AGENDA
ENGINEERING and OPERATIONS COMMITTEE
Thursday, March 4, 2021, at 9:00 am
Boardroom, 1701 North Lombard Street, Oxnard CA 93030

Meeting attendees should be aware that the meetings of the Committee are, as required by law, open to the public and the District has very limited powers to regulate who attends Committee meetings. Therefore, attendees must exercise their own judgement with respect to protecting themselves from exposure to COVID-19, as the District cannot ensure that all attendees at public meetings will be free from COVID-19.

In addition to its public Engineering and Operations Committee Meeting, people may choose to participate virtually using the Webex video conferencing application.

If you are new to Webex video conferencing, please visit this test page in advance of the meeting date and time:
https://www.webex.com/test-meeting.html

To access the meeting, click on this link:
https://unitedwaterconservationdistrict.my.webex.com/unitedwaterconservationdistrict.my/j.php?MTID=m0fec6bb5e5e8246835ed77cf5e60b32f

Meeting number: 142 485 9382 Password: EnOC (3662 from phones)
Join by phone call in to +1-408-418-9388 (toll rates apply) Access code: 142 485 9382

Call to Order – Open Session
Committee Members roll call

1. **Public Comment** (Proposed Time: 5 minutes)
   The public may comment on any matter not on the agenda within the jurisdiction of the Committee. All comments are subject to a five-minute time limit.

2. **Approval of Minutes** (Proposed Time: 5 minutes)
   The Committee will review the minutes from the February 4, 2021 Committee meeting.

3. **March 10, 2021 Board Meeting Motion Agenda Items**

   3.1 Oxnard Hueneme System Backup Generator Project Construction Contract Award to Oilfield Electric & Motor (Engineering Department) (Proposed Time: 10 minutes)
   The Committee will consider recommending approval of the motion item to the full Board that considers awarding a contract to the lowest responsible bidder, Oilfield Electric & Motor, in the amount of $771,000.00 and authorizing the General Manager to execute the contract with Oilfield Electric & Motor for the construction of the OH System Backup Generator.

   3.2 Execution of an Amendment to the Contributed Funds Agreement for the Physical Modeling of the Freeman Diversion Rehabilitation Project with the Bureau of Reclamation (Operations and Maintenance) (Proposed Time: 15 minutes)

The committee will review and consider recommending approval of the motion item to the full Board authorizing the General Manager or his designee to execute an amendment to the Contributed Fund Agreement (CFA) with the Bureau of Reclamation for the physical modeling of the two proposed project alternatives for the Freeman Diversion Rehabilitation Project, currently under engineering design by Stantec and Northwest Hydraulic Consultants.

4. **Project Highlights**

   4.1 Engineering and Operations Updates on recent Project Activities (Engineering and Operations and Maintenance) (Proposed Time: 25 minutes)

   4.2 Santa Felicia Dam Safety Improvement Project Environmental Regulatory Compliance Progress Update (Environmental) (Proposed Time: 15 minutes)

5. **Future Agenda Topics**

ADJOURNMENT

Directors:
Lynn Maulhardt, Chair
Edwin T. McFadden III
Daniel C. Naumann

Staff:
Mauricio E. Guardado Jr.
Anthony Emmert
Craig Morgan
Robert Richardson
Linda Purpus
Dr. Maryam Bral
Brian Collins
Michel Kadah
Adrian Quiroz

The Americans with Disabilities Act provides that no qualified individual with a disability shall be excluded from participation in, or denied the benefits of, the District's services, programs or activities because of any disability. If you need special assistance to participate in this meeting, please contact the District Office at (805) 525-4431. Notification of at least 48 hours prior to the meeting will enable the District to make appropriate arrangements.

Approved: ______________________________
Mauricio E. Guardado Jr., General Manager

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Dr. Maryam Bral, Chief Engineer

____
Brian Collins, Chief Operations Officer

Posted: (date) February 25, 2021 (time) 5 p.m. (attest) ***Destiny Rubio***
At: United Water Conservation District Headquarters, 1701 Lombard Street, Oxnard CA 93030

Posted: (date) February 25, 2021 (time) 5:15p.m. (attest) ***Destiny Rubio***
At: www.unitedwater.org

MINUTES
ENGINEERING & OPERATIONS COMMITTEE MEETING
Thursday, February 4, 2021, 9:00 A.M.
Board Room
UWCD, 1701 North Lombard Street, Oxnard CA 93030

In addition to its public Engineering and Operations Committee meeting, UWCD provided virtual access to the meeting via the Webex virtual meeting platform.

COMMITTEE MEMBERS
Director Lynn E. Maulhardt, chair
Director Edwin T. McFadden III (participated via Webex)
Director Daniel C. Naumann

STAFF ATTENDING
Mauricio E. Guardado, general manager
Anthony Emmert, assistant general manager (participated via Webex)
Dr. Maryam Bral, chief engineer
Brian Collins, chief operations officer (participated via Webex)
Joseph Jereb, chief financial officer
Josh Perez, human resources manager
Craig Morgan, senior engineer
Robert Richardson, senior engineer (participated via webex)
Michel Kadah, engineer (participated via webex)
Adrian Quiroz, associate engineer (participated via webex)
Tessa Lenz, associate environmental scientist (webex)
Erik Zvirbulis, GIS analyst (participated via Webex)
Zachary Plummer, IT administrator

PUBLIC PRESENT

OPEN SESSION: 9:00 a.m.
Chair Maulhardt called the Engineering & Operations Committee Meeting to order at 9:00 a.m.

Committee Members Roll Call
Administrative Assistant Destiny Rubio commenced Roll Call. Committee members: Chair Maulhardt, Director McFadden, and Director Naumann were present.

1. **Public Comment**
   Chair Maulhardt asked if there were any public comments for the Committee. None were offered.

2. Approval of Minutes

Motion to approve the Minutes from the January 7, 2021 Engineering and Operations Committee meeting, Director Naumann; Second, Director McFadden. Roll call vote: three ayes (Maulhardt, McFadden, Naumann). None opposed. Minutes approved unanimously 3/0.

3. February 10, 2021 Board Meeting Motion Agenda Items

3.1. Award a Contract to Best Drilling and Pump, Inc. for El Rio Water Well No. 19 Construction Project

Chief Engineer Maryam Bral provided an update and a slide (see attached) regarding the recommendation request to award a contract to Best Drilling and Pump, Inc. for construction of the El Rio Water Well No. 19 Project. She asked the committee to consider recommending approval of the motion to the full Board, awarding a contract to the lowest responsible bidder, Best Drilling and Pump, Inc., in the amount of $450,774 and authorizing the General Manager to execute the construction contract with Best Drilling and Pump, Inc.

Director McFadden inquired about the specifications of the well. Dr. Bral stated the well is 475 feet deep, the casing is 18” in diameter, and about 180 feet of the well is screened into intervals. Dr. Bral added that this motion item is only for the destruction and replacement of the well. Senior Engineer Craig Morgan stated that the pump and motor will be replaced in the future under a separate contract.

The committee members agreed to recommend approval of the motion item to the full Board.

4. Project Highlights

4.1 Operations and Maintenance - Update

Chief Operations Officer Brian Collins provided updates and slides (see attached) on the activities of the Operations and Maintenance department. Chair Maulhardt inquired about the location of the crack in the ground at Lake Piru (featured in Mr. Collins’ slide presentation). Mr. Collins stated that the crack is at the Lake Piru Water Treatment plant and staff has explored it with rebar to assess the situation. Director Naumann asked if there is also a pipeline at this location. Mr. Collins stated that yes, there is a pipeline below the crack location. Chair Maulhardt mentioned the possible upcoming rain and asked about the probability of water filling in the crack and reaching the facility. Mr. Collins stated that there is currently no clear and present danger and added that staff has proactively covered the sites to minimize any intrusion. Chair Maulhardt requested that staff look into the possibility of this issue being categorized as an emergency action so that it is addressed now rather than waiting until September. Dr. Bral added that Engineering has completed a geotechnical evaluation on the site and will follow up on mitigation. General Manager Mauricio E. Guardado, Jr. stated that staff will reevaluate the circumstances of the issue and report back to address the committees concerns. Director McFadden asked if there are certain tree species of concern in that area or if it is just nesting concerns that impact the time for repair. Mr. Collins stated that it is just nesting in general.

Mr. Collins stated that recently during a power outage, the moss screen facility did not have power for fourteen hours, as a result, staff had to go out with rakes to clear the leaves from the moss screen. He added, staff had planned on using the emergency generator as a backup but through communications with Southern California Edison staff was able to maintain operations without the generator. Director Naumann asked if staff currently has the emergency generator or if United needs to look into getting a mobile one. Mr. Collins replied that staff has a generator on a trailer that is mobile and there are currently discussions about installing a permanent generator at this location in the future. Director Naumann asked that staff provide updates to the committee on generators for key facilities.

Director McFadden asked if sand is a problem for the PTP system. Mr. Collins stated that all PTP wells are sand challenged, but staff recently completed the replacement of all the sand separators.

Director Naumann asked what United's allocation of State Water was for this year. Mr. Collins stated this year's allocation is projected at 10% of the 3150 AF currently, plus the carryover water acquired earlier this year (3100 AF from Casitas and 525 AF from Ventura).

5. Future Agenda Topics

No future agenda topics were offered.

ADJOURNMENT 9:48 a.m.

Chair Maulhardt adjourned the Engineering and Operations Committee meeting at 9:48 am.

I certify that the above is a true and correct copy of the minutes of the Engineering and Operations Committee Meeting of February 4, 2021.

ATTEST:____

Lynn Maulhardt, Chair

El Rio Well Replacement Program

Water Well No. 19 Construction Project

<u>Bid Results:</u>

Best Drilling and Pump: 450,775

Nor-Cal Pump & Well Drilling: $579,764

Zim Industries: $604,874

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ENGINEERING AND OPERATIONS COMMITTEE

FEBRUARY 4, 2021

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SFD and Lake Piru

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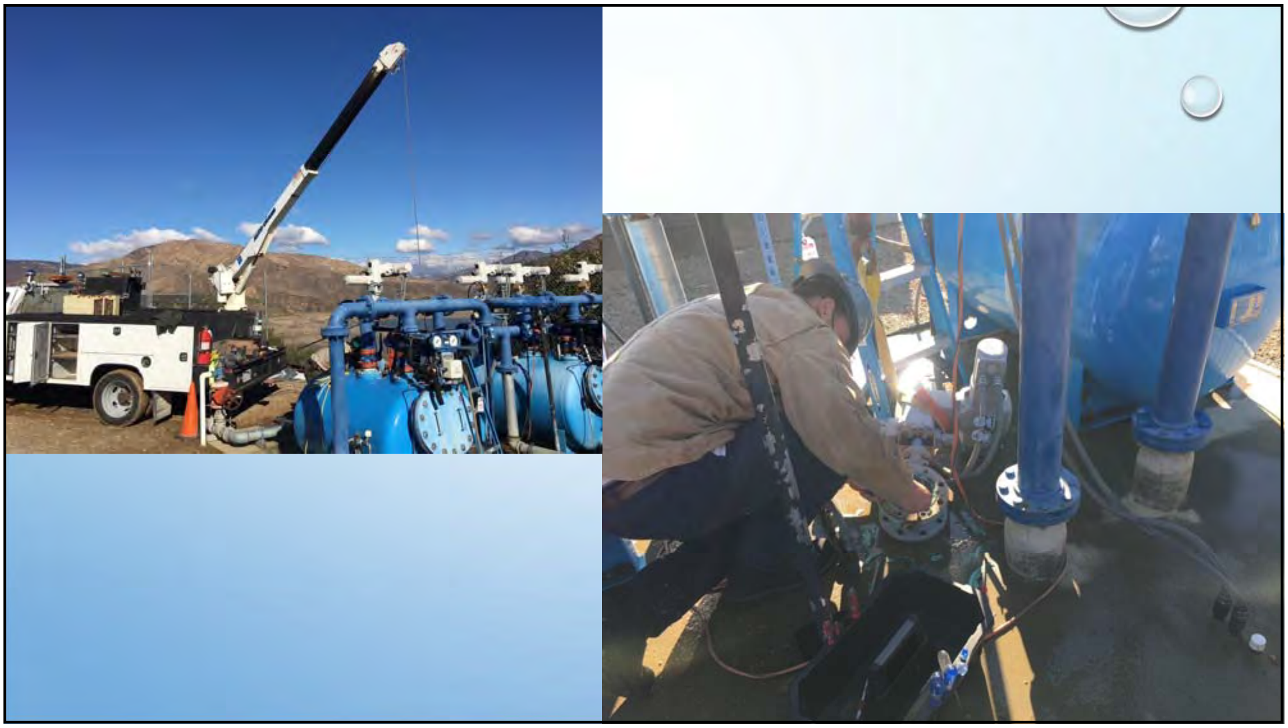

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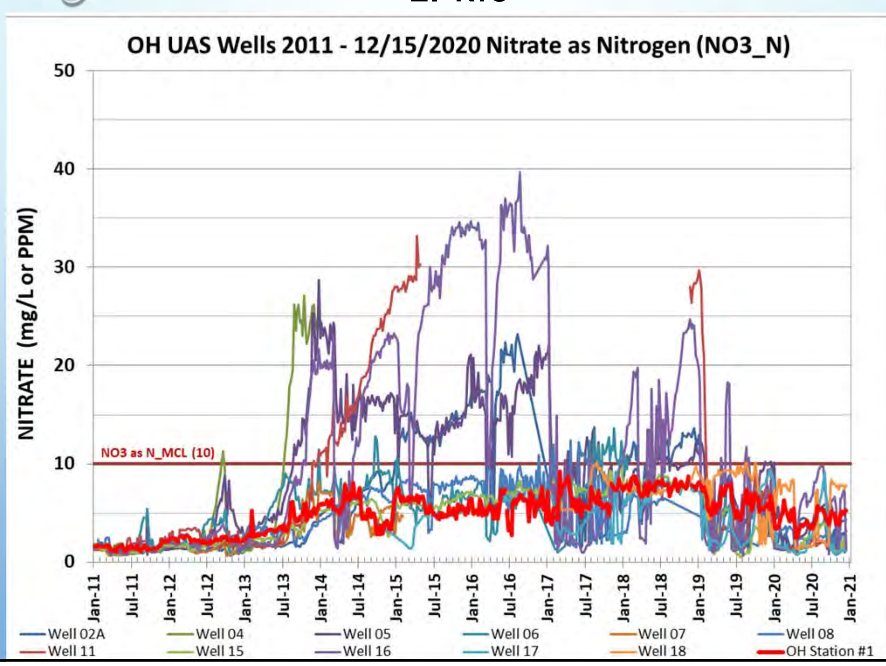
El Rio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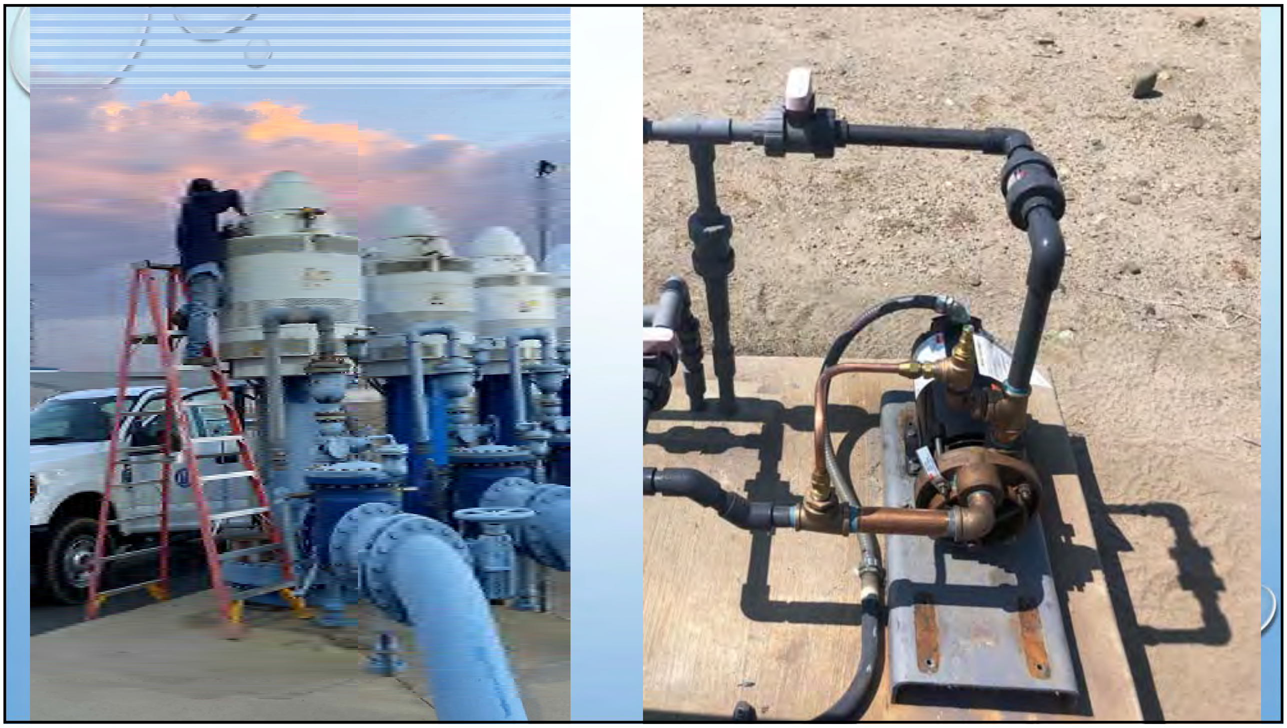

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PTP System

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STATE WATER PROJECT UPDATE

- 525 AF ACQUIRED FROM VENTURA WATER.
- 3,100 AF ACQUIRED FROM CASITAS MUNICIPAL WATER DISTRICT.

- **HISTORIC EVENT- 3 AGENCY REGIONAL COLLABORATION! FIRST TIME IN 47 YEARS!**

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Staff Report

To: Engineering and Operations Committee

Through: Mauricio E. Guardado, Jr., General Manager

From: Maryam Bral, Chief Engineer
Michel Kadah, Engineer

Date: February 23, 2021 (March 4, 2021 Committee Meeting)

Agenda Item: **3.1 Oxnard Hueneme System Backup Generator Project Construction Contract Award to Oilfield Electric & Motor**
Motion

Staff Recommendation:
The Engineering and Operations Committee will consider recommending approval of the motion item to the full Board that considers awarding a contract to the lowest responsible bidder, Oilfield Electric & Motor, in the amount of $771,000.00 and authorizing the General Manager to execute the contract with Oilfield Electric & Motor for the construction of the Oxnard Hueneme (OH) System Backup Generator.

Discussion:
The District is planning to install a new 800 kW backup emergency generator at the El Rio Water Treatment and Groundwater Recharge Facility to maintain the supply of safe and cost-effective drinking water to all OH Pipeline System customers during the Public Safety Power Shutoffs (PSPS) events.

The existing 750 kW diesel generator, engine, controls, panels, and feeders will be removed and disposed of by the District prior to start of the construction and a new 800kW generator will be furnished by the District to be installed by the contractor.

The construction of the OH System Backup Generator Project (Project) will be partially funded by the California Office of Emergency Services (CalOES) Hazard Mitigation Grant Program (HMGP). The grant funding of $646,537.00 equivalent to 75% of the total construction cost was awarded on November 10, 2020. This grant amount that was based on the 2019 Project cost estimates and included in the CalOES grant application needs to be amendment to take account of the updated Project cost. Staff is in the process of submitting a budget increase request to CalOES for approval. The CalOES HMGP requires the Project completion by August 26, 2021.

Staff advertised the Invitation to Bid for the OH System Backup Generator construction project on January 15, 2021. The notice inviting bids was posted on the District website and five (5) qualified contractors with experience in high voltage projects, including Diener Electric, High Volt Electric, Oilfield Electric & Motor, Pacific Industrial Electric, and Taft Electric were invited to bid the project. On February 22, 2021, the bid due, Staff received three (3) bids with the lowest responsible bid provided by Oilfield Electric & Motor. A summary of the bid results is as follows:

- Oilfield Electric & Motor $771,000.00
- Pacific Industrial Electric $1,084,036.00
- Taft Electric $1.094,404.00

Oilfield Electric & Motor is well qualified to perform the work and has successfully completed several projects for the District.

Staff recommends the Board to authorize the General Manager to award the construction contract to Oilfield Electric & Motor to install a new 800kW backup diesel-powered generator.

To ensure a timely project completion by the due date on August 26, 2021, Staff has placed an order in the amount of $203,159.65 with Quinn Company, Inc. for a new 800kW generator. The cost of the new generator is not included in the construction contract.

Fiscal Impact:
The total construction cost of $771,000.00 is included in the Fiscal Year 2020-21 Budget (CIP Project Account 451-400-81060-8036). In addition, the grant funding will also be available to support the construction project. No additional funding is requested.

Staff Report

To: Engineering and Operations Committee

Through: Mauricio E. Guardado, Jr., General Manager

From: Brian Collins, Chief Operations Officer

Date: February 23, 2021 (March 4, 2021 Committee Meeting)

Agenda Item: **3.2 Execution of a Contributed Funds Agreement Amendment for the Physical Modeling of the Freeman Diversion Rehabilitation Project with the Bureau of Reclamation.**
Motion

Staff Recommendation:
The Engineering and Operations Committee will consider recommending to the full Board that the Board authorize the General Manager or his designee to execute a contributed funds agreement (CFA) amendment with the Bureau of Reclamation (Bureau) for the physical modeling of the two proposed project alternatives for the Freeman Diversion Rehabilitation Project, currently under engineering design by Stantec and Northwest Hydraulic Consultants.

Discussion:
In response to National Marine Fisheries Service (NMFS) and California Department of Fish and Wildlife (CDFW) comments received from the initial modeling plan submitted by the District on November 23, 2020, District and Bureau staff have worked to develop an amended physical modeling plan to hydraulically model both the hardened ramp and the vertical slot project proposals within the Bureau's Technical Service Center (TSC) in Denver, Colorado.

In accordance with the court ordered stipulation, the District submitted the final Physical Modeling Plan on February 8, 2021 and are currently awaiting formal feedback comments from NMFS and CDFW for District consideration and potential inclusion within the finalized Physical Modeling Work Plan. Comments from NMFS and CDFW are due by March 10, 2021.

The current schedule timeline within the Physical Modeling Plan proposes to initiate work on the hardened ramp on February 15, 2021 and to conclude the vertical slot modeling by August 15, 2023.

Fiscal Impact:
Approval of this item would result in a budgeted expenditure of up to $2,156,955. These proposed activities were included within Fiscal Year 2020-21 Budget (421-400-81020 Project 8001) and sufficient funds are currently available.

Attachment A - Physical Modeling Plan DRAFT

BUREAU OF RECLAMATION

Physical Hydraulic Modeling Plan for Fish Passage at Vern Freeman Diversion Dam

Background

United Water Conservation District (United Water) contacted the Bureau of Reclamation's (Reclamation) Hydraulics Laboratory to establish a qualified path to accomplish court-mandated physical hydraulic modeling of two proposed fish passage alternatives for the Vern Freeman Diversion Dam (Freeman Dam) facility. Freeman Dam is a 28-ft-high, 1,200-ft-long roller compacted concrete gravity structure with an existing Denil fish ladder and diversion facilities. United Water currently diverts up to 375 cfs, but it plans to file for a water right to divert up to 750 cfs from the Santa Clara River.

The goal of both fish passage designs is to provide for successful upstream passage of adult steelhead during river flows of 45 to 6,000 cfs with little or no delay at Freeman Dam. It is desired to also provide successful upstream passage of adult Pacific lamprey. The Santa Clara River has a gravel-cobble bed with a characteristic slope of about 0.002. The river experiences high sediment loads with transport of very fine sand to medium boulders depending on the flow event. Medium sand is the bulk of the material transported during 2- to 100-year flow events (corresponding to 9,784 to 226,000 cfs, respectively, AECOM 2014). Transport of debris such as clumps of Arundo and smaller floating vegetative debris have been observed at discharges above 800 cfs, while larger floating debris such as tree-sized woody debris occurs at flows above about 6,000 cfs. Large-scale channel morphology is dependent on major flow events. Key concerns for the Freeman Dam fish passage project by the National Marine Fisheries Service (NMFS) and the California Department of Fish and Wildlife (CDFW) are the ability to maintain safe and effective fish passage while managing sediment and debris in and around fishway features.

Northwest Hydraulic Consultants specifies the 30% design for the hardened ramp fishway in their Design Development Report (2020) along with initial suggestions on a physical hydraulic modeling approach. The hardened ramp is designed to provide continuous upstream fish passage for steelhead and Pacific lamprey at river flows of 45 to 6,000 cfs without shutdown for sediment flushing operations. The 90-ft-wide and 420-ft-long hardened ramp is designed at a 5% slope with an asymmetric cross section to provide fish passage at acceptable water depths and velocities over a range of flow conditions. A 30-ft-wide triangular roughened low-flow section contains approximately 1- to 2-ft-diameter rocks with larger 3-ft-diameter rocks placed every 20 ft. The 60-ft-wide baffled ramp on a 30:1 cross slope contains 5-ft-wide vee-shaped sloped steel baffle plates with a 2.5-ft slot width. Four crest gates control flow into the hardened ramp. The design also contains a 15-ft-wide sediment flushing channel and a 1.5-ft-deep fixed ogee-shaped notch in the dam over 400 ft length to the right of the hardened ramp. More detailed information and drawings on the hardened ramp design can be found in Northwest Hydraulic Consultants' Design Development Report (2020).

The 30% design for the vertical slot fish passage design is documented in Stantec's Design Development Report (2020) and through technical communications on the amended design. The vertical slot fishway alternative includes construction of a vertical slot fish ladder, north and south fish ladder entrances, an auxiliary water system and associated fish screens, and crest gates. The fish ladder is designed to pass 34 cfs at the design upstream water level of 161.5 ft. The fish ladder flow ranges from 34-37 cfs over the design flow range. The auxiliary water system is designed to pass up to 570 cfs for a total of 600 cfs of attraction flow to the fishway entrance, which is 10 percent of the design river flow of 6,000 cfs. The dam will be notched about 10 ft deep and 73 ft long to accommodate new rubber bladder-style crest gates designed to control the forebay elevation and concentrate spill over the diversion crest to improve attraction to the ladder entrance. The downstream face of the dam below the crest gate will contain a fish transport tunnel which allows fish entering the north entrances to move into the fish ladder. The existing 15-ft-wide sediment flushing channel will be maintained from the existing features. More detailed information and drawings on the vertical slot fish ladder can be found in Stantec's Design Development Report (2020).

Physical Modeling Approach

Due to the importance of sediment and debris movement over a wide range of storm events in the Santa Clara River and the potential for adverse sediment and debris impacts in and around the proposed fishway features, this physical model plan includes a two-model approach to meeting modeling objectives. Two physical hydraulic models will be constructed and tested in Reclamation's Hydraulics Laboratory to assess the performance of the hardened ramp fishway and vertical slot fishway alternatives. A mobile bed model of the river and project features will be constructed at a 1:24 Froude scale and a primarily fixed bed model focusing on the left bank will be constructed at a 1:12 Froude scale. The latter model will include some movable sediment zones to enable evaluation of localized scour and deposition issues. There will be some overlap in the modeled river discharges between the two physical models to ensure continuity of boundary conditions.

The hardened ramp fish passage alternative will be tested first. The hardened ramp will be installed in the 1:24-scale model box, followed closely by installation in the 1:12-scale model box. Both models of the hardened ramp alternative will be available concurrently in the laboratory. When testing of the hardened ramp is complete, the hardened ramp will be removed and replaced with the vertical slot fish passage alternative in the 1:24-scale model box, followed closely by installation in the 1:12-scale model box. Both models of the vertical slot fish passage alternative will be available concurrently in the laboratory.

1:24-Scale Physical Hydraulic Model

The 1:24-scale physical model will include a larger section of the river width and length and will focus on higher flow events and movement of larger material in the river. The primary goal of the 1:24 Froude scale physical hydraulic model is to observe hydraulic, sediment, and debris conditions in a large section of the river channel and through project features for river flows up to the 100-year storm event (226,000 cfs). The model will simulate the distribution of flows through project features over a range of flow rates and operational scenarios. Hydraulic conditions including fishway attraction flows and exit conditions will be assessed in and around project features. Bed load transport will be modeled to identify locations of sediment deposition and erosion, formation of sand bars, and other bed changes. Accumulation of sediment and debris in and around proposed project features will be observed. Sediment flushing operations will be assessed to determine how fish passage operations may be impacted during sediment management. Design modifications may be recommended to improve fish passage performance based on general hydraulic and sediment trends. The 1:24-scale model will be used to identify the most appropriate bathymetry to use for each alternative tested in the 1:12-scale model.

The 1:24-scale model was described as a "comprehensive" model in the draft model plan proposed by NHC for the hardened ramp alternative. The 1:24-scale model has the same maximum discharge and will achieve the same model goals. The 1:24-scale model will include all fish passage project features and a section of the river width. The model will contain approximately 1,100 ft of river upstream of the dam, 620 ft of river downstream of the dam, and 300 ft of the dam crest to the right of the project features. For comparison, the draft model plan for the hardened ramp alternative proposed by NHC included approximately 200 ft of river upstream of the dam, 200 ft downstream of the ramp (equivalent to about 390 ft downstream of the dam), and 250 ft of the dam crest to the right of the ramp.

The physical model will represent river flow rates from approximately 5,000 cfs (less than 2-year event) to 226,000 cfs (100-year event) for both the hardened ramp and vertical slot fish passage alternatives. Since the physical model does not include the full river width, the corresponding model flow rates will be approximately 5,000-85,000 cfs in the modeled section.

Boundary condition hydraulics (flow rate and water surface elevations) for the selected model extents will be based on numerical model results provided by the respective design consultants to ensure that the modeled section experiences appropriate inflow conditions. Testing will generally be conducted under steady state flow conditions; however, the model discharges will be ramped up to, and ramped down from, higher flow conditions to avoid abrupt changes in model discharge.

The 1:24-scale model will be constructed with a fully mobile bed except in the hard topography areas that define the left bank of the channel. Baffling will be required to still the incoming flow into the model and the bathymetry just downstream of the baffle will be fixed to ensure that excessive erosion does not occur at the upstream boundary. The 1:24-scale model will focus on bed load movement of larger materials such as medium boulders, gravels, and coarse sands at higher flow rates. Sediment transport rates and material sizes entering the model will be set according to findings from sediment transport analyses (Hydroscience & Engineering LLC 2021, AECOM 2014) during various flow events. Larger material will be loaded manually, and smaller sediments will be introduced through a recirculating sediment pump system.

1:12-Scale Physical Hydraulic Model

The 1:12-scale physical model of the left bank will focus more closely on the performance of specific features for each fish passage alternative at flows rates that are typical of regular operations while allowing for overlap in modeled river discharges with the 1:24-scale model. The primary goals of the 1:12-scale model are to assess overall hydraulic performance of the proposed fishway designs, measure and observe localized hydraulic conditions in and around the proposed features, and identify issues related to sediment and debris movement and accumulation near project features. More detailed modifications to the existing designs may be recommended in the 1:12-scale model to improve design features and better meet fisheries objectives. If modifications are recommended that may create larger impacts to the river channel, the proposed modifications could be evaluated in the concurrent 1:24-scale model.

The 1:12-scale model was described as a "section" model in the draft model plan proposed by Northwest Hydraulic Consultants for the hardened ramp alternative. The Northwest Hydraulic Consultants draft model plan suggested a model scale of about 1:8 with a focus on obtaining detailed hydraulic and sediment information in the upstream section of the hardened ramp. The proposed model by Northwest Hydraulic Consultants included the full 90-ft width of the hardened ramp and the diversion intake, but only upstream 270 ft of the ramp length and none of the dam crest.

Although a 1:8-scale model can be achieved in Reclamation's Hydraulics Laboratory, the modeling team determined that a 1:12-scale model serves the same general function as the model proposed by Northwest Hydraulic Consultants while also providing key information about areas surrounding the hardened ramp. Modeling the full width and length of the hardened ramp in addition to adjacent project features allows modelers to better understand the hydraulic and sediment processes at the fishway entrance and assess how the fish passage system will work together.

The maximum expected river discharge in the 1:12-scale model is 18,900 cfs, which is equivalent to a model discharge of 10,000 cfs. Hydraulic performance data can be obtained inside the hardened ramp such as the interaction between the roughened low flow section and the baffled ramp, hydraulic drop, turbulence, and eddies. Baffles at the upstream and downstream ends of the ramp are most likely to require modifications; however, all baffles will be adjustable. The hardened ramp will be able to pass river flows from 45 to 6,000 cfs, but shallow water depths in the hardened ramp may preclude some direct hydraulic measurements at low flows. A flow rate of about 150 cfs prototype with a corresponding model water depth of approximately 1 inch is the minimum flow that can be passed through the hardened ramp without experiencing scale effects due to low Reynolds number. If detailed hydraulic data is needed at flows less than 150 cfs, data can be obtained from the existing Northwest Hydraulic Consultants CFD model of the hardened ramp and used in conjunction with general observations from the physical model as flows less than 150 cfs could only be used for qualitative purposes only.

Although a 1:12-scale model was originally proposed only for the study of the hardened ramp alternative, the modeling team has decided that a 1:12 Froude scale is also advantageous for the vertical slot fish passage alternative. This scale allows for a more detailed study of the vertical slot fishway with its auxiliary water system, crest gates, and sediment flushing channel and the localized conditions around these features.

The 1:12-scale model will have a fixed bed bathymetry based on results from the 1:24-scale model which will likely differ for the hardened ramp and vertical slot alternatives. Movable bed sections will be included upstream and downstream of project features to identify erosive and depositional areas. The model will focus on localized conditions due to suspended sediment movement, deposition, and erosion at lower flow rates. The modeled material will be largely sand which will be introduced through a recirculating sediment pump system. Details of the sediment pumping system will be developed in the final model design process and shared with project partners. Sediment transport rates and associated material sizes will be introduced to the model according to findings from sediment transport analyses (Hydroscience & Engineering LLC 2021 and AECOM 2014) during low flow events.

Hardened Ramp Fish Passage Alternative

1:24-Scale Physical Hydraulic Model

Model Objectives

1) Observe hydraulic, sediment, and debris conditions in and around project features for river flows up to the 100-year event
2) Identify locations of sediment deposition and erosion, formation of sand bars, and other river bed changes up to the 100-year event
3) Identify most appropriate bathymetry to use for the 1:12-scale model of the hardened ramp
4) Evaluate flow distribution and flow patterns near diversion intake, flushing channel, and hardened ramp exit
5) Observe downstream fishway attraction flows and entrance conditions, and upstream fishway exit conditions
6) Observe sediment flushing capability with and without construction of a flushing channel.
7) Determine if fish passage operations can be maintained while managing sediment.
8) Observe impacts of closing fishway exit gates at high flows
9) Observe qualitative sediment deposition and erosion patterns near diversion intake, flushing channel, hardened ramp entrance and exit, and inside the diversion
10) Observe debris transport and determine locations of debris accumulation, potential impact of debris on fishway operation, and potential flushing alternatives
11) Recommend design modifications to improve fish passage performance

Model Layout

For the 1:24-Froude scale physical hydraulic model of the hardened ramp, model features will include the hardened ramp with low-flow roughened section and baffled section, control structure crest gates, approximately 300 ft of the dam to the right of the hardened ramp (with 1.5-ft-deep notch), and canal headgates (piers and trashrack). Model testing will occur with and without the sediment flushing channel constructed adjacent to the hardened ramp (Figure 1). All baffles on the hardened ramp will be included. The canal fish screen and associated sediment jetting system will not be included in the 1:24-scale model; however a detailed model of these components may be considered at a scale ranging from 1:4 to 1:8 should the hardened ramp alternative be considered viable following physical modeling under the current test plan.

The hardened ramp physical model will be able to pass river flows from less than the 2-year event to the 100-year storm event. The model can be used to identify flow patterns, qualitative sediment deposition and erosion areas, and locations of debris accumulation. Due to the model scale, low flow depths and corresponding low Reynolds numbers limit the ability to collect detailed hydraulic data inside the hardened ramp at low flow rates. More detailed localized measurements of smaller-scale features (e.g. baffles) will be completed in the 1:12-scale model.

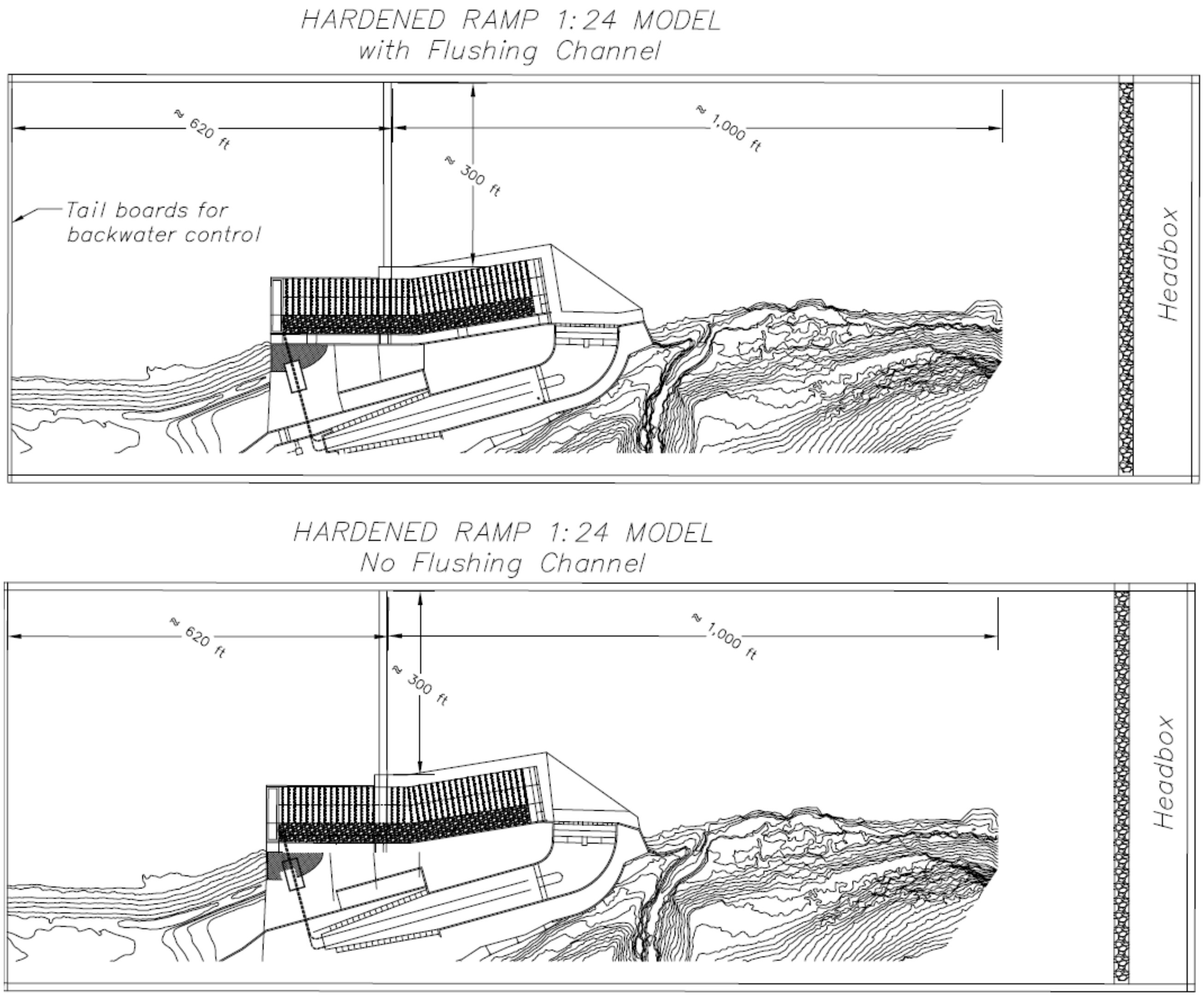


Figure 1. Proposed layout and features of the 1:24-scale mobile bed physical model with the hardened ramp fishway alternative based on the 30% design by NHC. The model box, headbox, and tailboards are depicted. Areas without topography will be a fully mobile bed. Model testing will occur with (top) and without (bottom) a sediment flushing channel. Flow is from right to left. Dimensions are in prototype ft.

Test Matrix

Testing will be completed over a range of relevant flow rates and operational conditions at a 1:24 model scale. Testing will be conducted with the existing dam crest and a flushing channel adjacent to the canal intake structure. Testing will also be conducted with a 1.5-ft ogee crest-shaped dam notch over the dam section to the right of the hardened ramp and no flushing channel. When the flushing channel is not constructed, the canal intake entrance structure will be moved out into the river and the flushing channel will be blocked off. Testing will generally be conducted under steady state flow conditions; however, the model discharges will be ramped up to, and ramped down from, higher flow conditions to avoid abrupt changes in model discharge.

The test runs have been organized into several categories (Table 1). Table 2 shows an example of a test matrix that includes key scenarios. The test matrix will be refined prior to the start of model testing with input from project partners. The modeling team expects the model testing to be an adaptive process with model results and observations informing additional model simulations. Changes to the model test matrix will be shared with project partners throughout the modeling program.

Table 1. Model test scenarios for 1:24-scale physical model of the hardened ramp alternative.

Scenario	Description
1. Run hydrologic scenarios with known field conditions to ensure that the physical model is appropriately replicating river conditions.	Flow rates of 6,000 cfs, 30,000 cfs, and 70,000 cfs will be modeled with the flushing channel open to replicate known river conditions.
2. Run scenarios up to and including the 100-year flow event to examine channel morphology, hydraulic patterns, and sediment movement and deposition with the hardened ramp fish passage alternative constructed.	Flows rates of 6,000 cfs, 30,000 cfs, 70,000 cfs, and 226,000 cfs will be modeled with various gate configurations to understand how sediment will move and deposit under high flow conditions.
3. Run debris scenarios with known field conditions to ensure that the physical model is appropriately replicating debris conditions.	Flow rates of 6,000 cfs, 30,000 cfs, and 70,000 cfs will be modeled with debris loading informed by the debris memorandum (United Water 2021). Model will be compared to known field conditions to ensure the physical model will replicate river conditions.
4. Run scenarios up to and including the 100-year low event to examine debris movement and accumulation with the hardened ramp fish passage alternative constructed.	Flow rates of 6,000 cfs, 30,000 cfs, 70,000 cfs, and 226,000 cfs will be modeled with debris loading informed by the debris memorandum (United Water 2021). Accumulated debris will be noted to ensure functionality of the fish passage facility at lower discharges.
5. Run scenarios to examine hydrodynamics in and around the hardened ramp including exit conditions, attraction flows, and dynamics between project features during high flow events.	Attraction flow will be observed at flow rates of 6,000 cfs. Comparisons to the 1:12-scale model will be observed. A model run at 10,000 cfs will also be considered to determine the maximum discharge at which the fishway may provide passage.
6. Run scenarios to examine sediment and debris management in and around the hardened ramp including operation of flushing channel during high flow events.	Flow rates of 6,000 cfs, 30,000 cfs, and 70,000 cfs will be modeled to examine sediment and debris accumulation and management in and around the fish passage, crest gates, flushing channel, and diversion intake. Various gate operations, and potential use of a debris boom, will also be assessed to determine how management of sediment and debris may be accomplished.

Table 2. Example test matrix showing key scenarios for the hardened ramp alternative in the 1:24-scale physical model.

Test #	Scenario #	Flow Exceedance in %*	River Flow (cfs)	Ramp Flow Estimated (cfs)	Diversion Flow (cfs)	Flushing Channel Flow (cfs)	Dam Crest (cfs)	Modified Dam Notch Flow (cfs)	S - Sediment D - Debris
R-1	2, 4, 5, 6	1.31%	6,000	3,030	750	1,745	475		S/D
R-2	1, 2	0.73%	10,000	4,000	0	0	3,000	3,000	
R-3	4, 5, 6	0.37%	18,900	Maximum			Remainder		S/D
R-4	2, 4, 5, 6	0.18%	30,000	Open	0	Closed			S/D
R-5	2, 4, 5, 6	0.18%	30,000	Closed	0	Closed			S/D
R-6	1, 2, 3, 4, 5, 6	0.18%	30,000	Closed	0	Open			S/D
R-7	2, 4, 5, 6	0.06%	70,000	Open	0	Closed			S/D
R-8	2, 4, 5, 6	0.06%	70,000	Closed	0	Closed			S/D
R-9	1, 2, 3, 4, 5, 6	0.06%	70,000	Closed	0	Open			S/D
R-10	2, 4, 5, 6	0.00%	226,000	Open	0	Closed			S/D
R-11	2, 4, 5, 6	0.00%	226,000	Closed	0	Closed			S/D
R-12	2, 4, 5, 6	0.00%	226,000	Closed	0	Open			S/D

* Exceedance based on average daily total river flow at the Freeman Diversion during primary migration period from January 1 to May 31.

Data Collection

The following data will be collected during testing:

- Water surface elevation upstream and downstream of the dam (headwater, tailwater), at top and bottom of hardened ramp, and in the canal diversion entrance
- Total model flow rate, canal diversion flow rate, fish bypass flow rate, and calculated fishway and dam crest flow rate
- Water surface elevations and point velocities at key locations, as needed
- Surface velocity maps of key locations, such as fishway attraction flow area
- Observations of general hydraulic conditions upstream and downstream of the hardened ramp to assess attraction flow, and downstream of dam notch to assess nuisance attraction flow
- Observations of sediment behavior and operational strategies to limit adverse impacts
- Observations of debris movement and accumulation and operational strategies to limit adverse impacts
- Bathymetric maps showing locations and extents of sediment deposition and erosion

1:12-Scale Physical Hydraulic Model

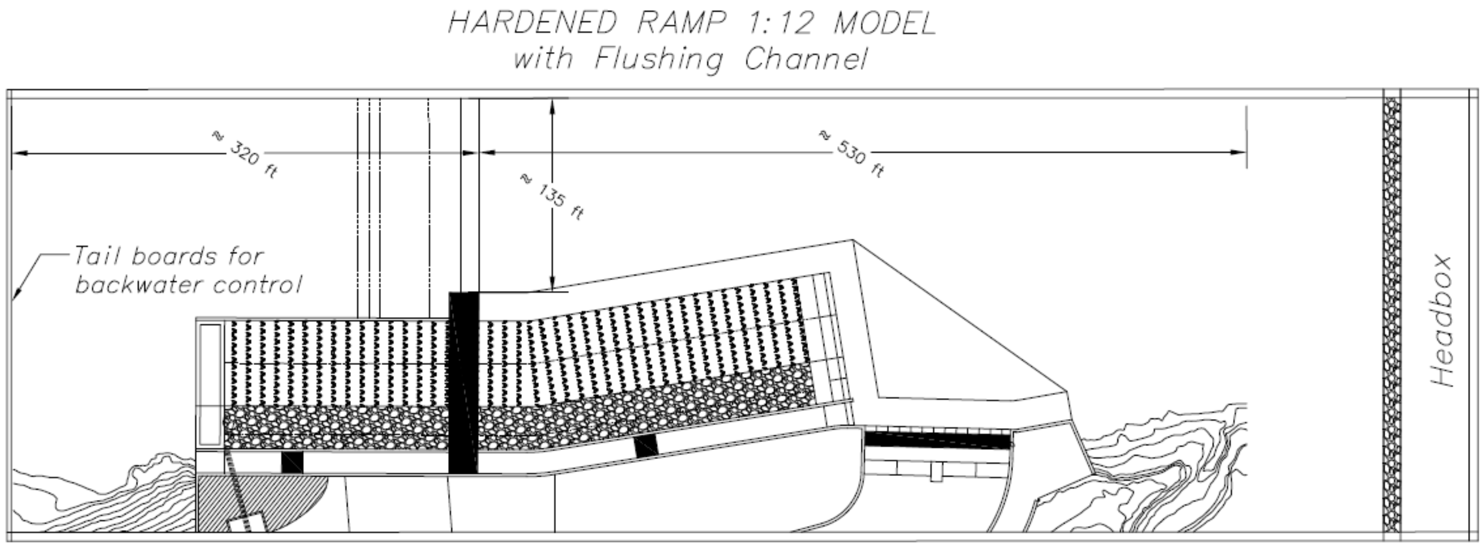
Model Objectives

1) Observe flow patterns within and around the hardened ramp including areas upstream and downstream of the hardened ramp and measure point water depths and velocities as needed.
2) Observe baffle performance and interaction of roughened low-flow channel with sloped baffle portion of the ramp.
3) Determine if baffle design or configuration should be modified to improve hydraulic performance and ensure that passage is available over a range of flows.
4) Observe recirculation zones or other adverse hydraulic conditions that may impact to attraction flow to the hardened ramp.
5) Observe sediment deposition and erosion patterns within and around the hardened ramp. If deposition occurs, determine how hydraulic conditions for fish passage are impacted.
6) Determine if sediment can be flushed from the ramp under certain flow conditions or with modified gate operations.
7) Determine hydraulics and sediment deposition in and around the flushing channel. Assess conditions with and without construction of a flushing channel.
8) Determine flow patterns related to notch in dam during hardened ramp operation to identify nuisance attraction flow. Modify notch as needed.
9) Observe debris collection or accumulation within and around the hardened ramp.

Model Layout

The 1:12-scale physical model of the hardened ramp alternative will contain approximately 530 ft of river upstream of the dam, 320 ft of river downstream of the dam, and 135 ft of the dam crest to the right of the project features (Figure 2). The model will have a fixed bed bathymetry based on results from the 1:24-scale model for the hardened ramp alternatives. The fixed bed may be constructed at least partially with material sized large enough to remain immobile at the highest modeled discharges.

The 1:12-scale physical model will represent river flow rates from 150 cfs to 18,900 cfs (10,000 cfs in model section) for the hardened ramp alternative. Boundary condition hydraulics for the selected model extents will be based on numerical model results provided by the respective design consultants to ensure that the modeled section experiences appropriate inflow conditions. Results from the 1:24-scale model can also be used to check hydraulic boundary conditions. Boundary conditions for sediment and debris will be obtained through sediment transport and debris studies as well as results from the 1:24-scale model.



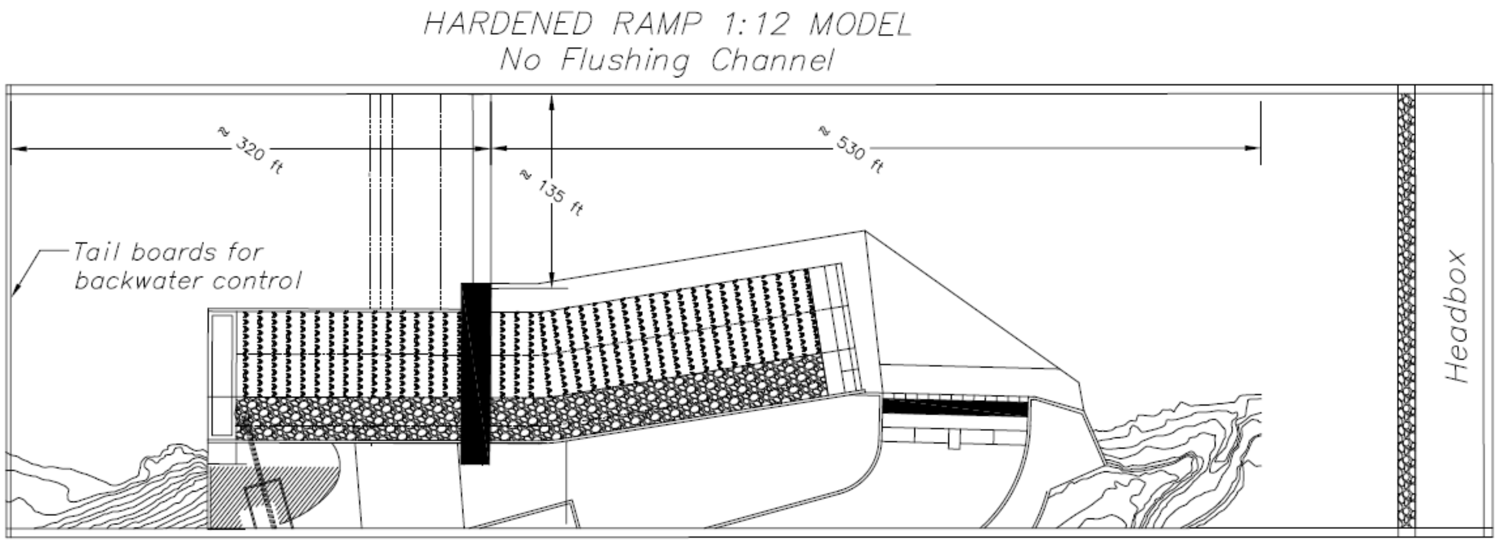


Figure 2. Proposed layout and features of the 1:12-scale fixed bed physical model with the hardened ramp fishway alternative based on the 30% design by NHC. The model box, headbox, and tailboards are depicted. Areas without topography will be mobile bed sections. Model testing will occur with (top) and without (bottom) a sediment flushing channel. Flow is from right to left. Dimensions are in prototype ft.

Test Matrix

Testing will be completed over a range of relevant flow rates and operational conditions at a 1:12 model scale. Testing will be conducted with the existing dam crest and a flushing channel adjacent to the canal intake structure. Testing will also be conducted with a 1.5-ft ogee crest-shaped dam notch over the dam section to the right of the hardened ramp and no flushing channel. When the flushing channel is not constructed, the canal intake entrance structure will be moved out into the river and the flushing channel will be blocked off. Testing will be conducted during steady state flow conditions.

Test runs have been organized into several categories (Table 3). Table 4 shows an example of a test matrix that includes key scenarios. The test matrix will be refined prior to the start of model testing with input from project partners. The modeling team expects the model testing to be an adaptive process with model results and observations informing additional model simulations. Changes to the model test matrix will be shared with project partners throughout the modeling program.

Table 3. Model test scenarios for 1:12-scale physical model of the hardened ramp alternative.

Scenario	**Description**
1. Run flow scenarios that overlap with conditions observed in the 1:24-scale model to ensure that the 1:12-scale physical model is appropriately replicating hydraulic and sediment conditions near project features.	Flow rates of 6,000 cfs, 10,000 cfs, and 18,900 cfs will be run on both models to verify that hydraulic, sediment, and debris are well replicated.
2. Run scenarios to examine hydrodynamics in and around project features including ramp hydraulics, exit conditions, attraction flows, and dynamics between project features during standard operating conditions.	Flow rates of 6,000 cfs, 10,000 cfs, and 18,900 cfs will be run to assess hydrodynamics in and around project features. Flow rates of 575 cfs, 1,500 cfs, 3,000 cfs, and 6,000 cfs will be run to ramp hydraulic conditions and attraction flow using various gate configurations including the flushing channel, crest gates, and the ramp itself.
3. Run scenarios to examine sediment and debris movement and accumulation in and around the hardened ramp and diversion intake during standard operating conditions.	Accumulation of debris will be analyzed at higher flow ranges including 18,900 cfs, 10,000 cfs, 6,000 cfs, and 1,500 cfs. Various amounts and sizes of debris will be added in accordance with the debris flow plan. Sediment will also be examined in the same flow ranges to determine the potential accumulation in and around the fish passage system and the diversion intake. Additionally, sediment will be analyzed at discharges of 410 cfs, 250 cfs, and 150 cfs to help determine how the bedload will pass the system during baseflow conditions and conservation releases.
4. Run scenarios to examine sediment and debris management in and around the hardened ramp including operation of flushing channel during standard operating conditions.	See #3

Table 4. Example test matrix showing key scenarios for the hardened ramp alternative in the 1:12-scale physical model.

Test #	Scenario #	Flow Exceedance in %*	River Flow (cfs)	Ramp Flow Estimated (cfs)	Diversion Flow (cfs)	Flushing Channel Flow (cfs)	Dam Crest (cfs)	Modified Dam Notch Flow (cfs)	S -Sediment D - Debris
R-13	3, 4	38.80%	150	150					S
R-14	3, 4	26.52%	250	50	200				S
R-15	3, 4	26.52%	250	200	50				S
R-16	3, 4	15.17%	410	45	375				S
R-17	2	13.68%	575	575	0				
R-18	3, 4	8.69%	950	200	750				S
R-19	2	5.51%	1,500	1,125	375				
R-20	3, 4	5.51%	1,500	750	750				S/D
R-21	3, 4	5.51%	1,500	1,500					S
R-22	3, 4	2.54%	3,000	1,787.5	750	Remainder			S
R-23	2	2.54%	3,000	1,787.5	750		Remainder		
R-24	2	2.54%	3,000	1,787.5	750			Remainder	
R-25	2	2.54%	3,000	3,000	0	0	0	0	
R-26	3, 4	2.54%	3,000	3,000					
R-27	3, 4	2.54%	3,000			3,000			
R-28	2, 3, 4	1.31%	6,000	3,030	750	1,745	475		S/D
R-29	2, 3, 4	1.31%	6,000	3,600	750	0	1,650	0	S/D
R-30	2, 3, 4	1.31%	6,000	3,600	0	0	2,400	0	S/D
R-31	2, 3, 4	1.31%	6,000	2,900	750	0		2,350	
R-32	1,2,3,4	1.31%	6,000	3,030	750	1,745	475		S/D
R-33	1,2	0.73%	10,000	4,000	0	0	3,000	3,000	
R-34	1,2,3,4	0.37%	Model Maximum (18,900)	Maximum			Remainder		S/D

* Exceedance based on average daily total river flow at the Freeman Diversion during primary migration period from January 1 to May 31.

Data Collection

The following data will be collected during testing:

- Water surface elevation upstream and downstream of the dam (headwater, tailwater), at top and bottom of hardened ramp, and in the canal diversion entrance
- Total model flow rate, canal diversion flow rate, fish bypass flow rate, and calculated fishway and dam crest flow rate.
- Water surface elevations and point velocities around fishway baffles to assess performance and identify resting zones
- Point velocities in front of the canal intake structure and upstream and downstream of the hardened ramp
- Surface velocity maps of key flow conditions, as needed
- Observations of hydraulic conditions inside the hardened ramp, and upstream and downstream of hardened ramp
- Observations of hydraulic conditions downstream of dam notch to assess nuisance attraction flow
- Observations of sediment behavior and operational strategies to limit adverse impacts
- Mapped locations of sediment deposition and erosion with approximate lateral extents and depths
- Observations of debris movement and accumulation and operational strategies to limit adverse impacts

Schedule for Hardened Ramp Fish Passage Alternative

The hardened ramp fishway alternative will be constructed inside the 1:24-scale model box first, followed by construction in the 1:12-scale model box. Model design drawings and ordering of materials for the 1:24-scale model is expected to commence on February 15, 2021 with model construction initiating around April 15, 2021. As testing on the 1:24-scale model occurs, construction of the 1:12-scale model will begin. The models will be available concurrently.

For both the 1:24- and 1:12-scale models, shakedown of physical model instrumentation, components, and test procedures will occur during the first two weeks after model construction. Clear-water tests will be run to measure hydraulic conditions in the model, followed by sediment testing and debris testing. During the test period, a site visit will be planned for United Water and project partners to view the physical models in person and/or via remote streaming. The model schedule may be revised if unanticipated changes to the model plan and test matrix are required.

Table 5. Estimated physical modeling schedule for hardened ramp fish passage alternative.

Physical Model Study Tasks	Start Date	End Date
1:24-Scale Model Design Drawings and Order Materials	2/15/2021	4/15/2021
1:24-Scale Model Review of Model Design Drawings by United Water and Project Partners	4/1/2021	4/8/2021
1:24-Scale Model Construction	4/15/2021	7/15/2021
1:24-Scale Model Shakedown and Testing	7/15/2021	12/15/2021
1:24-Scale Project Partner Site Visit	8/1/2021	12/15/2021
1:12-Scale Model Design Drawings and Order Materials	4/15/2021	7/15/2021
1:12-Scale Model Review of Model Design Drawings by United Water and Project Partners	7/1/2021	7/15/2021
1:12-Scale Model Construction	8/15/2021	11/15/2021
1:12-Scale Model Shakedown and Testing	11/15/2021	4/15/2022
1:12-Scale Project Partners Site Visit	12/1/2021	4/15/2022
Draft Report	4/1/2022	5/1/2022
Submit Revised Draft Report to Project Partners for Comment	5/1/2022	6/1/2022
Finalize Report	6/1/2022	6/15/2022
Submit Final Report to United Water and Project Partners		6/15/2022

Vertical Slot Fish Passage Alternative

1:24-Scale Physical Hydraulic Model

Model Objectives

1) Observe hydraulic, sediment, and debris conditions in and around project features for river flows up to the 100-year event
2) Identify locations of sediment deposition and erosion, formation of sand bars, and other bed changes up to the 100-year event
3) Identify most appropriate bathymetry to use for the 1:12-scale model of the vertical slot fishway
4) Evaluate flow distribution and flow patterns near diversion intake, vertical slot fishway exit, and crest gates
5) Observe fishway attraction flows at the north and south fish entrance pools with and without crest gate spill
6) Observe qualitative sediment deposition and erosion patterns near the south entrance, on the apron adjacent to the entrance structure, and near the north entrance.
7) Observe qualitative sediment deposition and erosion patterns near the diversion intake, flushing channel, fishway exit, and inside the diversion
8) Determine how flushing channel operations impact downstream flow conditions
9) Observe debris transport and determine locations of debris accumulation, potential impact of debris on fishway operation, and potential flushing alternatives
10) Evaluate the potential benefit of widening the spillway
11) Recommend design modifications to improve fish passage system performance

Model Layout

For the 1:24-Froude scale physical hydraulic model of the vertical slot fishway, model features will include the vertical slot fishway and control structure, north fishway entrance and tunnel, south fishway entrances, auxiliary water system, crest gates, flushing channel, canal headgates (piers and trashrack), and independently operated auxiliary water and canal control gates (Figure 3). All vertical slot elements will be included. The canal and auxiliary fish screens and associated sediment jetting systems will not be included; however, a detailed model of these components may be considered at a scale ranging from 1:4 to 1:8 should the vertical slot fish passage alternative be considered viable following physical modeling under the current test plan.

The vertical slot physical model will be able to pass river flows from less than the 2-year event to the 100-year storm event. The 1:24-scale model can be used to identify flow patterns, qualitative sediment deposition and erosion areas, and locations of debris accumulation. Due to the model scale, low flow depths and corresponding low Reynolds numbers limit the ability to collect detailed hydraulic data inside vertical slot fish passage components such as auxiliary water system and fishway exit. More detailed localized measurements of smaller-scale features will be completed in the 1:12-scale model.

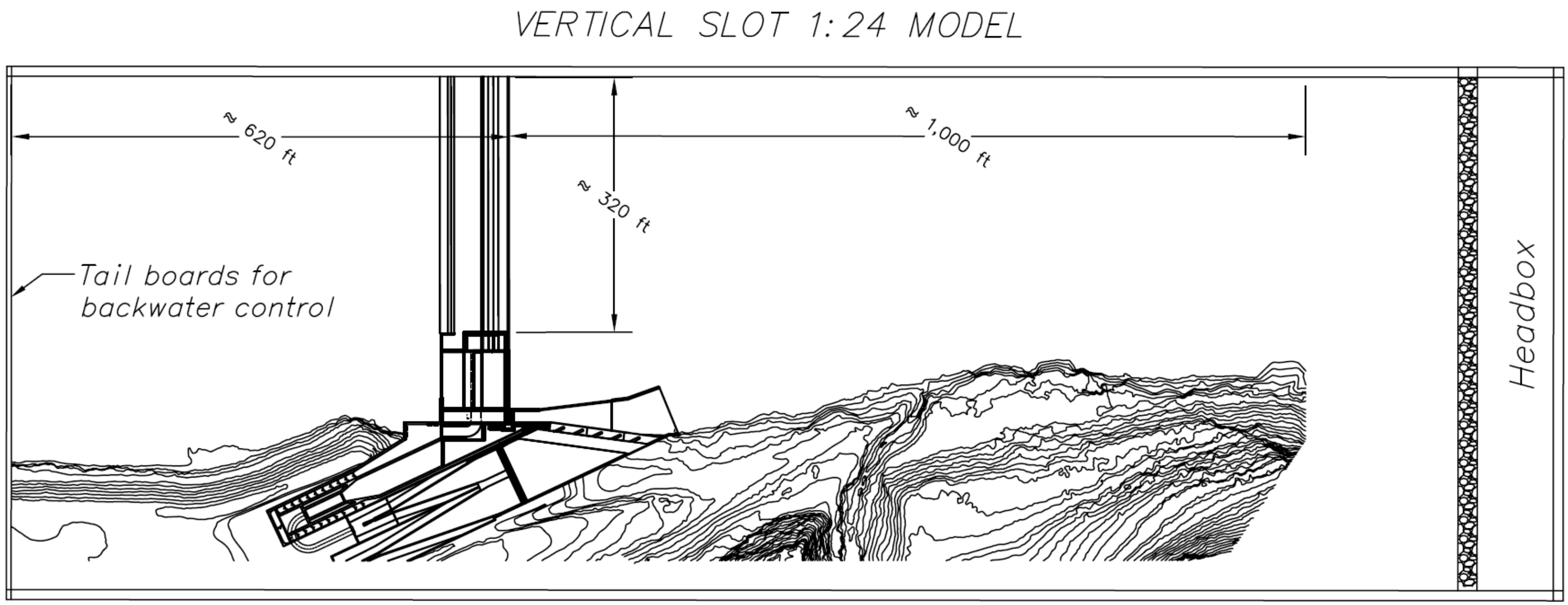


Figure 3. Proposed layout and features of the 1:24-scale mobile bed physical model with the vertical slot fishway alternative based on the 30% design by Stantec. The model box, headbox, and tailboards are depicted. Areas without topography will be a fully mobile bed. Model testing will occur with and without operation of the sediment flushing channel. Flow is from right to left. Dimensions are in prototype ft.

Test Matrix

Testing will be completed over a range of relevant flow rates and operational conditions for the vertical slot fish passage alternative at a 1:24 model scale. Testing will be conducted with and without operation of the flushing channel. The flushing channel gates will simply be closed during testing without the flushing channel. In the 1:24-scale model, the crest gates will be either in the up or down position. Testing will generally be conducted under steady state flow conditions; however, the model discharges will be ramped up to, and ramped down from, higher flow conditions to avoid abrupt changes in model discharge.

The test runs have been organized into several categories (Table 6). Table 7 shows an example of a test matrix that includes key scenarios. The test matrix will be refined prior to the start of model testing with input from project partners. The modeling team expects the model testing to be an adaptive process with model results and observations informing additional model simulations. Changes to the model test matrix will be shared with project partners throughout the modeling program.

Table 6. Model test scenarios for 1:24-scale physical model of the vertical slot fish passage alternative.

Scenario	Description
1. Run hydrologic scenarios with known field conditions to ensure that the physical model is appropriately replicating river conditions.	Flow rates of 6,000 cfs, 30,000 cfs, and 70,000 cfs will be modeled with the flushing channel open to replicate known river conditions.
2. Run scenarios up to and including the 100-year flow event to examine channel morphology, hydraulic patterns, and sediment movement and deposition with the vertical slot fish passage alternative constructed.	Flow rates of 6,000 cfs, 30,000 cfs, 70,000 cfs, and 226,000 cfs will be modeled with various gate configurations to understand how sediment will move and deposit under high flow conditions.
3. Run debris scenarios with known field conditions ensure that the physical model is appropriately replicating debris conditions.	Flow rates of 6,000 cfs, 30,000 cfs, and 70,000 cfs will be modeled with debris loading informed by the debris memorandum (United Water 2021). Model will be compared to known field conditions to ensure the physical model will replicate river conditions.
4. Run scenarios up to and including the 100-year low event to examine debris movement and accumulation with the vertical slot fish passage alternative constructed.	Flow rates of 6,000 cfs, 30,000 cfs, 70,000 cfs, and 226,000 cfs will be modeled with debris loading informed by the debris memorandum (United Water 2021). Accumulated debris will be noted to ensure functionality of the fish passage facility at lower discharges.
5. Run scenarios to examine hydrodynamics in and around the vertical slot fish passage and crest gate features including exit conditions, attraction flows, and dynamics between project features during high flow events.	Attraction flow will be observed at flow tests runs of 6,000 cfs. Comparisons to the 1:12 scale model will be observed. A model run at 10,000 cfs will also be considered to determine the maximum discharge at which the fish ladder may provide passage.
6. Run scenarios to examine sediment and debris management in and around the vertical slot fish passage and crest gate features including operation of flushing channel during high flow events.	Flow rates of 6,000 cfs, 30,000 cfs, and 70,000 cfs will be modeled to examine sediment and debris accumulation and management in and around the fish passage, crest gates, flushing channel, and diversion intake. Various gate operations, and the potential benefit of a debris boom, will also be assessed to determine how management of sediment and debris may be accomplished.

Table 7. Example test matrix showing key scenarios for the vertical slot fish passage alternative in the 1:24-scale physical model.

Test #	Scenario #	Flow Exceedance in %*	River Flow (cfs)	Ladder Flow (cfs)	Diversion Flow (cfs)	Canal Fish Bypass Flow (cfs)	Auxiliary Water Flow (cfs)	Auxiliary Water Fish Bypass Flow (cfs)	Crest Gate Flow (cfs)	Flushing Channel Flow (cfs)	Dam Crest Flow (cfs)	River Flow Downstream (cfs)	S -Sediment D - Debris
VS-1	5	1.31%	6,000	34	750	24	570	24	4,598			5,250	
VS-2	5	1.31%	6,000	34	0	0	570	24	5,372			6,000	
VS-3	1, 2	1.31%	6,000	0	0	0	0	0	0	Open	Remainder	6,000	S
VS-4	2	1.31%	6,000	0	0	0	0	0	Open	0	Remainder	6,000	S
VS-5	2	1.31%	6,000	0	0	0	0	0	Open	Open		0	S
VS-6	3, 4	1.31%	6,000	34	750	24	570	24	4,598			5,250	S/D
VS-7	2, 5	0.73%	10,000	34		0	570	24	9,372			10,000	S
VS-8	1, 2, 3, 4, 5	0.18%	30,000	0	0	0	0	0	Open	Open		30,000	S/D
VS-9	1, 2, 3, 4, 5	0.06%	70,000	0	0	0	0	0	Open	Open		70,000	S/D
VS-10	2	0.00%	226,000	0	0	0	0	0	Open	Open		226,000	S/D

* Exceedance based on average daily total river flow at the Freeman Diversion during primary migration period from January 1 to May 31.

Data Collection

The following data will be collected during testing:

- Water surface elevation upstream and downstream of the dam (headwater, tailwater), upstream and downstream of vertical slot fishway, and in the canal diversion entrance
- Total model flow rate, canal diversion flow rate, auxiliary water system flow rate, fish bypass flow rate, and calculated fishway and dam crest flow rate
- Water surface elevations and point velocities at key locations, as needed
- Surface velocity maps of key locations, such as fishway attraction flow area
- Observations of general hydraulic conditions upstream and downstream of the vertical slot fishway
- Observations of flow patterns, eddies, or adverse hydraulic conditions downstream of crest gates during operation and the associated impact on approach conditions to the north and south fish entrances
- Observations of sediment behavior and operational strategies to limit adverse impacts
- Observations of debris movement and accumulation and operational strategies to limit adverse impacts
- Bathymetric maps showing locations and extents of sediment deposition and erosion

1:12-Scale Physical Hydraulic Model

Model Objectives

1) Evaluate attraction flow conditions to north and south fish entrances with and without crest gate spill.
2) Evaluate hydraulics within and downstream of auxiliary water system (e.g. stilling area, diffuser) to determine if adverse impacts such as eddies occur in the south fishway entrance pool and to assess the probable zone of passage from the entrance gates and tunnel to the ladder.
3) Observe hydraulics in the north fish entrance pool and in the tunnel to the north fish entrance.
4) Observe qualitative sediment deposition and erosion downstream of the fishway near the south entrance, on the apron adjacent to the entrance structure, and in front of and within the north fishway entrance. Observe if sediment deposits can be resuspended and flushed away from north and south fishway entrances.
5) Observe qualitative sediment deposition or erosion upstream of crest gates to the mouth of the approach channel.
6) Observe qualitative sediment deposition in the fishway exit channel, within the auxiliary water system, in the canal entrance channel between the trashrack and auxiliary water system and canal control gates, and near the fish screens.
7) Determine how flushing channel operations impact downstream flow conditions.
8) Evaluate strategic operation of crest gates by opening and closing specified gates to minimize impacts on sediment deposition and attraction flows.
9) Evaluate vanes, interior guide walls, or other modifications to maintain sufficient flow depth on the spillway during low spillway flows.

Model Layout

The 1:12-scale physical model of vertical slot alternative will contain approximately 530 ft of river upstream of the dam, 330 ft of river downstream of the dam, and 80 ft of the dam crest to the right of the project features (Figure 4). The model will have a fixed bed bathymetry based on results from the 1:24-scale model which for vertical slot alternatives. The fixed bed may be constructed at least partially with material sized large enough to remain immobile at the highest modeled discharges.

The 1:12-scale physical model will represent river flow rates from 150 cfs to 10,000 cfs for the vertical slot alternative. Boundary condition hydraulics for the selected model extents will be based on numerical model results provided by the respective design consultants to ensure that the modeled section experiences appropriate inflow conditions. Results from the 1:24-scale model can also be used to check hydraulic boundary conditions. Boundary conditions for sediment and debris will be obtained through sediment transport and debris studies as well as results from the 1:24-scale model.

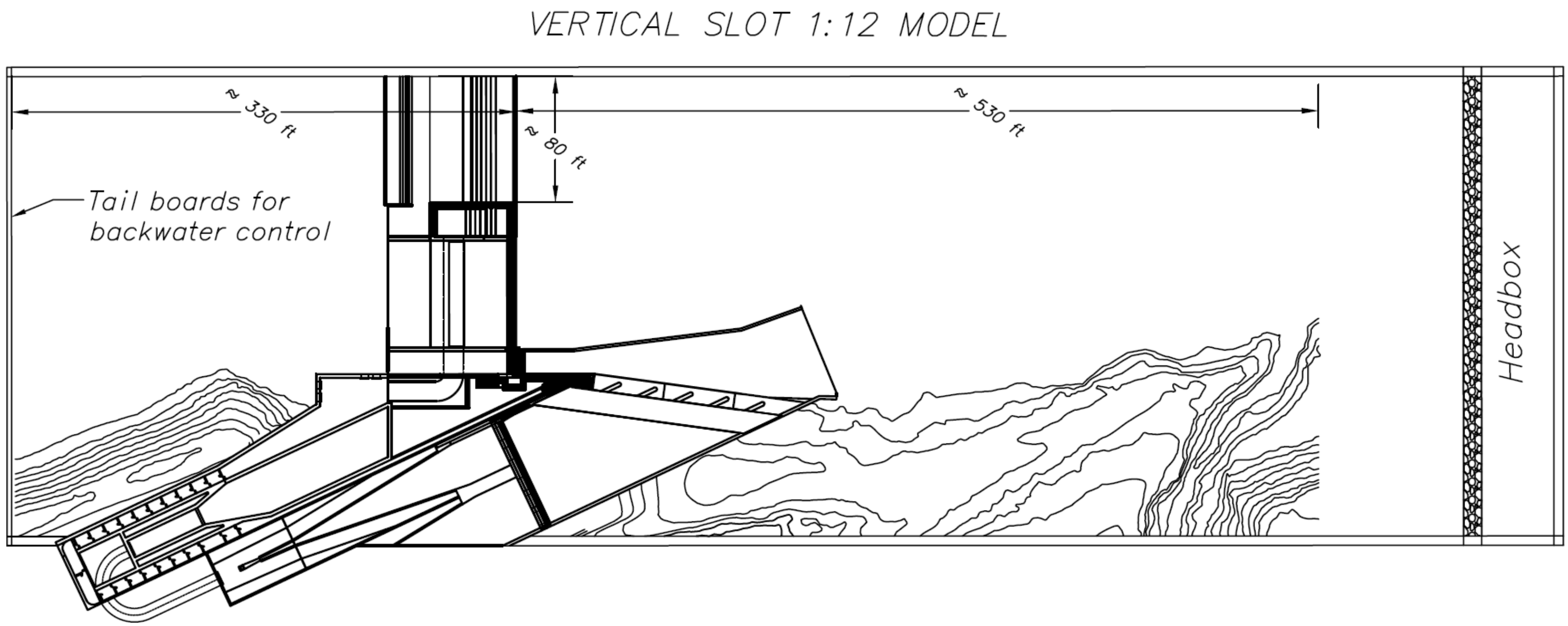


Figure 2. Proposed layout and features of the 1:12-scale fixed bed physical model with the vertical slot fish passage alternative based on the 30% design by Stantec. The model box, headbox, and tailboards are depicted with a fully functional fishway and AWS pipe. Areas without topography will be mobile bed sections. Model testing will occur with and without operation of a sediment flushing channel. Flow is from right to left. Dimensions are in prototype ft.

Test Matrix

Testing will be completed over a range of relevant flow rates and operational conditions for the vertical slot fish passage alternative at a 1:12 model scale. Testing will be conducted with and without operation of the flushing channel. The flushing channel gates will simply be closed during testing without the flushing channel. Variable gate operation for the crest gates will be completed for flow rates less than 6,000 cfs, although details of the gate operation have not yet been determined. Testing will be conducted during steady state flow conditions.

The test runs have been organized into several categories (Table 8). Table 9 shows an example of a test matrix that includes key scenarios. The test matrix will be refined prior to the start of model testing with input from project partners. The modeling team expects the model testing to be an adaptive process with model results and observations informing additional model simulations. Changes to the model test matrix will be shared with project partners throughout the modeling program.

Table 8. Model test scenarios for 1:12-scale physical model of the vertical slot alternative.

Scenario	Description
1. Run flow scenarios that overlap with conditions observed in the 1:24-scale model to ensure that the 1:12-scale physical model is appropriately replicating hydraulic and sediment conditions near project features.	Flow rates of 6,000 cfs and 10,000 cfs will be modeled in both the 1:12 model and the 1:24 model to ensure that sediment, debris and, hydrodynamics are consistent between the two scales.
2. Run scenarios to examine hydrodynamics in and around project features including vertical slot and crest gate hydraulics, entrance and exit conditions, attraction flows, and dynamics between project features during standard operating conditions.	Flow rates of 6,000 cfs, 10,000 cfs and 18,900 cfs will be run to assess hydrodynamics in and around project features.
3. Run scenarios to examine sediment and debris movement and accumulation in and around the vertical slot fish passage features, crest gate, and diversion intake during standard operating conditions.	Accumulation of debris will be analyzed at higher flow ranges including 18,900 cfs, 10,000 cfs, 6,000 cfs, and 1,500 cfs. Various amounts and sizes of debris will be added in accordance with the debris flow plan. Sediment will also be examined in the same flow ranges to assess potential accumulation in and around the fish passage system and the diversion intake.
4. Run scenarios to examine sediment and debris management in and around the vertical slot fish passage features and crest gate including operation of flushing channel during standard operating conditions.	See # 3

Table 9. Example test matrix showing key scenarios for the vertical slot fish passage alternative in the 1:12-scale physical model.

Test #	Scenario #	Flow Exceedance in %*	River Flow (cfs)	Ladder Flow (cfs)	Diversion Flow (cfs)	Canal Fish Bypass Flow (cfs)	Auxiliary Water Flow (cfs)	Auxiliary Water Fish Bypass Flow (cfs)	Crest Gate Flow (cfs)	Flushing Channel Flow (cfs)	Dam Crest Flow (cfs)	River Flow Downstream (cfs)	S - Sediment D - Debris
VS-1	2	31.43%	200	34	40	24	0	102	0	0		160	
VS-2	2	10.30%	800	34	0	24	570	24	148	0		800	
VS-3	2	10.30%	800	34	375	24	343	24	0	0		425	
VS-4	2, 3, 4	10.30%	800	0	0	0	0	0	800	0		800	S
VS-5	3, 4	5.51%	1,500	34	750	24	168	24	500	0		750	S
VS-6	2, 3, 4	5.51%	1,500	34	375	24	168	24	875			1,125	S
VS-7	3, 4	5.51%	1,500	0	0	0	0	0	0	open		1,500	S
VS-8	3, 4	5.51%	1,500	0	0	0	0	0	open	open			S
VS-9	2	2.54%	3,000	34	750	24	570	24	1,598			2,250	
VS-10	2	2.54%	3,000	34	375	24	570	24	1,973			2,625	
VS-11		2.54%	3,000	34	375	24	570	24	1,973			2,625	
VS-12		1.31%	6,000	34	375	24	570	24	4,973			5,625	
VS-13	2, 3, 4	2.54%	3,000	34	750	24	300	24	1,868			2,250	S
VS-14	1, 2, 3, 4	1.31%	6,000	34	750	24	300	24	4,868			5,250	S
VS-15		1.31%	6,000	34	750	24	570	24	4,598			5,250	
VS-16	1	1.31%	6,000	34	0	0	570	24	5,372			6,000	
VS-17	1, 3, 4	1.31%	6,000	34	750	24	570	24	4,598			5,250	S/D
VS-18	1, 2, 3, 4	0.73%	10,000	34		0	570	24	9,372			10,000	S

* Exceedance based on average daily total river flow at the Freeman Diversion during primary migration period from January 1 to May 31.

Data Collection

The following data will be collected during testing:

- Water surface elevation upstream and downstream of the dam (headwater, tailwater), upstream and downstream of vertical slot fishway, inside fishway entrance and exit, and in the canal diversion entrance
- Total flow rate entering the model box, through the auxiliary water system, through the fish bypass, and through the canal diversion
- Point velocities in front of the canal intake structure, upstream and downstream of the vertical slot fishway, and at the fishway entrance at auxiliary water system diffuser
- Surface velocity maps during key flow conditions, as needed
- Observations of hydraulic conditions inside auxiliary water system stilling area and through the auxiliary water system diffuser
- Observations of hydraulic conditions in north fishway entrance and tunnel
- Observations of flow patterns, eddies, or adverse hydraulic conditions downstream of crest gates during operation and the associated impact on approach conditions to the north and south fish entrances. Remedial options to improve attraction flows during crest gate operation will be explored.
- Observations of sediment behavior and operational strategies to limit adverse impacts
- Mapped locations of sediment deposition and erosion with approximate lateral extents and depths
- Observations of debris movement and accumulation and operational strategies to limit adverse impacts

Schedule for Vertical Slot Fish Passage Alternative

When model testing of the hardened ramp is complete, the vertical slot fishway alternative will be constructed inside the 1:24-scale model box, followed by construction in the 1:12-scale model box. As testing on the 1:24-scale model occurs, construction of the 1:12-scale model will begin. The models will be available concurrently.

For both the 1:24- and 1:12-scale models, shakedown of physical model instrumentation, components, and test procedures will occur during the first two weeks after model construction. Clear-water tests will be run to measure hydraulic conditions in the model, followed by sediment testing and debris testing. During the test period, a site visit will be planned for United Water and project partners to view the physical models in person and/or via remote streaming. The model schedule may be revised if unanticipated changes to the model plan and test matrix are required.

Table 10. Estimated physical modeling schedule for vertical slot fish passage alternative.

Physical Model Study Tasks	Start Date	End Date
1:24-Scale Model Design Drawings and Order Materials	4/15/2022	6/15/2022
1:24-Scale Model Review of Model Design Drawings by United Water and Project Partners	6/1/2022	6/8/2022
1:24-Scale Model Construction	6/15/2022	9/15/2022
1:24-Scale Model Shakedown and Testing	9/15/2022	2/15/2023
1:24-Scale Project Partner Site Visit	10/1/2022	2/15/2023
1:12-Scale Model Design Drawings and Order Materials	8/15/2022	10/15/2022
1:12-Scale Model Review of Model Design Drawings by United Water and Project Partners	10/1/2022	10/15/2022
1:12-Scale Model Construction	11/1/2022	2/1/2023
1:12-Scale Model Shakedown and Testing	2/1/2023	6/1/2023
1:12-Scale Project Partners Site Visit	2/15/2023	6/1/2023
Draft Report	6/1/2023	7/1/2023
Submit Revised Draft Report to Project Partners for Comment	7/1/2023	8/1/2023
Finalize Report	8/1/2023	8/15/2023
Submit Final Report to United Water and Project Partners		8/15/2023

Sediment Modeling Approach

1:24-Scale Physical Hydraulic Model

The 1:24-scale model will have a fully mobile bed except in hard topography areas that define the left bank of the channel as shown in Figures 1 and 3. The primary objectives of sediment modeling at this scale will be to simulate deposition and scour within the river channel during moderate to high discharge (up to 100-yr) flow events that may affect the entrance and exit areas of the fish passage features, including important attraction flow zones of the river channel near the fishway entrances. The gradation of bed material used in the model will be scaled with the primary objective of accurately simulating incipient motion of bed material and transport rates at moderate to high discharges.

The prototype bed material size range is very broad, ranging from fine sand to boulders (approximately 0.3 mm up to 700 mm), with the bulk of sediment transport volume involving medium sand. The coarsest material in the gradation is likely to be geometrically scaled, while the sizes of finer material may be adjusted to account for nonlinear effects of viscosity (grain Reynolds number) as depicted on the Shields critical shear stress diagram. The coarsest portion of the bed material gradation will not be mobile even at 100-yr discharges, so exact scaling of these particle sizes will not be crucial. At a 1:24 scale, the model material gradation may not include some of the finest material in the gradation, since that material would act primarily as wash load (passing through the model domain in continuous suspension) at the flow rates of interest. Low-density sediment surrogates (crushed coal or walnut shells) will be used if necessary, but standard quartz-based sediment is likely to work well at this model scale. Adjustment of the model slope will also be considered, if necessary, to achieve proper inception of motion and sediment transport. Details of the sediment modeling will be refined in final model design and informed by the supplemental sediment analysis (Hydroscience & Engineering LLC).

1:12-Scale Physical Hydraulic Model

The 1:12-scale model will have a primarily fixed bed with mobile bed zones near the upstream and downstream ends of the fishways (Figures 2 and 4). The primary objectives of sediment modeling in the 1:12-scale model will be to simulate local deposition and scour around the fishway entrance and exit areas and deposition within the fishways at operational discharges. The gradation of sediment material used in the model will be determined primarily by considering settling velocity of sediment particles, with the objective of achieving settling velocities that are scaled down by the square root of the model length scale ($12^{0.5}$=3.46). This maintains dynamic similarity with water flow and accurately reproduces the distribution of suspended sediment within the water column. Incipient motion of prototype and modeled particles will be compared to ensure that initiation of sediment movement is appropriately simulated.

Although exact representation of the entire gradation is not expected, the bulk of the gradation will be represented. The smallest prototype particles may not be included in the model gradation or may be adjusted to avoid causing cohesive soil behavior in the model that is not representative of the prototype. The largest prototype particles (cobbles and boulders) will not be mobile in the 1:12-scale model.

Sediment used for the model will be selected based on availability from local quarries. Alternate model materials such as coal or ground walnut shells are not expected to be needed for this model, which will simplify construction and operation of the model and enable testing of more flow scenarios. The model is expected to indicate qualitative trends, patterns, and locations of deposition or degradation in the field but not accurately represent actual quantities or rates of accumulation.

For sediment test runs, material will be located in the movable bed sections. Additional sediment will be introduced into the model flow via a conveyor or hopper system at the inlet to the model box, or via a closed loop system of recirculated sediment laden flow depending on material size. Detailed design of the model sediment feeding system will be completed during final model design and shared with project partners.

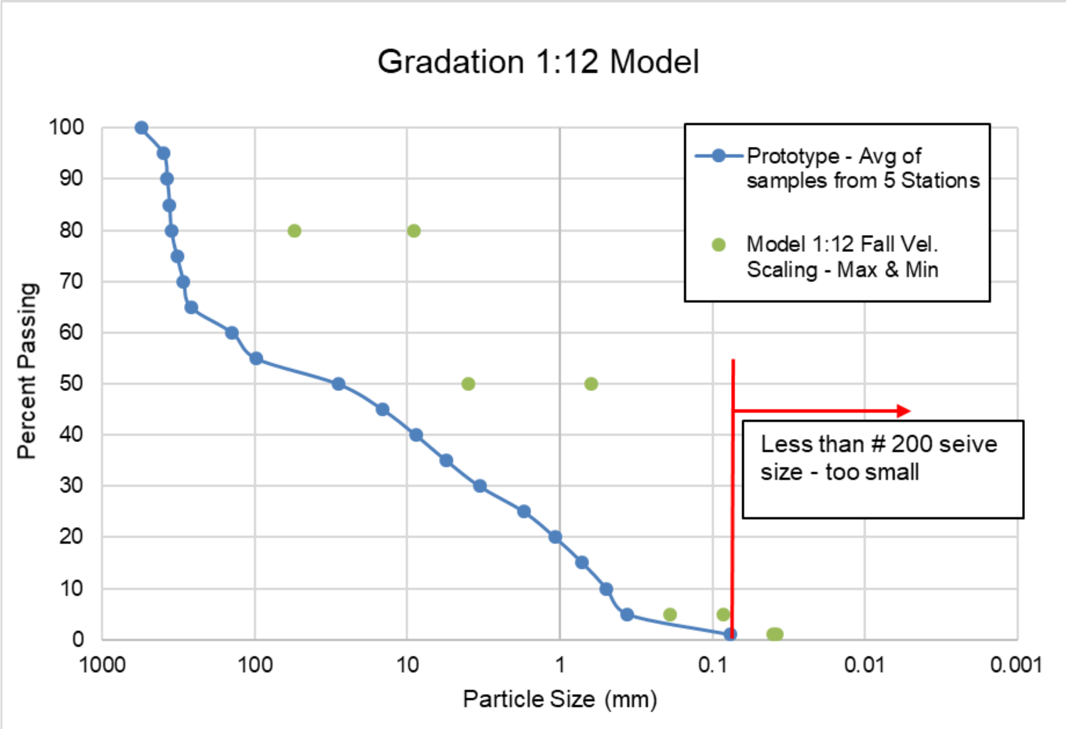


Figure 5. Sediment gradation curves representing the prototype (average of 5 river station samples from AECOM Sediment Transport Analysis-Santa Clara River at Freeman Diversion, 2014) in blue. The green dots represent the range of acceptable sediment sizes at d_{80}, d_{50}, and d_5 that meet fall velocity scaling requirements at the proposed model scale of 1:12.

Debris Modeling Approach

Transport of debris such as clumps of Arundo and smaller floating vegetative debris have been observed at discharges above 800 cfs, while larger floating debris such as tree-sized woody debris occurs at flows above about 6,000 cfs (United Water 2021). In the 1:24-scale model, floating and neutrally buoyant medium to large debris elements mimicking woody debris and clumps of Arundo will be introduced at the upstream end of the model for river flow rates from 6,000 to 226,000 cfs. In the 1:12-scale model, small to medium size debris elements mimicking floating vegetation (watercress and cattails) and clumps of Arundo will be introduced at the upstream end of the model for river flow rates from 1,500 to 6,000 cfs.

Debris will be manually loaded into the model as individual pieces or in integrated mats. Debris type, size, composition, and quantity will be based on river flow rate (United Water 2021). Modeled debris elements may be natural material or artificial material depending on material properties. Debris transport will be observed along with locations of debris accumulation and recruitment. Potential debris management options such as flushing operations and debris booms will be explored to avoid adverse impacts to fish passage operation.

Instrumentation

The following instrumentation is planned for physical measurements during model testing. Final instrument selection will be completed during the model design process. Modifications to measurement methods and/or instrumentation may be required during shakedown testing as determined by the modeling team.

Water Surface Elevations – Water depths will be measured with down-looking ultrasonic meters with an accuracy to within ±0.25%.

Model Flow Rate – Measurements will be acquired using the laboratory flow measurement system (Venturi meters) calibrated to within ±0.5%.

Feature Flow Rates – In-line flowmeters or open channel flow measurement structures will be used for direct flow measurements.

Velocities – Point velocities can be measured using acoustic Doppler velocity meters (ADV) at specific locations. Surface velocities will be measured with particle tracking using large-scale particle image velocimetry (LSPIV) in critical areas.

Gate Position – Crest gate position will be determined using templates or string position sensors to set proper gate openings.

Flow Patterns – Flow patterns and recirculation zones will be observed using dye tracing or surface tracking particles. Results will be documented with photographs and videos.

Sedimentation – Sedimentation patterns and trends will be observed using physical measurements of lateral extents and depths, photographs and videos, and/or photogrammetry or laser scanning.

Overall Observations – All model runs will be documented using photographs and videos.

Limitations

The diversion intake will be included in both the hardened ramp and vertical slot fish passage models, but the fish screens and associated sediment jetting systems will not be modeled in detail. General information about sediment deposition areas may be identified inside the diversion, but detailed information about sediment accumulation and sediment management at the fish screens cannot be determined. For the vertical slot fish passage alternative, the vee-screen for the auxiliary water system is a critical component of the fishway attraction system and excessive sediment accumulation has the potential to impact fishway operation. If the vertical slot fishway is deemed a viable alternative following testing in the 1:24- and 1:12-scale models, a smaller scale physical hydraulic model focused strictly on fish screen performance may be considered. A smaller scale physical model of the fish screening system may also be appropriate for the hardened ramp alternative if this option is deemed viable after 1:24- and 1:12-scale model testing.

Bed load and suspended sediment will be added to the model inflow water during sediment tests. Sediment results will provide qualitative information about erosive and depositional zones and transport patterns within and near modeled features and can provide comparative data between different flow configurations and operational scenarios. Results from sediment tests are not quantitative and cannot be used to predict the depth of sediment erosion or deposition. Due to scaling limitations, armoring and sediment sorting processes are unlikely to be accurately represented in the models.

Predictions of the amount of time required to flush sediment from in front of the canal headworks would require information about exact sediment quantities that deposit in this location. Since the physical model can only provide qualitative information about sediment deposition, relative flushing channel timing can be assessed, but exact sluiceway operational duration will not be determined. Additional documented field observations of the existing flushing conditions, combined with model simulations, should be used to inform future flushing operations.

Impact forces will not be measured in the physical model and damage assessment will not be conducted. Structural assessment requires appropriate representation of materials and material properties at model scale. Evaluation of sediment deposition and areas of debris accumulation can be used as an indicator of potential damage locations.

Both models will include a portion of the channel width. The models will require appropriate boundary conditions for hydraulics, sediment, and debris which will be provided from existing CFD model results and information provided through sediment transport and debris studies. Uncertainty in modeled boundary conditions will affect model accuracy.

Communication Plan

A communication plan has been developed to ensure that the model decision-making process is transparent and pertinent information is shared with project partners throughout the modeling progress.

The physical modeling team consists of Reclamation modeling staff, United Water, and United Water's Senior Advisor, Dr. Larry Weber. The modeling team will be responsible for the day-to-day operation of the models. The modeling team will ensure that the physical modeling efforts address model objectives and modeling activities meet professional engineering standards.

Project partners include NMFS, CDFW, and United Water's design consultants, Northwest Hydraulic Consultants and Stantec. Project partners have been given the opportunity to review and comment on the physical model plan and test matrix. Project partners will be given the opportunity to review model drawings and provide input on boundary conditions and sediment and debris loadings prior to model construction.

A total of four project partner model visits will be conducted with the physical modeling team at Reclamation's Hydraulics Laboratory. Site visits will be conducted in person and/or via remote streaming. NMFS, CDFW, and Northwest Hydraulic Consultants will be invited to observe the 1:24- and 1:12-scale models of the hardened ramp alternative. NMFS, CDFW, and Stantec will be invited to observe the 1:24- and 1:12-scale models of the vertical slot fish passage alternative.

Reclamation will provide a weekly email update to project partners on modeling progress. As preliminary data becomes available at various modeling milestones (e.g. shakedown testing, hydraulic testing, sediment and debris testing) for each modeled alternative, project partners will be provided with data and meetings will be scheduled as needed.

As modeling progresses, modifications may be recommended by the physical modeling team. Modifications may be physical changes to design elements or layouts based on model data and observations. Modifications to the test matrix will likely be made as certain flow or operational scenarios may be less consequential than expected while other operational scenarios appear to be more significant. The modeling team expects the model testing to be an adaptive process with model results and observations informing additional model simulations. United Water will share recommended model modifications with applicable project partners.

Deliverables

Two peer-reviewed model reports will be produced: (1) hardened ramp fish passage alterative and (2) vertical slot fish passage alternative.

Draft modeling reports will undergo internal independent peer-review according to quality control guidance in Reclamation's Technical Service Center Operating Guidelines. Reclamation will submit draft model reports to United Water and United Water's Senior Advisor for initial review and comment. United Water will submit a revised draft model report to project partners for review and comments. Edits and comments will be incorporated, or if not incorporated, a rebuttal will be provided to describe why changes were not made.

The final peer-reviewed model report will be submitted to United Water. All collected data including spreadsheets, text documents, photographs, and videos will be delivered to United Water.

Risk Register for Physical Model Schedule

The risk register shows anticipated risks to project schedule along with potential ways to manage risk.

Table 11. Risk Register for physical modeling projects.

Risk	Risk Description & Potential Impacts	Severity (H, M, L)	Probability (H, M, L)	Risk Mitigation
Building Closure or Staff Illness Due to COVID-19 Pandemic	Temporary laboratory closure or limitation of the number of staff allowed on-site due to COVID-19 restrictions would impact schedule. Significant loss of key staff due to illness would impact schedule.	H	M	There is no way to mitigate a building closure due to mandatory orders. If this situation arises, communication with the client will occur immediately and updates will be provided on a time frame for re-opening, as available. There will be redundancy in qualified staff where possible to limit staff-related impacts due to illness.
Late Changes to Model Test Plan	Model schedule assumes that model planning can begin on February 15, 2021. Late changes to the model scale, extents, major features, and test plan by regulatory agencies could impact model drawings or ordered materials.	H	L	Clear communication is required to ensure that project partners agree on major features of the model study. If unanticipated late changes to the test plan occur, a Change Order to adjust schedule will be required.

Material Availability	Availability of model materials and sediment depends on current stock and delivery times which have been considerably longer due to COVID-19 impacts.	M	L	Materials will be ordered in February after the final test plan is submitted to regulatory agencies to provide substantial time for delivery.

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