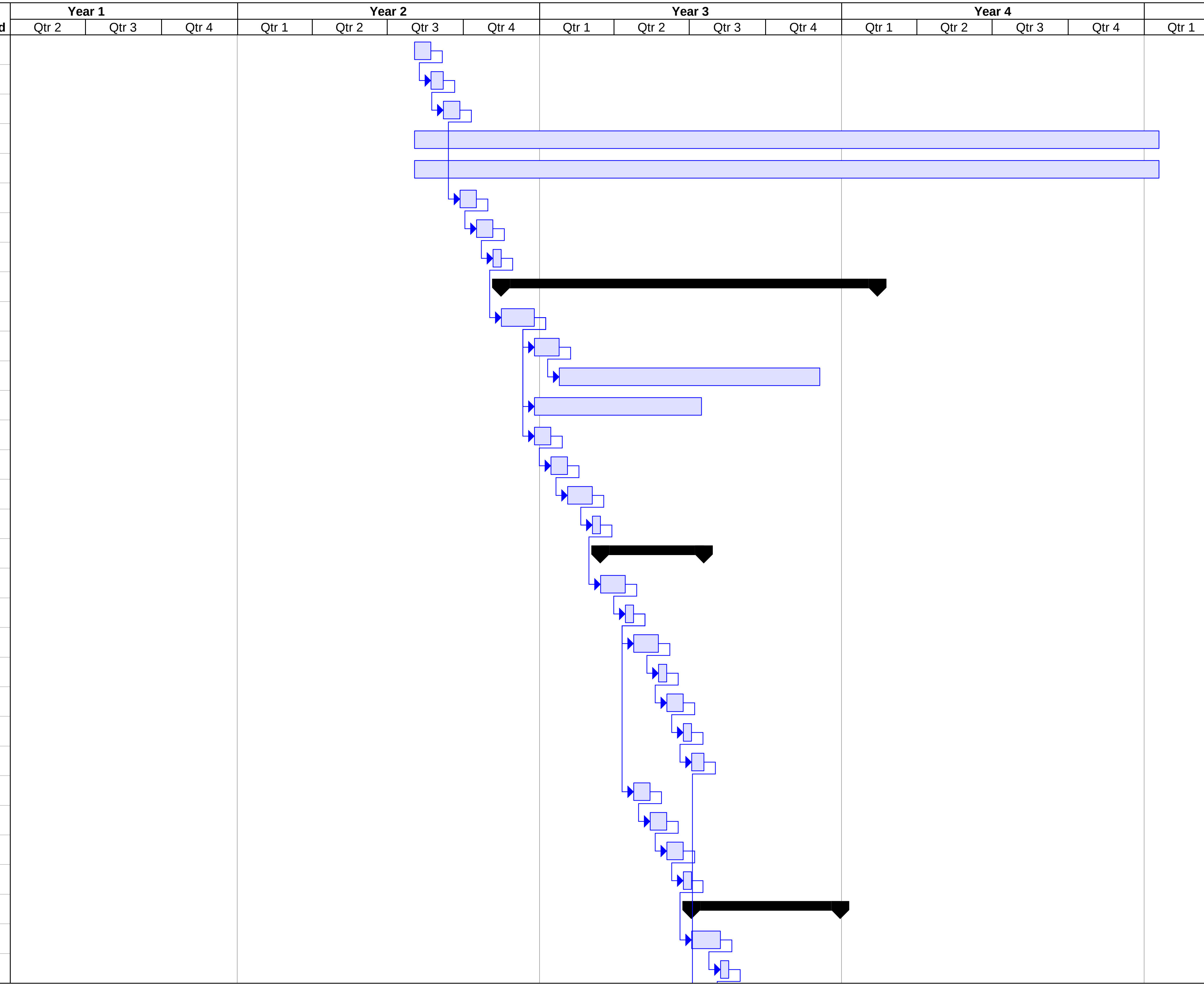


Project:
Date: 11/16/98

Task		Milestone	◆	Rolled Up Task		Rolled Up Progress	
Progress		Summary		Rolled Up Milestone	◇		

Schedule: Dissolved Gas Abatement Study Alternative 4: Sluices Under Existing Spillway Design Bonneville Dam

ID	Task Name	Duration	Start	Finish	Pred
1	Sluices in Spillway Design/Rec'd Funding	4w	8/3/98	8/22/98	
2	Scope - General Design Memo No. 1	3w	8/23/98	9/6/98	1
3	Issue Notice to CBD - FDM No. 1	4w	9/7/98	9/26/98	2
4	Coordination w/Navigation & Power Interest	900d	8/3/98	1/18/01	
5	Coordinate w/USF&WS & Wash. F & G	900d	8/3/98	1/18/01	
6	Issue Request for Proposal - FDM No.1	4w	9/27/98	10/16/98	3
7	Receive Proposals, Select & Issue NTP	4w	10/17/98	11/5/98	6
8	Project Site Visits & Collect Data	2w	11/6/98	11/15/98	7
9	**Draft Report - Feasibility**	**455d**	**11/16/98**	**2/13/00**	
10	Draft Economic Report	8w	11/16/98	12/25/98	8
11	Complete Final Model Construction	6w	12/26/98	1/24/99	10
12	Complete Model Testing	63w	1/25/99	12/5/99	11
13	Complete Explorations	202d	12/26/98	7/15/99	10
14	Issue Notice to CBD for Cofferdam Design	4w	12/26/98	1/14/99	10
15	Issue Request for Proposal	4w	1/15/99	2/3/99	14
16	Receive Proposals, Select & Issue NTP	6w	2/4/99	3/5/99	15
17	Project Site Visits & Collect Data	2w	3/6/99	3/15/99	16
18	**Report Cofferdam Design EM1110-2-2503**	**125d**	**3/16/99**	**7/18/99**	
19	30% Draft Report (EM1110-2-2503)	6w	3/16/99	4/14/99	17
20	30% Draft Review Meeting	2w	4/15/99	4/24/99	19
21	60% Draft Report w/Explorations	6w	4/25/99	5/24/99	20
22	60% Draft Review Meeting	2w	5/25/99	6/3/99	21
23	90% Draft Report	4w	6/4/99	6/23/99	22
24	90% Review Meeting	2w	6/24/99	7/3/99	23
25	Final Report & Submit to Division	3w	7/4/99	7/18/99	24
26	Issue Notice to CBD for Spillway Design	4w	4/25/99	5/14/99	20
27	Issue Request for Proposal Spillway Design	4w	5/15/99	6/3/99	26
28	Receive Proposals, Select & Issue NTP	4w	6/4/99	6/23/99	27
29	Project Site Visits & Collect Data	2w	6/24/99	7/3/99	28
30	**Report Spillway Design EM1110-2-1603**	**180d**	**7/4/99**	**12/30/99**	
31	30% Draft Report for EM1110-2-1603	7w	7/4/99	8/7/99	29
32	30% Draft Review Meeting	2w	8/8/99	8/17/99	31



Project:
Date: 11/16/98

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress

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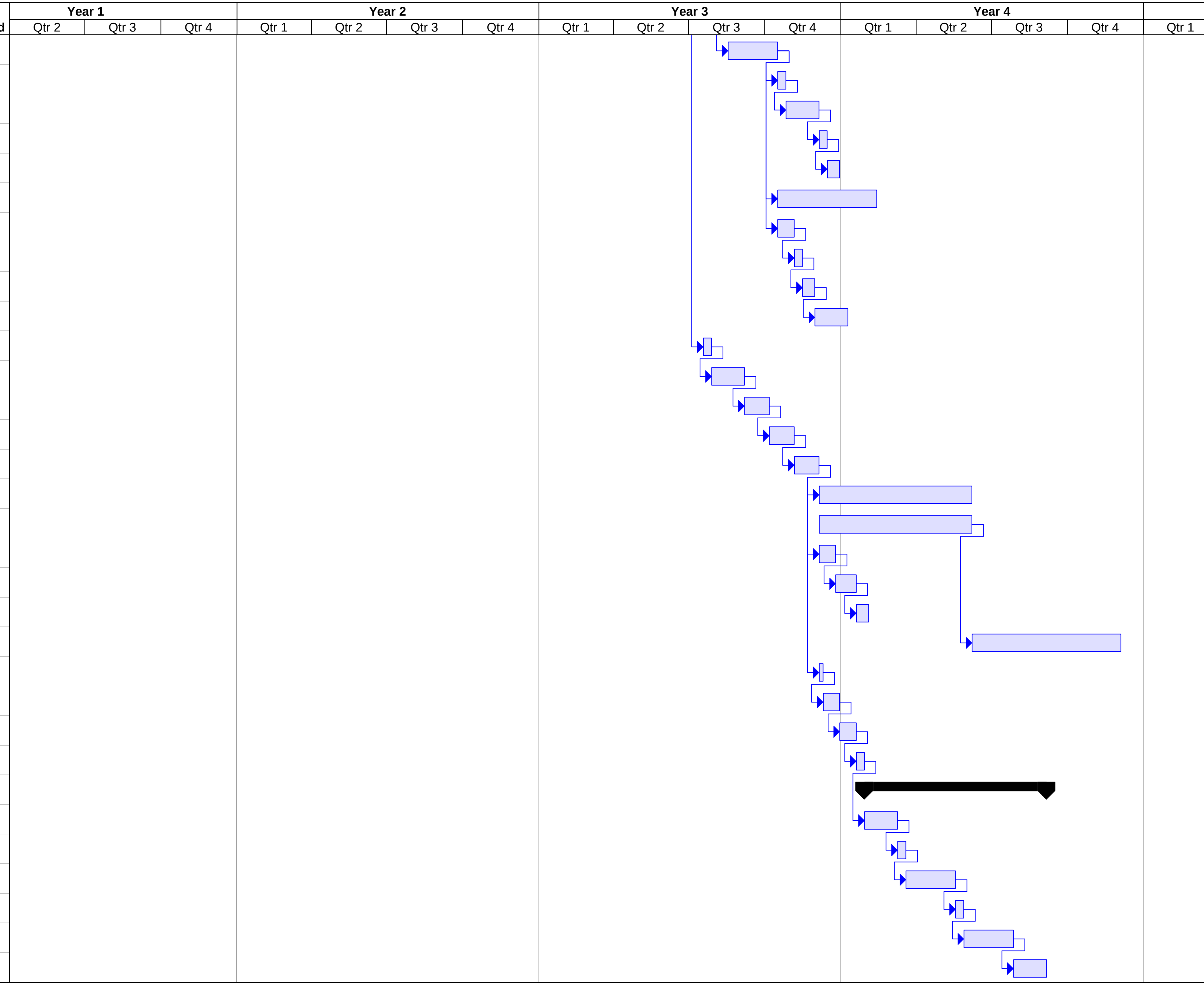
Schedule: Dissolved Gas Abatement Study Alternative 4: Sluices Under Existing Spillway Design Bonneville Dam

ID	Task Name	Duration	Start	Finish	Pred
33	60% Draft Report w/Model Study	12w	8/18/99	10/16/99	32
34	60% Draft Review Meeting	2w	10/17/99	10/26/99	33
35	90% Draft Report	8w	10/27/99	12/5/99	34
36	90% Review Meeting	2w	12/6/99	12/15/99	35
37	Final Report & Submit to Division	3w	12/16/99	12/30/99	36
38	Apply, Review & Issue 404 Permits	24w	10/17/99	2/13/00	33
39	90% Draft Feasibility Report	4w	10/17/99	11/5/99	33
40	90% Review Meeting	2w	11/6/99	11/15/99	39
41	Final Feasibility Report	3w	11/16/99	11/30/99	40
42	Submit Feasibility Report to Division	8w	12/1/99	1/9/00	41
43	Incorporate Division Comments	2w	7/19/99	7/28/99	25
44	Submit Feasibility Report to USACE	8w	7/29/99	9/6/99	43
45	Receive Approval	6w	9/7/99	10/6/99	44
46	Submit to Committee & Testify to Congress	6w	10/7/99	11/5/99	45
47	Receive Authorized Funds for Planning & Engineer:	6w	11/6/99	12/5/99	46
48	Design New Spillway Crane (HDC)	37w	12/6/99	6/7/00	47
49	Receive Funds for Steel C/D, Crane, & Bulkheads	37w	12/6/99	6/7/00	
50	Issue Notice to CBD for Cofferdam Steel & Crane	4w	12/6/99	12/25/99	47
51	Issue IFB for Cofferdam Steel & Crane	5w	12/26/99	1/19/00	50
52	Open Bids and Award C/D Steel & Crane	3w	1/20/00	2/3/00	51
53	Issue NTP for Supply Contract for C/D Steel & Crar	36w	6/8/00	12/4/00	49
54	Issue Notice to CBD - Sluices in Spillway	1w	12/6/99	12/10/99	47
55	Issue Request for Proposal P & S Sluices	4w	12/11/99	12/30/99	54
56	Receive Proposals, Select & Issue NTP	4w	12/31/99	1/19/00	55
57	Project Site Visits & Collect Data	2w	1/20/00	1/29/00	56
58	**Plans & Specifications Sluices**	**220d**	**1/30/00**	**9/5/00**	
59	30% Plans & Specifications Submittal	8w	1/30/00	3/9/00	57
60	30% Plans & Specifications Review Meeting	2w	3/10/00	3/19/00	59
61	60% Plans & Specifications Submittal	12w	3/20/00	5/18/00	60
62	60% Plans & Specifications Review Meeting	2w	5/19/00	5/28/00	61
63	90% Plans & Specifications Submittal	12w	5/29/00	7/27/00	62
64	Final Plans & Specifications	8w	7/28/00	9/5/00	63



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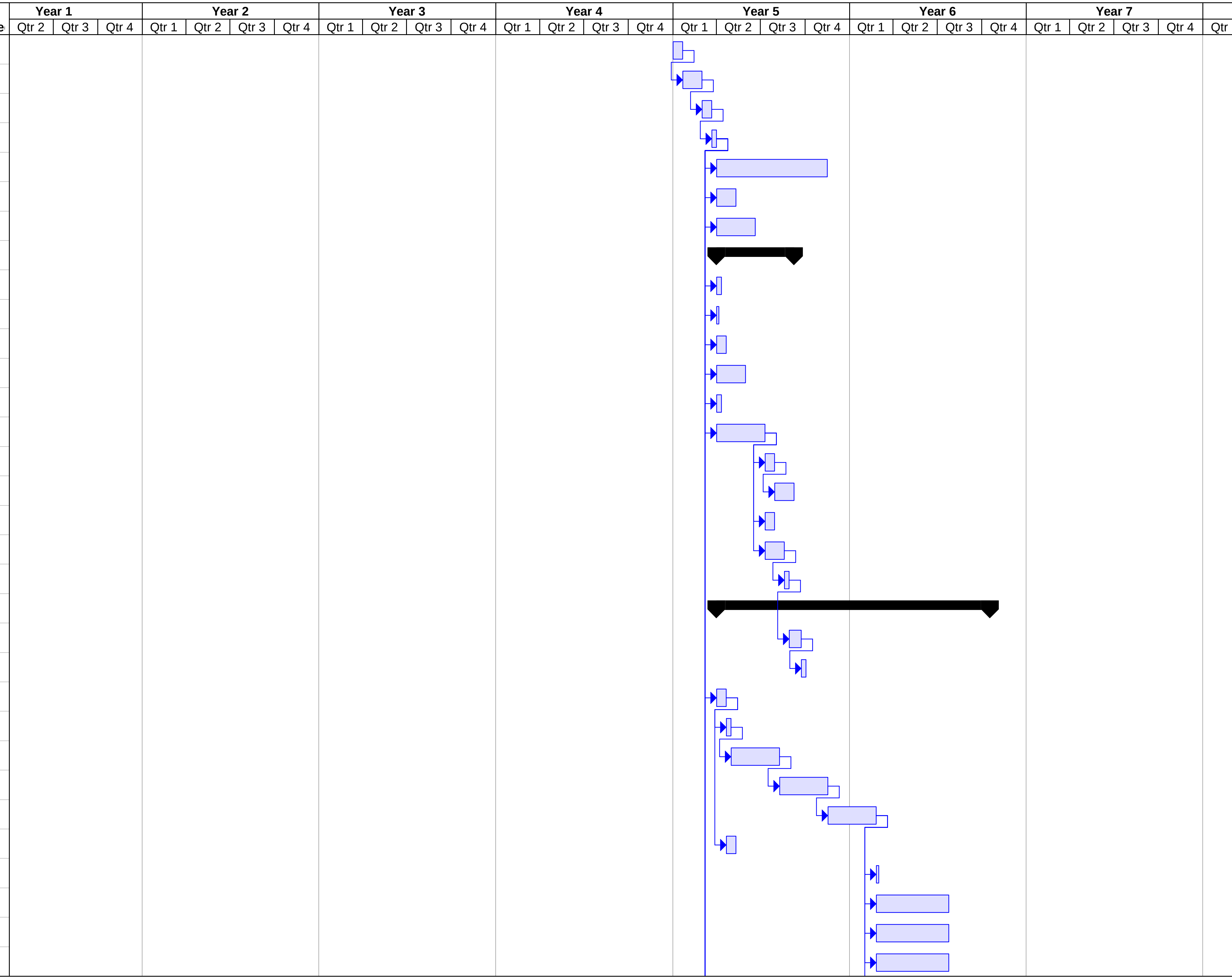
Date: 11/16/98

Task		Milestone		Rolled Up Task		Rolled Up Progress	
Progress		Summary		Rolled Up Milestone			

Schedule: Dissolved Gas Abatement Study Alternative 4: Sluices Under Existing Spillway Construction Bonneville Dam

ID	Task Name	Durati	Start	Finish	Pre
1	Issue Notice to CBD for Construction	4w	1/2/01	1/21/01	
2	Issue IFB for Construction	8w	1/22/01	3/2/01	1
3	Open Bids & Award Contract	4w	3/3/01	3/22/01	2
4	Issue Notice to Proceed	2w	3/23/01	4/1/01	3
5	Mobilization & Order Prestressed S/W Girders	229d	4/2/01	11/16/01	4
6	Preparatory Site Work	8w	4/2/01	5/11/01	4
7	Floating Batch Plant & Move Equipment	16w	4/2/01	6/20/01	4
8	**Upstream Spillway Gantry Crane**	**160d**	**4/2/01**	**9/8/01**	
9	Remove Guardrails and Parapet Wall	2w	4/2/01	4/11/01	4
10	Spillway Pier Concrete Bay 13-17	1w	4/2/01	4/6/01	4
11	Drill Concrete for Post -Tensioning	4w	4/2/01	4/21/01	4
12	Install Post-Tensioning Units	12w	4/2/01	5/31/01	4
13	Remove One Existing S/W Cranes	2w	4/2/01	4/11/01	4
14	Remove Concrete Foil U/S Corbels	20w	4/2/01	7/10/01	4
15	Place Resteel for Corbel	4w	7/11/01	7/30/01	14
16	Place Concrete for Corbel	8w	7/31/01	9/8/01	15
17	Place Crane Rail Girders	4w	7/11/01	7/30/01	14
18	Dredge & Disposal of Foundation Blankets	8w	7/11/01	8/19/01	14
19	Place U/S Floating Bulkhead	2w	8/20/01	8/29/01	18
20	**Downstream Cellular Cofferdam Bays 13-17**	**565d**	**4/2/01**	**10/18/02**	
21	Installed New Gantry Crane	5w	8/30/01	9/23/01	19
22	Dredging / Folding Deep Holes	2w	9/24/01	10/3/01	21
23	Install Floating Wing Walls	4w	4/2/01	4/21/01	4
24	Install Cell Template	2w	4/22/01	5/1/01	23
25	Install C/D Cells & Found Blanket	20w	5/2/01	8/9/01	24
26	Remove Cell Template	20w	8/10/01	11/17/01	25
27	Fill Cells with Gravel	20w	11/18/01	2/25/02	26
28	Install Pumps in D/S C/D	4w	4/22/01	5/11/01	23
29	Dewater D/S C/D	1w	2/26/02	3/2/02	27
30	Concrete Removal	30w	2/26/02	7/25/02	27
31	Concrete Sluices	30w	2/26/02	7/25/02	27
32	Concrete Stilling Basin	30w	2/26/02	7/25/02	27



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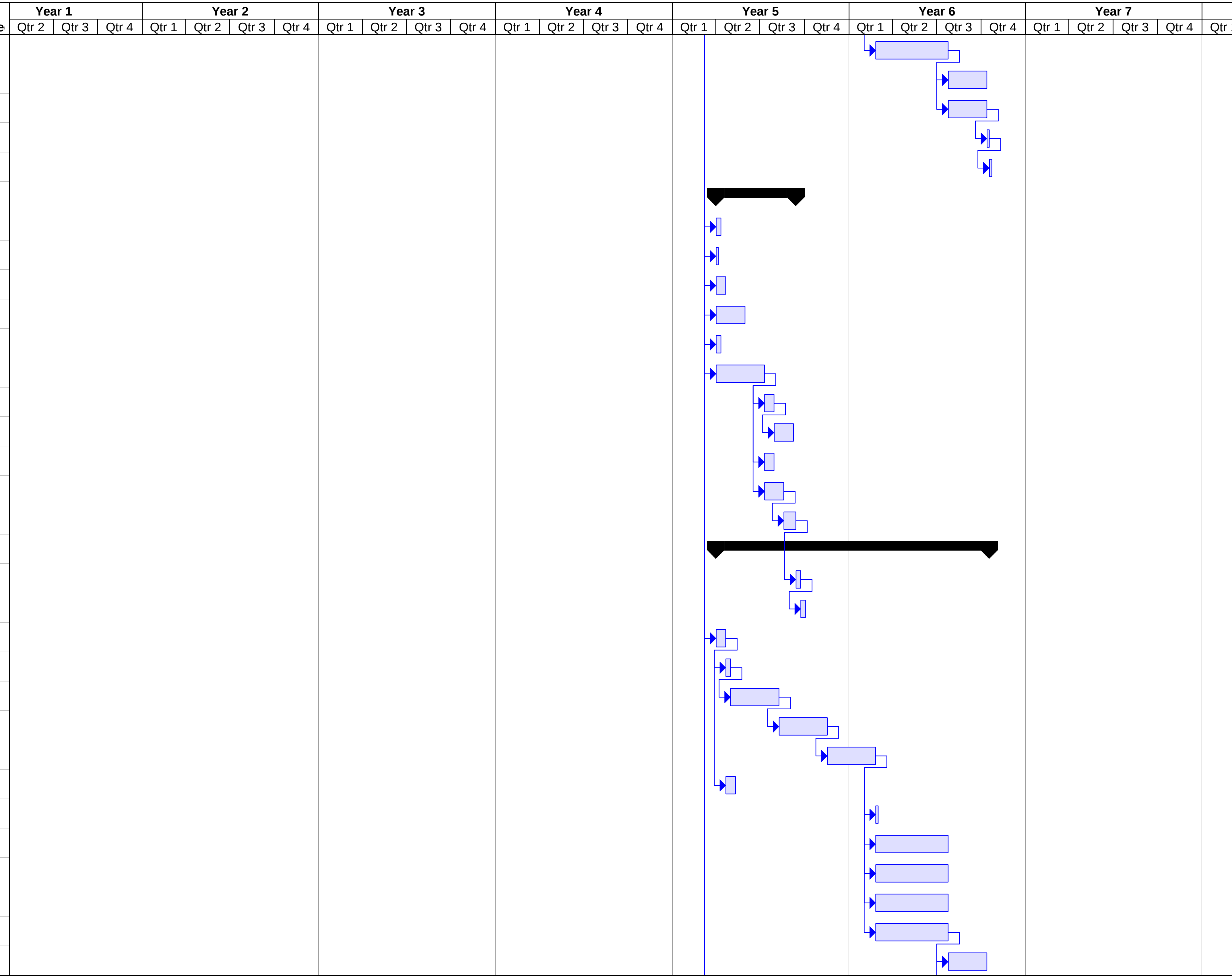
Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

Schedule: Dissolved Gas Abatement Study Alternative 4: Sluices Under Existing Spillway Construction Bonneville Dam

ID	Task Name	Durati	Start	Finish	Pre
33	Concrete Bulkhead Slots	30w	2/26/02	7/25/02	27
34	Install Bulkhead	16w	7/26/02	10/13/02	33
35	Install Hoists & Equipment	16w	7/26/02	10/13/02	33
36	Install Spillway Gates Bays 7-12	1w	10/14/02	10/18/02	35
37	Floating Batch Plant & Move Equipment	1w	10/19/02	10/23/02	36
38	**Upstream Spillway Gantry Crane**	**165d**	**4/2/01**	**9/13/01**	
39	Remove Guardrails and Parapet Wall	2w	4/2/01	4/11/01	4
40	Spillway Pier Concrete Bay 13-17	1w	4/2/01	4/6/01	4
41	Drill Concrete for Post -Tensioning	4w	4/2/01	4/21/01	4
42	Install Post-Tensioning Units	12w	4/2/01	5/31/01	4
43	Remove One Existing S/W Cranes	2w	4/2/01	4/11/01	4
44	Remove Concrete Foil U/S Corbels	20w	4/2/01	7/10/01	4
45	Place Resteel for Corbel	4w	7/11/01	7/30/01	44
46	Place Concrete for Corbel	8w	7/31/01	9/8/01	45
47	Place Crane Rail Girders	4w	7/11/01	7/30/01	44
48	Dredge & Disposal of Foundation Blankets	8w	7/11/01	8/19/01	44
49	Installed New Contractor Gantry Crane	5w	8/20/01	9/13/01	48
50	**Downstream Cellular Cofferdam Bays 1-6**	**565d**	**4/2/01**	**10/18/02**	
51	Place U/S Floating Bulkhead	2w	9/14/01	9/23/01	49
52	Dredging / Folding Deep Holes	2w	9/24/01	10/3/01	51
53	Install Floating Wing Walls	4w	4/2/01	4/21/01	4
54	Install Cell Template	2w	4/22/01	5/1/01	53
55	Install C/D Cells & Found Blanket	20w	5/2/01	8/9/01	54
56	Remove Cell Template	20w	8/10/01	11/17/01	55
57	Fill Cells with Gravel	20w	11/18/01	2/25/02	56
58	Install Pumps in D/S C/D	4w	4/22/01	5/11/01	53
59	Dewater D/S C/D	1w	2/26/02	3/2/02	57
60	Concrete Removal	30w	2/26/02	7/25/02	57
61	Concrete Sluices	30w	2/26/02	7/25/02	57
62	Concrete Stilling Basin	30w	2/26/02	7/25/02	57
63	Concrete Bulkhead Slots	30w	2/26/02	7/25/02	57
64	Install Bulkhead	16w	7/26/02	10/13/02	63



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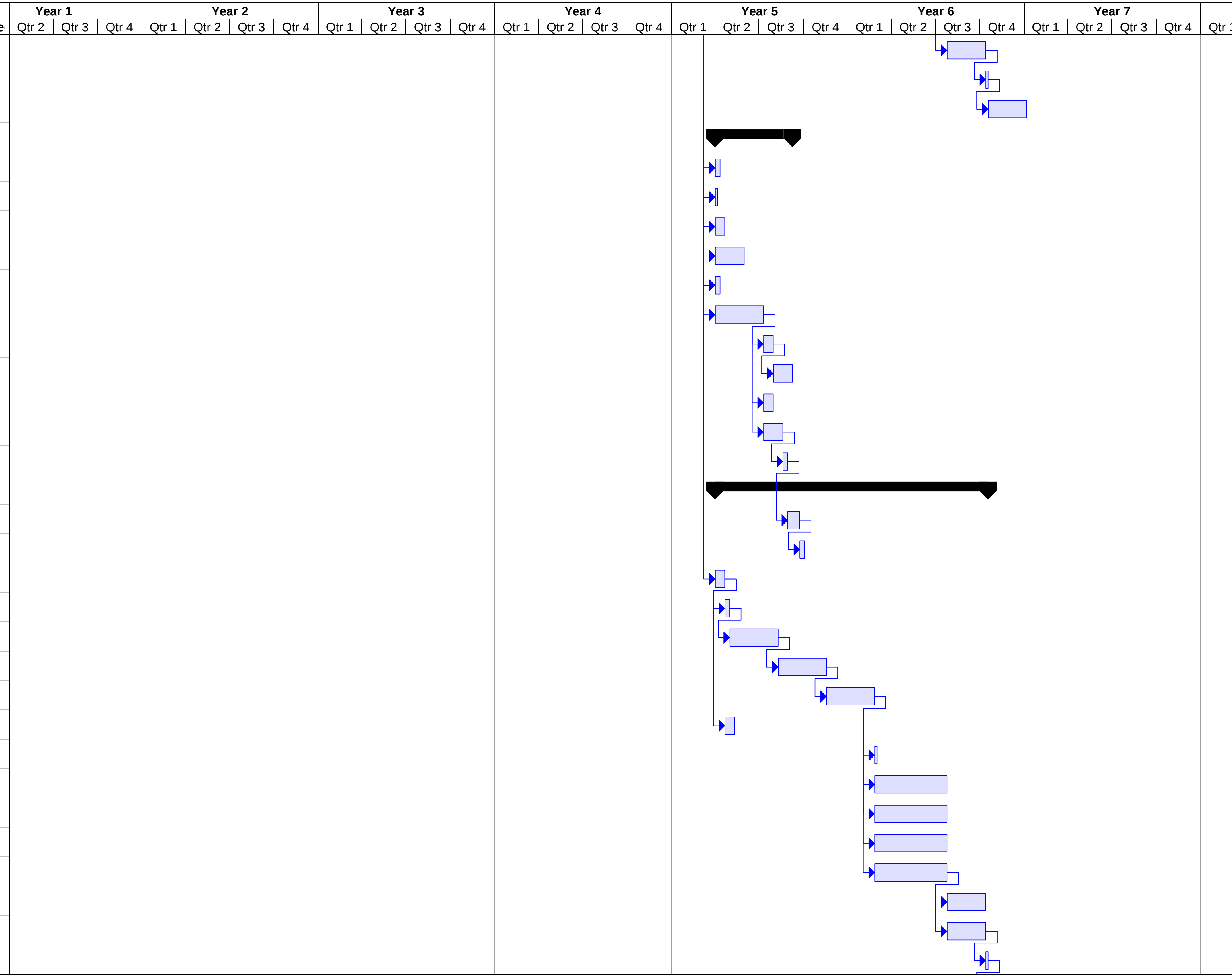
Date: 11/16/98

Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

Schedule: Dissolved Gas Abatement Study Alternative 4: Sluices Under Existing Spillway Construction Bonneville Dam

ID	Task Name	Durati	Start	Finish	Pre
65	Install Hoists & Equipment	16w	7/26/02	10/13/02	63
66	Install Spillway Gates Bays 1-6	1w	10/14/02	10/18/02	65
67	Floating Batch Plant & Move Equipment	16w	10/19/02	1/6/03	66
68	**Upstream Spillway Gantry Crane**	**160d**	**4/2/01**	**9/8/01**	
69	Remove Guardrails and Parapet Wall	2w	4/2/01	4/11/01	4
70	Spillway Pier Concrete Bay 13-17	1w	4/2/01	4/6/01	4
71	Drill Concrete for Post -Tensioning	4w	4/2/01	4/21/01	4
72	Install Post-Tensioning Units	12w	4/2/01	5/31/01	4
73	Remove One Existing S/W Cranes	2w	4/2/01	4/11/01	4
74	Remove Concrete Foil U/S Corbels	20w	4/2/01	7/10/01	4
75	Place Resteel for Corbel	4w	7/11/01	7/30/01	74
76	Place Concrete for Corbel	8w	7/31/01	9/8/01	75
77	Place Crane Rail Girders	4w	7/11/01	7/30/01	74
78	Dredge & Disposal of Foundation Blankets	8w	7/11/01	8/19/01	74
79	Place U/S Floating Bulkhead	2w	8/20/01	8/29/01	78
80	**Downstream Cellular Cofferdam Bays 13-17**	**565d**	**4/2/01**	**10/18/02**	
81	Move New Gantry Crane	5w	8/30/01	9/23/01	79
82	Dredging / Folding Deep Holes	2w	9/24/01	10/3/01	81
83	Install Floating Wing Walls	4w	4/2/01	4/21/01	4
84	Install Cell Template	2w	4/22/01	5/1/01	83
85	Install C/D Cells & Found Blanket	20w	5/2/01	8/9/01	84
86	Remove Cell Template	20w	8/10/01	11/17/01	85
87	Fill Cells with Gravel	20w	11/18/01	2/25/02	86
88	Install Pumps in D/S C/D	4w	4/22/01	5/11/01	83
89	Dewater D/S C/D	1w	2/26/02	3/2/02	87
90	Concrete Removal	30w	2/26/02	7/25/02	87
91	Concrete Sluices	30w	2/26/02	7/25/02	87
92	Concrete Stilling Basin	30w	2/26/02	7/25/02	87
93	Concrete Bulkhead Slots	30w	2/26/02	7/25/02	87
94	Install Bulkhead	16w	7/26/02	10/13/02	93
95	Install Hoists & Equipment	16w	7/26/02	10/13/02	93
96	Install Spillway Gates Bays 7-12	1w	10/14/02	10/18/02	95



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Date: 11/16/98

Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

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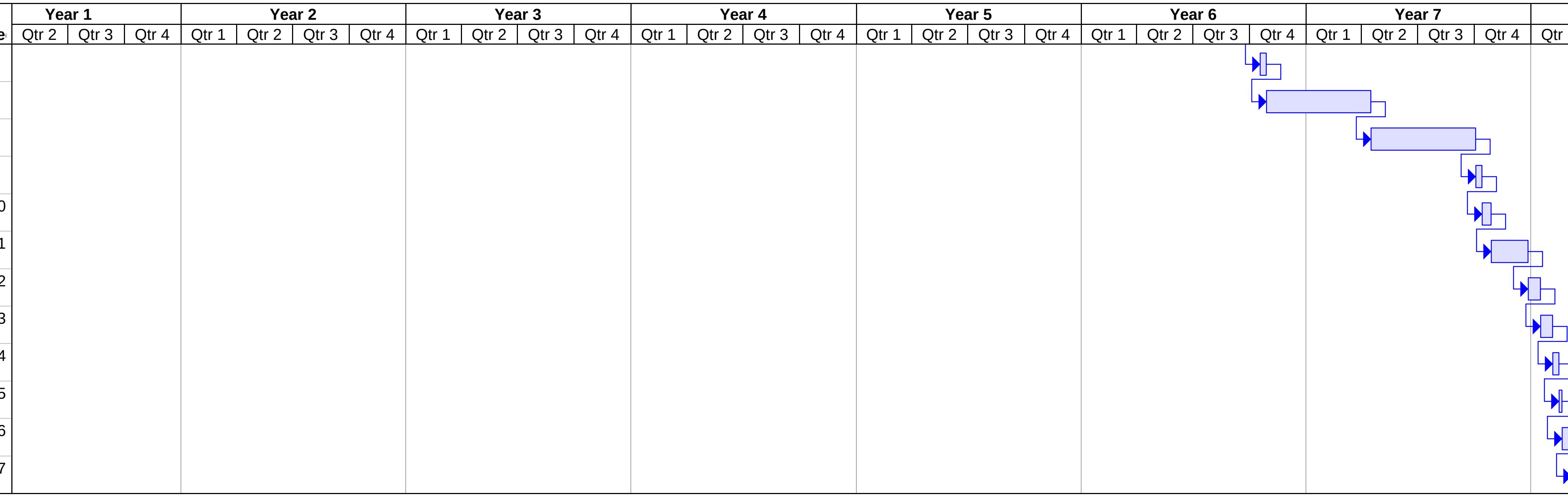
Schedule: Dissolved Gas Abatement Study Alternative 4: Sluices Under Existing Spillway Construction Bonneville Dam

ID	Task Name	Durati	Start	Finish	Pre
97	Finishing Paint Gates	2w	10/19/02	10/28/02	96
98	Install S/W Mechanical Equipment	34w	10/29/02	4/16/03	97
99	Install S/W Electrical	34w	4/17/03	10/3/03	98
100	Install Electrical Pullboxes & Conduits	2w	10/4/03	10/13/03	99
101	Install Permanent Power Supply & Controls to PH	3w	10/14/03	10/28/03	100
102	Remove Required Sheet Pile	12w	10/29/03	12/27/03	101
103	Pave Bridge Approaches	4w	12/28/03	1/16/04	102
104	Install Guardrail, Security Fence, & Gates	4w	1/17/04	2/5/04	103
105	Reestablish Pavement and Striping	2w	2/6/04	2/15/04	104
106	Diving Inspection of Stilling Basin	1w	2/16/04	2/20/04	105
107	Test Electrical/Mechanical Systems	3w	2/21/04	3/6/04	106
108	Conduct Spillway Tests for Dissolved Gas	4w	3/7/04	3/26/04	107



Project:
Date: 11/16/98

Task | Milestone | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone

APPENDIX D

References

REFERENCES

The following hydraulic design references were used to assist in the design of the gas abatement alternatives:

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Daily, James W., Donald R.F. Harleman. *Fluid Dynamics*. Addison-Wesley Publishing Company, Inc., Massachusetts, 1966.

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Hydraulic Design of Spillways, EM 1110-2-1603, Corps of Engineers, 16 January 1990.

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.

Christodoulou, George C. "Energy Dissipation on Stepped Spillways." *Journal of Hydraulic Engineering.* American Society of Civil Engineers, Hydraulics Division. Vol. 119, No. 5, May 1993, pp. 644-650.

Degoutte, G., L. Peyras, and P. Royet. "Skimming Flow In Stepped Spillways." *Journal of Hydraulic Engineering*. American Society of Civil Engineers, Hydraulics Division. Vol. 118, No. 1, January 1992, pp. 111-114.
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Stephenson, D. "Energy Dissipation Down Stepped Spillways." *Water Power & Dam Construction*. September 1991. p.p. 27-30.

Kenny Dam Release Facilities, Spillway Hydraulics & Gas Transfer Model Studies, Northwest Hydraulic Consultants, April 19, 1991.

The following biological study reports, project information reports, and physical hydraulic model study reports were used to assist in the development of gas abatement concepts:

Memorandum For Commander, U.S. Army Corps of Engineers, Portland. Subject: Data Report, Bonneville Spillway Sectional Model, Columbia River, Oregon. CEWES-CR-S. 31 August 1997.

Johnson, G.E., R.M. Sullivan, M.W. Erho. "Hydroacoustic Studies for Developing a Smolt Bypass System at Wells Dam," Fisheries Research, 14, pp. 221-237. Elsevier Science Publishers, Amsterdam, 1992.

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Hydraulic Model Investigation - Libby Reregulating Dam, Kootenai River, Montana. Technical Report No. 160-1. U.S. Army Corps of Engineers, Seattle District. Bonneville Hydraulic Laboratory. July 1983.

Hydraulic Model Investigation - Spillway Deflectors at Bonneville, John Day and McNary Dams on Columbia River, Oregon-Washington and Ice Harbor, Lower Monumental and Little Goose Dams on Snake River, Washington. U.S. Army Corps of Engineers, Portland and Walla Walla Districts. Bonneville Hydraulic Laboratory. September 1984.

Milo C. Bell, "Fisheries Handbook of Engineering Requirements and Biological Criteria", Contract No. DACW57-68-C-0086, Revised 1980.

The following structural, mechanical and electrical design references were used to assist in the design of the gas abatement spillways:

Engineering Manuals (EM)

EM 1110-2-1151	*Engineering Design for Civil Works Projects*
EM 1110-2-1603	*Hydraulic Design of Spillways*
EM 1110-2-2000	*Standard Practice for Concrete Civil Works Structures*
EM 1110-2-2006	*Roller-compacted Concrete*
EM 1110-2-2102	*Waterstops and Other Joint Materials*
EM 1110-2-2104	*Strength Design for Reinforced Concrete Hydraulic Structures*
EM 1110-2-2105	*Design of Hydraulic Steel Structures*
EM 1110-2-2200	*Gravity Dam Design*
EM 1110-2-2502	*Retaining and Flood Walls*
EM 1110-2-2503	*Design of Sheet Pile Cellular Structures*
EM 1110-2-2901	*Tunnels and Shafts in Rock*
EM 1110-2-2902	*Conduits, Culverts and Pipes*
EM 1110-2-3001	*Planning and Design of Hydroelectric Power Plant Structures*
EM 1110-2-3102	*General Principles of Pumping Station Design*
EM 1110-2-3104	*Structural Design of Pumping Stations*
EM 1110-2-3105	*Mechanical and Electrical Design of Pumping Stations*

Engineering Regulations (ER)

ER 1110-2-1	*Provisions for Future Hydropower Installation at Corps of Engineers Projects*
ER 1110-2-1150	*Engineering and Design for civil Works Projects*
ER 1110-2-1806	*Earthquake Design and Analysis for Corps of Engineers Projects*
ER 1110-2-8152	*Planning and Design of Temporary Cofferdams and Braced Excavations*
ER 1110-345-53	*Structural Steel Connections*
ER 1110-345-700	*Design Analysis*
ER 1110-345-710	*Drawings*
ER 1110-345-720	*Construction Specification*

Engineering Technical Letters (ETL)

ETL 1110-2-254	*Finite Element Analysis Interpretation and Documentation*
ETL 1110-2-276	*Structural and Geotechnical Design Considerations for Addition of Hydropower Facilities at Existing Corps of Engineer Projects*
ETL 1110-2-303	*Earthquake Analysis and Design of Concrete Gravity Dams*
ETL 1110-2-312	*Strength Design Criteria for Reinforced Concrete Hydraulic Structures*
ETL 1110-2-332	*Modeling of Structures for Linear Elastic Finite Element Analysis*
ETL 1110-3-446	*Revision of Thrust Block Criteria in TM-813-6*
ETL 1110-3-447	*Engineer of Record and Design Responsibilities*
ETL 1110-8-13	*Structural Engineering Responsibilities for Civil Works Projects*

Engineering Circulars (EC)

EC 1110-2-268	*Engineering and Design for Civil Works Projects*
EC 1110-2-6050	*Response Spectra and Hydraulic Analysis for Hydraulic Structures*

Technical Manuals (TM)

TM 5-809-1	*Structural Design Criteria Loads*

Civilian Standards

For those areas of design not addressed by government publications, the following civilian codes and standards will be used. The specific edition of each reference is the one in current use at the time design begins.

Uniform Building Code, ICBO
Building Code and Commentary, ACI 318
Environmental Engineering Concrete Structures, ACI 350
Anchorage to Concrete, ACI 355
Steel Construction Manual, Load and Resistance Factor Design, AISC
Structural Welding Code, AWS
Minimum Design Loads for Buildings and Other Structures, ASCE/ANSI
Steel Pipe - A Guide for Design and Installation, AWWA M11
Buried Steel Penstocks, Steel Plate Engineering Data - Volume 4, AISI
Steel Penstocks, ASCE Manuals and Reports on Engineering Practice No. 79, ASCE

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