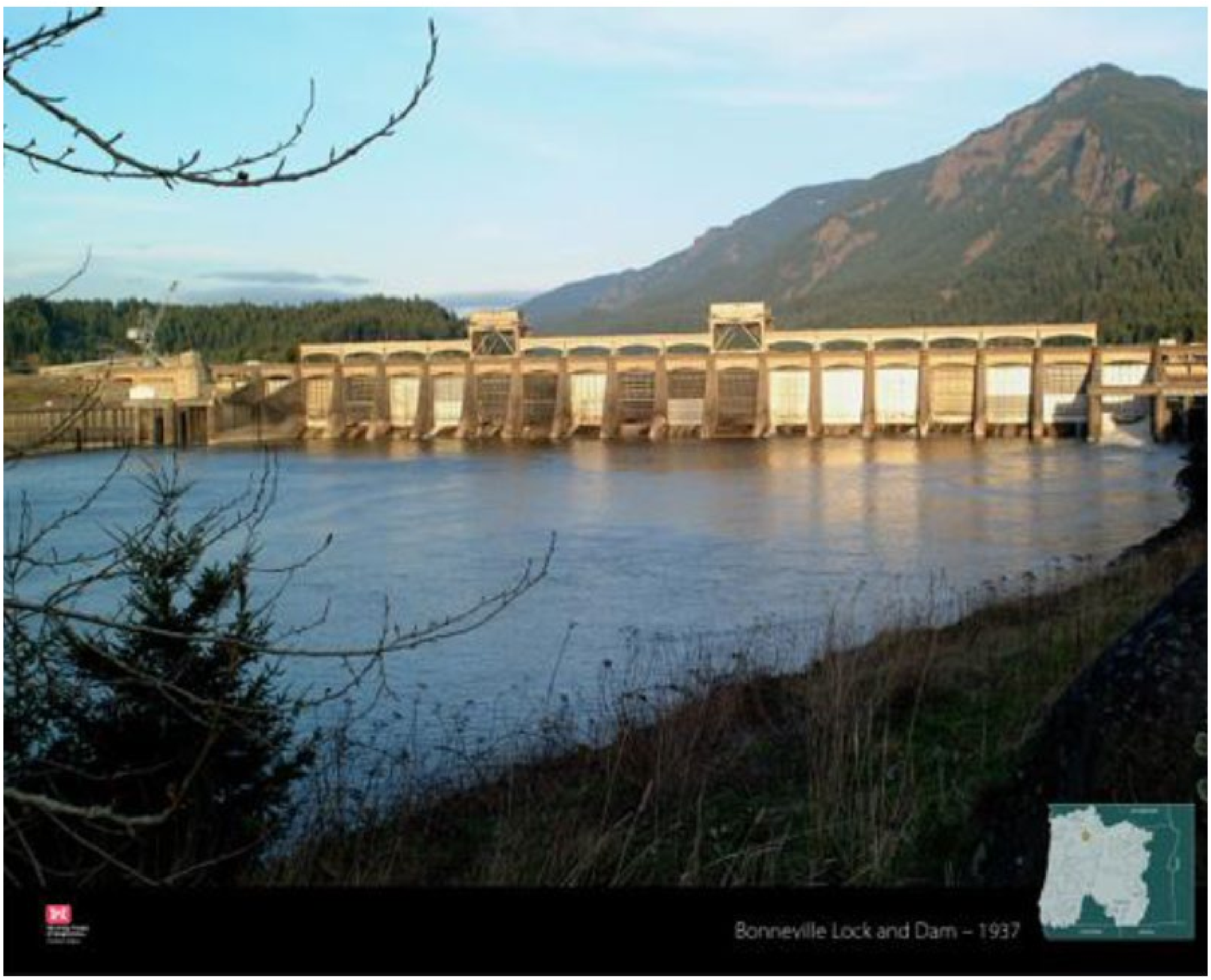
US Army Corps of Engineers®
Portland District

DESIGN DOCUMENTATION REPORT

BONNEVILLE DAM
COLUMBIA RIVER BASIN
COLUMBIA RIVER, OREGON

Bonneville Spillway Rock Mitigation



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January 2025

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EXECUTIVE SUMMARY

1. INTRODUCTION

In the last decade, hydrosurveys conducted in the Bonneville Dam spillway have found rocks migrating upstream towards and into the stilling basin. Model studies have concluded the movement of the rocks is due to the hydraulic patterns within the tailrace. The fast-moving layer of water near the surface caused by the flow deflectors creates a hydraulic pattern akin to a vertical eddy and water velocities near the bedrock of the spillway are large enough in magnitude to move material in the upstream direction. Loose rocks in this current can migrate to the apron, up the apron, and into the stilling basin. Once rocks have entered the stilling basin, they cause damage to the concrete from ball milling effects. Rocks in the stilling basin must be removed mechanically by cranes and divers as part of non-routine maintenance that is required to extend the life of the spillway and stilling basin.

2. PURPOSE

The purpose of this project is to design and construct a solution to the rock migration problem that will prevent rocks from entering and causing damage to the stilling basin. In addition, this project also aims to replace the non-routine maintenance contract framework for rock removal with a long-term, recurring maintenance contract framework for rock removal.

A Phase 1a report was completed for this project in June 2022 which examined several alternatives to prevent rock migration into the stilling basin at Bonneville Dam. The PDT determined that construction of two pre-cast concrete barriers constructed on the spillway apron downstream of Pier 3 and Pier 11 would effectively act as physical barriers to prevent rock from migrating up the apron and into the stilling basin. The barrier locations were selected to be in line with existing piers to reduce flow forces and at locations on the barrier that provide a sufficient elevation difference between the downstream rock and the apron to prevent material from bypassing the barriers. The conceptual design favored the placement of hollow, pre-cast concrete cells on the apron which would be backfilled with tremie concrete.

A Value Engineering (VE) study was completed for this project in April 2023. The VE team determined that a cast-in-place (CIP) structure would result in a significant cost savings and would likely be easier than constructing the barrier out of pre-cast blocks. At the time, the PDT concurred with the findings of the VE study and decided to develop a design using the CIP concept. As design progressed, it was determined that the cost of the cast-in-place structure had escalated significantly above the VE estimate. The PDT convened a constructability workshop in April 2024 to solicit expert opinions and discuss alternatives to reduce cost. Following the workshop, the PDT decided to pursue the original design concept of pre-cast concrete cells backfilled with tremie concrete.

3. PROJECT LOCATION

Bonneville Dam straddles the Columbia River between Oregon and Washington approximately 40 miles east of Portland, Oregon at River Mile 146.1. Work will be performed in the spillway stilling basin.

4. DESCRIPTION OF FACILITY

Bonneville Lock & Dam, built and operated by the U.S. Army Corps of Engineers, was the first federal lock and dam on the Columbia and Snake rivers. The project's first powerhouse, spillway and original navigation lock were completed in 1938 to improve navigation on Columbia River and provide hydropower to the Pacific Northwest. A second powerhouse was completed in 1981, and a larger navigation lock in 1993.

5. CONSTRUCTION ACCESS

The work will be performed in-water and will likely be performed from a floating plant. The project has numerous potential staging areas that will be coordinated with the project office. This includes identifying areas where pre-cast concrete members can be constructed onsite.

6. CONSTRUCTION SCHEDULE

Placement and filling of the cells will be conducted during the in-water work period and is expected to take approximately 16 weeks. Onsite construction of the concrete cells prior to the in-water work period is anticipated to take approximately 17 weeks, which includes two weeks of float to account for any delays, for a total on-sight construction period of 33 weeks.

7. OPERATIONS DURING CONSTRUCTION

Construction will be scheduled during the in-water work period and the schedule will be modified to ensure minimal disruption to spillway, power, navigation and fish passage operations.

8. LESSONS LEARNED

Subject matter experts (SME) with experience in underwater concrete placements were consulted to assist in developing the design. Brian Lucarelli, PE, (LRD Structural SME) provided example specs, drawings, mix designs and contractor submittals for the Chicago Lock Floor and Wall Replacement which involved underwater concrete placement at a USACE navigational project. These materials were instrumental in developing the technical specifications for underwater concrete placement.

A constructability workshop/design charette was conducted on April 25, 2024 following the initial development of 60% design. The workshop was initiated due to high risk and uncertainty identified during development of the cost estimate associated with uncertainties about construction methods of cast-in-place concrete structures. The workshop included members from the NWP design and construction branch and subject matter experts in underwater construction/concrete from LRP. Following the charette, the team decided to move forward with a structure of hollow-cell precast blocks filled with tremie concrete. The Dalles Spillwall project was used as an example where precast blocks were constructed on the spillway apron by lifting the precast elements with screw jacks, the bottoms and gaps between blocks formed and the structure was backfilled in one continuous closure pour. The team determined that this method had significant advantages over a cast-in-place structure by eliminating construction of substantial underwater forms and thermal effects of placing mass concrete. The pre-cast members can be constructed onsite outside of the In-water-work period providing more time for the contractor to complete the phases of work without the limitations of this timeframe.

8. COST

The first iteration of the 60% Phase 1 P&S included a cost estimate for cast-in-place barriers of approximately $22.0M including 79% contingency. After completing the constructability workshop and redesigning a pre-cast structure, the revised total project cost (design and construction) estimated at the 60% Phase 1 milestone is $13.1M. This includes construction and S&A costs and 55% contingency. An Independent Government Estimate (IGE) is being developed concurrent with design and an updated cost estimate will be completed prior to BCOES.

CONTENTS

TABLES

FIGURES

APPENDICES

DRAINAGE AREA	240,000 square miles
Pool Regulation Elevations (Draft Water Control Manual Update, 2018)	
Length of Reservoir	46.9 miles
Maximum Regulated Pool Elevation	80.3 ft-NAVD88
Normal Operating Pool Elevation Range	74.8 ft-NAVD88 to 79.8 ft-NAVD88
Minimum Operating Pool Elevation	73.3 ft-NAVD88
Maximum Spillway Design Operating Pool Elevation (1,600,000 cubic feet per second)	85.8 ft-NAVD88
Normal High Tailwater Elevation	38.3 ft-NAVD88
Normal Low Tailwater Elevation	10.3 ft-NAVD88
Spillway	
Type	Concrete Gravity, Gate Controlled, Ogee
Overall Length	1,450 feet
Gate Type	Split (two) Leaf, Vertical Sliding
Operating Gates	(18) 60 feet H x 50 feet W
Spare Gates	(2) 60 feet H x 50 feet W
Gantry Cranes *	(2) 350-ton with Backup Generators
Gate Hoists *	(16) Gen 1, 2, and 3
Ogee Crest Elevation	27.3 ft-NAVD88
Deck Elevation	100.3 ft-NAVD88
Spillway Design Flow	1,600,000 cubic feet per second
* = Operated from Control Room	
First (Original) Navigation Lock (Currently Out of Service)	
Type	Single Lift
Length	500 feet
Width	76 feet
Vertical Lift	30 to 70 feet
Minimum Depth over Lower Miter Gate Sill	21 feet
Depth Over Upper Sill	34 feet
Datum Conversion	
NGVD29 =	NAVD88 -3.34 feet

PREVIOUS REPORTS

Number	Title	Date
1	Bonneville Dam Spillway Rock Mitigation – Phase 1a Report	January 2022
2	Bonneville Dam Spillway Rock Mitigation – Value Study Report	May 2023

ACRONYMS

Acronym	Description
1D	One-Dimensional
PDT	Project Delivery Team
USACE	United States Army Corps of Engineers
BiOp	Biological Opinion
FFDRWG	Fish Facility Design Review Work Group
FPOM	Fish Passage Operations Maintenance
FPP	Fish Passage Plan
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
EIS	Environmental Impact Statement
CRS	Columbia River System
CRSO	Columbia River System Operation
ROD	Record of Decision
FOP	Fish Operation Plan
CFD	Computational Fluid Dynamics
cfs	cubic feet per second
kcfs	thousand cubic feet per second
fps	feet per second
MSL	Mean Sea Level
TDG	Total Dissolved Gas

SECTION 1 - PURPOSE AND INTRODUCTION

In the last decade, hydrosurveys conducted in the Bonneville Dam (Figure 1-1) spillway have found rocks migrating upstream towards and into the stilling basin (Figure 1-2). Model studies have concluded the movement of the rocks is due to the hydraulic patterns within the spillway. The fast-moving layer of water near the surface caused by the flow deflectors creates a hydraulic pattern akin to a vertical eddy and water velocities near the bedrock of the spillway are large enough in magnitude to move material in the upstream direction. See section 7 for more on hydraulics. Loose rocks in this current can migrate to the apron, up the apron, and into the stilling basin. There is no incremental loss of life risk attributable to the accumulation of rocks in the stilling basin, however, long-duration spills result in ball milling and scouring of the stilling basin by the accumulated rocks. Currently, the operational solution is for periodic over-water rock removal. This is a significant maintenance project that requires one or two months to accomplish in one IWWW. The most recent contract was awarded for $411,736. This is the approximate annual baseline cost of the current condition without the project alternative.

Figure 1-1: Bonneville Project.

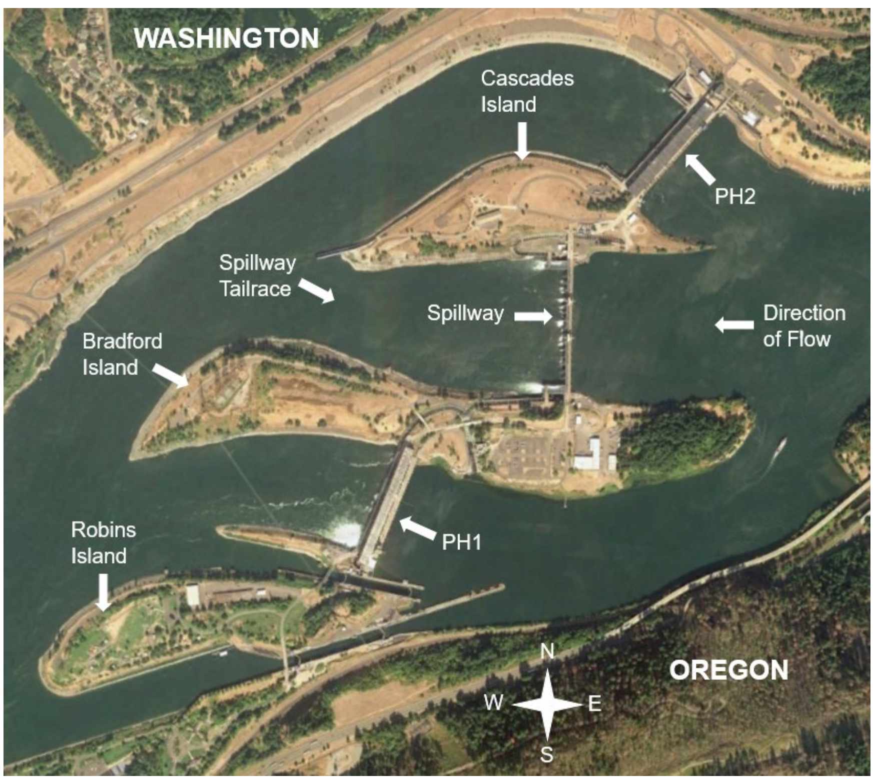
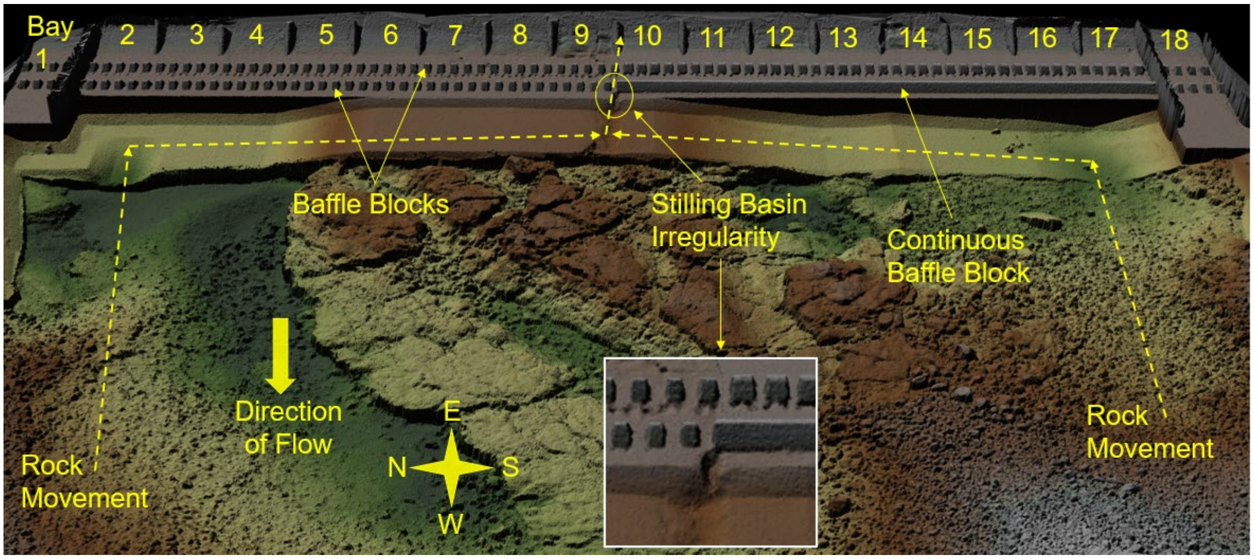


Figure 1-2: Bonneville Spillway.



The purpose of this project is to design and construct two concrete barriers on the spillway apron to act as physical barriers to prevent rock from migrating up the spillway apron and into the stilling basin. Hydraulic modeling suggests that rocks will be retained by these structures and periodic flushing spills will be effective in removing rock debris from the apron. These barriers are intended to eliminate or reduce the frequency of the periodic, non-routine maintenance for rock removal.

1.1 PREVIOUS STUDIES AND REPORTS

1.1.1 Phase 1a – Alternatives Analysis (2022)

A Phase 1a report was completed for this project in January 2022 which examined several alternatives to prevent rock migration into the stilling basin at Bonneville Dam. The PDT determined that construction of two pre-cast concrete barriers constructed on the spillway apron downstream of Pier 3 and Pier 11 would effectively act as physical barriers to prevent rock from migrating up the apron and into the stilling basin. The original conceptual design involved the placement of hollow, pre-cast concrete cells on the apron which would be backfilled with tremie concrete.

1.1.1.1 *Phase 1a Criteria*

Major criteria identified in the Phase 1a included considerations for design and future operation of the selected alternative. The major considerations were the exclusion of rocks from the stilling basin, no permanent changes to spillway or fish passage operations, adherence to the In-Water-Work (IWW) period, no impacts to dam safety, the ability of the structure to withstand a 100-year flood and 144-operational basis earthquake (OBE), and no additional, cumbersome O&M requirements.

1.1.2 Value Engineering Study (2023)

A Value Engineering (VE) study was completed for this project in April 2023. The VE team determined that a cast-in-place (CIP) structure would result in a significant cost savings and would likely be easier than constructing the barrier out of pre-cast blocks. A CIP structure would also have the benefit of filling a gap where the upstream structure meets a sloped fillet section. The gap could potentially allow debris to bypass the barrier. The PDT concurred with the findings of the VE study and decided to develop a design using the CIP concept. However, after further developing the CIP design it was determined that the cost was much higher than the VE estimate. After further evaluation, the PDT decided to pursue the original hollow pre-cast structure with a better understanding of construction methods which reduced the cost.

1.2 PROJECT LOCATION

Bonneville Dam straddles the Columbia River between Oregon and Washington approximately 40 miles east of Portland, Oregon at River Mile 146.1. Work will be performed in the spillway tailrace.

1.3 DESCRIPTION OF FACILITY

Bonneville Lock & Dam, built and operated by the U.S. Army Corps of Engineers, was the first federal lock and dam on the Columbia and Snake rivers. The project's first powerhouse, spillway and original navigation lock were completed in 1938 to improve navigation on Columbia River and provide hydropower to the Pacific Northwest. A second powerhouse was completed in 1981, and a larger navigation lock in 1993.

1.4 PROJECT DESCRIPTION

The two concrete structures will be constructed on the spillway apron parallel with the direction of flow. The structures will be approximately 85 feet long x 13 feet wide x 17 feet tall and will be constructed downstream of Pier 3 and Pier 11 (See Figure 1-3 and Figure 1-4). Construction will be done in the wet during the in-water-work window (IWW) between December 1 and February 28. Means and methods will be determined by the Contractor but it's assumed that underwater form work will require divers and a floating plant. The Contractor will be responsible for designing and constructing the temporary form work used to construct the barriers. Concrete mix designs will include provisions for anti-washout admixtures to ensure minimal concrete disperses into the water column.

1.5 PROJECT DATUM

All design features are referenced to Bonneville Project Datum. Bonneville Project Datum = NAVD88 – 3.34 ft.

Figure 1-3: Isometric View of concrete barriers.

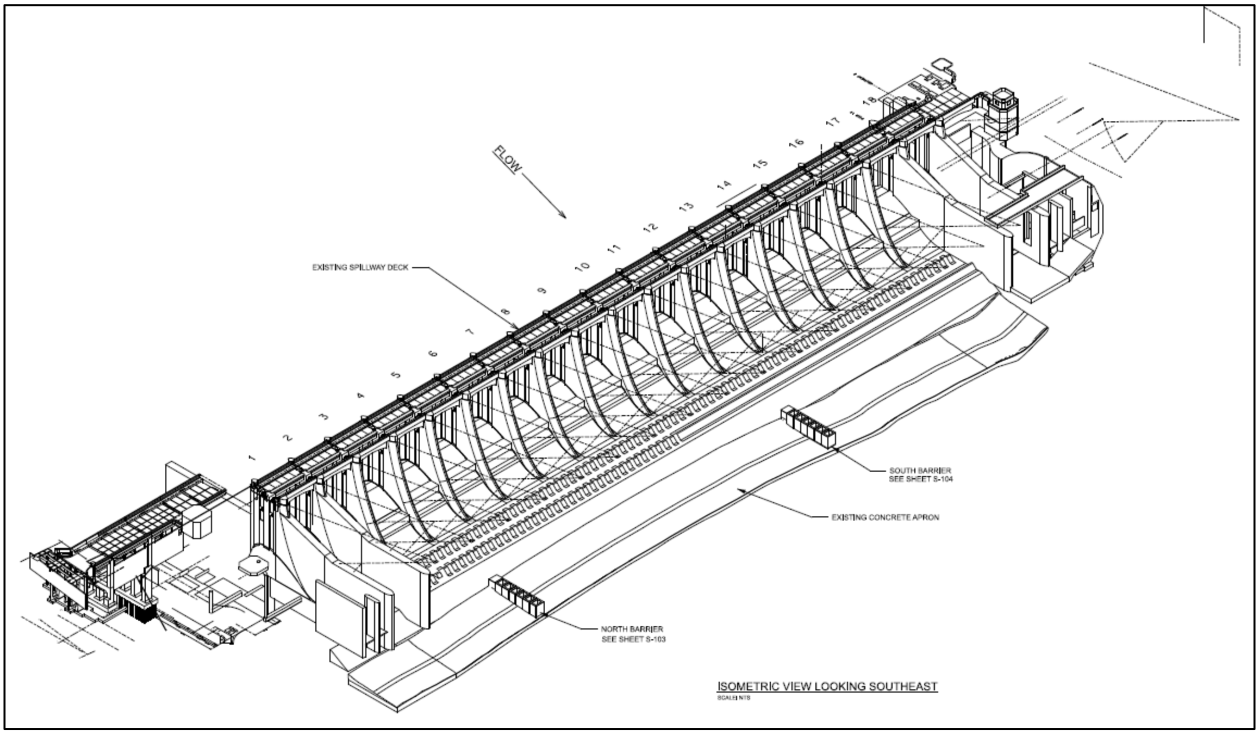
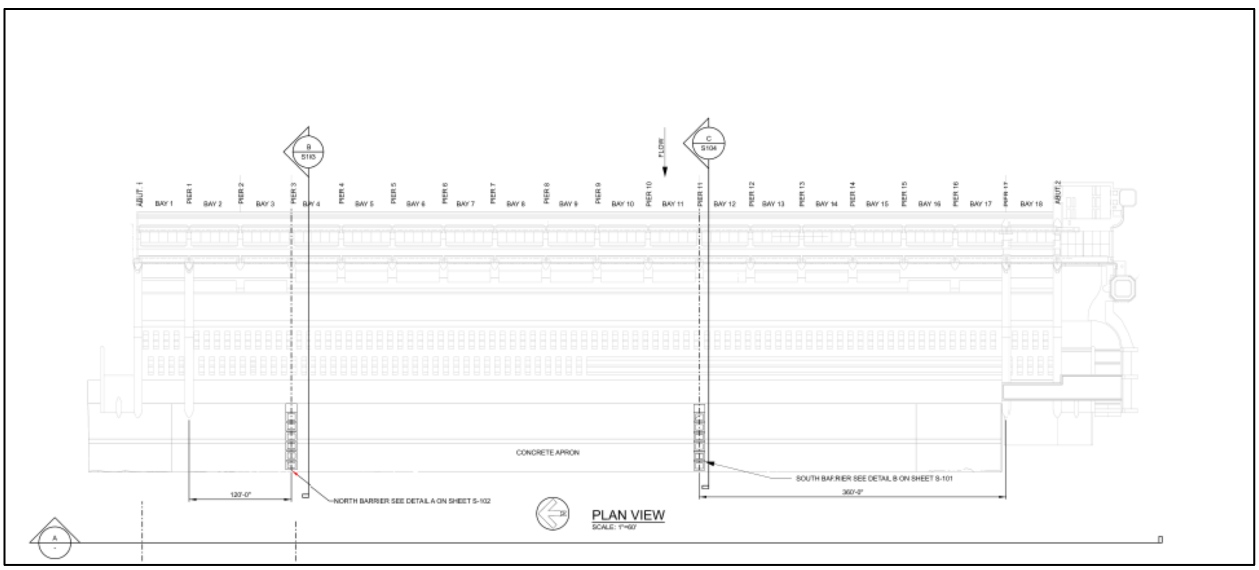


Figure 1-4: Plan View of concrete barriers.



1.6 PROJECT CONSTRAINTS

The project will not be allowed to impact normal operation of the spillway or the fish passage operations at the site.

1.6.1 Spillway Operation

The construction project will not be allowed to interfere with normal operation of the spillway. Construction will be scheduled during the in-water work window, common practice to in-water work at the project. The project specifications will include provisions for evacuating the spillway tailrace if necessary to facilitate flood control operations.

Coordination with the NWD Reservoir Control Center (RCC) and Bonneville Power Administration will be required to regulate flows during construction. Both have been notified of the project schedule and will be contacted when construction start dates are better defined.

1.6.2 Spillway Bridge

The north end of the spillway bridge has load restrictions that prohibit heavy construction traffic. It's not anticipated that this area will be required for construction and will be excluded from the work limits.

1.6.3 Fish Passage

Design and construction will comply with the National Oceanic and Atmosphere Administration (NOAA) National Marine Fisheries Service (NMFS) 2020 Columbia River System (CRS) Biological Opinion. The construction project and barriers will not be allowed to interfere with fish passage operations at the dam.

Fish Passage Spill

In September 2020, USACE signed a Record of Decision (ROD) adopting the Preferred Alternative described in the Action Agencies' (Bonneville Power Administration, US Bureau of Reclamation, US Army Corps of Engineers) Final Environmental Impact Statement for the long-term coordinated operation and management of the Columbia River System Operation (CRSO EIS ROD). The proposed action implements flexible spring spill operations in an attempt to improve the survival of spring-migrating juvenile salmon and steelhead through the dams to help improve adult returns. Refer to Chapter 2 of the Fish Passage Plan (FPP) for detailed operating information regarding fish migration seasons, gate openings, spill patterns, and spill volumes. Appendix E of the Fish Passage Plan contains the 2024 Fish Operations Plan (FOP) for Bonneville Dam's juvenile spill operations which is updated on an annual basis and describes the processes for adaptive management and in-season management for provisions outlined in the CRSO EIS ROD. Table 1-1 provides a summary for the current spring and summer spill operations implemented at Bonneville Lock & Dam. Fall and winter spill operations from September 1-April 09, have no minimum spill level requirements beyond daytime attraction flow spill where spill bays 1 and 18 are each open to one stop (6") to provide adjacent attraction flow to the Cascades Island and Bradford Island B-Branch adult fish ladder entrances when the ladders are operational (FPP Section 2.2.4.4). Spill releases beyond specified and required fish passage spill volumes are characterized as involuntary. Involuntary spill releases are when water is spilled through a spillway when it cannot be passed through turbines to generate electricity, such as during maintenance activities, periods of low energy demand, or periods of high river flow. Involuntary spill is most common in the spring during peak fish outmigration coinciding with spring freshet runoff. Involuntary spill releases during juvenile fish passage spill season (April 10 – August 31) are a concern, as this is when involuntary spill volumes exceed the 150 kcfs ‘threshold’. If involuntary spill exceeds the 150 kcfs ‘threshold,’ rocks tend to move upstream and make their way into the stilling basin. Since Bonneville typically spills more than 150 kcfs every year, rocks are found within the stilling basin most years.

Table 1-1: Spill Seasons at Bonneville Lock and Dam for Juvenile Fish Passage

Season	**Dates**	**Spill Operation**
Spring	April 10 – June 15	24 hours/day: 150 kcfs 125% Gas Cap
Summer	June 16 – August 14	24 hours/day: 95 kcfs
	August 15 – August 31	24 hours/day: 50 kcfs

Information in table is summarized from the 2023 FOP (Appendix E of the 2023 FPP).

<u>Fish Passage Design Considerations for Barriers</u>

The barrier design cannot negatively impact the movement of fish and must incorporate a design that will minimize the risk to fish if they do interact with the barriers. Fish interaction with the structure is unknown, however, interactions are anticipated to be low due to the location and depth of the barriers. The historic minimum tailwater (between 1974-1999) was recorded at 7 feet (Phase 1a). This yields a minimum depth of 25 feet of water between the top of the barriers (-18 feet) and the historic minimum tailwater surface elevation. The 10-year average tailwater measured at Cascades Island ranges between the years 2013-2022 ranged from 8.6 feet to 23.4 feet (DART, 2023). Using the lowest tailwater from the most recent 10-year average tailwater elevation, the distance between the top of the barriers would remain greater than the 25’ feet minimum depth. Due to the unknowns with fish interaction with the barriers, the barrier design will have precautionary design features adopted from the National Marine Fisheries Service’s National Oceanic and Atmospheric Administration Fisheries West Coast Region Anadromous Salmonid Passage Design Manual (2022).

The NMFS NOAA Design Manual (2022) states the following considerations for finishes on structures that are located in the flow path used by migrating fish:

Section 5.11.3 Edge and Surface Finishes

> *All metal edges in the flow path used for fish migration should be ground smooth and rounded to minimize risk of lacerations. Concrete surfaces should be finished to ensure smooth surfaces, with 1-inch-wide, 45-degree corner chamfers.*
>
> *Section 5.11.4 Protrusions*
>
> *Protrusions that fish could contact, such as valve stems, bolts, gate operators, pipe flanges, and permanent ladders rungs, should not extend into the flow path of the fishway.*

The design of the barriers will be coordinated and reviewed through the regional forum hosted by Portland District's Lower Columbia River Fish Facility Design Review Work Group (FFDRWG) which comprises of federal, state, and tribal representatives. The 60/90% draft DDR milestones will be distributed to FFDRWG representatives for a 30 day review period. USACE shall provide written responses to agency comments during the DDR milestone reviews. Comments received are documented in Appendix F. Please note that the 30% DDR milestone review was not sent out to FFDRWG representatives because the content of the DDR pertained only to structural and seismic calculations and did not have any written content.

<u>Biological Considerations for Barrier Construction</u>

All construction and maintenance that requires in-water-work at Bonneville Dam, must adhere to the in-water-work window between December 1 through the end of February. This time period coincides with overall lower passage numbers of both upstream and downstream migrating salmonids to help reduce impacts to fish.

Construction planning for the barriers shall be coordinated in advance to adhere to Bonneville Dam's Fish Passage Plan requirements. Specific operations during the construction period for the barrier install are not yet known but will be investigated in order to include these operations in the specifications package and to coordinate any deviation of operations set forth by the Fish Passage Plan through the Fish Passage Operations Maintenance regional forum.

Since the installation of the barriers will require access to the spillway tailrace via barges and/or a floating plant, a boat restricted zone permit will need to be coordinated.

> *FPP Section 2.1.1 All activities within boat restricted zones (BRZ) will be coordinated with the Project at least two weeks in advance, unless deemed an emergency.*

Fish Ladder Flows

There are two adult fish ladder entrances located in the Bonneville Dam spillway tailrace. The fish ladder entrance located on the north side of the spillway is the Cascades Island Fish Ladder Entrance, and the entrance on the south side of the spillway is the Bradford Island B-Branch Fish Ladder Entrance. One of the two adult fish ladders servicing the spillway will be fully operational during the annual winter maintenance period. The operational fish ladder must meet established FPP criteria to meet the required flow conditions to enable upstream migrants to ascend the ladder and continue their migration upriver.

The required flow requirements for upstream migrants are outlined in the following sections of the FPP:

> *Section 2.2.4.4. From September 1 through April 9, during daytime hours defined in FPP Chapter 2 Bonneville Dam, Table BON-5, spill will occur from Bays 1 and 18 each open one stop (6”) to provide attraction flow to the Cascades Island and Bradford Island B-Branch entrances, respectively. From December 1 through the end of February, spill will only occur from the spill bay(s) adjacent to an operating ladder entrance.*

The spill volume for adjacent ladder attraction flow spill is approximately 1200 -1500 cfs per bay. The water velocity in the work area adjacent to fish ladder attraction spill is approximately one knot.

> *FPP Section 2.4.2.4. Maintain head on all fish ladder entrances in the range of 1’–2’ (1.5’ preferred).*

A clear flow path along the shore shall be maintained at all times such that fish seeking the ladder are not delayed in reaching the entrance.

Chum Flows
Each year during November through approximately April, Bonneville outflow and tailwater elevation is closely monitored and regulated to provide sufficient water conditions to support chum salmon spawning, incubation, and emergence at the Ives/ Pierce Island complex below Bonneville Dam. These operations are coordinated with the Action Agencies through the Technical Management Team (TMT). More information regarding chum operations can be found at http://pweb.crohms.org/tmt/.

Avian lines
Avian guide wires are installed as a passive abatement measure to deter piscivorous bird predation at Bonneville Dam (FPP Section 2.3.2.3. & Appendix L Section 3.2.a). Avian wires are located in the tailraces of Powerhouse 1, Powerhouse 2, spillway, and Bonneville 2 Corner Collector outfall. If construction requires the removal of avian wires, this must be coordinated in advanced through FPOM and Bonneville Project. A replacement plan must be in place and with wires installed prior to April 10.

SECTION 2 - STRUCTURAL DESIGN

The purpose of the concrete barriers from a structural standpoint is to prevent rocks from migrating into the spillway stilling basin. The proposed concrete barrier features will be designed to meet all applicable USACE engineering manuals and regulations. The barriers are intended to be gravity structures with no subsurface anchorage in the spillway slab or underlying bedrock. These foundation considerations are described in more detail in Chapter 3 – Geotechnical Design. A stability analysis of previous shapes was performed in the phase 1A. Upon various iterations of design, a square profile was chosen as the most efficient option.

2.1 DESIGN REFERENCES

Design of new features will conform to following technical manuals, regulations, and codes:

- American Concrete Institute (ACI). ACI 318-19, Building Code Requirements for Structural Concrete.
- USACE. 2016. EM 1110-2-2104, Strength Design for Reinforced-Concrete Hydraulic Structures.
- USACE. 2003. EM 1110-2-2400, Structural Design of Spillway and Outlet Works.
- USACE. 2005. EM 1110-2-2100, Stability Analysis of Concrete Structures.
- USACE. 2007. EM 1110-2-6053, Engineering and Design - Earthquake Design and Evaluation of Concrete Hydraulic Structures.
- USACE. 2014. ETL 1110-2-584, Design of Hydraulic Steel Structures.
- USACE. 2016. ER 1110-2-1806, Earthquake Design and Evaluation for Civil Works Projects
- U.S. Geological Survey (USGS). 2014. National Seismic Hazard Maps.
- Seismic Hazard Analysis for Six Dams in the Willamette Valley, Oregon, 2017

2.2 STRUCTURAL DESIGN CONSIDERATIONS

2.2.1 Design Criteria

All concrete structures will be evaluated based on the strength requirements of EM 1110-2-2104.

2.2.2 DESIGN LOADS

2.2.2.1 *Dead Load*

Dead load consists of the weight of concrete of the barrier. Concrete unit weight is assumed to be 150 pounds per cubic foot (lb/ft3).

2.2.2.2 *Hydrodynamic – Seismic*

During an earthquake, there will be inertial dynamic forces due to movement of water in the spillway tailrace. These forces are estimated by the Westergaard's formula (ETL 1110-2-584, Equation 3-2) which is based on the peak ground acceleration (PGA) and the mass of water in the stilling basin, which is assumed to move with the structure. Westergaard's equation, shown below, calculates an equivalent pressure distribution on the face of the structure.

Equation 2-1. Westergaard Equation

$$F = 36.5 * H^{\frac{1}{2}} * h^{\frac{3}{2}} * \frac{a_c}{g}$$

Where:

- F = hydrodynamic force (lbf)
- W = unit weight of water (62.4 lb/ft^3)
- a_c = the maximum acceleration (expressed as a fraction of gravitational acceleration)
- h = the barrier height (to the bottom of the dam, ft)
- H = the total depth below the pool surface (ft)

2.2.3 Seismic

The evaluation of structures for earthquake ground motions should be performed in phases in order of increasing complexity progressing from simple equivalent lateral force methods to linear elastic response-spectrum and time-history analysis, to nonlinear methods, if necessary.

2.2.3.1 *Seismic Coefficient Method*

The seismic coefficient method has traditionally been used to evaluate seismic stability of structures. According to ER 1110-2-1806 this method may still be used in the preliminary design and stability analyses. In the seismic coefficient method, earthquake forces are treated simply as static forces and are combined with the hydrostatic pressures, uplift, backfill soil pressures, and gravity loads. The analysis is primarily concerned with the rotational and sliding stability of the structure treated as a rigid body. The inertia forces acting on the structure are computed as the product of the structural mass, times a seismic coefficient. The magnitude of the seismic coefficient is often taken as a fraction of the peak ground acceleration expressed as a decimal fraction of the acceleration of gravity.

The seismic coefficient method is used to calculate seismic loads. Earthquake loading is treated as an inertial force applied statically to the structure through the center of gravity. Two types of seismic loads are applied: inertia force due to the horizontal acceleration of the structure and hydrodynamic forces resulting from the reaction of the reservoir water against the structure. The magnitude of the inertia forces is computed by the product of mass and the seismic coefficient as shown in the equation below. The magnitude of the seismic coefficient is taken as a fraction of the peak ground acceleration expressed as a decimal fraction of the acceleration of gravity.

Equation 2-2. Seismic Coefficient Equation

$$F_h = m * a = k_h * W$$

Where:

- F_h = horizontal component of the inertial force (lb)
- m = mass of structure (slug)
- pga=peak ground acceleration (a/g)
- a = seismic acceleration (ft/s^2)
- W = gross weight of the barrier structure
- k_h = seismic coefficient = 2/3*pga
- g = acceleration of gravity (32.2 ft/s^2)

2.3 SEISMIC PARAMETERS

2.3.1.1 Maximum Design Earthquake (MDE)

The MDE is the maximum level of ground motion for which a structure is designed or evaluated. The associated performance requirement is that the project performs without loss of life or catastrophic failure (such as uncontrolled release of the reservoir) although severe damage or economic loss may be tolerated. For critical features, the MDE is the same as the MCE. For all other features, the minimum MDE is an event with 10 percent probability of exceedance in 100 years (average return period of 950 years).

Design ground motions are determined using a recent site specific study completed in 2018 for Bonneville Dam. A mean peak ground acceleration of 0.27g (975-year event) is assumed based on the location of the barriers at the north site of Bonneville dam. This is considered as the MDE event (See Figure 2-1).

Figure 2-1: Probabilistic Ground Motions at Bonneville Dam – North Site

(b) Bonneville Dam – North Site (enveloped over V_S30 of 400 ± 160 m/sec)

Return Period (years)	PGA (g)			0.2 sec SA (g)			1.0 sec SA (g)			3.0 sec SA (g)		
	Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile
144	0.11	0.044	0.15	0.27	0.18	0.39	0.12	0.072	0.16	0.020	0.014	0.030
475	0.20	0.11	0.27	0.50	0.34	0.67	0.24	0.16	0.33	0.049	0.030	0.077
975	0.27	0.15	0.35	0.66	0.46	0.86	0.34	0.23	0.46	0.082	0.047	0.12
2,475	0.37	0.22	0.48	0.89	0.64	1.13	0.51	0.34	0.67	0.13	0.085	0.18
4,975	0.46	0.28	0.60	1.09	0.79	1.42	0.65	0.44	0.85	0.17	0.12	0.23
9,950	0.56	0.34	0.72	1.34	0.94	1.74	0.81	0.55	1.04	0.22	0.15	0.29
30,000	0.73	0.45	0.94	1.79	1.19	2.32	1.09	0.74	1.39	0.31	0.21	0.40
100,000	0.95	0.58	1.12	2.37	1.46	3.06	1.45	0.99	1.80	0.42	0.28	0.55

2.4 DESIGN METHODS

Table 2-1 below illustrates the materials used in this design and their mechanical properties.

Table 2-1. Properties of Structural Materials

Material	Yield Strength, Fy (psi)	Compressive Strength, f'c (psi)	Modulus of Elasticity, E (psi)	Additional
Concrete				
Existing	-	3,000	3,122,000	
New (contacting water)	-	5,000@ 28 days	3,800,000	Poisson's Ratio = 0.2
Steel Reinforcement				
ASTM A615 (New)	60,000	-	29,000,000	
ASTM A615 (Exist.)	40,000	-	-	

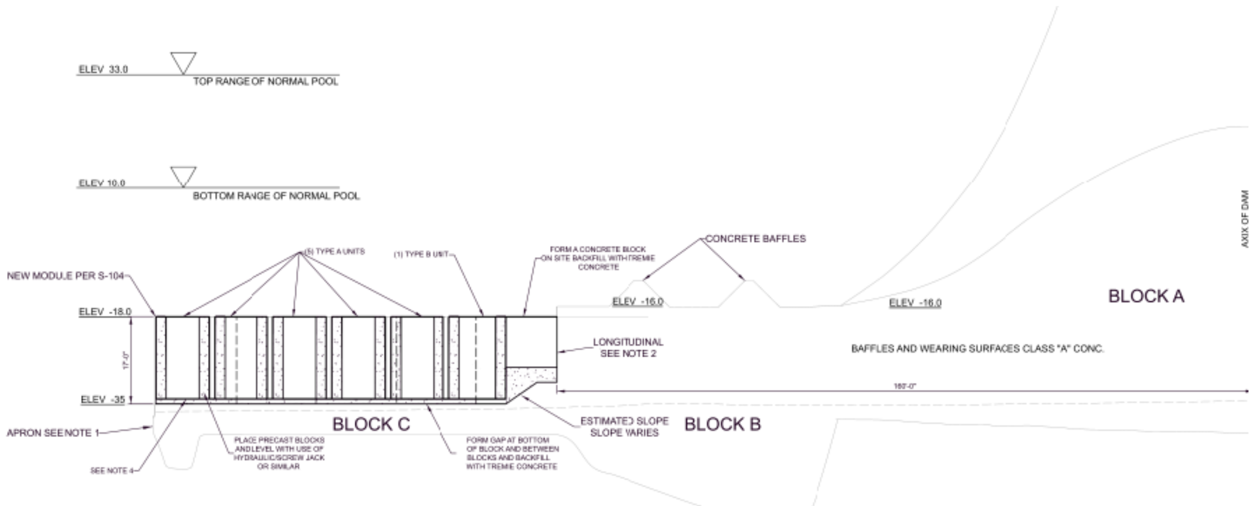
2.4.1 Pre-Cast Concrete Structure

As mentioned previously, the Phase 1a report examined several alternatives to prevent rock migration into the stilling basin at Bonneville Dam. The design recommendation presented in the Phase 1a involves two barriers constructed on the spillway apron consisting of hollow, pre-cast cells which would be backfilled with tremie concrete. A Value Engineering (VE) study was conducted in April 2023 and determined that construction of two cast-in-place concrete (CIP) barriers constructed on the spillway apron would likely result in cost savings and have considerable constructability benefits. The pre-cast structures will be designed by the Contractor to include reinforcement details and will be submitted to the government for approval.

The CIP concept was carried forward through 60% design. High risk/cost factors were identified during the 60% design largely due to uncertainties about construction methodology. The PDT decided to pause design and host a constructability workshop/design charette with members from the design and construction branch as well as subject matter experts from Pittsburgh District with substantial experience in underwater concrete/marine construction. The charette was hosted in April 2025 and the team determined that a precast structure was preferable for several reasons including difficulty of placing/constructing large forms underwater and considerations for thermal control during pouring of the concrete. The team determined precast blocks could be placed on the apron and suspended by a screw/hydraulic jack system 1 to 2 feet off the ground surface; blocks will be placed with a 1 to 2-foot gap between individual sections. After placing and leveling the blocks, the gaps will be formed and each cell will be tremie poured. A similar structure was constructed for the Dalles Spillwall project.

The structures will be steel reinforced to prevent spalling due to impact of rocks. The concrete barriers will have a compressive strength of F'c=5000 psi at 28 days and the mix design includes requirements for anti-washout admixtures to prevent segregation of the concrete mix and transport into the water column. The new barriers are shown in a cross section view of the dam shown in Figure 2-2 below.

Figure 2-2. New Concrete Barrier in section



2.4.2 Seismic Stability

A stability analysis of the rectangular shape shown in Figure 2-1 identified that the structure contained sufficient mass to meet stability factors of safety for floatation, sliding and overturning. At normal maximum tailwater elevation 40 feet, the factor of safety for floatation was found to be 2.4 compared to a usual factor of safety of 1.3 as required in Engineering Manual (EM) 1110-2-2100. Barrier was designed to meet normal, unusual, and extreme loading conditions including seismic loading on the structure.

The PDT determined that the 975-year seismic event would be the appropriate level of design. This results in a peak ground acceleration (PGA) of 0.27g. The average tailwater elevation of elevation 20 feet was considered the concurrent tailwater elevation for this level of seismic analysis. The analysis showed that the structure as depicted was sufficiently heavy enough to hold down the barrier without the need for using concrete anchors. The overturning factor of safety was found to be 1.65. The sliding factor of safety was found to be 1.21 with a required factor of safety for extreme loadings of 1.1 per EM 1110-2-2100. For the sliding analysis a coefficient of friction of 0.65 was used for wet concrete to wet concrete.

Structural calculations are included in APPENDIX B.

SECTION 3 - GEOTECHNICAL DESIGN

This Section describes the probable foundation conditions and the geotechnical design parameters pertaining to the construction of the cast-in-place concrete structures on the spillway apron slab. The information and recommendations contained in this Section are based on existing references listed in SECTION 16 References.

3.1 GEOLOGY

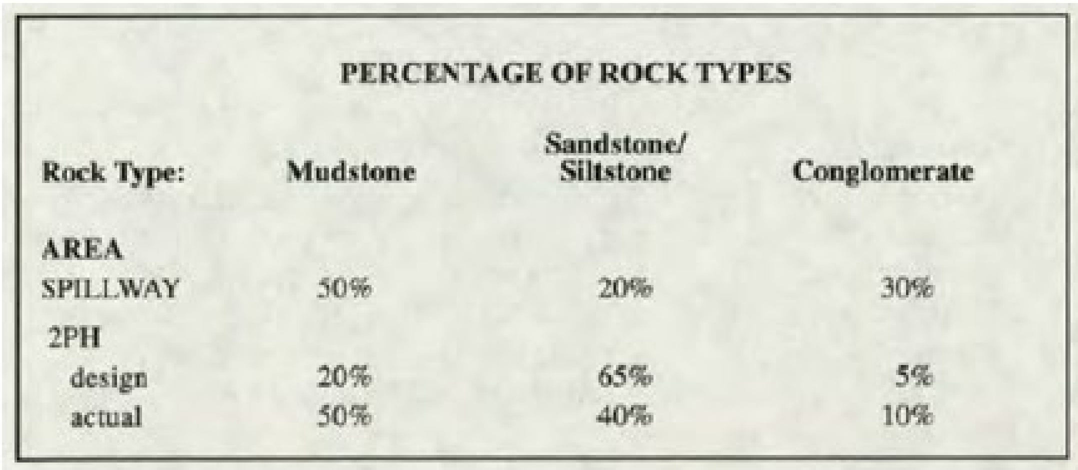
The spillway dam is founded on sedimentary beds informally named the Weigle Formation. The Weigle Formation is weak bedrock composed of poorly indurated sandstone, siltstone, and conglomerate. The bedding of the Weigle Formation generally dips down to the southeast at approximately 15 degrees below horizontal. Approximately 2/3 of the clastic materials which make up this formation were originally deposited as volcanic glass. The remaining 1/3 was predominantly lithic fragments. Materials were transported by water and/or slurries where they were deposited probably at the distal edge of an ancient volcano(es) on slopes or lakes. Stratification is described as extremely varied and discontinuous. Bedding thicknesses range from less than 0.1 inch to greater than 20 feet but most of the unit is composed of beds less than 3 feet thick. Bedding contacts are variable ranging from sharp distinct to gradual and indistinct. Many of the beds were reported to show scour and fill. From the second powerhouse, only major conglomerate beds can be traced across the site.

Sedimentary beds do not form large continuous sheets but form multitudes of thinner discontinuous beds. Unlike most marine sedimentary rock, this material was subjected to hot fluid circulation from the nearby volcanoes when they were being buried and consolidated. This combination of hot fluids, unstable volcanic glass and other unstable mineralogy led to the volcanic glass completely devitrifying and other minerals being altered. This clay alteration has significantly weakened the rock. The foundation rock now has geotechnical engineering properties between that of a true clay deposit and unaltered sedimentary rock. These foundation rocks should be considered weak rock.

Mudstones (bentonitic or claystone is also commonly used in earlier site studies) are described as massive, unstratified rock which are very fine-grained aphanitic with little or no texture, fabric, or other relict features. The overall strength of the mudstones is controlled by the aphanitic matrix materials which are predominantly autogenetic clay and zeolite minerals derived from the alteration of the original volcanic glass constituents. Field testing of cores show crater quality; this equates to an approximate intact unconfined compressive strength of 1,000 to 3,000 psi.

Proportion of rock types were made during the second powerhouse design and construction. Tabulated values for the major rock types found in the spillway may be found in Figure 3-1.

Figure 3-1: Major rock types found in the Bonneville spillway



PERCENTAGE OF ROCK TYPES

Rock Type:	Mudstone	Sandstone/ Siltstone	Conglomerate
AREA			
SPILLWAY	50%	20%	30%
2PH			
design	20%	65%	5%
actual	50%	40%	10%

3.2 GEOTECHNICAL MATERIAL PROPERTIES

Geotechnical material properties were studied extensively during design and construction of the second powerhouse and are summarized in the Foundation Report for the Second Powerhouse (USACE, 1994).

3.2.1 Bearing Capacity

The overall adopted bearing capacity for the foundation rock is 33 kips per square feet (ksf). This value is well within the range of structural loads exerted on the same foundation rock unit for the spillway dam foundation. Loading by the spillway dam ranges from 22 to 60 ksf. The 100-year performance record of this structure with no adverse cracking or excessive settlement is testimony to the validity of the adopted value.

3.2.2 Modulus of Deformation

During design of the 2nd powerhouse, modulus of deformation was estimated to be in the range of 300,000 to 450,000 psi. During the construction phase of the work, ongoing foundation explorations, i.e., Menard pressure meter testing, Borehole Extensometer and underground benchmark data all indicated an overall modulus of deformation value for the foundation rock closer to 200,000 psi. Although this value is about half of the original design value, the effect of this lowered modulus was found to be insignificant with respect to other design parameters for the original design for the powerhouse.

For the purposes of this evaluation, a deformation modulus of 200,000 psi was adopted in the barrier design, representing a 'Best-Estimate' value. To address sensitivity of the deformation modulus, a lower bound modulus of 32,000 psi was adopted based on empirical correlations (Hoek and Diederichs 2006) and recent lab tests on core samples collected for the spillway bridge (Cornforth 2009). Details of this described in the settlement calculations contained in APPENDIX C.

3.3 GEOTECHNICAL ANALYSIS

3.3.1 Bearing Capacity

The barriers will sit on the apron, and the apron itself will act to redistribute the loads over foundation rock. For this reason, the typical failure modes associated with conventional bearing failure (i.e., general shear) was not considered relevant for the barriers. Rather, settlement (if any) is expected to govern the design.

3.3.2 Settlement

As discussed in Section 3.3.1, settlement is expected to be the controlling factor for bearing. As such, settlement was evaluated using an elastic analysis. Details of the analysis are presented in APPENDIX C.

The results of the analysis indicate maximum total settlement is expected to less than ¼-inch. The analysis was found to be relatively insensitive to the range of deformation modulus considered. In general, these settlements are considered tolerable for most structures but this statement should be validated by the Structural Design Team for the existing apron.

3.4 DESIGN CONSIDERATIONS

3.4.1 Foundation Anchorage

It was determined during the Phase 1a that anchoring the barriers would be problematic. There is little or no engineering guidance on how the clay-rich rock will perform as a result of repetitive load cycling due to hydraulic loading under turbulent spill condition. There is concern that repetitive loading could induce fatigue on the anchor grout/rock interface or induce creep in the heavily stressed rock column surrounding an anchor which could lead to gradual loss of anchor tension. Additionally, foundation anchorages would be difficult and expensive to construct. It is uncertain whether an anchor can be tensioned underwater by divers. Lastly, anchor heads would be continuously underwater with no way to inspect, conduct non-destructive testing, or conduct lift off tests to determine if there has been loss of tension of anchorage.

Avoiding barrier anchorage (accepting the risk and consequences of sliding) removes uncertainties and risks associated with designing and depending on anchors. The apron is a greater critical feature from an operational and dam safety point of view than the rock barrier which is more of an enhanced maintenance.

3.4.2 Rock Removal

ROV inspections are conducted annually and indicate that rock has accumulated on the spillway apron slab. The surveys do not indicate the size or expected volume of material that will need to be removed prior to constructing the barriers. Once funding is secured for construction, a bathymetric survey and ROV survey should be conducted as close to the expected construction window as practical to determine the amount of rock that will need to be removed prior to constructing the barriers.

SECTION 4 - CIVIL DESIGN

No significant civil design is required for this project.

SECTION 5 - ENVIRONMENTAL DESIGN

5.1 WATER QUALITY CONSIDERATIONS

5.1.1 Water Quality Permitting

The design calls for cast in place concrete within the Columbia River. The CWA section 401 requires Water Quality Certificate (WQC) for all placement of dredged or fill material in Waters of the United States. Permitting is delegated to the states in this location; as one barrier is located on the Oregon side of the Columbia River, and one is located on the Washington side of the Channel this will require the completion of two WQC; one for Washington Department of Ecology (WADOE) and another for the Oregon Department of Environmental Quality (ODOE). These applications will include all state-required permits and are referred to as Joint Aquatic Resource Permit Application (JARPA) for WADOE and Joint Permit Application (JPA) for ODOE. Corps intends to apply for both permits under the Nationwide Permit (NWP) for Maintenance (NWP 3), although applicability of this NWP is still under review at this time.

The primary concerns for water quality for cast-in place concrete are alkalinity and hazardous chemical leaching during the concrete curing phase. Corps PME-E staff will work with State agency staff at WADOE and ORDOE to determine the required controls to meet CWA standards as determined by the jurisdictional agencies. These requirements will be in the WQC's issued by the states which will be included in the Specifications prior to documents being released for bid. Specifications will require adherence to these requirements.

It is likely that water quality monitoring will be part of one or both of the WQC issued for this action; monitoring and reporting of water quality results will be a part of this work and listed within the Specifications. Monitoring of Contractor compliance will be performed by NWP-EC Construction Control Inspector/ Government Quality Assurance Representative.

The spillway apron will be cleared of debris if necessary to ensure a positive connection between existing and cast in place Concrete. This provision will be included in the CWA applications.

5.1.2 Stormwater Discharge

If the Contractor will disturb more than one acre of land at a staging area as part of the work, they will be required to obtain a NPDES stormwater discharge permit from the agency with jurisdiction of the staging area. This will be included in the specifications under special conditions.

5.1.3 CWA 404(b) 1 Compliance

While the Corps does not issue 404 permits to itself, PME-E will perform a 404 (b) (1) equivalency review to ensure the proposed action is in compliance with this section of the CWA. This documentation will be included in the administrative record for the action.

5.2 HAZARDOUS CHEMICAL CONTROL

5.2.1 Contractor Hazardous Chemical Control

As part of the Specifications, the Contractor will be required to submit an Environmental Protection Plan (EPP) for Government review. The plan will include the Contractor's plan for preventing, controlling, reporting, and cleaning up hazardous chemical discharges. EPP will include the name and location where hazardous chemicals will be stored on site and the Best Management Practices for the prevention of spills. Contractor plan will include the name of the Contractor's Environmental Control Coordinator (ECC) responsible for administering the EPP. ECC will also be in charge of all reporting to Federal and State agencies in the event of a spill and notifying the Corps when spills occur, or in the unlikely event that an existing spill is identified in the course of the proposed action (see section 5.2.2).

5.2.2 Existing hazardous chemicals onsite

Whenever work is done and a Corps operational facility, the Specifications will direct the Contractor on how to proceed should an existing spill be uncovered during the course of Contract work. While no existing spills are anticipated in the location of the action, being ready for this possibility will help prevent reportable spills within the waterway. Specifications will define "Contractor generated hazardous waste" and "Corps hazardous waste". Any hazardous material brought onsite by the Contractor for the performance of the work is considered Contractor-generated hazardous waste. Any hazardous waste onsite identified during the work is considered Corps-generated hazardous waste. The Specification will identify control, clean-up and reporting of Corps-generated waste.

Final specifications will instruct the Contractor to stop work that risks further spread of the material, to contain the material if it is safe to do so and immediately notify the Corps. Given the location of the proposed action the most likely place for this to happen is the staging area.

The PDT will provide staging area to the Corps Bonneville Project Bradford Island CERCLA working group for review. The area is not within the CERCLA site however all action within the project require notification. Initial communications with the working group were made by PME-E, and the working group stated that they had no concerns. However, re-checking when the staging area is determined will ensure that PDT has the latest information available.

5.3 ESA COMPLIANCE

5.3.1 ESA-Listed Fish

Proposed action will be performed in accordance with the CRS BiOp; therefore, no additional ESA consultation will be required. In order to meet the requirements of the BiOp all work will be done in accordance with FFDRWG and FPOM (see Section 5.5.2 of this document.). FFDRWG and FPOM concurrence that the action is consistent with CRSO BiOp will be included in the REC administrative record for this proposed action. Should either group determine that the proposed action is not covered under CRS BiOp, PME-E will notify PM.

5.3.2 Other ESA-Listed Species

PME-E will review sources and determine if the proposed action is likely to impact any other ESA-listed species. Initial review indicates a determination of No Affect or Not Likely to Adversely Affect ESA listed species known to be within the vicinity of the proposed action. Should PME-E determine any adverse impacts to listed species the PM will be notified promptly. If the determination(s) are NA/NLAA the information will be included in the NEPA documents (see section 5.5 of this document).

5.4 MARINE MAMMAL PROTECTION ACT

As marine mammals are known to be in the vicinity of the proposed action, PME will evaluate the proposed action to determine if an Incidental Harassment Authorization (IHA) is required by NMFS. Noise levels of on water and nearshore work will be evaluated given the best available information and if an IHA is required PME-E will complete the application and required consultations with the Corps. Activities typically requiring IHA authorization are those including in-water impact drilling or pile placement. At this time PME assumes that an IHA will be required however PME-E will consult with NMFS marine mammal POC to verify. Should IHA be required the IHA letter will be included in the specification listing all special conditions required to ensure with compliance with MMPA.

5.5 NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) OF 1969, 42 U.S.C. §4321

PME-E will review the plan and determine whether the project qualifies and a Categorical Exclusion (CatEx) under the Corps regulations for implementing NEPA, 33 CFR §230.9 (b) which allows for CatEx Activities at completed Corps projects which carry out the authorized project purposes. Examples include routine operation and maintenance actions, general administration, equipment purchases, custodial actions, erosion control, painting, repair, rehabilitation, replacement of existing structures and facilities such as buildings, roads, levees, groins and utilities, and installation of new buildings utilities, or roadways in developed areas. Guidance for this category of work allows for the inclusion of modifications to existing facilities as required by changing conditions or advances in technology. This determination is generally completed at the 60% Plans and Specs level; however, PME-E does not foresee the need for an

Environmental Assessment at this stage of the process. Should changes to design or new information or guidance on the application of this CaEx category PME-E will notify PM. Cat/Ex or Final EA as applicable will be included in the administrative record for this project.

SECTION 6 - CULTURAL RESOURCES

6.1 CULTURAL AND HISTORIC RESOURCES

Compliance with all applicable cultural resources laws and regulations will be required. Per Section 106 of the National Historic Preservation Act of 1966 (implementing regulations 36 CFR 800), any federal undertakings that may directly or indirectly effect historic properties will require consultation with the State Historic Preservation Office (SHPO), Tribes and Tribal Historic Preservation Officers (THPOs), and other interested parties, as appropriate. Additionally, any action involving ground disturbance could require archaeology survey. Consultation with SHPO and any Tribes that ascribe cultural associates and significance within the Area of Potential Effects (APE) will be required.

Bonneville Dam Historic District (BDHD) was listed on the National Register of Historic places as a National Historic Landmark in 1986, and subsequently declared a National Historic Landmark (NHL) in 1987. BDHD's principal elements consist of Bonneville Dam, Powerhouse 1 (PH1), Navigation Lock #1, Old Swing Bridge, the fishways and fish hatchery, Bradford Island Fish Ladder, Administration Building, Auditorium Building, and the surrounding Bonneville Dam landscape.

Any alterations that will diminish the characteristics that qualify the property for listing, beyond those rehabilitation and replacement actions that meet the Secretary of the Interior's (SOI) Standards will likely be considered an adverse effect. If adverse effects cannot be feasibly avoided, appropriate mitigations will need to be determined in consultation with SHPO, Tribes, and THPOs, and other interested parties, captured in a Memorandum of Agreement (MOA), and then carried out by USACE within the agreed upon timeframe and funded by the project.

6.2 SUMMARY AND STATUS OF CULTURAL RESOURCES CONSULTATION

The Corps initiated consultation with the Oregon State Historic Preservation Office (SHPO), the National Park Service (NPS), the Washington Department of Archaeology and Historic Preservation, the Confederated Tribes of Siletz Indians, the Confederated Tribes of the Grand Ronde Community of Oregon, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama Nation, the Nez Perce Tribe, and the Cowlitz Indian Tribe on 26 APRIL 2023 at which time we provided the delineated boundaries of the Area of Potential Effect (APE) for this undertaking. The Corps also requested that the Oregon SHPO act as lead SHPO on behalf of Washington DAHP, pursuant to §800.3(c)(2).

On 10 JANUARY 2025, the Corps sent a findings of effects letter to the Oregon State Historic Preservation Office (SHPO), the National Park Service, the Oregon State Historic Preservation Office, the Confederated Tribes of Grand Ronde Community of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama Nation, the Confederated Tribes of Siletz Indians, the

Confederated Tribes of the Warm Springs Reservation of Oregon, the Nez Perce Tribe, and the Cowlitz Indian Tribe regarding the identification of historic properties and finding of no adverse effect to historic properties (36 CFR §800.5(b)).

The 30-day comment period ended on 8 February 2025, and no additional comments were received. As such, the Corps has no further obligations under Section 106.

SECTION 7 -

SECTION 7 - HYDRAULIC DESIGN

7.1 PROJECT BACKGROUND

During the 1970s, modifications to the Bonneville spillway started to be implemented that improved water quality and overall fish passage. Adult fish in the Bonneville tailrace were exposed to high levels of total dissolved gas (TDG) which negatively impacted their health. Additionally, the spillway is a major fish passage route for out-migrating juveniles. To address water quality downstream of the spillway and downstream fish passage though the spillway, flow deflectors were installed. Spillway flow deflectors are designed to minimize the saturation of TDG caused by spillway releases. A properly designed flow deflector forces the spill flow to skim the surface of the receiving tailwater. The purpose is to prevent the highly aerated water from being exposed to the hydrostatic pressures within the lower depths of the stilling basin. The Biological Opinion (BiOp) developed by the National Marine Fisheries Services (NMFS) currently mandates that spillway releases be maximized and within TDG criteria, during the juvenile fish out-migration season.

Laboratory investigations resulted in construction of spillway flow deflectors on thirteen of Bonneville's 18 spillway bays. All thirteen deflectors were constructed at elevation 14 feet mean sea level (MSL) on bays 4-15 and bay 18; they are 12 feet long, with a 6-foot radius transition from the spillway slope to the horizontal surface of the deflector. From the 1970s to the 1990s, spill patterns were developed to aid in fish passage and survival needs.

Because of spill requirements for juvenile fish passage and the related TDG issues, a re-investigation of spillway flow deflectors was conducted in 1999-2000. The purpose of these investigations was to evaluate the existing deflector design under current operating conditions and to design a deflector for the remaining five non-deflected spillway bays. The goal was to optimize the deflector design to perform well for both voluntary (or juvenile fish spills) and involuntary spills. The model investigations resulted in a 12.5-foot long deflector at elevation 7 feet MSL. The lower deflector elevation was necessary to prevent plunging flow from occurring under low tailwater conditions.

In 2002, five new flow deflectors were installed at elevation 7 feet MSL on bays 1-3, 16, and 17 and the flow deflector in bay 18 was modified from elevation 14 feet MSL to elevation 7 feet MSL. Currently, all bays have flow deflectors. Bays 1-3 and 16-18 have flow deflectors at elevation 7 feet MSL and bays 4-15 have flow deflectors at elevation 14 feet MSL.

7.2 FLOW DEFLECTOR COMPLICATIONS

The effect of deflected spillway flows on ogee and stilling basin erosion was not thoroughly documented during either of the deflector model investigations. However, some general observations were made during the original physical model effort by seeding the model with sand and gravel. In general, there are two distinct flow patterns generated by the deflected spillway release that would appear to cause erosion at the toe of the ogee adjacent to the spillway piers, and across the pier nose. Erosion at these locations is clear in stilling basin surveys. The first flow condition occurs when the tailwater elevation is relatively high. The deflected spillway jet generates a large circulation cell, which has the potential to carry bedload material (large rocks and cobbles) from the downstream river channel upstream along the floor of the basin to the ogee toe. See Figure 7-1. The heavier material is deposited in the corner pockets formed by the ogee toe and the adjacent pier walls. As the tailwater elevation lowers during the late summer periods, the spillway flow begins to plunge from the deflectors and the circulation cell beneath the jet becomes much more intense and focused at the ogee toe and corner pockets. The very intense circulation of flow, combined with any bed load material that may have been deposited under the higher tailwater conditions, generates a ball milling action with an extreme potential for erosion.

The newer deflectors at elevation 7 feet MSL are less likely to cause plunging flow and will reduce the potential for ball milling of deposited material. However, the initial thirteen deflectors, which were designed for higher involuntary spill flows and higher tailwater elevations are now subjected to operations throughout the fish passage season that results in skimming and then plunging flow conditions.

Although the hydraulic characteristics of deflected spillway flow have been thoroughly investigated and well defined, the potential for erosion has not. Uncertainties include the sources and availability of bed load material for transportation into the stilling basin and the carrying capacity of the vertical circulation cells generated by the deflected flow. The lower deflectors may reduce the potential for erosion caused by ball-milling of deposited material but may increase the potential to transport material from the downstream channel up to the spillway.

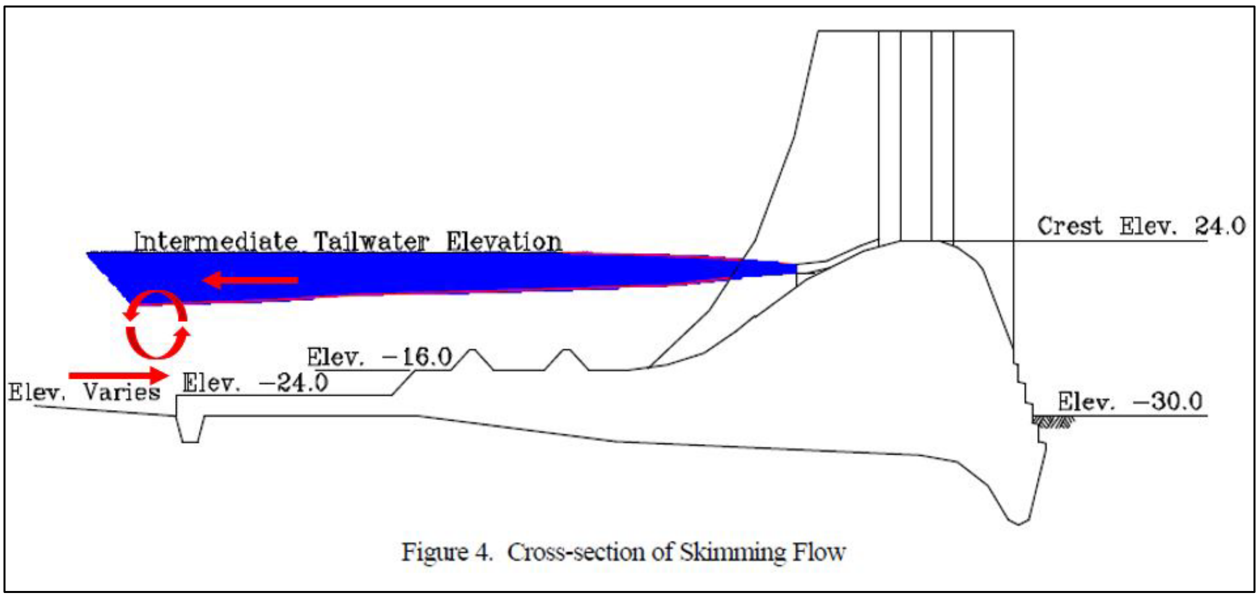
7.3 ROCK MOVEMENT

The condition of the Bonneville spillway has been monitored on a yearly basis since 2006. Hydrosurveys are conducted annually if spill hits 150,000 cubic feet per second (150 kcfs) or higher. The 2011 spill season was the first time in recent times where the rock movement resulted in material in the stilling basin. After the 2011 spill season, 1150 cubic yards of material were found deposited in the stilling basin. Dive surveys showed that the material was well rounded rock, ranging in size from gravel up to 4 feet in diameter. The source of the rocks is believed to be cobbles and boulders being derived from erosion/scour of the underlying bedrock. Earlier surveys have shown movement of material in the spillway downstream of the apron, but this was the first time that material was found between the flow deflectors and baffle blocks.

The 1:55 scale Bonneville spillway physical model was used to investigate rock movement after the 2011 spill season. Spill volumes of 125, 150, 175, 200, and 300 kcfs were evaluated. No rock movement was noted at 125 kcfs but at 150 kcfs, rock movement was initiated. Observations from the physical model showed that rocks generally start on the bedrock downstream of bays 16 and 17, move on to the apron, move up the apron towards the center of the spillway, and maneuver into the stilling basin. Near the middle of the spillway, the apron and stilling basin invert are nearly level, making it possible for the rocks to move into the stilling basin. Most rocks entered at bay 9, just north of the continuous baffle block, and moved laterally towards bays 2 and 17.

The movement of the rocks is due to the hydraulic patterns within the spillway. The fast-moving layer of water near the surface caused by the flow deflectors creates a hydraulic pattern akin to a vertical eddy. Figure 7-1. Physical model studies have estimated water velocities near the bedrock of the spillway to be on the order of 60 feet per second in the upstream direction. See Figure 7-2. Loose rocks in this current can migrate to the apron, up the apron, and into the stilling basin. Once in the stilling basin, rocks cause damage to the concrete from ball milling effects. Because the spillway is used for five months of the year, the cumulative ball milling damage is potentially serious. Rocks in the stilling basin cannot be removed via a flushing spill operation; they must be removed mechanically by cranes and divers as part of non-routine maintenance that is required to extend the life of the spillway and stilling basin. Rocks on the apron, however, can be removed via a flushing spill operation. If spill exceeds the 150 kcfs 'threshold,' rocks tend to move upstream and make their way into the stilling basin. Since Bonneville typically spills more than 150 kcfs every year, rocks are found within the stilling basin most years.

Figure 7-1. BON Skimming Flow and Vertical Eddy.



Note: straight arrows show downstream and upstream flows; curved arrows show the "vertical eddy."

Figure 7-2. Physical Model Upstream and Downstream Velocities.

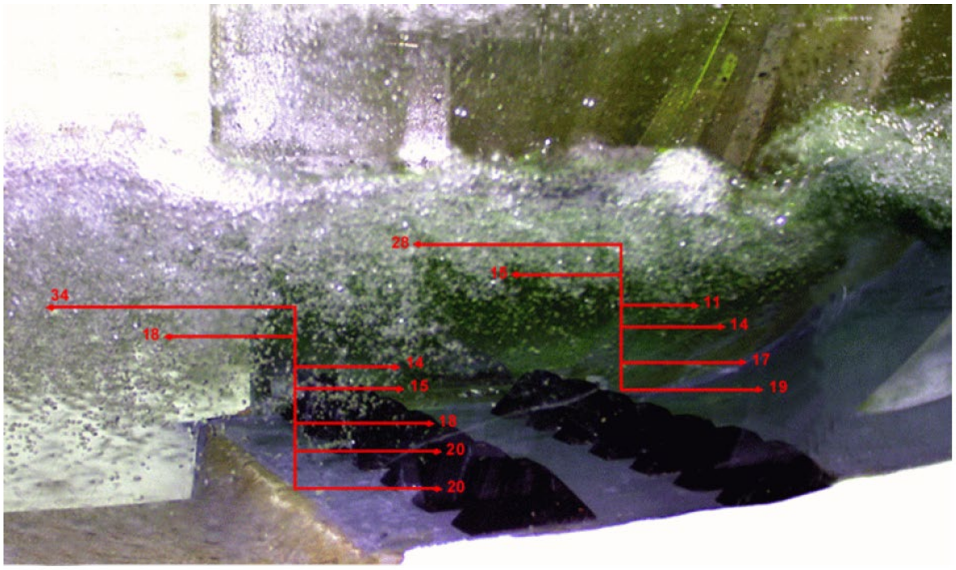


Figure 15. Skimming Surface Jet, Modified Bonneville Deflector,
6,700 cfs/bay, 1-1/2 bays, TW el -21.0, HW - 74.0

7.4 DESIGN METHODS

The majority of the hydraulic design for the barriers was conducted for the Phase 1A report. Both numerical and physical models were implemented in the assessment of alternatives and investigation of the barrier design. See the Phase 1A report and associated modeling report for further information. This DDR also say a small numerical modeling effort that refined the expected hydrodynamic loads on the barriers. The associated modeling report is located in Appendix G.

7.5 DESIGN ASSUMPTIONS

7.5.1 Fish Passage Spill Volumes

The Bonneville spillway is a major passage route for downstream-migrating juvenile fish. Bonneville maximizes spill during the juvenile migration season to encourage juvenile fish passage through the spillway. Fish passage spill volumes are on the threshold of spill levels that are known to move rocks (150 kcfs). The project is assumed to continue to spill for fish, implying rocks are likely to move towards, if not into, the stilling basin every year.

7.5.2 Run-of-the-River Spill Volumes

Bonneville is a run-of-the-river project, meaning the project passes the flows that approach it. As inflow increases, it is first run through the powerhouses. If there is a lack of power demand or the capacity of the powerhouses is exceeded, the spillway is opened to pass inflow. This creates moments of high spill volumes during the freshet.

These flowrates regularly exceed flowrates that have been known to cause rock movement (150 kcfs), implying rocks are assumed to likely move towards, if not into, the stilling basin every year.

7.5.3 Inspection and Removal

Seven non-routine rock removal projects have been executed since 2011 when the issue of rock accumulation was first identified. Rock removal quantities are available for three of the contracts (2018-2020) and removed an average quantity of 575 cubic yards of material. The contract in 2011, the first project executed, removed a significantly larger amount of material although there is no estimate available.

It's assumed that rocks will accumulate on the down-apron side of each barrier. A routine inspection (hydrosurvey) and removal of accumulated material will prevent the accumulated material growing in height such that rocks overtop and bypass the barrier.

Physical model testing (2021) indicated flushing spill can push accumulated rocks off of the downstream side of the apron. The flushing spill operation within the physical model testing did not removal all rocks from the apron, but a significant portion was removed.

A flushing spill operation is recommended for the prototype as the routine rock removal method. If the flushing spill operation cannot be accomplished, or is deemed ineffective at removing rocks, ad-hoc maintenance contracts can be awarded for mechanical removal.

7.6 DESIGN CRITERIA

7.6.1 Spillway Capacity

The capacity of the Bonneville spillway cannot be diminished from its existing condition. The project must be capable of passing the same amount of flow before and after the barrier design has been constructed.

7.6.2 Design Flood

The barrier design must be functionally capable of withstanding the 100-year (or 500 kcfs) flood event with little or repairable damage.

7.7 DESIGN CONSIDERATIONS

- The barriers must be designed to be sufficiently heavy and structurally robust to withstand turbulent spillway flows. The barrier must be designed parallel to flow to minimize the hydraulic load acting upon them.

- Small movements of the barrier (a few feet) are not expected to impair its functionality. Any gaps identified between the barrier and the apron or barrier and end sill wall should be sealed. This will prevent rocks from bypassing the barrier.

- The tops of the barriers must not exceed the sill height of the stilling basin to prevent exposure to high-velocity flow and retain spillway hydraulic capacity.

- Various barrier locations were investigated via CFD runs. Runs with the barriers placed in-line with spillway piers and towards the middle of a spillbay were conducted. The lateral hydrodynamic loads on the barrier towards the middle of a spillbay were slightly larger compared to runs where the barrier was in-line with a spillway pier. To avoid larger barrier dimensions to withstand the larger loads, the PDT agreed that the design should include the barriers be placed in-line with spillway piers.

7.8 DESIGN CALCULATIONS

In mid-2023 it was discovered that the Phase 1A structural calculations of the barriers did not consider hydrodynamic loading. Hydrodynamic loads are forces imparted by moving water. A series of hydraulic calculations were conducted to estimate the expected hydrodynamic loads that the barrier must withstand. A 1-dimensional (1D) analysis was completed but it was deemed over-conservative. Consequently, a refined computational fluid dynamics (CFD) analysis was completed which yielded a more accurate estimate.

7.8.1 1D Calculation

The initial hydrodynamic loads provided to Structural Design for the barrier design was based on a drag force acting on the entire width of the barrier. The velocity was assumed to be 15 feet per second (fps) acting North-South across the barrier. The velocity value was based on the maximum apron velocities documented in the Phase 1A modeling report. The subsequent calculation generated an extremely large force and necessitated the barrier double in width to prevent overturning.

It was determined that assuming the maximum velocity of 15 fps velocity acts over the entire length of the barrier was an extremely conservative assumption. The average velocity a barrier might experience over its entire length, at any given time, would be slower than 15 fps.

7.8.2 CFD Analysis

To provide a more reasonable estimate of the hydrodynamic loads on the barrier, a CFD model was developed, run, and probed to provide additional information. The full modeling report can be found in Appendix G.

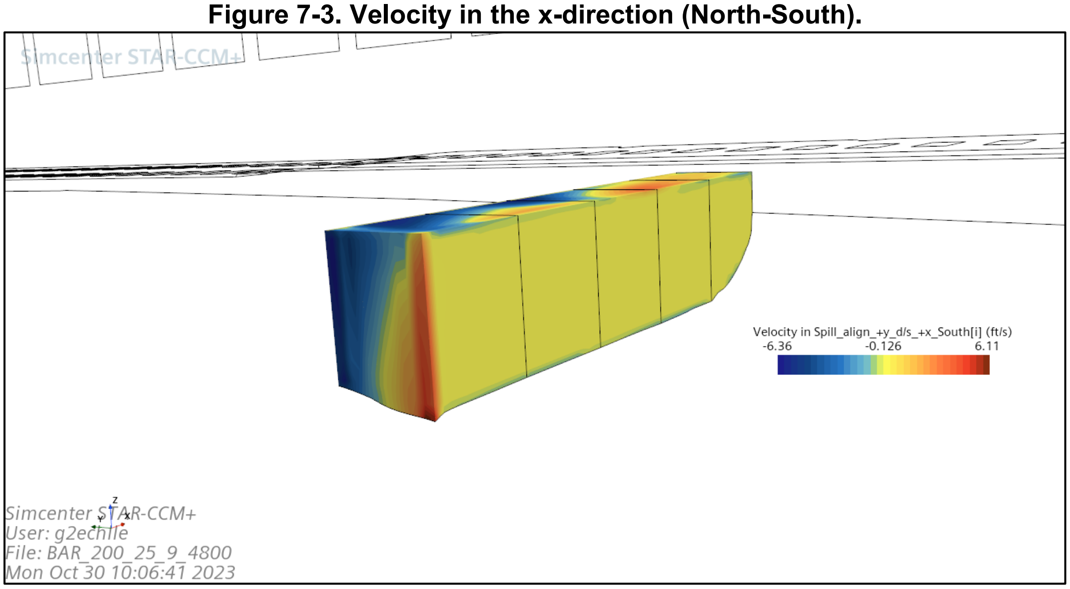
An existing spillway model served as the template for this CFD effort. Barrier geometry was added and several spill and tailwater conditions were evaluated in the CFD model. See Table 7-1. The spill pattern used was taken from the 2023 Fish Passage Plan spill pattern for Bonneville.

Table 7-1. CFD Flow Conditions.

Spill Volume (kcfs)	Tailwater Elevation (ft)
80	15
100	15
125	20
150	20
200	17
200	25.9
200	**33**
300	33
400	36
500	40

For each run, the resulting minimum, average, and maximum velocities imparted on the barriers were identified and tabulated. See Figure 7-3.

Figure 7-3. Velocity in the x-direction (North-South).



Note: this CFD output is from the 200 kcfs spill, 25.9-ft tailwater flow condition.

Utilizing the velocity data and other variables, the drag force (i.e. hydrodynamic force) can be calculated. A spill volume vs drag force rating curve was developed for the modeled runs and extrapolated to larger spill volumes. See Figure 7-4, Table 7-2, and Table 7-3.

Figure 7-4. Spill Volume vs. Drag Force Rating Curve.

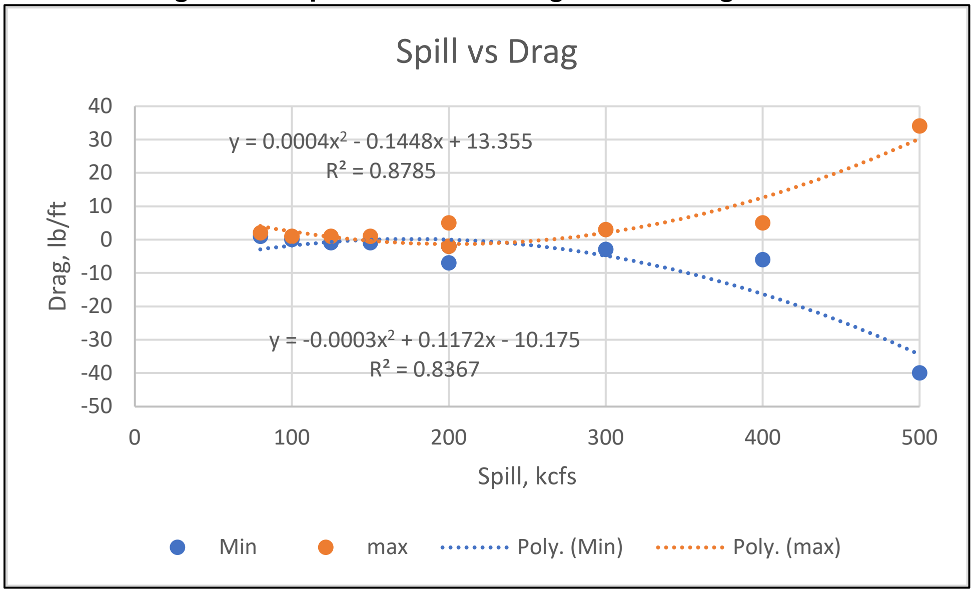


Table 7-2. Extrapolated Spill Volume vs. Drag Force.

Spill Volume (kcfs)	Drag Force (lbs/ft)
500	40.955
600	70.475
700	107.995
800	153.515
900	207.035

Table 7-3. Design Pressures at Usual, Unusual, and Extreme Events.

Event	Spill Volume (kcfs)	Recurrence (yr^{-1})	Drag Force (lbs/ft)	Pressure (lbs/ft^2)
Usual	200	1	10	0.59
Unusual	500	10	45	2.65
Extreme	680	100	100	5.88

Structural Design typically utilize the forces associated with the usual event, the unusual event, and the extreme event. These events correspond to the spill volume recurrence intervals of 1 year, 10 years, and 100 years, respectively. The 100-year event at Bonneville is around 680 kcfs and is recommended to be applied as the extreme event for this design. For the extreme event, the barriers should be able to withstand a maximum hydrodynamic force of 100 lbs/ft and a maximum hydrodynamic pressure of 6 lb/ft^2.

SECTION 8 - RESERVOIR REGULATION

The project will require coordination with the NWD Reservoir Control Center (RCC) to coordinate construction activities with spillway operations. RCC has been notified of the project and a representative will be assigned to the project during construction. RCC will attend weekly construction meetings with the Contractor to ensure proper coordination with planned spillway activities and construction sequencing.

SECTION 9 - DAM AND LEVEE SAFETY

The concrete structures are expected to be stable under the design loading scenarios and were designed as gravity structures to avoid anchoring to the existing spillway apron avoiding the possibility of damaging the existing structure. It was determined that the project does not constitute a life safety risk, therefore, a Safety Assurance Review (SAR) is not required and risk management authority resides within the Northwest Division. Construction of the barriers is not expected to alter operation of the spillway or other project features once completed although lifting of the 140 kcfs spill restriction has been discussed to aid fish passage operations. It’s expected that completion of the project will prevent further damage to the stilling basin and prolong the life of the project. In summary, the project does not increase risk to the continued operation or integrity of the structure and does not present a life safety risk.

SECTION 10 -

SECTION 10 - REAL ESTATE

All work will be performed on USACE property and will not require no acquisition or occupation of any additional real estate outside of USACE project boundaries.

SECTION 11 - CONSTRUCTION

11.1 GENERAL

This section presents the basic construction considerations, restrictions, and coordination of the major feature construction for the Bonneville Spillway Rock Mitigation.

11.2 SCHEDULE

General Information. Construction activities will be constrained by several parameters as indicated below. It is estimated that the contractor will spend approximately 33 weeks on site, with the mob and construction of the cells taking 17 weeks and the placement and filling of the cells taking 16 weeks. Preconstruction work, to include NTP, is expected to take approximately 26 weeks. Post construction submittals is expected to take approximately 13 weeks for a total of 72 weeks to complete the project. Project award is expected in February 2028. Contractor mobilization to the site will likely occur in August 2028 so that in-water work can begin December 2028. It is anticipated that construction will not be impacted by spillway operations. Provisions will be included in the contract to modify the schedule to accommodate flood control operations. A project schedule is included in APPENDIX E.

11.3 FEATURE CONSTRUCTION

Feature construction details are covered in the appropriate discipline sections. Construction at this site will include several complex factors including in-water work, barge crane utilization, precast concrete placement and underwater formwork and tremie concrete. Rock removal from the stilling basin and spillway apron may also be required.

A constructability workshop was conducted on April 25, 2024 which included members of the NWP construction branch, design branch and subject matter experts on marine and underwater concrete construction. The workshop was initiated due to high risk identified during development of the cost estimate due to uncertainties in construction methods. The workshop team developed several strategies to mitigate uncertainties and lower risk of construction. The main developments included:

- Eliminate cast-in-place barrier construction in favor of pre-cast structure due to difficulty of placing/constructing forms underwater

- Eliminate leveling slab due to difficulty of placing underwater. Concerns about hydraulic loads creating instability between leveling slab and placed pre-cast elements

- Design team favored a pre-cast structure with individual hollow-cell blocks suspended by a screw/hydraulic jack system (similar to Dalles Spillwall project).

Bottom will be formed and structure tremie grouted in one lift to create a cohesive foundation and interior

11.4 FEATURES OF WORK

Barrier Construction

The hollow barrier cells will be constructed in sections on land and the sections will then the jack screws or commercial jacks will be attached. The cells will be placed on the spillway apron by barge crane and divers, and then divers will adjust the jacks as necessary. Divers will build forms along the bottom of the cells that will then be filled with tremie concrete. The cells will have a closure section of 1 to 3 feet, depending on the contractor means and methods, between each section that will be formed by the divers in the wet. The concrete is expected to be pumped onto a barge and then tremie placed into each cell section. Special mix design requirements are included in the technical specifications to ensure consistent and unform placement and to minimize potential washout of cementitious material into the water column.

Rock Removal

Rocks have migrated onto the barrier and it is possible that rock debris may encroach into the footprint of the proposed barriers prior to construction. A flushing spill has been effective at clearing rock debris from the spillway apron and will be used prior to construction to clear rock debris from the barrier footprint. Rocks were removed from the stilling basin in 2019 and flushing spills are not effective at removing debris once it has reached the stilling basin. A bathymetric survey will be conducted prior to construction to determine if there is rock debris in the stilling basin. Optional rock removal will be included in the contract to remove debris from the stilling basin and spillway apron during construction.

11.5 RESTRICTED ACCESS

Public Access

The barriers will be completed underwater and will not be subject to public access for the lifetime of the project. The top elevation of the barriers will be constructed at -18 feet MSL and will not interfere with navigation or boat traffic.

Bonneville Project - Boat Restricted Zone Entry Procedure (BZP)

The Bonneville BZP outlines procedures for entry into Boat Restricted Zones (BRZ) at the project. The BZP is intended to ensure that boat/barge traffic on the project does not interfere with any operations pertaining to power, navigation, fish operations, etc. The BZP will be provided to the Contractor as part of the solicitation and workplans will be required to conform to the requirements of the BZP.

North Spillway Bridge – Load Restrictions

The north spillway bridge is load restricted and will be noted on the Contract drawings. It is not anticipated that the Contractor will require this area to complete the work but no heavy equipment will be permitted to cross the north spillway bridge and the area will be excluded from the work limits.

11.6 PROJECT SUPPORT & COORDINATION

Project Support. Project support will consist of accommodating a considerable amount of construction activity in an area adjacent to the spillway and any proposed staging areas at the project. The Contractor may elect to use trucks or an onsite batch plant to provide concrete for the barrier. Spillway clearances will be required and significant traffic coordination or restrictions may be required on the spillway deck and adjacent areas particularly during placement of the concrete. The contract will include provisions for modifying work schedules and removing personnel and equipment from the work area if the spillway is required for flood control.

Spillway Operations. Spillway operations will be coordinated to facilitate construction activities in the stilling basin. Work will be performed during the designated in-water work period to minimize restrictions on spillway operations.

Concurrent Construction Activities. There are no anticipated concurrent construction projects, however, given the unclear date of construction, any concurrent construction will be coordinated by the Construction Office.

11.7 CONTRACTOR OPERATIONS

Contractor Work, Office, Staging, Parking. The parking area outside the powerhouse gate will be utilized for the Contractor office, staging, parking and stockpile area as shown on the contract drawings.

Concrete Wash Water. Wash water from batching and washout of trucks, pumps, pipes, hoses, etc. shall be captured in a Contractor-designed settlement and infiltration containment. Settled solids that have solidified and the containment structure shall be removed and disposed of.

Environmental Controls. All Federal, State, and local laws and regulations concerning this work will be complied. All runoff from construction site activities will be controlled with Best Management Practices provided by the Construction Contractor and approved by the Government. Controls implemented under the National Pollutant Discharge Elimination System (NPDES) Permit and the Erosion and Sediment Control Plan (ESCP) will also be provided by the Construction Contractor and approved by the Government. Capture of job site runoff in retention ponds will allow settlement of sediments and removal of contaminants.

11.8 QUALITY ASSURANCE AND CONTRACTOR QUALITY CONTROL

Quality Assurance. Quality Assurance will be accomplished by a well programmed policy as covered in the Resident Office Quality Assurance Plan (QAP). The QAP will be augmented by a site-specific Quality Assurance (QA) Plan Supplement prepared by the Construction Project Engineer. Staffing of the QA surveillance will be by assigning one Project Engineer and a suitable number of Government Quality Assurance Representatives (GQAR) to perform the day-to-day surveillance, to assure adherence to specification requirements for quality and safety. The product development team will periodically travel to the site to participate in partnering meetings, periodic scheduling meetings, and to observe the work as part of required Engineering During Construction (EDC) protocols.

Contractor Quality Control. Contractor Quality Control will be monitored by the QA team, Project Engineer and GQAR(s), as part of the QAP and QA Supplement requirements. The Contractor will be required to follow the guidelines of Division 1 specifications, particularly Quality Control System, Submittal Procedures, and Contractor Quality Control. These Sections specify criteria for outlining the work to be performed as well as communicating the quality to the workers performing the work. A Quality Manager responsible for executing all quality related matters, to include preparing submittals and conducting the three phases of control for each definable feature of work, is required to be on the Contractor Staff.

SECTION 12 - OPERATIONS AND MAINTENANCE

There is no expected change to operations at the project after installation of the barriers is complete. It’s assumed that non-routine rock removal will not be required and the annual flushing spills will be sufficient to remove accumulated rock from spillway apron. Worst case scenario, rock could manually be removed from the spillway with an infrequent, non-emergency rock removal contract (vs. current frequent ad-hoc, emergency contract). Hydrosurveys are conducted annually and will determine the effectiveness of the flushing spills and prevention of rock migration into the stilling basin. A decision by NWP Hydraulic Design (ENC-HD) will be made as to whether rock removal is required depending on the results of the hydrosurvey. Generally, ENC-HD recommends a rock removal contract be executed if the quantity of material in the stilling basin exceeds 50CY.

No rock removal contracts were executed from 2021 - 2023. High spill and low tailwater combined to eliminate the upstream hydraulic path that moves rocks. However, this operational condition isn't recommended since it's outside the design parameters of the spillway and is suspected to be harmful to downstream-migrating juvenile fish.

It’s been determined that if the barriers slide/fail, they pose no significant life or dam safety risk. Given their size, the barriers would be left in place and the non-routine rock removal resume until an alternative engineering solution could be designed.

SECTION 13 - VALUE ENGINEERING

A Value Engineering (VE) study was conducted in April 2023 by Value Management Strategies, Inc. The purpose of the VE study was to develop and evaluate alternatives to the PDT design that could result in cost savings, improve functionality, reduce operational costs, and reduce constructability risk. A major issue that surfaced during the value engineering (VE) study was the discovery that there was an error in the cost estimate. To summarize, only one barrier had been factored into the construction cost instead of two during the Phase 1a report. The cost estimate provided to the VE study team showed an Estimated Total Project Cost of $6,647,000. The actual cost, with both barriers included, was estimated by the VE team to be approximately $10.3 million. The $10.3 million estimated cost was used as the basis for which all cost analyses were compared. After developing the CIP design, the cost estimate was significantly higher ($22.0M) due largely to a high level of uncertainty about construction methods, significant and complicated underwater formwork, uncertainty about if the project could be executed within the IWW, and thermal effects of concrete. The PDT solicited expert opinions and decided to progress with a pre-cast structure which significantly reduced cost.

The value team developed a total of 11 alternatives to the pre-cast concrete structure including pre-cast culvert sections, rock-filled gabion baskets, articulated concrete block mats, and sheet pile structures. The value team determined that cast-in-place (CIP) structure has several advantages to the pre-cast concrete design including being able to accommodate the uneven apron foundation, close a gap at the fillet section of the apron/stilling basin interface, and less time required to pour the mass concrete. The concept involves constructing underwater formwork and pouring the two barriers in sections. The VE team determined that the selected alternative would result in an approximate cost savings of $2.7M. The VE report is attached as APPENIDX D.

SECTION 14 - COST ESTIMATES

14.1 GENERAL

This section presents the cost estimate for the Bonneville Spillway Rock Mitigation project. The Total Project Cost (TPC, design and construction) estimate at 60% DDR phase is approximately $13.1 million including a 55% contingency. With a 55% contingency the construction contract is estimated at $10.4 million. The construction contract is estimated to take 9 weeks. The risk analysis and total project cost summary sheet can be found in APPENDIX E.

14.2 CRITERIA

ER 1110-2-1302, Engineering and Design Civil Works Cost Engineering, provides policy, guidance, and procedures for cost engineering for all Civil Works projects in the US Army Corps of Engineers. For a project at this phase the cost estimates are to include construction features, lands and damages, relocations, environmental compliance, mitigation, engineering and design, construction management, and contingencies. The cost estimating methods used are to establish reasonable costs to support a planning evaluation process.

14.3 BASIS OF THE COST ESTIMATE

The cost estimate is based on engineering calculations from the design team and data presented in the DDR. The estimate is calculated with Micro Computer Cost Estimating System (MCACES) MII, using historical data, labor and equipment crews, quantities, production rates, and material prices.

Prices are updated for August 2024 and escalated to the midpoint of construction.

14.4 COST ITEMS

The cost estimate includes engineering costs for plans and specifications, construction costs, engineering during construction, construction management for supervision and administration, escalation costs, and contingency to account for unforeseen details at this level. Other possible costs are not shown separately, such as lands and damages, relocations, cultural resources, environmental mitigation, environmental compliance, and (HTRW) cost. These costs are either not applicable or integrally part of the construction costs and are included in the construction features. Escalation costs to account for inflation according to EM 1110-2-1304 Civil Work Construction Cost Index system.

<u>Construction Schedule/Construction Windows</u>. It is anticipated that the total construction schedule including pre-construction through project closeout will be approximately 32 weeks in duration. Construction time excluding pre-construction and closeout is approximately 9 weeks. This contract will include in-water work and will be scheduled for the in-water work period at Bonneville Dam (Dec 1-Feb 28).

Overtime. A 40-50 hour work week is assumed for the remaining construction outside of the in water work period.

Acquisition Plan. The cost estimate assumes competitive pricing will be obtained by a single phase request for proposals with a best value source selection.

14.5 SUBCONTRACTING PLAN

The cost estimate is based on the work being accomplished by a general construction Contractor being the prime Contractor to perform concrete and formwork. Barge, crane, and dive work will be performed by an experienced specialty subcontractor.

14.6 PROJECT CONSTRUCTION

Site Access. Access to the project is through gated access at the Bonneville project. Equipment staging will be allowed on the south shore of the reservoir with barges staged in the spillway tailrace.

Materials. Aggregate and civil materials required for the project are readily available by commercial sources. The nearest established suppliers are in the Hood River area approximately 25 miles from the site. The cost estimate assumes concrete will be trucked to the site from concrete plants in the Hood River area. Material is also available from Portland (40 miles)

Government-Furnished Property. None.

Construction Methodology. Underwater construction methods will be required for this project and will include rock removal from the spillway apron and stilling basin, underwater formwork, and underwater concrete placement. Divers will likely be required for formwork and concrete placement. The Contractor may elect to use redi-mix trucks or construct an onsite batch plant.

Unusual Conditions (Water, Weather). The work site is in the Bonneville spillway tailrace, stilling basin, and apron. Spillway clearances will be required to perform the work and operations will conform to the Bonneville BRZ which dictates in-water work at the project. Construction requires additional attention to eliminate all spills and control of debris to prevent it from entering the river as well as provisions to minimize segregation and migration of concrete into the river.

Unique Construction Techniques. None anticipated.

Equipment/Labor Availability and Distance Traveled. Labor and equipment are available within a 200 mile radius of the project and includes the areas of Hood River (25 miles) and Portland (40 miles). Mobilization and demobilization are based on a 200 mile travel distance.

Overhead, Profit, and Bond. Rule of Thumb markups are assumed for the estimate. For the Prime Contractor Home Office Overhead is 15 percent, Job Office overhead is 6.45

percent, Profit of 12 percent, Gross Receipts Tax is 0.57 percent, and Bond and Insurance is 0.94 percent. For the Subcontractors on site, Home Office Overhead is 10 percent, Profit is 12 percent, Gross Receipts Tax is 0.75 precent, and no bond since the prime Contractor carries this.

14.7 ENVIRONMENTAL AND CULTURAL RESOURCES CONCERNS

Normal best practices are to be employed during construction.

14.8 EFFECTIVE DATES FOR LABOR, EQUIPMENT, & MATERIAL PRICING

Effective date for all pricing is August 2024. The most recent Multnomah Davis-Bacon labor rates were used. The Region 8 2022 Equipment database was employed, as was the 2023 Cost Book Database of MII, which are the most recent MII databases available.

14.9 FUNCTIONAL COSTS

Planning Engineering and Design

Engineering and design costs are determined from the budgets for the expected design and engineering effort. These costs include engineering costs for design and development of a contract package (plans and specifications), Portland District review, contract advertisement, award activities, and engineering during construction. This effort is estimated to cost $2.13M

Construction Management.

Construction Management costs are determined from the budget of the expected effort for supervision, administration and quality assurance for the construction contract. This effort is estimated to be $1.17M

14.10 LOST POWER REVENUE

There is no anticipated loss of revenue for power production.

14.11 BREAK-EVEN ANALYSIS

A break-even analysis was conducted comparing the status quo (rock removal) vs. construction of the barriers. The analysis considered a 50-year lifecycle cost of removing rocks on average 7 out of 10 years (based on historic record) and the cost of barrier construction. A design life of 50 years was used as the assumption for the concrete barriers and the stilling basin will be in use for the design life of the project. The rock removal considered a contract cost of $420,000 and extrapolated over a 50 year period resulting in a present worth over 50 years of $8.3M. The cost of the barriers over the same period resulted in a present worth of $12.3M. Although the barrier construction is more expensive over the 50-year lifecycle, the break-even analysis did not consider the cost of damage to the spillway that will occur if the barrier construction is not carried forward and rocks continue to accumulate in the stilling basin. If the current rock removal plan continues, it's assumed that repair of the stilling basin will be required within the next 50 years. This cost is not directly factored into the break-even analysis but would require complex marine construction methods and underwater concrete work. Additional benefits include non-quantifiable benefits to fish passage if the current spill restriction is lifted as a result of barrier construction. Based on these additional benefits, the PDT determined that the barrier construction is justified. The break-even analysis is included in Appendix E.

14.12 PATH FORWARD AND FUTURE ISSUES

Changes to the design will need to be incorporated into the IGE following completion of 60 percent Quality Check and ATR reviews.

SECTION 15 - CONCLUSIONS AND RECOMMENDATIONS

15.1 CONCLUSIONS

Based on the results of previous reports and findings of this report, the construction of two precast concrete barriers on the Bonneville Dam spillway apron will be effective at reducing the amount of rock that reaches the stilling basin and reduce the long-term operational cost of rock removal in the future. The estimated Total Project Cost for this project is approximately $13.1M and will be constructed in one season during the in-water-work period at the Bonneville project.

Hydraulic modeling indicates that flushing spills will be effective at removing accumulated rock from the down-apron side of the barrier. Annual hydrosurveys will be conducted in the stilling basin to monitor the effectiveness of the flushing spill maintenance and the overall performance of the barriers.

15.2 RECOMMENDATIONS

- This project will be shelved following the 90% DDR milestone until construction funding is obtained. When funding is secured the project will undergo BCOES review prior to contract award. A memorandum will be drafted following the 90% review summarizing any significant outstanding issues that will need to be addressed during BCOES and attached as an addendum to the DDR.

- There are considerable environmental considerations for this project including placement of underwater concrete that will require substantial permitting with lead times of up to one year. The necessary permits are being obtained by PM-E and may require coordination with regulating agencies. The design may need to be altered depending on the results of the consultation. PM-E has started the work to obtain the necessary permits and will continue this effort while design is on hiatus. It should be noted that water quality certificates are valid for 5 years after issuance and if construction funding cannot be secured in this timeframe the application process will need to be renewed.

- Cultural review and consultation was started following the 60% design and is currently in the comment period. No significant cultural impacts are anticipated for this project.

- The PDT anticipates that a best-value contract will be the preferred procurement method. Contractors should be evaluated based on previous experience on projects of similar scope and size. A detailed work plan will be evaluated including all features of work with particular emphasis on construction staging, sequencing, underwater work details and provide the qualifications of proposed personnel who will plan and execute the construction contract. Contracting has advised the PDT that the Div 00 specs will be developed prior to BCOES review.

SECTION 16 - REFERENCES

Columbia River DART, Columbia Basin Research, University of Washington. (2024). River Environment Graphics & Text. Available from https://www.cbr.washington.edu/dart/query/river_graph_text

McCann, J., B. Chockley, E. Cooper, B. Hsu, S. Haeseker, R. Lessard, C. Petrosky, T. Copeland, E. Tinus, A. Storch, and D. Rawding. 2018. "Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye: 2018 Annual Report." BPA contract #19960200, contract #77836. Comparative Survival Study Oversight Committee and Fish Passage Center.

NMFS (National Marine Fisheries Service). 2008. Endangered Species Act - Section 7 Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation: consultation on remand for operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program (Revised and reissued pursuant to court order, NWF v. NMFS, Civ. No. CV 01-640-RE (D. Oregon)). NMFS, Portland, Oregon, 5/5/2008.

NMFS (National Marine Fisheries Service). 2010. Endangered Species Act Section 7(a)(2) Consultation, Supplemental Biological Opinion on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program. National Marine Fisheries Service, Portland, Oregon, 5/20/2010.

NMFS (National Marine Fisheries Service). 2014. Endangered Species Act - Section 7(a)(2) Consultation, Supplemental Biological Opinion. Consultation on remand for operation of the Federal Columbia River Power System. National Marine Fisheries Service, Portland, Oregon, January 17, 2014.

NMFS (National Marine Fisheries Service). 2019. Endangered Species Act - Section 7(a)(2) Consultation, Biological Opinion. Consultation on Continued Operation and Maintenance of the Columbia River System. National Marine Fisheries Service, Portland, Oregon, March 29, 2019.

Ploskey, G.R., M.A. Weiland, and T.J. Carlson. 2012. "Route-Specific Passage Proportions and Survival Rates for Fish Passing through John Day Dam, The Dalles Dam, and Bonneville Dam in 2010 and 2011." PNNL-21442, Interim Report to U.S. Army Corps of Engineers, Portland District. Pacific Northwest National Laboratory, Richland, Washington.

USACE, 1937, Final Geologic Report on the Bonneville Project, Portland District

USACE, 1994, Foundation Report, Bonneville Second Powerhouse, Portland District.

U.S. Army Corps of Engineers. 2024. Final 2024 fish passage plan (FPP) Chapter 2 - Bonneville Lock & Dam. Fish Passage Operations and Maintenance (FPOM). Retrieved September 27, 2024, from https://pweb.crohms.org/tmt/documents/fpp/2024/.

Weiland, M.A., C.M. Woodley, T.J. Carlson, B. Rayamajhi, J. Kim, and K. Gillies. 2016. "Systematic Review of JSATS Passage and Survival Data at Bonneville and The Dalles Dams during Alternative Turbine and Spillbay Operations from 2008–2012." PNNL-24260, Report to the U.S. Army Corps of Engineers, Portland District. Pacific Northwest National Laboratory, Richland, Washington.