Nature Like Fishways: Modern Perspectives and Techniques Sessions 5 & Project Spotlight

A Workshop at the 41st Annual Salmonid Restoration Conference
Santa Rosa, California, March 26-29, 2024

Workshop Coordinators:

- Tyler Kreider, PE, *Kleinschmidt*
- Mike Garello, PE, *HDR, Inc.*
- Mike Love, PE, *Michael Love & Associates*

This instructor-led workshop, organized by the American Fisheries Society–Bioengineering Section, with funding from the Resources Legacy Fund, to presents a two-day-nature-like fishway workshop. This in-person workshop took place over two days and was instructed by several leading practitioners in the field of Nature Like Fishways (NLF) implementation, including representatives from both private and public agencies. The list of speakers includes Michael Garello (HDR), Michael Love (MLA), Jesus Morales (U.S. Fish and Wildlife Service), Tyler Kreider (Kleinschmidt), Bjorn Lake (NOAA Fisheries), Barry Chilibeck (Northwest Hydraulic Consultants), Brian Cluer (NOAA Fisheries), and Marcin Whitman (retired California Department of Fish & Wildlife). The goal of the workshop was to share knowledge of nature-like fishway design and long-term stability observations among practitioners, regulators, and operators to improve the collective awareness of contemporary NLF science and design methodologies to ultimately provide more effective and sustainable passage for fish. This workshop included the following topics:

- History and state of nature-like fishways
- Application of NLFs to natural and built environments
- Site reconnaissance, project assessment, project development
- Identifying data and modeling needs and necessary in-field data collection
- Example design methods, practices, constraints, and uncertainties—also highlight current/ forthcoming design guidance documents
- Construction methods and oversight
- Monitoring
- Lessons learned from previously constructed NLFs
- Risk evaluation in NLF Design
- Getting the right rocks and placing them for long-term stability

Presentations

Session 5

Contracting and Implementation

AGENDA

01 Contracting methods & construction documentation

02 Construction methods, considerations, & challenges

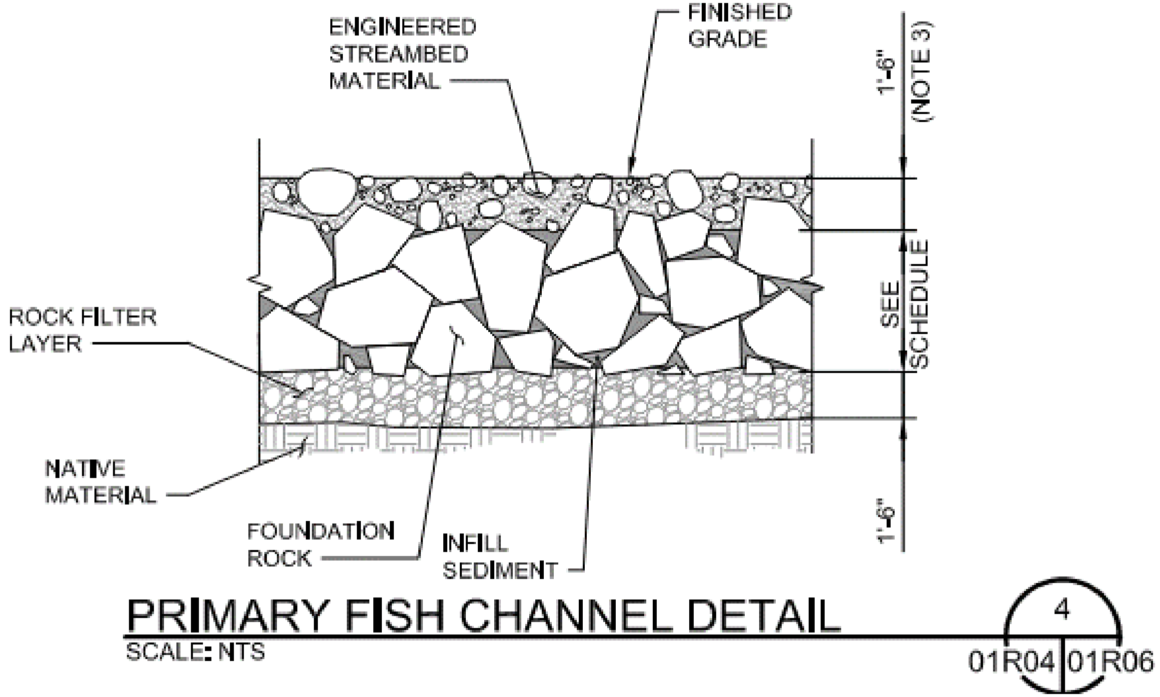
03 Project Spotlights

04 *Break*

05 Project spotlights

06 Closing Statements

01



Contracting methods and construction documentation

- Overview of NLF Project Delivery Methods
- Use of contract documents as a communication tool for NLF construction
- Contract execution

Overview of NLF Project Delivery Methods

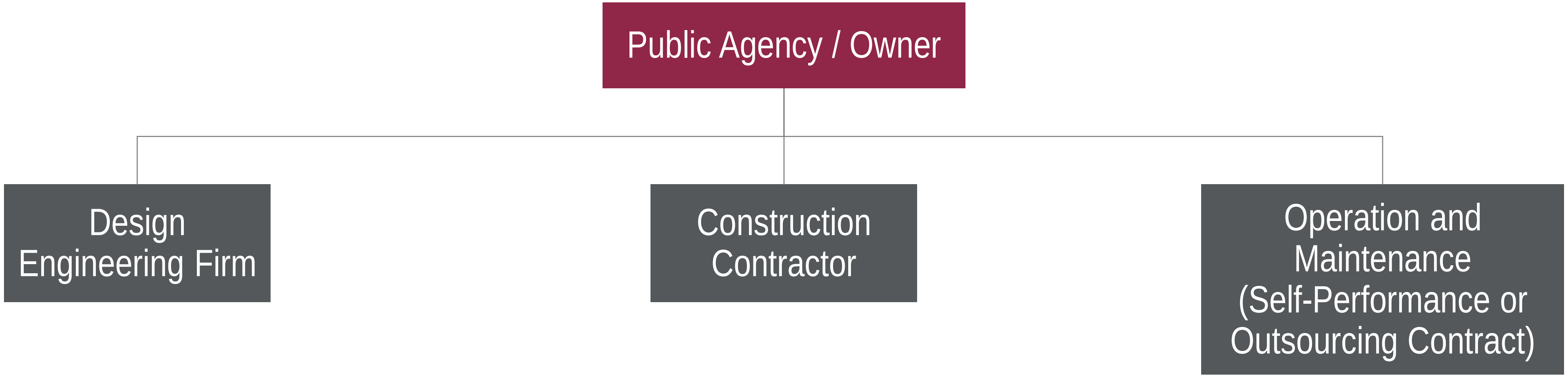
NLF Project Delivery Methods Overview

- Design Bid Build
- Construction Manager at Risk
- Design Build
- Progressive Design Build
- Design Build Operate
- Design Build Finance and Operate

NLF Project Delivery Methods Overview

Design Bid Build

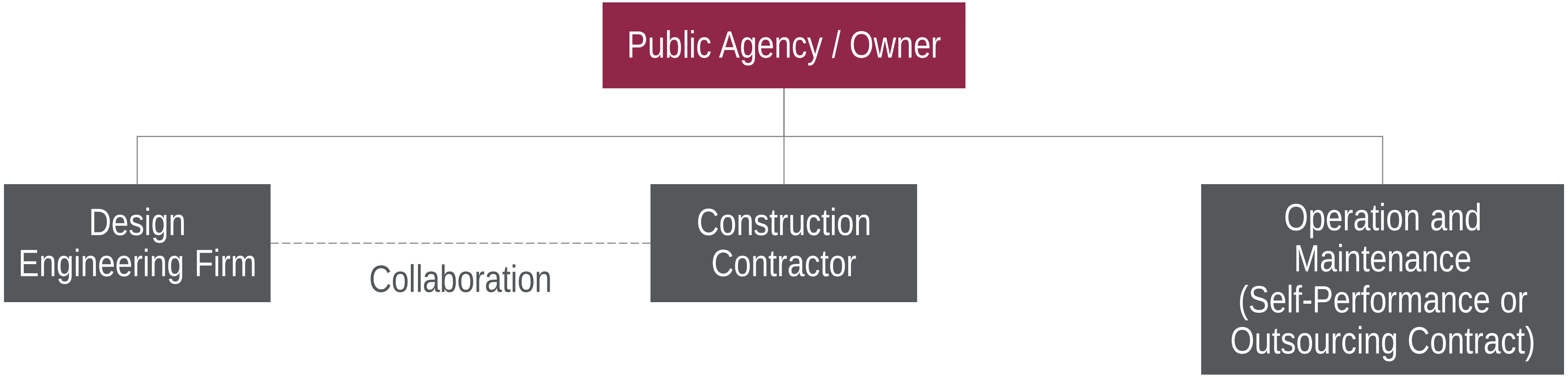
design team and a general contractor working directly for the owner under separate contracts



NLF Project Delivery Methods Overview

Construction Manager at Risk

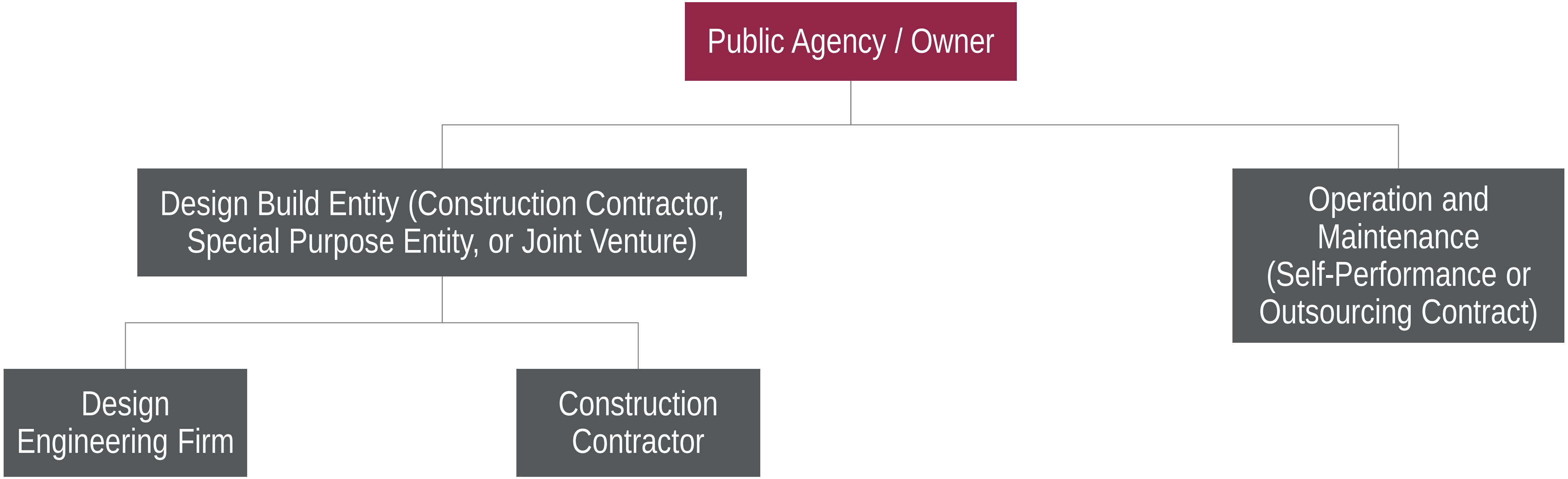
The construction manager acts as a representative for the owner during the design and construction phases, and the CM takes on project risk (usually with a contract that has a guaranteed maximum price).



NLF Project Delivery Methods Overview

Design Build

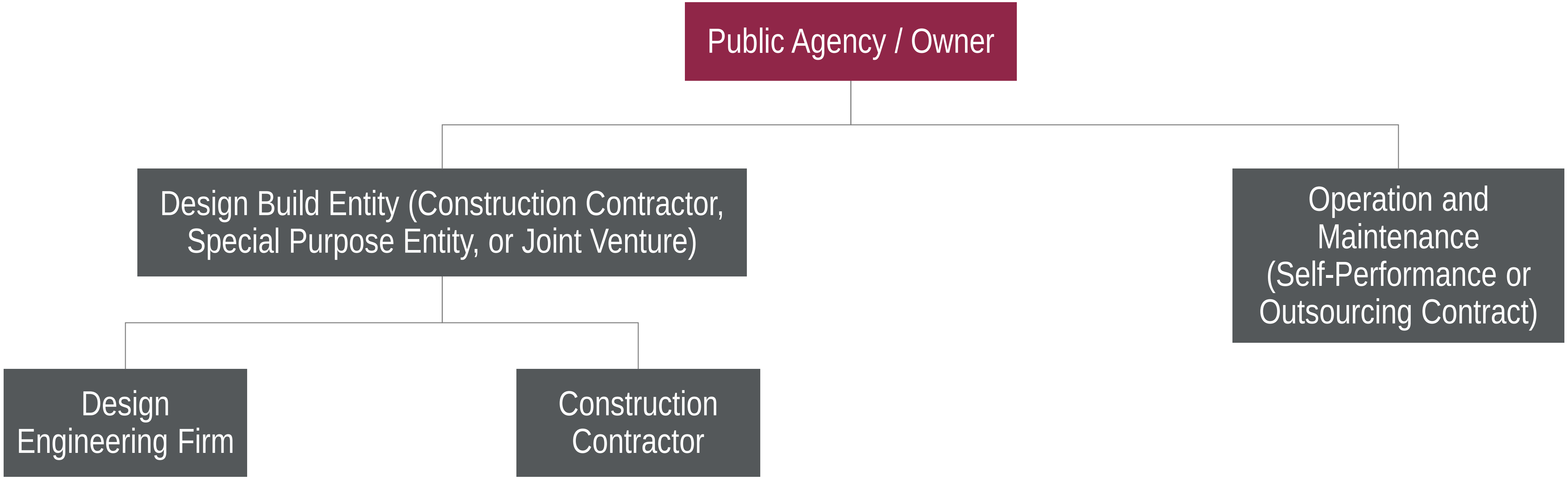
In design-build construction, an owner enters into a single contract to cover both the architectural design services and the physical construction of the build, streamlining the collaboration, communication, and coordination process.



NLF Project Delivery Methods Overview

Progressive Design Build

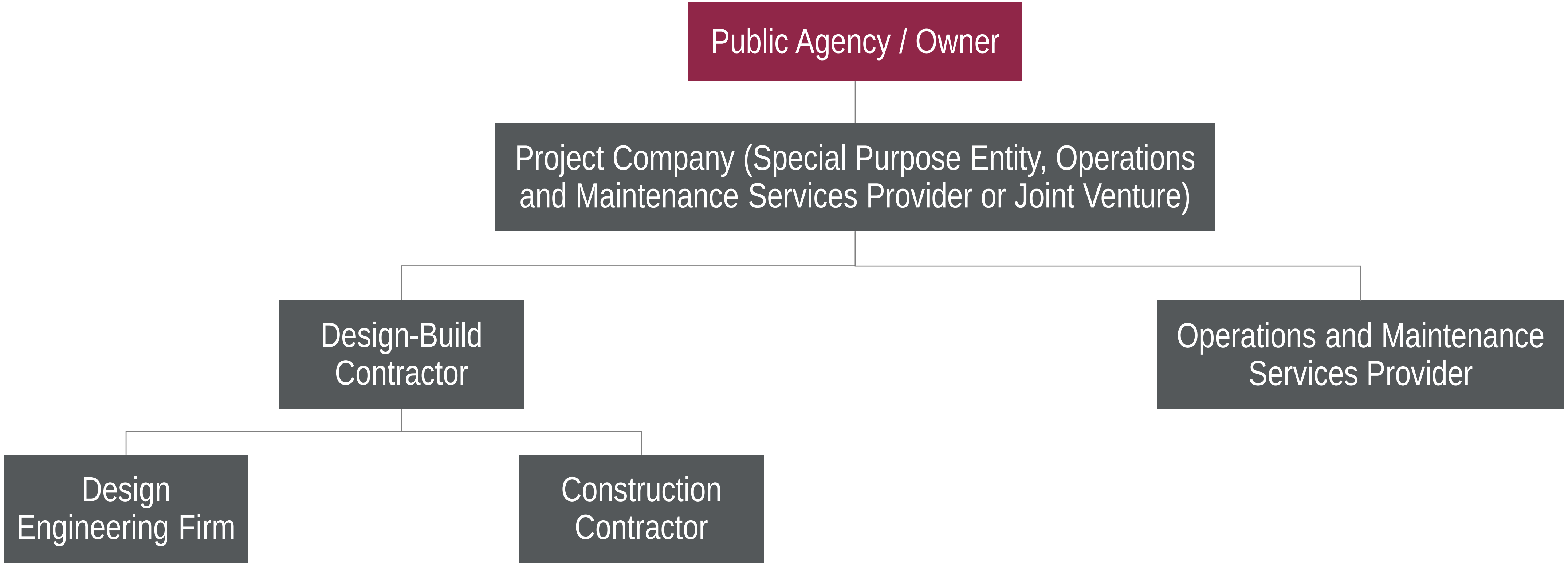
Offramp at 60% level of project definition. If the owner and contractor cannot agree on the design or budget for construction services, the owner can decide to use the "off ramp" built into the PDB agreement.



NLF Project Delivery Methods Overview

Design Build and Operate

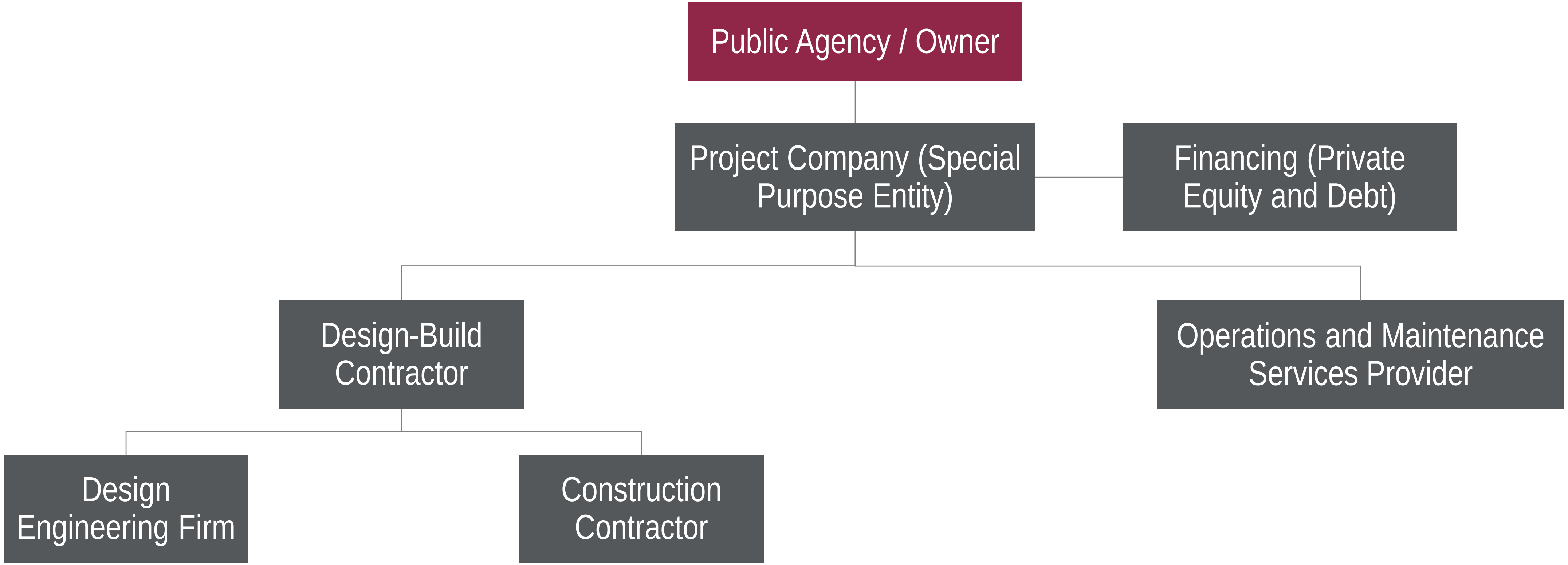
In design-build operate construction, an owner enters a single contract to cover both the engineering design services, the physical construction of the project, and operation of the constructed project. Operation is paid for a specific duration and then renewed via additional operation contracts by owner and operator.



NLF Project Delivery Methods Overview

Design Build Finance and Operate, Public Private Partnership (PPP)

A private company and government entity collaborate on a project, typically funded by the government entity and managed by the private company.



Construction Delivery Methods Overview

- Two Most Common Delivery Methods for NLF Projects

Design Bid Build

Construction Manager at Risk

Design Build

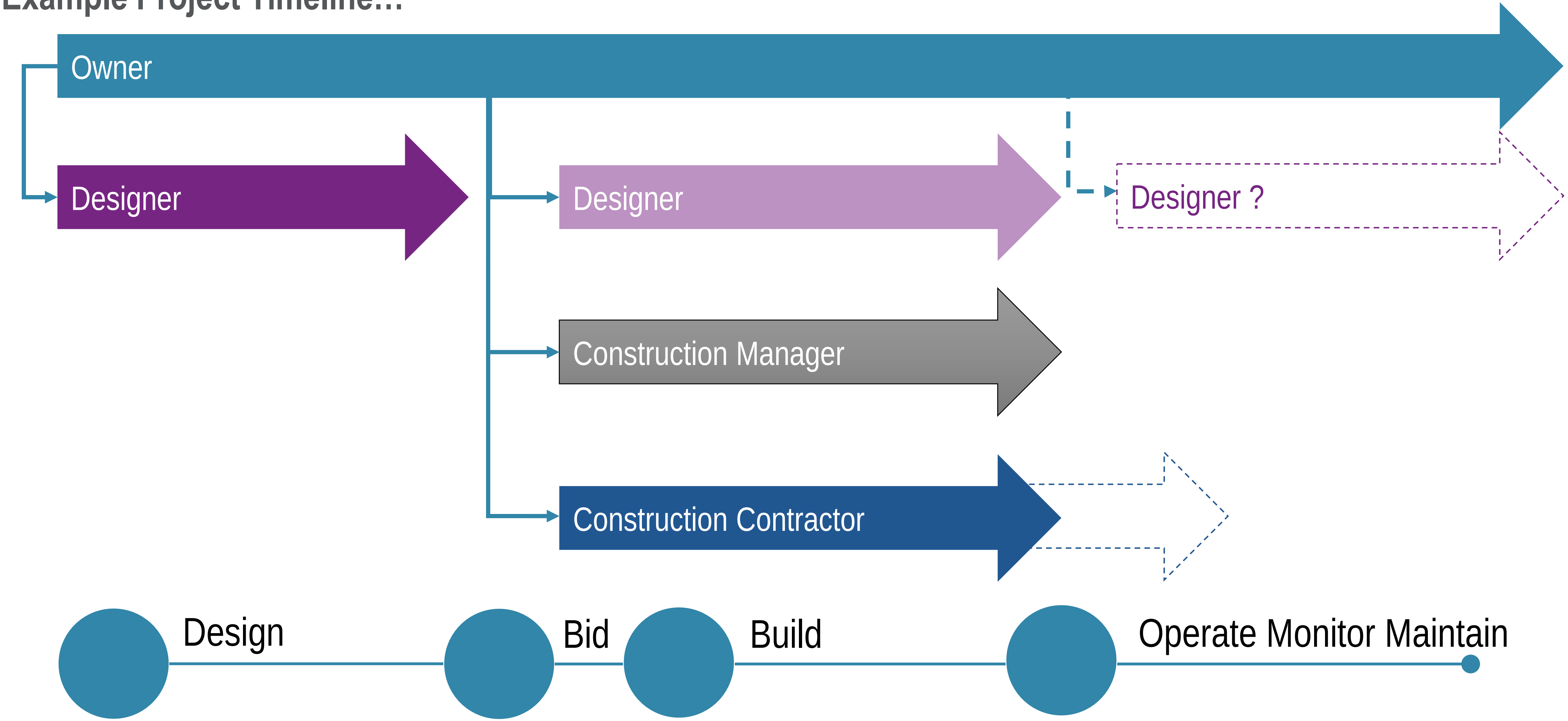
Progressive Design Build

Design Build Operate

Design Build Finance and Operate

Design Bid Build

Example Project Timeline…



Design Bid Build

Advantages

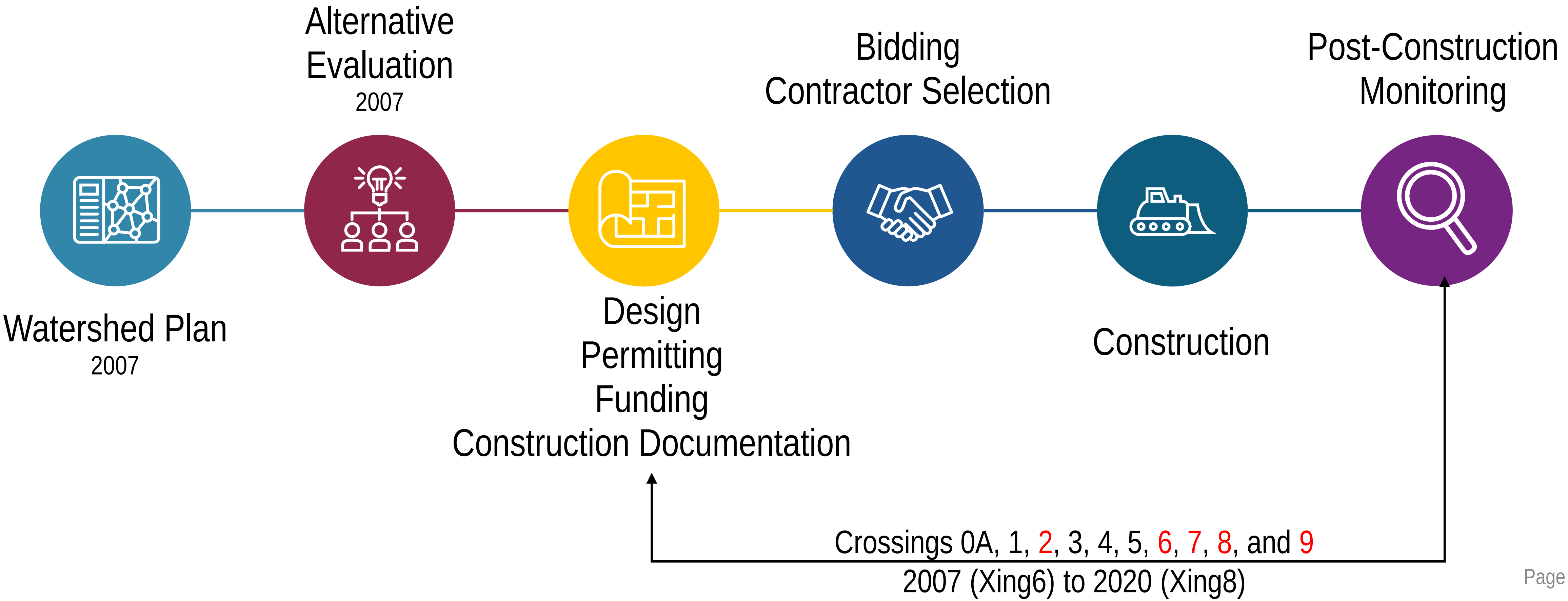
- Widely used method for public agency projects
- Agencies typically have developed standard contracts and procedures based on experiences from many projects
- Owners are comfortable with the DBB approach
- Owner maintains a high level of control during the design phase
- Typically, a large pool of contractors
- Owner and contractor familiar with the process
- Ability to attract competition

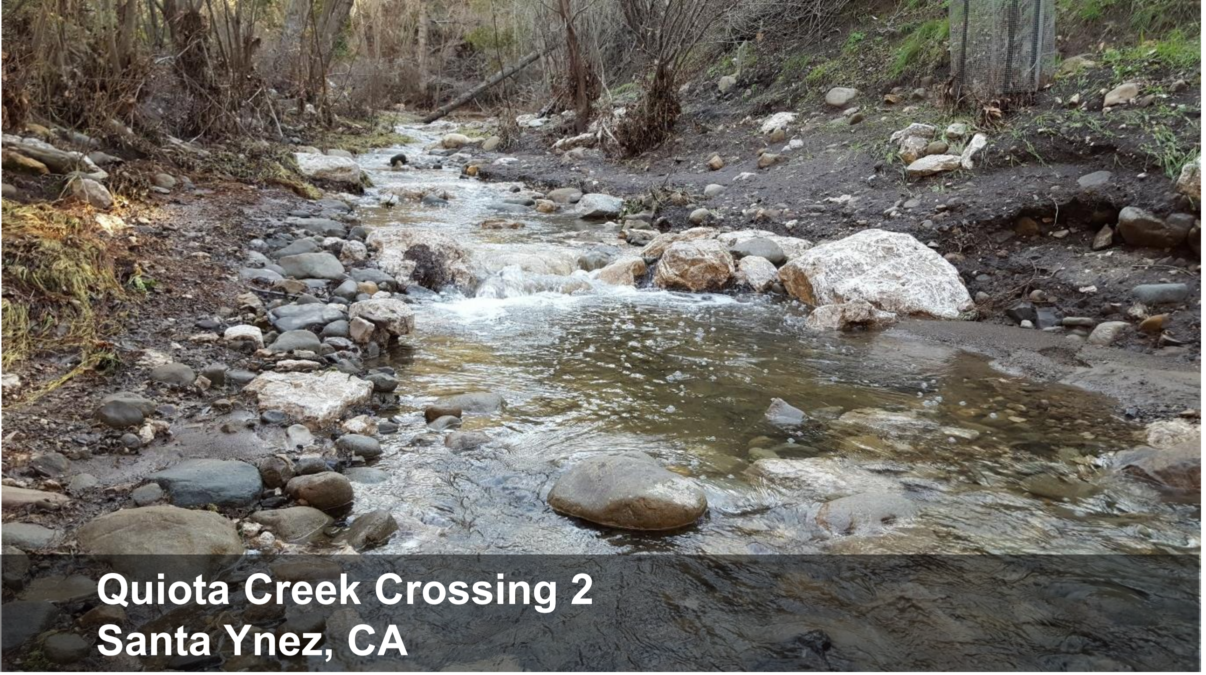
Disadvantages

- Requires the longest time for design and construction
- No design competition
- Little collaboration between designers, builders and operators
- Lack of emphasis on life cycle costs
- Firm construction costs are not known until bidding process is complete
- Prone to change orders
- Low bid contractor selection increases risk of performance problems
- Owner retains the risk for design errors and project performance

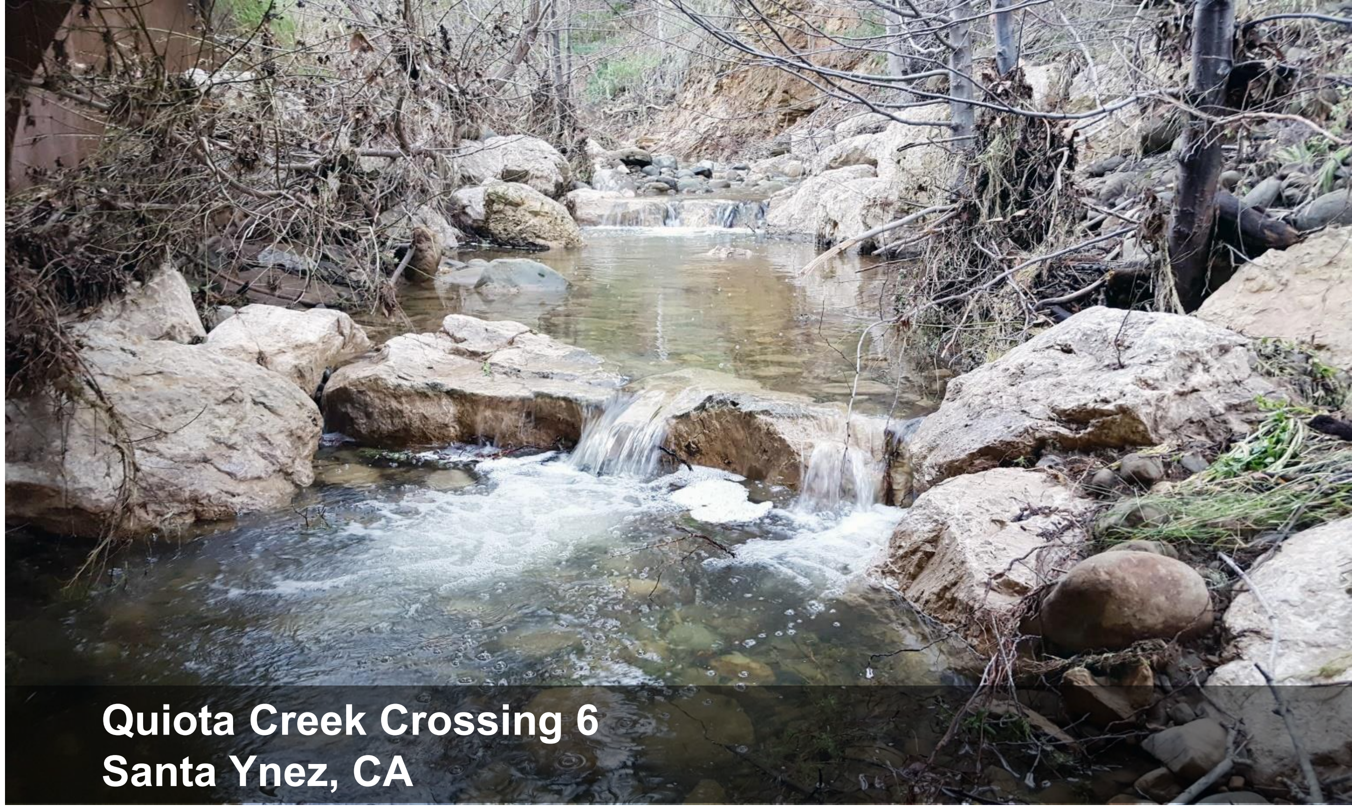
Design Bid Build

Example Project – Quiota Creek Watershed Fish Passage Restoration Program
Cachuma Operation and Maintenance Board, *Quiota Creek, Santa Ynez, CA*

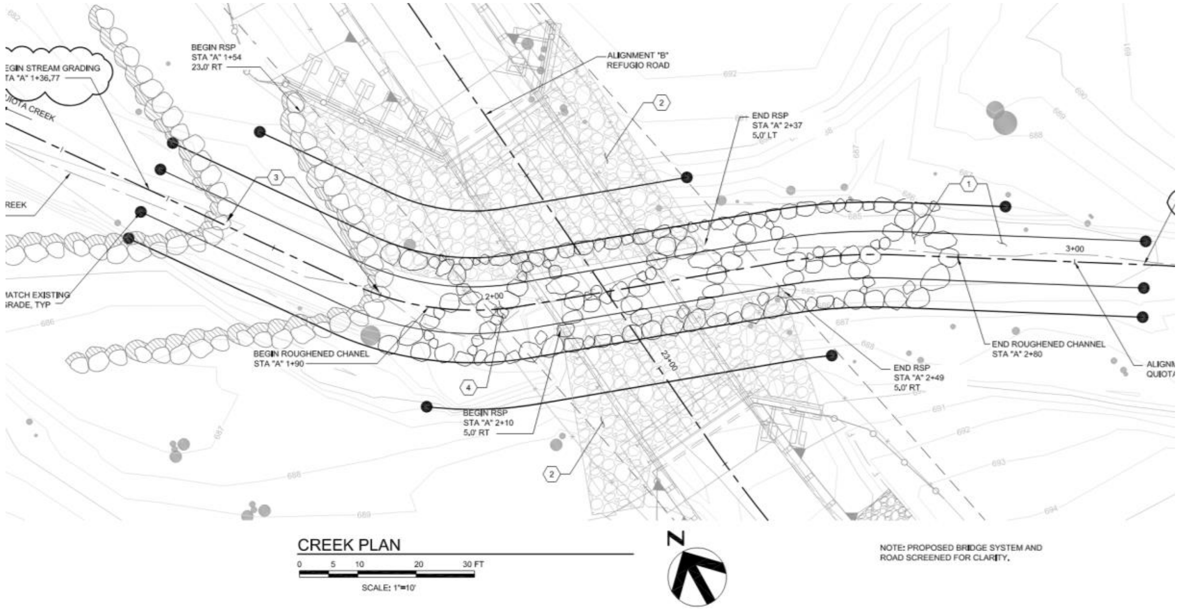




Quiota Creek Crossing 2
Santa Ynez, CA



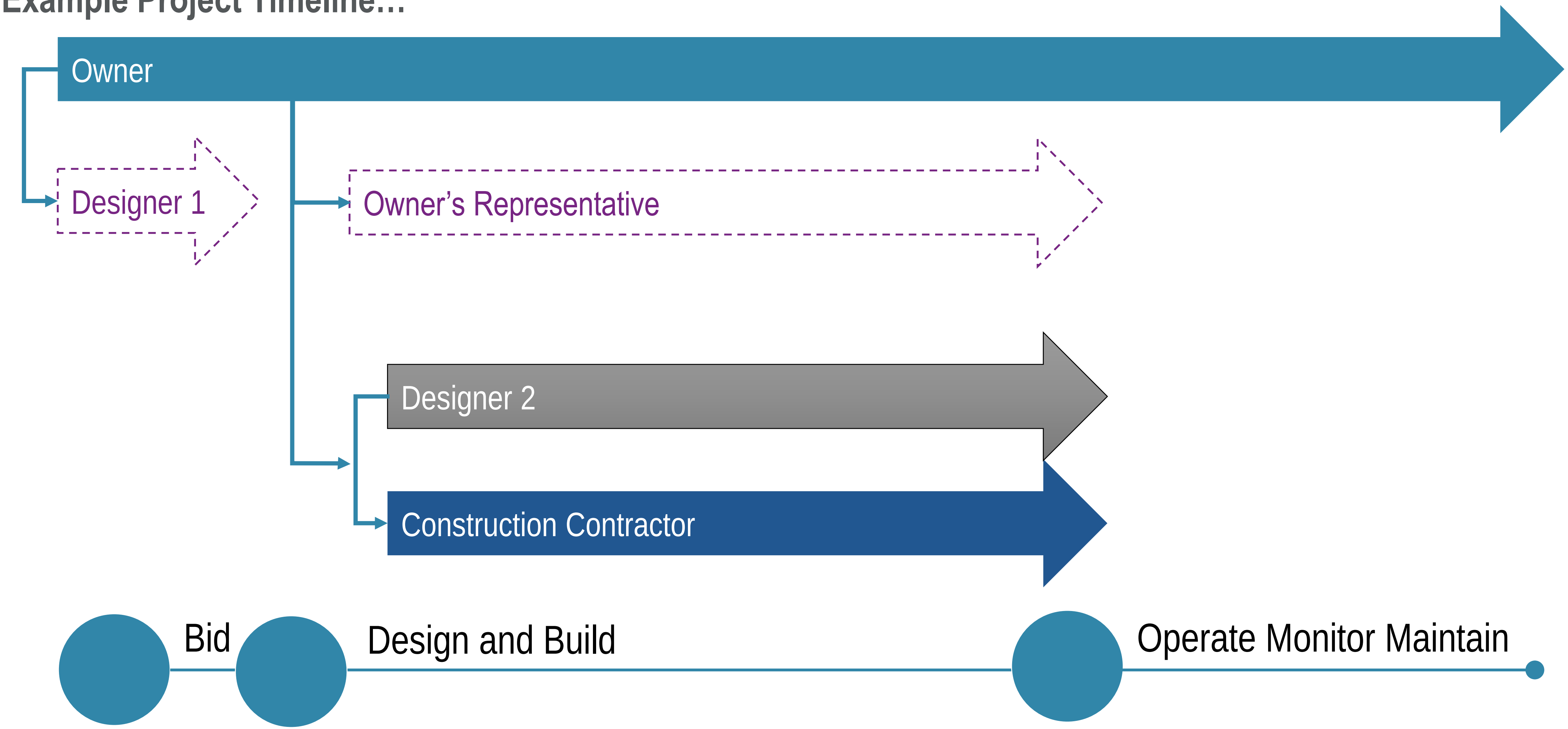
Quiota Creek Crossing 6
Santa Ynez, CA



Quiota Creek Crossing 4
Santa Ynez, CA

Design Build

Example Project Timeline…



Design Build

Example Project – Manastash Creek Restoration Program
Kittitas County Conservation District and Bonneville Power Administration
Manastash Creek, WA

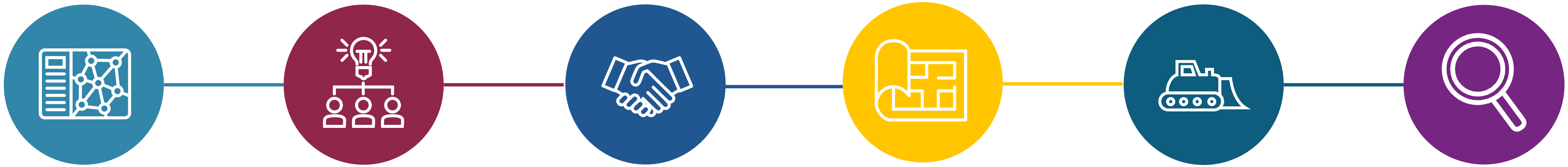
Watershed Plan
2006

Preliminary Design
2007

Contractor Selection
Funding
3 Projects
2009

Design
Permitting
Construction Documentation
Construction

Post-Construction
Monitoring



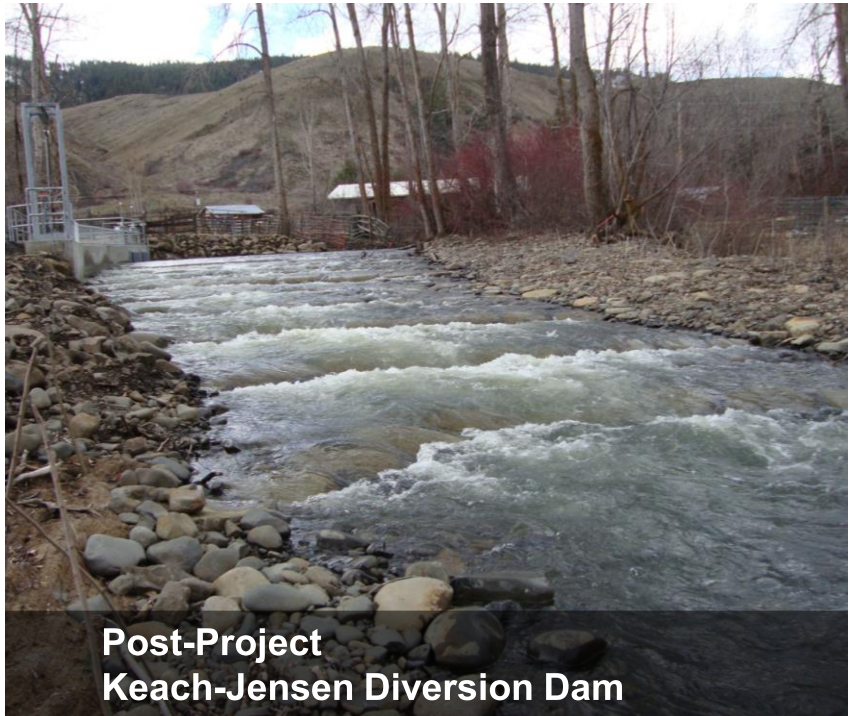
Manastash Diversion NLF (2010)
Keach-Jenson NLF (2011)
Barnes Road NLF (2012)

Pre-Project
Manastash Diversion Dam

Pre-Project
Keach-Jensen Diversion Dam

Pre-Project
Barnes Road Diversion

Post-Project
Manastash Diversion Dam

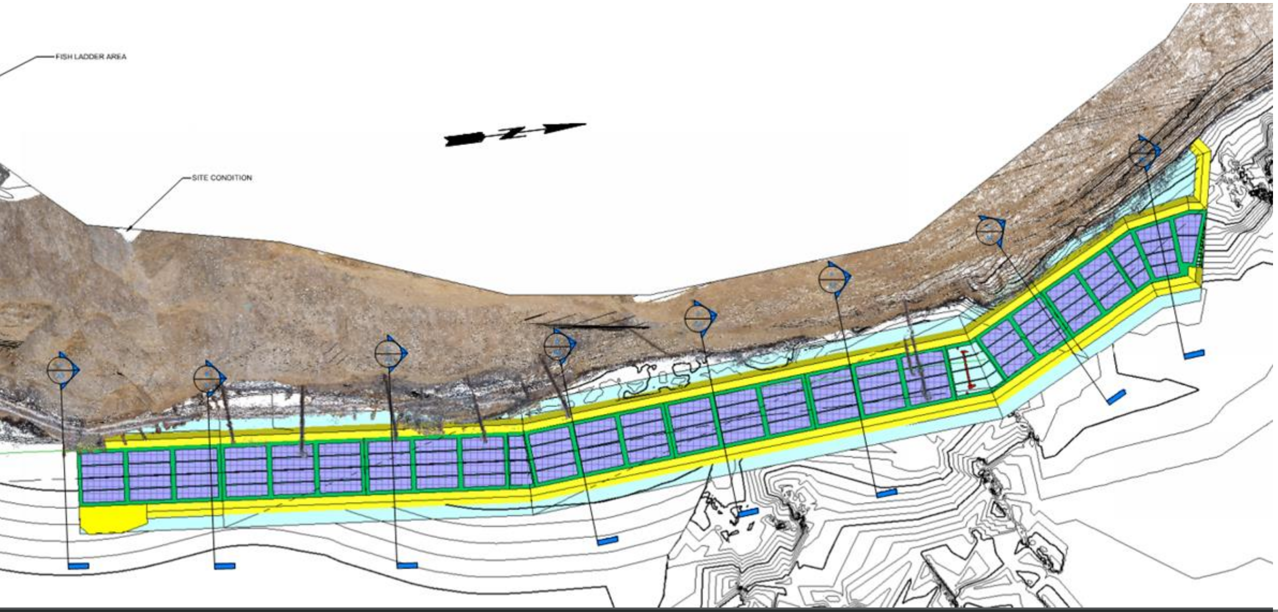


Post-Project
Keach-Jensen Diversion Dam

Post-Project
Barnes Road Diversion

Pre-Project
Big Bar, Fraser River, Lillooet, BC

Pre-Project
Big Bar, Fraser River, Lillooet, BC



Reference Design – Permanent Double Vertical Slot Fishway
Big Bar, Fraser River, Lillooet, BC

Temporary Emergency Passage
Big Bar, Fraser River, Lillooet, BC

Design Build

Advantages

- Builder and designer are selected on qualifications and overall best value
- Can use prequalification to narrow field of proposers to best qualified.
- Builder’s and designer’s interests are aligned. Limits contract changes.
- Transfer of design, construction and performance risk to the design-builder
- Single contract for design and construction shields the owner from disputes between designer and builder
- Shortens project schedule and potentially reduces overall project cost and cost risk.

Disadvantages

- Owners have less familiarity
- Best value proposal evaluation can be complex to prepare and select. Longer, more involved procurement phase
- Owner gives up more control of details. Limited opportunity for the owner and DB contractor to collaborate once price is set
- Design drawings are less detailed than in DBB
- Regulatory agencies may not have a procedure in place to review partially complete designs
- Limited focus on life cycle costs. Owner retains the operating risk.

Construction Delivery Methods Overview

Which delivery methods is right for your project…

- Speed of Delivery – Amount of schedule reduction, inflation
- Risk Allocation – Manage risks, dispute avoidance, transfer of risks
- Owner Control of Design – Which design vision is most critical
- Cost Certainty – Early cost certainty, manage change
- Procurement Considerations – market and political viability, selection system simplicity
- Relative Costs – Is there a potential for substantial savings
- Performance Certainty – Allow for innovation

Construction Documentation

Construction Documentation

Overview

- A contractual framework between the Owner and the Builder or Design-Builder composed of multiple parts
- Provides scope of work, payment terms, work timelines, constraints, requirements, guidelines, stipulations, and change management protocol the Owner and the Builder or Design-Builder agree to adhere to.
- Is a communication tool between owner, designer, and builder throughout a construction project
- Not all construction contracts and documentation are assembled the same way
    - Terms and conditions, standards, and overall content vary by Owner and unique project composition
    - Level of detail and complexity can be scaled dependent upon the contract type and situation.

Construction Documentation

Summary of Basic Construction Contract Elements

Instructions to Bidders
Bid documentation requirements
Qualifications
Communication during bidding
Basis of selection

Scope of Work
Bid Item Descriptions
Specifications
Plans and drawings
Permitting requirements

Project Cost and Payment Terms
Lump sum / Schedule of Values
Unit Cost

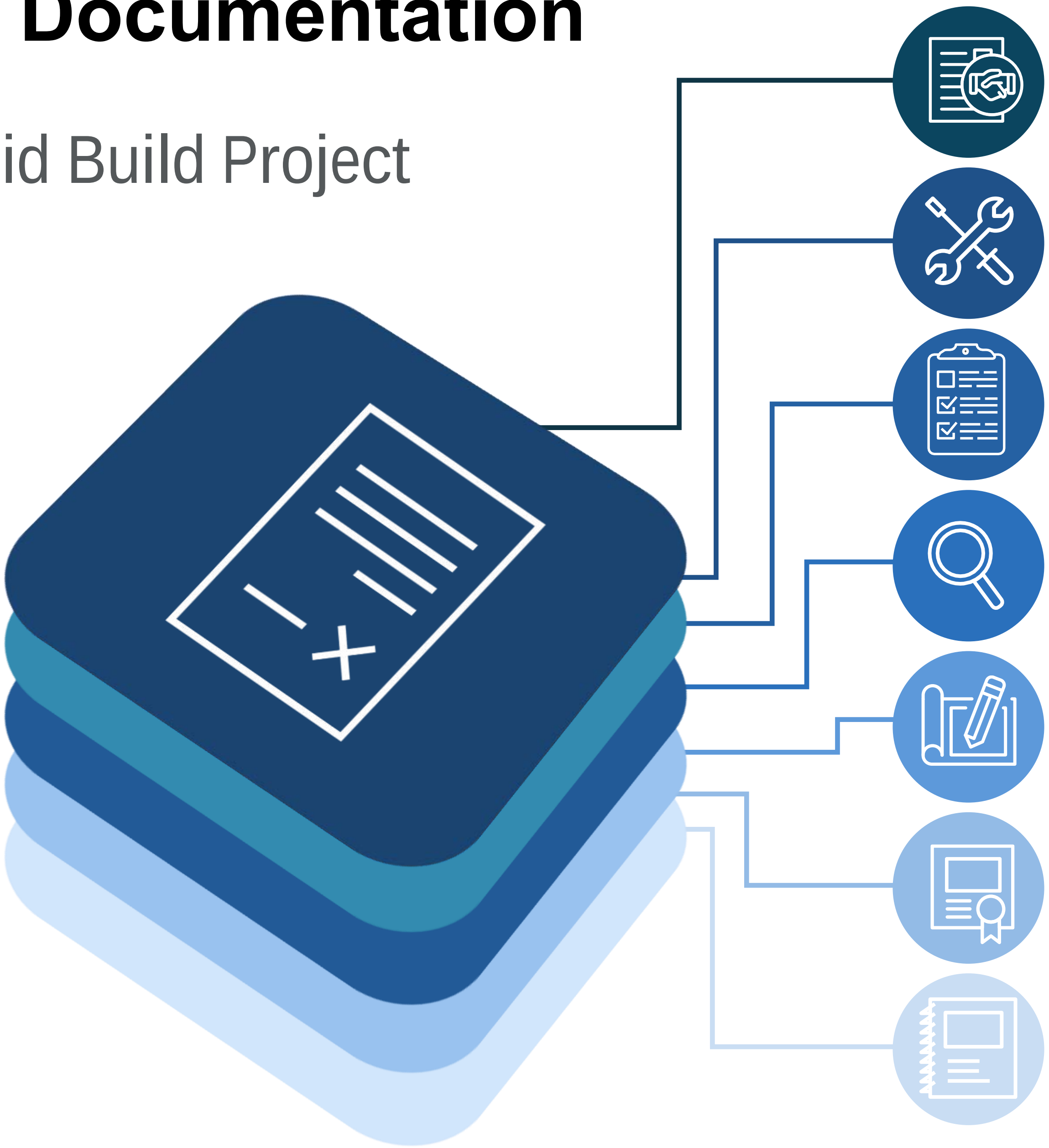
Schedule of Work
Time constraints
Substantial completion
Final completion
Warranty periods

Authority
Matrix of authority
Communication protocols
Change or decision protocols
Site and worker safety

Reference Information
Geotechnical or design reports
Property or easement delineation
As-built documentation
Etc.

Construction Documentation

Example Design Bid Build Project



- Bid proposal and instructions
- Contracting Requirements and Agreement
- General Requirements
- Technical Specifications and Special Provisions
- Design Plans
- Project Permits and Associated Stipulations
- Other Supplementation Information

Construction Documentation

Scenario 1 - DBB with Low Bidder Selection Requirement

- Requires a higher level of detail with higher level of effort spent on developing linkages between plans, notes, specifications, and contract authority
- Minimum responsive requirements for contractor qualifications and experience must be clearly written into bidding requirements
- Additional clarity required on **material standards, acceptance of materials**, and requirements during **execution of work** – emphasis on notes and specifications within overall contract
- Assume that construction may be executed with or without original engineer of record
- Risk Mitigation strategies include:
  - Execute a prequalification process if possible so that only experienced contractors provide bid proposals
  - Negotiate and plan for a higher level of effort during design to accommodate level of detail
  - Communicate clear recommendations to owner to involve design engineer and or qualified and experienced inspectors during construction
  - Prepare for more cost and schedule overruns – elevate contingency funds – standard of care is ~10%

Construction Documentation

Scenario 2 - DBB with Best Value Selection Process

- Contractor qualifications and experience can be evaluated with their price proposal during selection
- Selected contractor may not be the least costly, but may result in the best, most cost-effective project overall
- **Material standards, acceptance of materials**, and requirements during **execution of work** are likely better recognized and understood by the selected contractor
- There is a higher probability that a highly qualified contractor will execute more effective means and methods – less schedule and cost risk
- Risk Mitigation strategies include:
  - Execute a prequalification process if possible so that only experienced contractors provide bid proposals
  - Communicate clear recommendations to owner to involve design engineer and or qualified and experienced inspectors during construction
  - As budget allows, provide a similar level of detail and level of effort spent on developing linkages between plans, notes, specifications, and contract authority.
  - Invite the contractor to provide value proposals during the bidding process

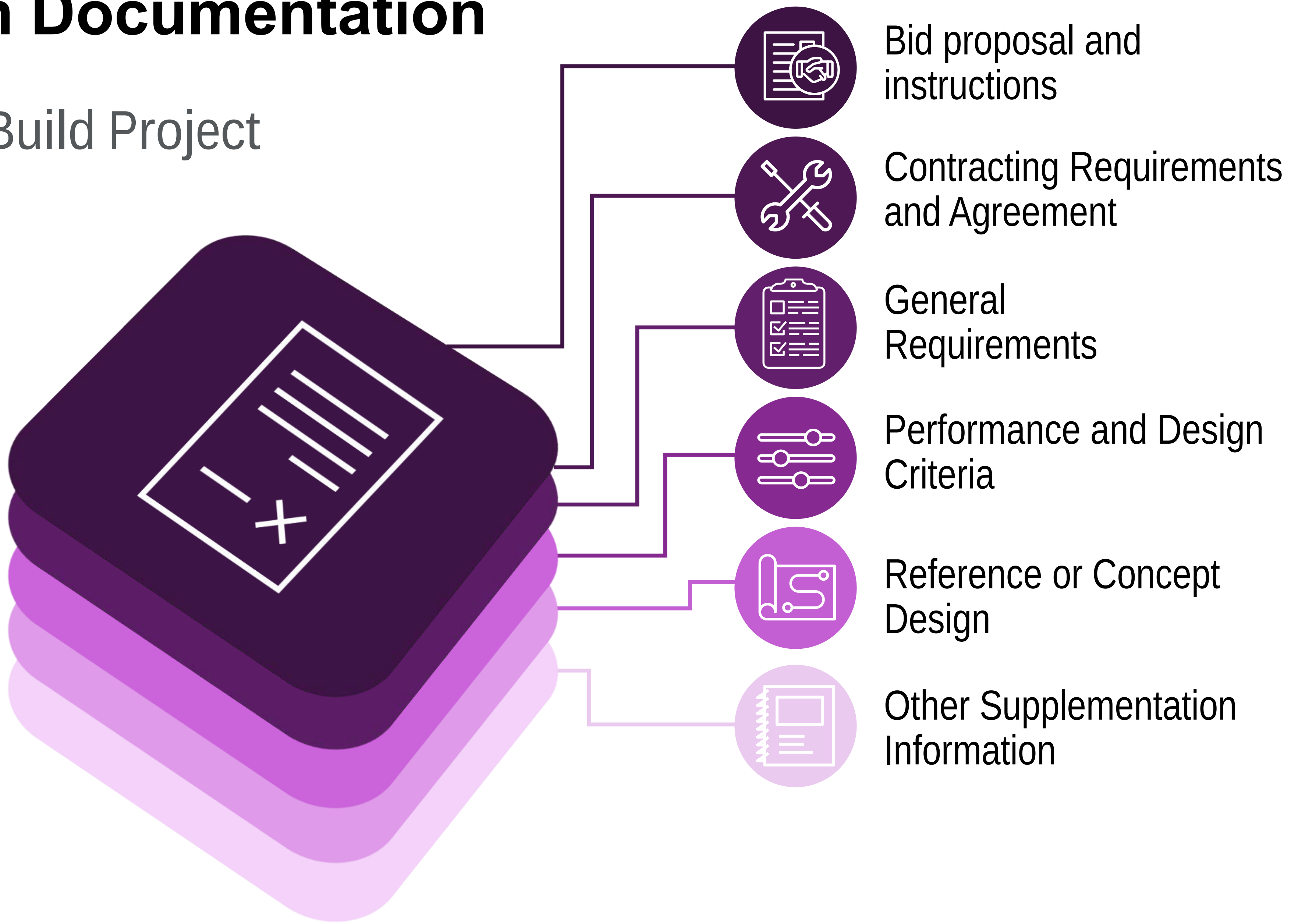
Construction Documentation

Scenario 3 - DBB with Engineer of Record as CM

- Involving a highly experienced contractor coupled with the experienced engineer of record provides the greatest likelihood of success.
- **Material standards, acceptance of materials**, and requirements during **execution of work** are likely better recognized, understood, and implemented by the selected contractor. The design intent can be clearly communicated by the design engineer.
- In this case, the level of effort can focus on the scope of work, timeline constraints, and material requirements needed by the contractor to accomplish the work. Execution of work can be communicated by the engineer.
- Decisions are more effectively navigated using the processes provided by the contract authority
- Risk Mitigation strategies include:
  - Execute a prequalification process if possible so that only experienced contractors provide bid proposals
  - Provide adequate time and budget for the engineer of record to participate throughout construction execution
  - Invite the contractor to provide value proposals during the bidding process

Construction Documentation

Example Design Build Project



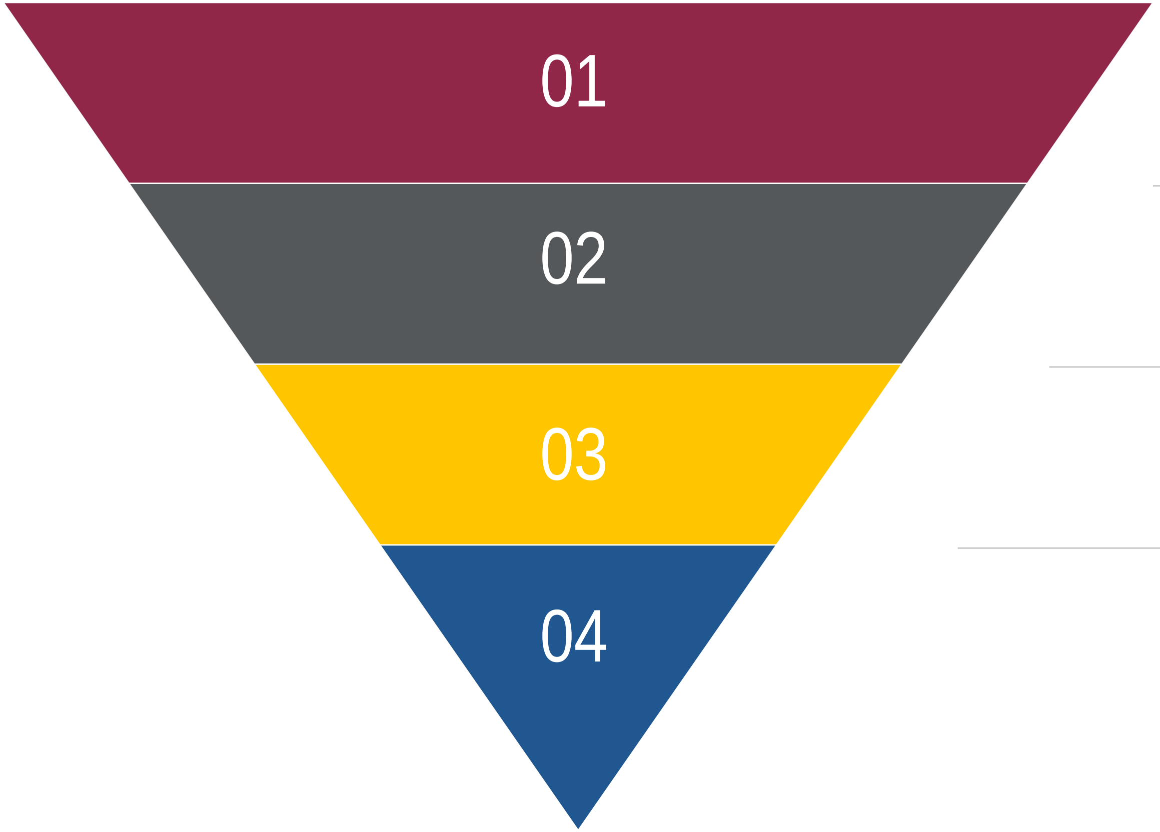
Construction Documentation

Scenario 1 - DB with Engineer of Record as Owner Representative

- Contractor qualifications and experience can be evaluated with their price proposal during selection
- Selected contractor may not be the least costly, but may result in the best, most cost-effective project overall
- There is a higher probability that a highly qualified contractor will execute more effective means and methods – less schedule and cost risk
- **Material standards, acceptance of materials**, and requirements during **execution of work** are the responsibility of the design builder after a design has been accepted. They assume the risk.
- Risk Mitigation strategies include:
  - Execute a prequalification process if possible so that only experienced design-builder teams provide bid proposals
  - Provide a clear set of expectations, scope of work, timeline constraints, environmental standards, and any guidelines to be followed by the design-builder. Execution of work is the responsibility of the design-build team.
  - Provide clear expectations regarding the extent and duration of communications and any review and acceptance practices to be followed.

Construction Documentation

Contract Authority – Resolution of Conflicts or Discrepancies



Contract Terms and Conditions

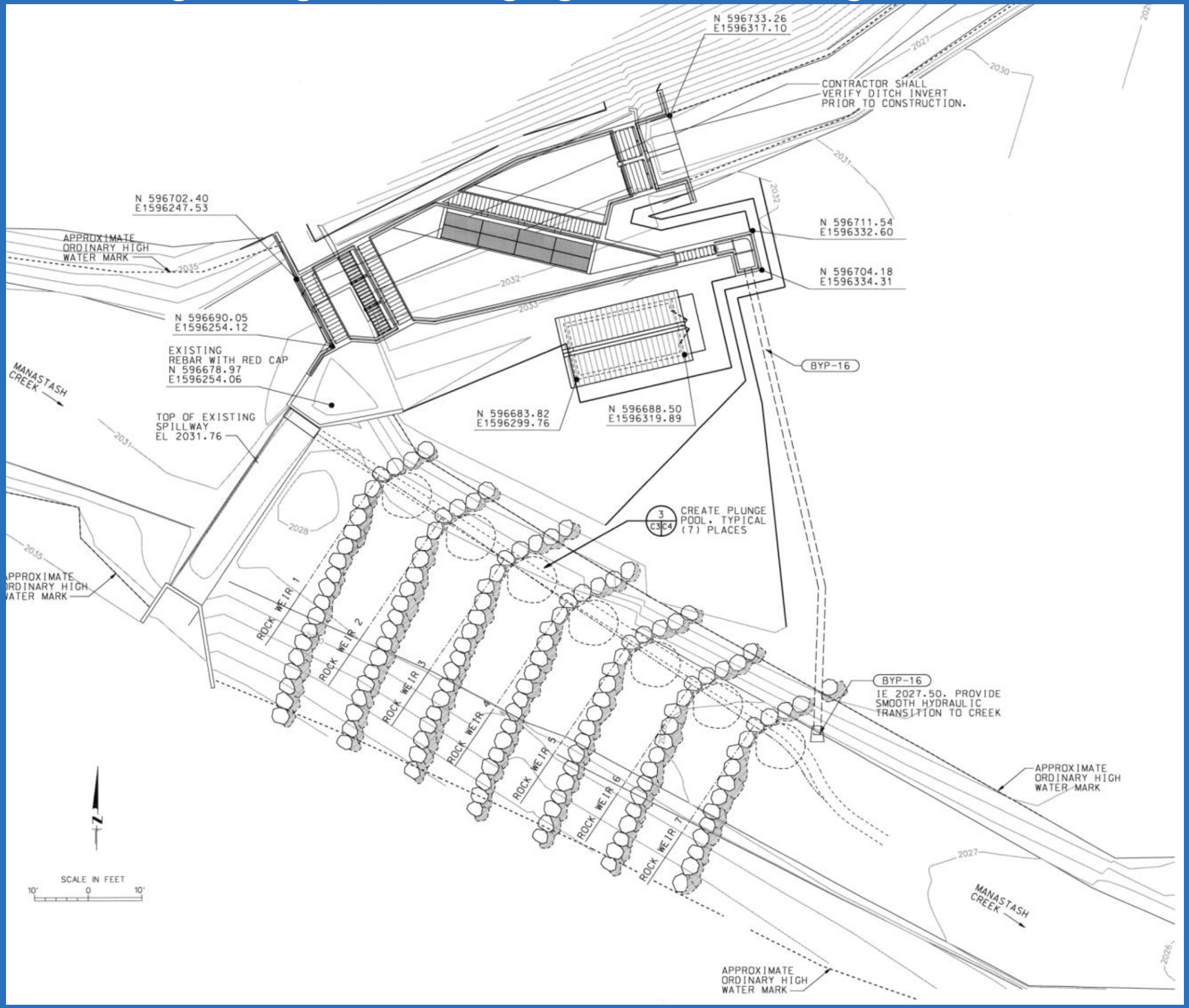
Supplemental Conditions to the Contract

Technical Specifications, Special Provisions

Plans, Drawings, and Details

Construction Documentation

- Example drawings and specifications
- Lower level of detail
- High engineer engagement during construction



SPECIFICATIONS

GENERAL SPECIFICATIONS

A. THE CONTRACTOR IS DEFINED HEREIN AS THE ENTITY RESPONSIBLE FOR ON SITE INSTALLATION OF ALL ITEMS SPECIFIED AND SHOWN IN THE CONTRACT DOCUMENTS.

B. UNLESS OTHER ARRANGEMENTS ARE MADE THE CONTRACTOR SHALL LIMIT THEIR ACTIVITIES TO THE STAGING AND ACCESS AREAS INDICATED ON THE DRAWINGS.

C. THE CONTRACTOR IS RESPONSIBLE FOR IMPLEMENTING WHATEVER MEASURES ARE NECESSARY FOR THE PROTECTION OF ALL EXISTING FACILITIES, INCLUDING THOSE ASSOCIATED WITH TEMPORARY ACCESS OR STAGING ON ADJOINING PROPERTIES, DURING THE COURSE OF THE CONSTRUCTION. ANY REPAIRS, REPLACEMENTS OR RESTORATION MEASURES MADE NECESSARY BY THE CONTRACTOR'S ACTIVITIES WILL BE MADE AT THE CONTRACTOR'S EXPENSE.

D. THE CONTRACTOR SHALL VERIFY ALL ON SITE MEASUREMENTS OF EXISTING STRUCTURES PRIOR TO SUBMISSION OF SHOP DRAWINGS OR COMMENCING WITH ANY STRUCTURAL FABRICATION. CONTRACTOR TO NOTIFY ENGINEER IMMEDIATELY OF ANY DISCREPANCIES FOUND THAT MAY AFFECT THE INTENDED WORK.

E. THE SAFETY OF ALL ON SITE WORKERS SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR. USE EXTREME CAUTION AT ALL TIMES WHILE WORKING UNDER, IN AND AROUND THE WATER. CONFORM TO ALL LAWS AND CODES GOVERNING UNDERWATER WORK.

F. ALL ITEMS ON THE PLANS INDICATED AS NIC (NOT IN CONTRACT) SHALL BE INSTALLED BY THE WASHINGTON DEPARTMENT OF FISH AND WILDLIFE'S YAKIMA SCREEN SHOP (YSS). THE CONTRACTOR IS RESPONSIBLE FOR COORDINATION WITH YSS ON ALL COMPONETS IDENTIFIED TO ASSURE THAT THE SCHEDULING, DELIVERY AND INSTALLATION IS ACCOMPLISHED WITHOUT DELAY AND THAT DIMENSIONAL REQUIREMENTS FOR THE NIC INSTALLATION COMPONETS ARE MET FOR THE REQUIRED FIT TO THE INFRASTRUCTURE IDENTIFIED ON THESE PLANS AND SPECIFICATIONS. CLOSE COORDINATION IS NECCESARY THROUGH OUT THE PROJECT SO THAT PRECISE FINAL DIMENSIONS OF THE RECEIVING PORTIONS OF THE STRUCTURE TO ACCOMODATE THE NIC COMPONETS INDICATED. IT IS THE CONTRACTOR'S RESPONSIBILITY TO CONSTRUCT AND COORDINATE ACCORDINGLY. THE CONTACT FOR YSS IS CHUCK LINDBURG, TELEPHONE (509)575-2733, EMAIL LENBECPI@DFW.WA.GOV

CIVIL SPECIFICATIONS

A. EXISTING CONTOUR INFORMATION ARE BASED ON SURVEYS CONDUCTED IN 2004-2005 BY HUIBREGTSE, LOUMAN ASSOCIATES, INC, 801 NORTH 39th AVE, YAKIMA, WASHINGTON 98902 PHONE:509-965-3800

B. THE CONTRACTOR IS RESPONSIBLE FOR FURNISHING, INSTALLING AND MAINTAINING ALL NECESSARY MEASURES TO CONTROL EROSION IN ACCORDANCE WITH APPLICABLE STATE AND FEDERAL REGULATIONS.

C. CLEARING AND GRUBBING SHALL NOT EXCEED LIMITS OF CONSTRUCTION SHOWN ON THE DRAWINGS. THE CONTRACTOR IS RESPONSIBLE FOR DISPOSAL OF CLEARING DEBRIS. DEBRIS SHALL BE DISPOSED TO A STATE APPROVED OFF-SITE FACILITY OR AT THE DIRECTION OF THE OWNER.

D. THE CONTRACTOR IS RESPONSIBLE FOR THE REMOVAL AND DISPOSAL OF THE EXISTING DIVERSION STRUCTURE EXCLUDING SILL WITHOUT DISTURBING ADJOINING PROPERTY. DEBRIS FROM DIVERSION STRUCTURE DEMOLITION SHALL BE DISPOSED TO A STATE APPROVED OFF-SITE FACILITY AT THE EXPENSE OF THE CONTRACTOR. MATERIALS TO BE SALVAGED MAY BE TEMPORARILY STOCKPILED IN A LOCATION ACCEPTABLE TO THE OWNER. HOLES AND PITS CREATED BY REMOVING EXISTING STRUCTURE SHALL BE BACKFILLED AND COMPACTED WITH STRUCTURAL BACKFILL MATERIAL, IN ACCORDANCE WITH PARAGRAPH G AND H.

E. THE CONTRACTOR IS RESPONSIBLE FOR MAINTAINING A SAFE WORKING AREA. ALL DISCHARGE FROM DEWATERING EFFORTS SHALL BE ROUTED TO THE IRRIGATION CANAL AND SHALL MEET ALL STATE AND FEDERAL REGULATIONS. SHORING, WHERE NECESSARY, SHALL BE PERFORMED IN ACCORDANCE WITH THE FOLLOWING:

1) IT IS THE CONTRACTOR'S RESPONSIBILITY TO DESIGN, INSTALL, AND MAINTAIN FUNCTIONALLY EFFECTIVE AND STRUCTURALLY SOUND SHORINGS. THE FAILURE OF THE SHORING EITHER IN FUNCTION OR STRUCTURALLY FOR ANY REASON, SUBSURFACE CONDITIONS INCLUSIVE, AND THE CONSEQUENCES OF SUCH A FAILURE AND LIABILITY FOR SUCH A FAILURE, SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR. IN THE EVENT THE SHORING HAS FAILED OR IS NOT FUNCTIONAL AS DESIGNED, THE CONTRACTOR SHALL REPAIR OR REBUILD THE SHORING AT NO ADDITIONAL COST TO THE OWNER.

2) SHORINGS OR OTHER PROTECTIVE WORKS SHALL BE CONSTRUCTED, MAINTAINED, AND REMOVED USING MATERIALS AND METHODS WHICH DO NOT PRODUCE SILTATION OR OTHER DEGRADATION OF THE WATER QUALITY OF THE RIVER OR STREAM WHICH EXCEEDS THE LIMITS OF APPLICABLE FEDERAL, STATE AND LOCAL REGULATIONS.

3) THE PROPOSED PLAN FOR SHORINGS AND PROTECTIVE WORKS WHICH SHALL ADDRESS, AS A MINIMUM, THE FOLLOWING ITEMS:

a) TYPE OF SHORING OR OTHER PROTECTIVE WORKS TO BE USED.

b) SEQUENCE OF CONSTRUCTION FOR SHORING OR OTHER PROTECTIVE WORKS RELATED WORK ITEMS.

c) PROVISION FOR LIMITING SILTATION OR OTHER EFFECTS ON THE RIVERS AND STREAMS.

d) PROVISIONS FOR REMOVAL OF TEMPORARY SHORINGS OR PROTECTIVE WORKS AND REPLACEMENT OR GRADING OF THE FOUNDATION AREAS FOLLOWING REMOVAL.

e) PROVISIONS FOR EXCAVATING AND DEWATERING INSIDES OF THE SHORINGS OR PROTECTIVE WORKS.

f) ALL CALCULATIONS REQUIRED SUBSTANTIATING THE DESIGN OF THE SHORING AND PROTECTIVE WORKS.

4) THE SUBMITTAL SHALL BE PREPARED AND SIGNED BY A PROFESSIONAL ENGINEER REGISTERED IN THE STATE OF WASHINGTON AND EXPERIENCED WITH SHORING DESIGN.

F. THE CONTRACTOR SHALL PERFORM ALL EXCAVATION AND BACKFILL WORK TO THE LINES, DIMENSIONS AND ELEVATIONS INDICATED ON THE DRAWINGS. THE CONTRACTOR SHALL THOROUGHLY FAMILIARIZE THEMSELVES WITH THE EXISTING SOIL CONDITIONS AT THE SITE BY PERSONAL EXAMINATION OF THE SITE. THE STOCKPILE LOCATION IS SHOWN ON THE DRAWINGS, AND IS LOCATED SO AS NOT TO INTERFERE WITH OTHER WORK OR DISTURB ADJOINING PROPERTY OWNERS.

G. STRUCTURAL FILL, PIPE BEDDING FILL, AND COMMON BACKFILL SHALL MEET ALL REQUIREMENTS SPECIFIED HEREIN.

1) STRUCTURAL FILL SHALL BE A FREE-DRAINING MINERAL SOIL, FREE FROM ORGANIC MATTER, FROZEN OR LUMPY MATERIALS, VEGETATION, ROOTS, DEBRIS AND ANY OTHER DELETERIOUS MATTER. STRUCTURAL FILL SHALL MEET THE FOLLOWING REQUIREMENTS WHEN TESTED IN ACCORDANCE WITH ASTM C136.

SIEVE	% PASSING (DESIGNATION BY WEIGHT)
2 INCH	100
1/2 INCH	80-100
NO. 4	30-80
NO. 200	0-5

2) PIPE BEDDING MATERIAL FOR PIPE SHALL BE CLEAN SAND/GRAVEL MIXTURE FREE FROM ORGANIC MATTER AND CONFORMING TO THE FOLLOWING GRADATION WHEN TESTED IN ACCORDANCE WITH ASTM D 422:

SIEVE	% PASSING (DESIGNATION BY WEIGHT)
3/4 INCH	100
3/8 INCH	70 - 100
NO. 4	55 - 100
NO. 10	35 - 95
NO. 40	20 - 80
NO. 100	1 - 10
NO. 200	0 - 3

3) COMMON BACKFILL MATERIAL SHALL CONSIST OF ON-SITE UNCLASSIFIED EXCAVATION MATERIAL FREE FROM ORGANICS, WOOD, BROKEN CONCRETE, FROZEN CHUNKS OR DEBRIS OF ANY KIND AND STONES/ROCKS OVER 4 INCHES IN DIAMETER.

4) COBBLE FILL SHALL CONSIST OF ROUNDED RIVER ROCK WITH A MINIMUM SPECIFIC WEIGHT (PCF) OF 2.6 AND THE FOLLOWING GRADATION:

PERCENT LIGHTER BY WEIGHT	STONE WEIGHT, LBS MIN.	MAX.
W100	35	86
W50	17	26
W15	5	13

5) GRADE CONTROL ROCK AND RIVER BANK MATERIAL SHALL CONSIST OF ROCK WITH A MINIMUM SPECIFIC WEIGHT (PCF) OF 2.6 AND THE FOLLOWING GRADATION:

PERCENT LIGHTER BY WEIGHT	STONE WEIGHT, LBS MIN.	MAX.
W100	3700	1500
W50	2300	950
W15	1700	720

- BACKFILL UPSTREAM FACE OF ROCK WEIR WITH NATIVE MATERIAL AT APPROXIMATELY 10H:1V SLOPE TO TOP OF WEIR.
- WASH FINES INTO ROCK WEIR FACE UNTIL SPACES ARE PLUGGED
- GRADE TO FINISHED ELEVATIONS INDICATED
- NO STONE SHALL HAVE AN a/c RATIO GREATER THAN 3.5

6) ROCK SLOPE PROTECTION MATERIAL SHALL CONSIST OF ROCK WITH A MINIMUM SPECIFIC WEIGHT (PCF) OF 2.6 AND THE FOLLOWING GRADATION:

PERCENT LIGHTER BY WEIGHT	STONE WEIGHT, LBS MIN.	MAX.
W100	675	1688
W50	388	500
W15	105	250

H. COMPACTION SHALL BE ACCOMPLISHED BY APPROVED EQUIPMENT. THE MAXIMUM COMPACTION LIFTS SHALL NOT EXCEED 8 INCHES EACH LAYER SHALL BE AT LEAST 95 PERCENT OF LABORATORY MAXIMUM DENSITY. A MINIMUM OF ONE SOIL CLASSIFICATION AND ONE MOISTURE-DENSITY RELATION TEST SHALL BE PERFORMED ON MATERIAL USED FOR BEDDING, STRUCTURAL BACKFILL AND COMMON BACKFILL. FIELD COMPACTION TESTING SHALL BE DETERMINED IN ACCORDANCE WITH ASTM 2922 AT +/- 2% OPTION MOISTURE CONTENT, IN ACCORDANCE WITH ASTM D3017.

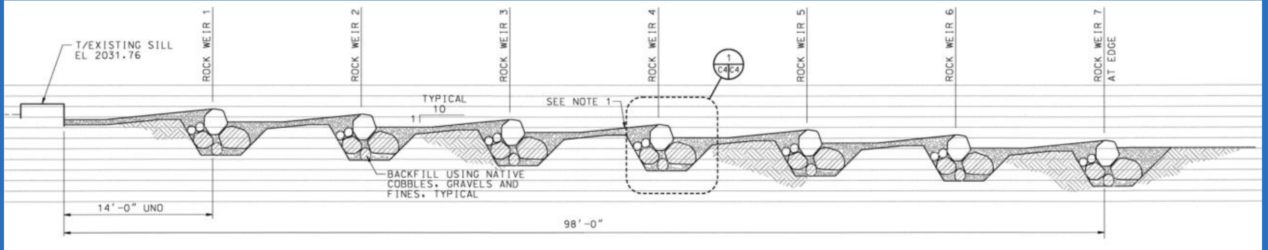
1) AT A MINIMUM, FOUR FIELD COMPACTION TESTS SHALL BE TAKEN AT THE DIVERSION STRUCTURE.

2) COPIES OF THE TEST RESULTS SHALL BE SUBMITTED TO THE OWNER. ANY LAYER OR PORTION OF A LAYER WHICH HAS NOT ATTAINED THE REQUIRED DENSITY SHALL BE SCARIFIED, MOISTURE ADDED IF REQUIRED, AND RECOMPACTED UNTIL THE REQUIRED DENSITY IS OBTAINED AT NO ADDITIONAL EXPENSE TO THE OWNER.

J. SITE RESTORATION.

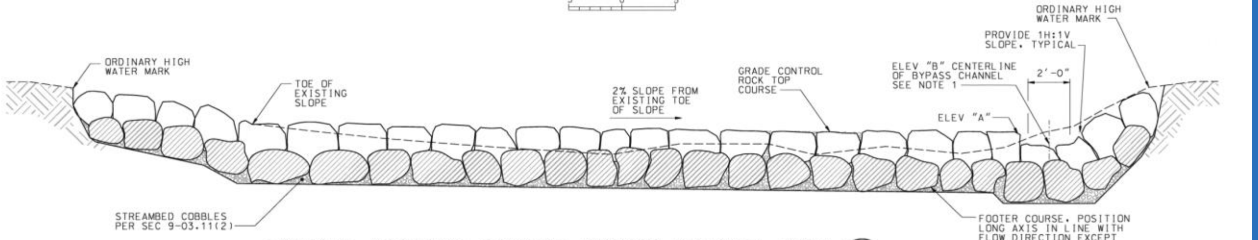
1) WILLOWS SHALL BE PLANTED DURING CONSTRUCTION IN AREAS INDICATED ON PLANS. PLANTING OF WILLOWS WILL BE PERFORMED BY THE KITTITAS COUNTY CONSERVATION DISTRICT (KCCD) AND WILL NOT BE PART OF THIS CONTRACT. CONTRACTOR SHALL COORDINATE WITH KCCD THREE WEEKS IN ADVANCE OF ANTICIPATED WILLOW PLANTINGS.

2) AREAS DISTURBED BY CONSTRUCTION ACTIVITIES SHALL BE HYDROSEEDED WITH AN EROSION CONTROL GRASS MIX CONTAINING GRASSES NATIVE TO THE ELLENSBURG, WA AREA. THE HYDROSEED MIX SHALL BE APPROVED BY PROJECT ENGINEER PRIOR TO APPLICATION.



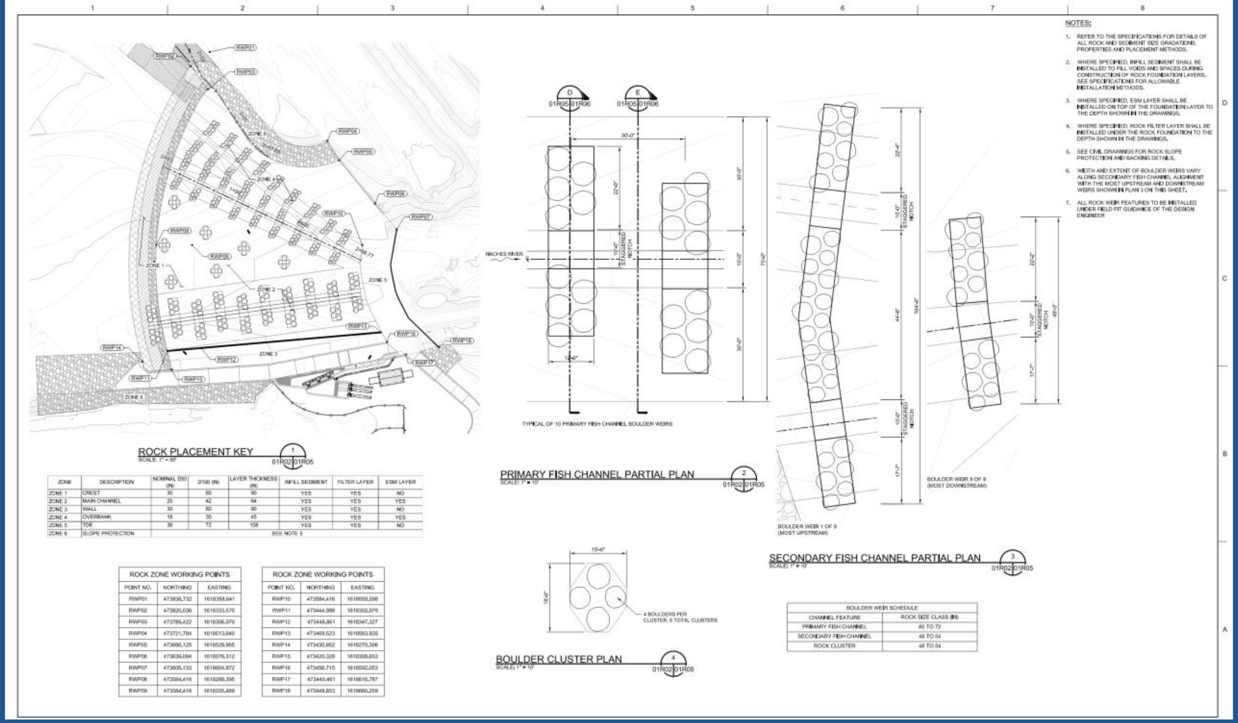
TYPICAL ROCK WEIR PROFILE (A, C2 C4)

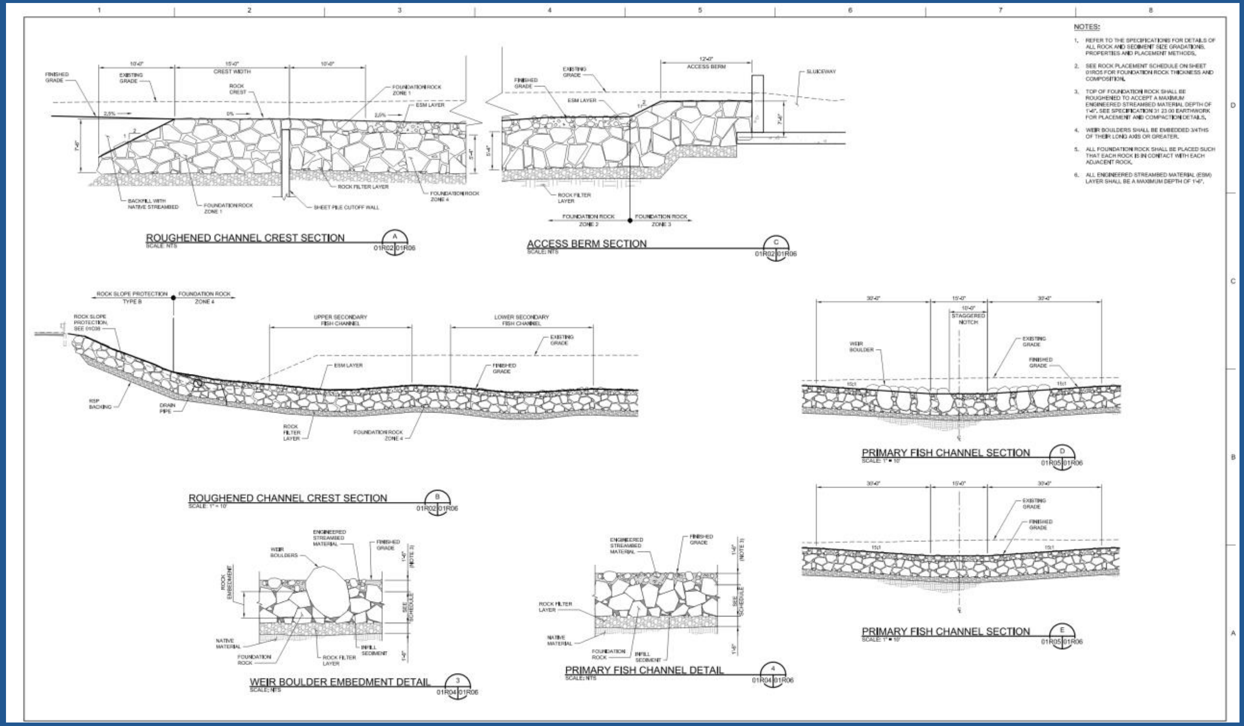
SCALE IN FEET



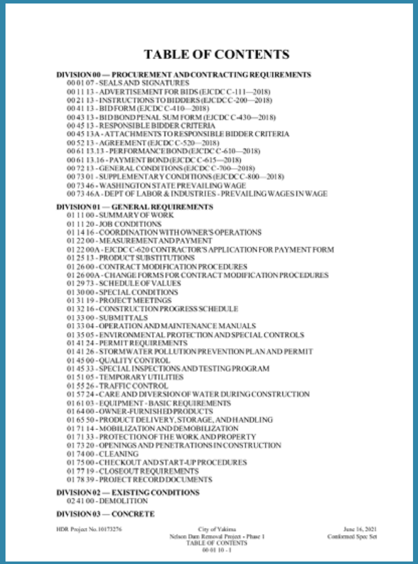
TYPICAL SECTION THROUGH BYPASS CHANNEL AREA (B, C2 C4)

SCALE IN FEET





Project Manual over 1,000 pages …



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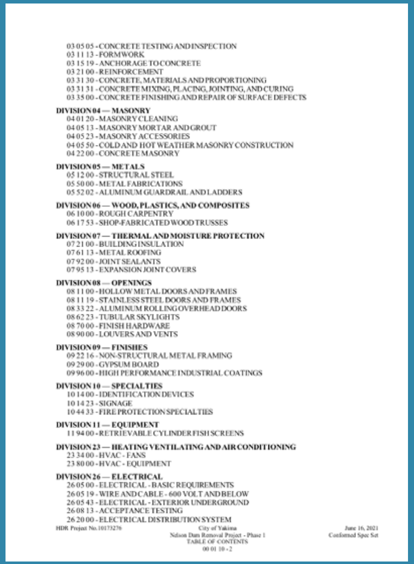


Construction Documentation

- DBB delivery with low-bid municipal environment
- Example drawings and specifications
- Higher level of detail

Construction Documentation

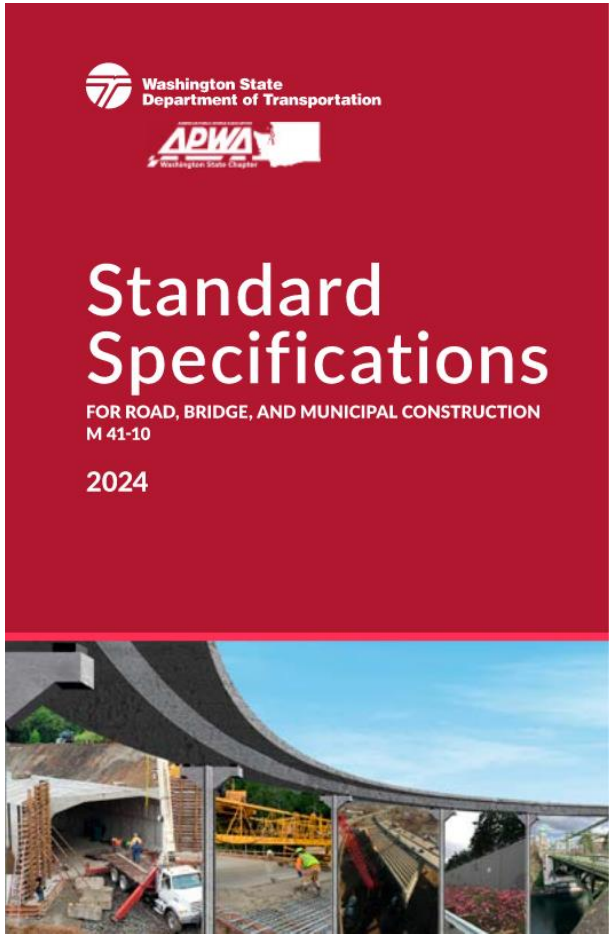
Specifications are Not Created Equal

- Federal Standards and formats
- State Standards (e.g., WSDOT, Caltrans, etc.)
- Municipal Standards (County or City)
- Construction Specifications Institute (CSI) Format
- Owner specific formats
- Special provisions

Construction Documentation

8-30 Water Crossings
8-31 Temporary Stream Diversions

Example Specifications - WSDOT



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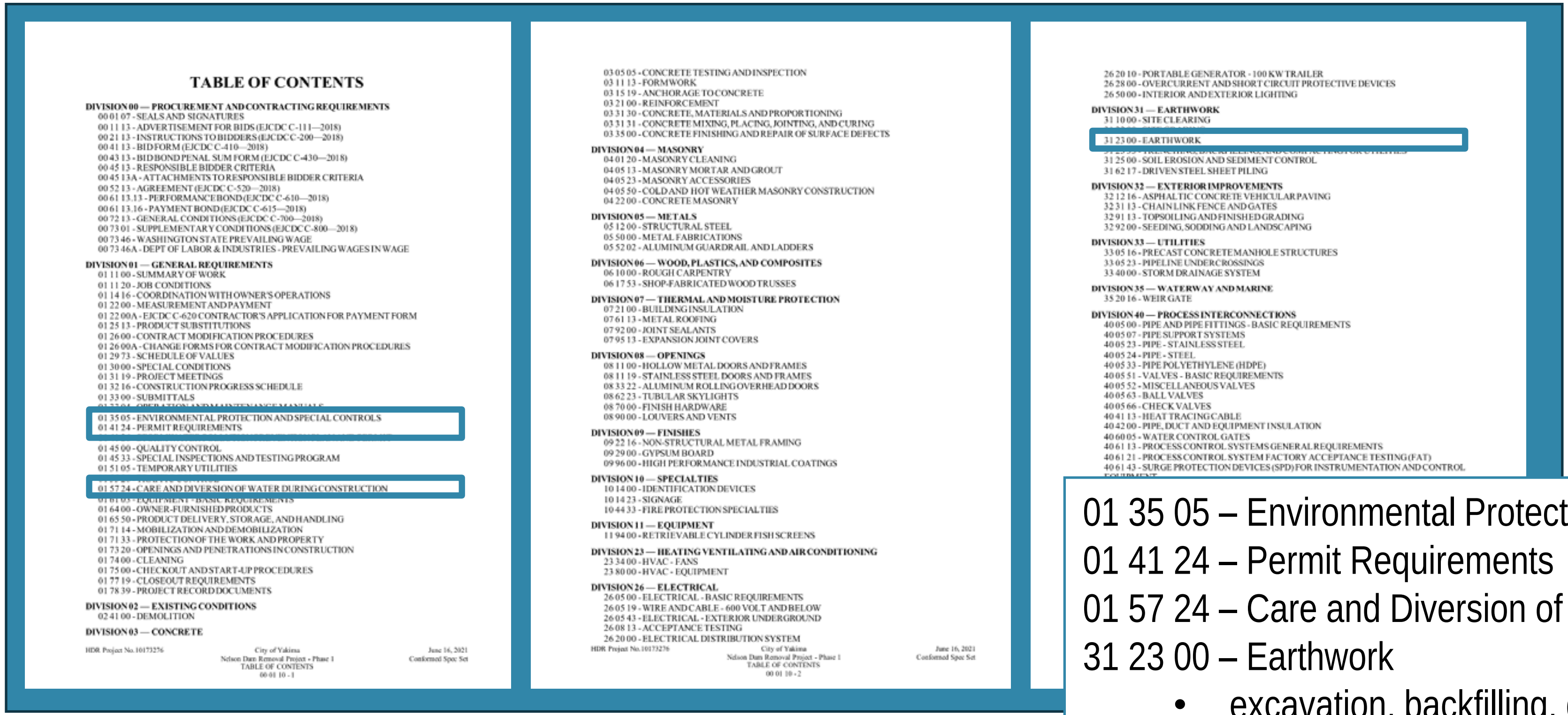
9-03.11(5) Streambed Boulders . . . 9-21

Construction Documentation

Example Specifications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00 11 13 - ADVERTISEMENT FOR BIDS (EJCDC C-111—2018)
00 21 13 - INSTRUCTIONS TO BIDDERS (EJCDC C-200—2018)
00 41 13 - BID FORM (EJCDC C-410—2018)
00 43 13 - BID BOND PENAL SUM FORM (EJCDC C-430—2018)
00 45 13 - RESPONSIBLE BIDDER CRITERIA
00 45 13A - ATTACHMENTS TO RESPONSIBLE BIDDER CRITERIA
00 52 13 - AGREEMENT (EJCDC C-520—2018)
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01 14 16 - COORDINATION WITH OWNER'S OPERATIONS
01 22 00 - MEASUREMENT AND PAYMENT
01 22 00A - EJCDC C-620 CONTRACTOR'S APPLICATION FOR PAYMENT FORM
01 25 13 - PRODUCT SUBSTITUTIONS
01 26 00 - CONTRACT MODIFICATION PROCEDURES
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01 29 73 - SCHEDULE OF VALUES
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01 71 33 - PROTECTION OF THE WORK AND PROPERTY
01 73 20 - OPENINGS AND PENETRATIONS IN CONSTRUCTION
01 74 00 - CLEANING
01 75 00 - CHECKOUT AND START-UP PROCEDURES
01 77 19 - CLOSEOUT REQUIREMENTS
01 78 39 - PROJECT RECORD DOCUMENTS

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03 11 13 - FORMWORK
03 15 19 - ANCHORAGE TO CONCRETE
03 21 00 - REINFORCEMENT
03 31 30 - CONCRETE, MATERIALS AND PROPORTIONING
03 31 31 - CONCRETE MIXING, PLACING, JOINTING, AND CURING
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DIVISION 04 — MASONRY
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05 12 00 - STRUCTURAL STEEL
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05 52 02 - ALUMINUM GUARDRAIL AND LADDERS

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06 10 00 - ROUGH CARPENTRY
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DIVISION 07 — THERMAL AND MOISTURE PROTECTION
07 21 00 - BUILDING INSULATION
07 61 13 - METAL ROOFING
07 92 00 - JOINT SEALANTS
07 95 13 - EXPANSION JOINT COVERS

DIVISION 08 — OPENINGS
08 11 00 - HOLLOW METAL DOORS AND FRAMES
08 11 19 - STAINLESS STEEL DOORS AND FRAMES
08 33 22 - ALUMINUM ROLLING OVERHEAD DOORS
08 62 23 - TUBULAR SKYLIGHTS
08 70 00 - FINISH HARDWARE
08 90 00 - LOUVERS AND VENTS

DIVISION 09 — FINISHES
09 22 16 - NON-STRUCTURAL METAL FRAMING
09 29 00 - GYPSUM BOARD
09 96 00 - HIGH PERFORMANCE INDUSTRIAL COATINGS

DIVISION 10 — SPECIALTIES
10 14 00 - IDENTIFICATION DEVICES
10 14 23 - SIGNAGE
10 44 33 - FIRE PROTECTION SPECIALTIES

DIVISION 11 — EQUIPMENT
11 94 00 - RETRIEVABLE CYLINDER FISH SCREENS

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23 34 00 - HVAC - FANS
23 80 00 - HVAC - EQUIPMENT

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26 05 00 - ELECTRICAL - BASIC REQUIREMENTS
26 05 19 - WIRE AND CABLE - 600 VOLT AND BELOW
26 05 43 - ELECTRICAL - EXTERIOR UNDERGROUND
26 08 13 - ACCEPTANCE TESTING
26 20 00 - ELECTRICAL DISTRIBUTION SYSTEM

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26 20 10 - PORTABLE GENERATOR - 100 KW TRAILER
26 28 00 - OVERCURRENT AND SHORT CIRCUIT PROTECTIVE DEVICES
26 50 00 - INTERIOR AND EXTERIOR LIGHTING

DIVISION 31 — EARTHWORK
31 10 00 - SITE CLEARING
31 23 00 - EARTHWORK
31 25 00 - SOIL EROSION AND SEDIMENT CONTROL
31 62 17 - DRIVEN STEEL SHEET PILING

DIVISION 32 — EXTERIOR IMPROVEMENTS
32 12 16 - ASPHALTIC CONCRETE VEHICULAR PAVING
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40 60 05 - WATER CONTROL GATES
40 61 13 - PROCESS CONTROL SYSTEMS GENERAL REQUIREMENTS
40 61 21 - PROCESS CONTROL SYSTEM FACTORY ACCEPTANCE TESTING (FAT)
40 61 43 - SURGE PROTECTION DEVICES (SPD) FOR INSTRUMENTATION AND CONTROL

01 35 05 – Environmental Protection and Special Controls
01 41 24 – Permit Requirements
01 57 24 – Care and Diversion of Water During Construction
31 23 00 – Earthwork

- excavation, backfilling, grading, compaction, disposal of waste and surplus materials, aggregate, stone, rock, placement of materials, construction of rock features, shoring, bracing, and other Earthwork related work.

Q&A

02

Construction methods, considerations, and challenges

- An overview of NLF construction considerations, methods, and challenges

Construction methods, considerations, and challenges

- Rock material properties and gradation
- Material handling
- Material sourcing
- Equipment, equipment limitations, constructability
- Use of hydraulic jetting as a tool for settlement and plugging interstitial space
- Care of water

Rock Gradation and Quality

- Shape – Angular, Subangular, Rounded
- Specific Gravity – Density
- Hardness – Breaking and fracturing
- Durability – Response to abrasion
- Size and Gradation – Size class and distribution of sizes

Rock Gradation

Testing Methods Differentiated

Designation: D 5519 – 94 (Reapproved 2001)

INTERNATIONAL

Standard Test Method for
Particle Size Analysis of Natural and Man-Made Riprap Materials[1]

This standard is issued under the fixed designation D 5519; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

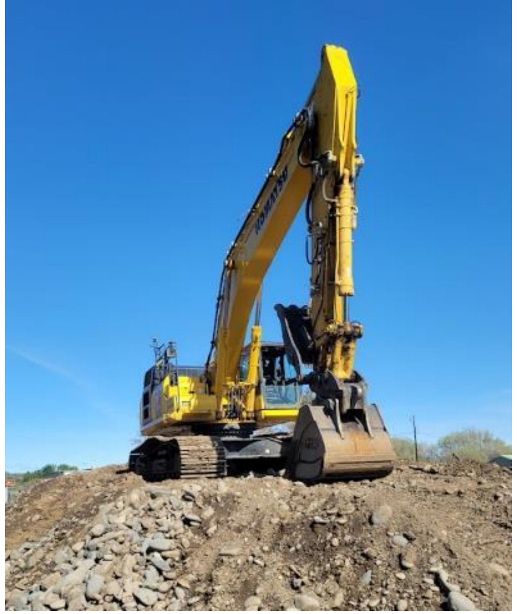
1.3 Three alternate procedures are provided. The procedure used shall be as indicated in the specification for the material being tested. If no procedure is specified, the choice should be selected and confirmed by the testing agency. The procedures and referenced sections are:

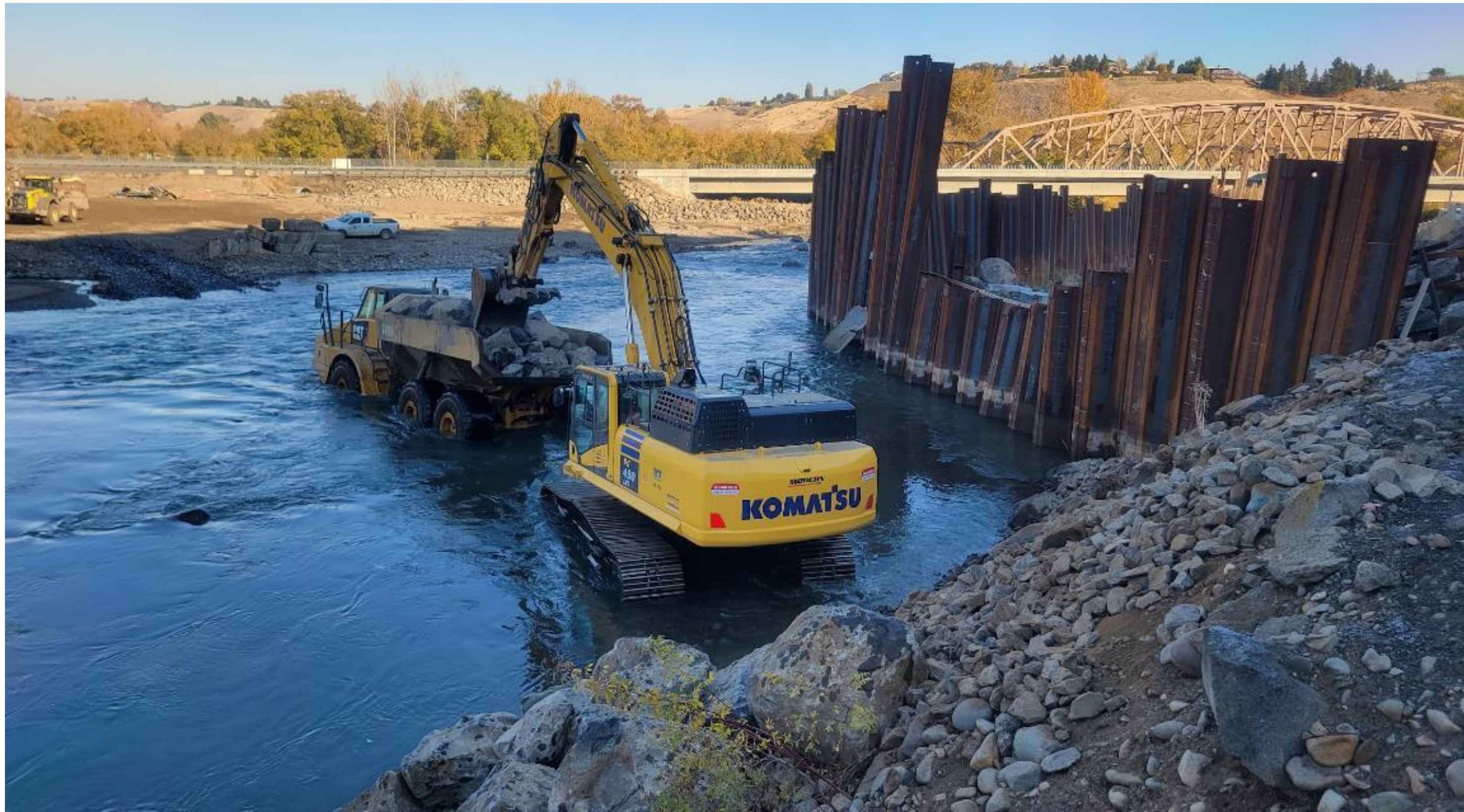
1.3.1 *Test Method A: Size-Mass Grading*—Grading of the material based on both the size and mass. See 9.2.

1.3.2 *Test Method B: Size-Range Grading*—Determination of the grading of the material based on the sizes of the individual particles. See 9.3.

1.3.3 *Test Method C: Mass-Range Grading*—Determination of the grading of the material based on the mass of the individual particles. See 9.4.

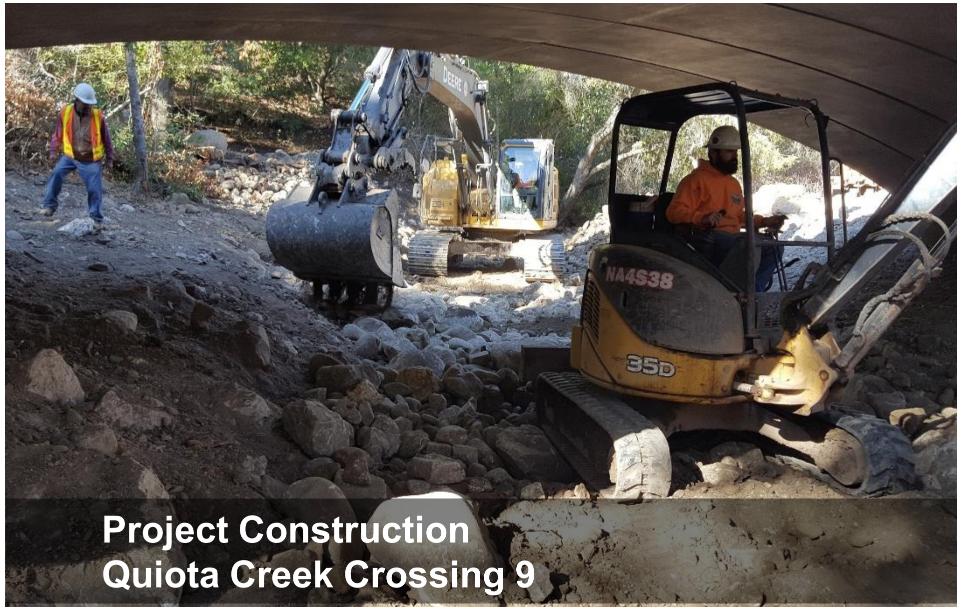
Onsite Material Receiving, Sorting, and Handling





Project Construction
Cota Street Bridge NLF


Project Construction
Eagle Creek (courtesy Michael Love)



Project Construction
Quiota Creek Crossing 9

Large Rock Handling

Environmental permitting efforts should consider construction means and methods to the extent possible. Changes in construction tactics not covered by approved permits can result in costly schedule delays.

Care of Water, Construction Isolation, Temporary Stream Diversions, and Dewatering

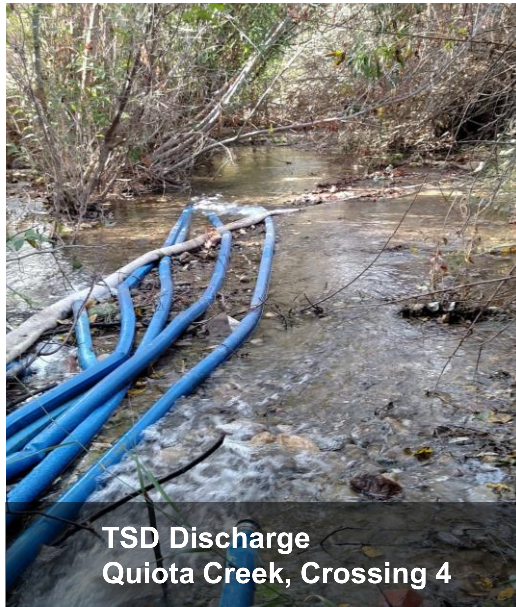
A broad variety of materials can be used to develop coffer dams for temporary stream diversions

Temporary stream diversions are configured to meet the need and complexity of the project to accommodate the anticipated range of flows during construction.

Project Construction
Eagle Creek (courtesy Michael Love)

Pumped dewatering and discharge pipe networks
Nelson Dam Removal and Replacement

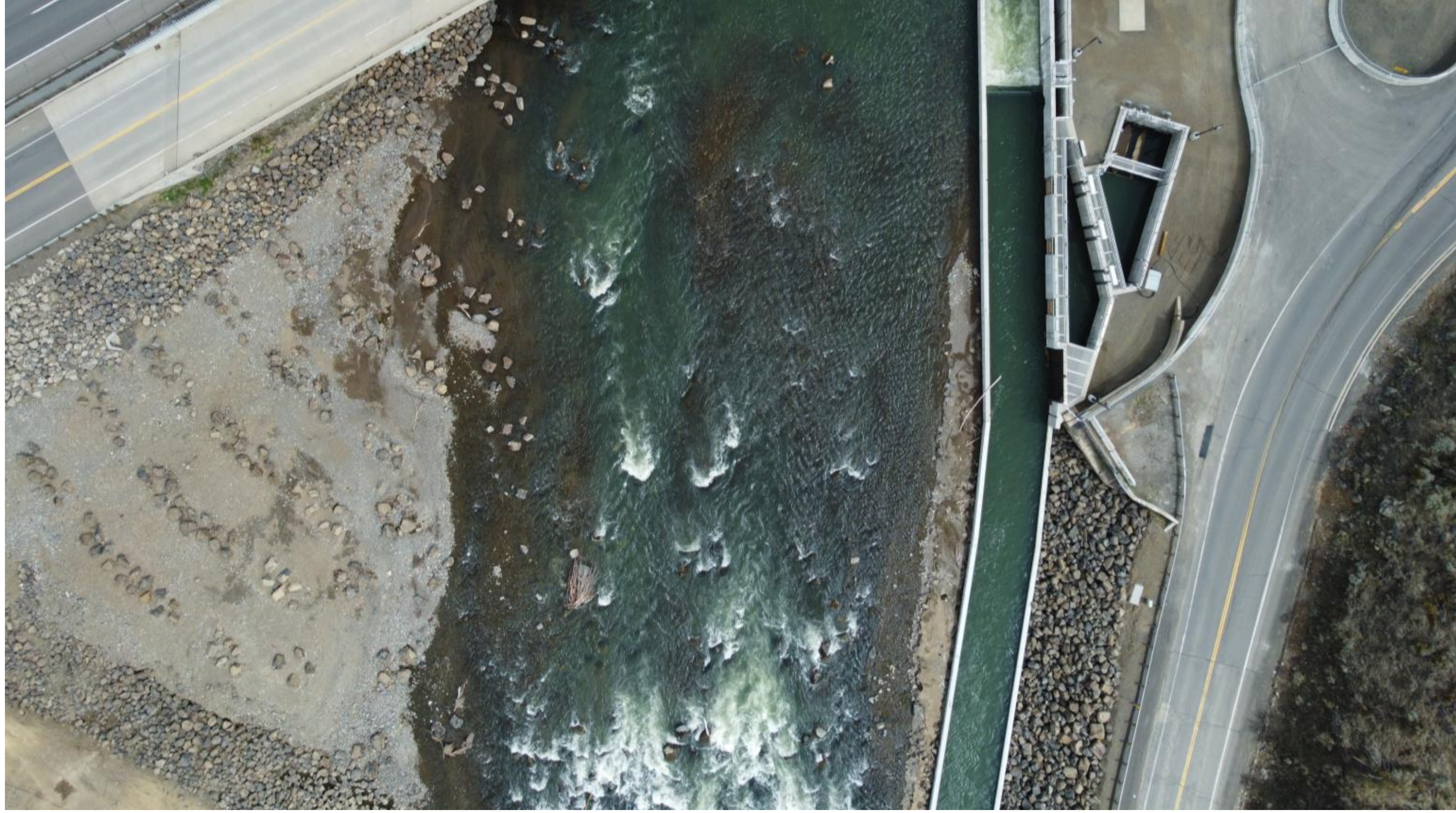
Project Construction
Cota Street Bridge NLF



TSD Discharge
Quiota Creek, Crossing 4

Construction Monitoring

- Traditional survey methods
  - Set project benchmark and reference points
  - Grade rods, transits, and levels
- Modern survey techniques
  - RTK Survey equipment with cell phone capable real-time differential correction
  - Drone LiDar
  - 3D LiDar scanning
  - 3D terrain capable excavators



Construction methods, considerations, and challenges

Open Discussion…

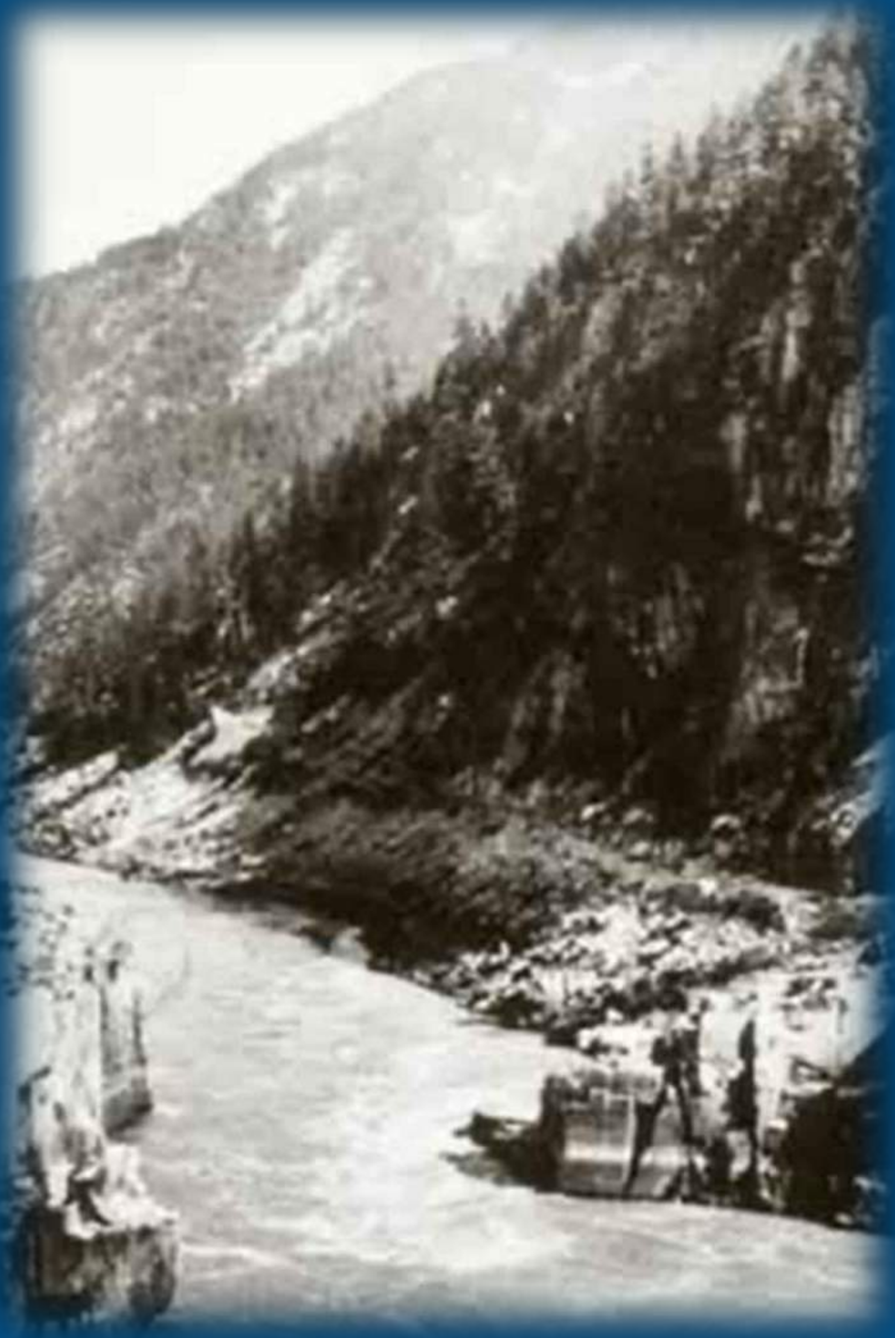
Successes and failures during construction?

Q&A

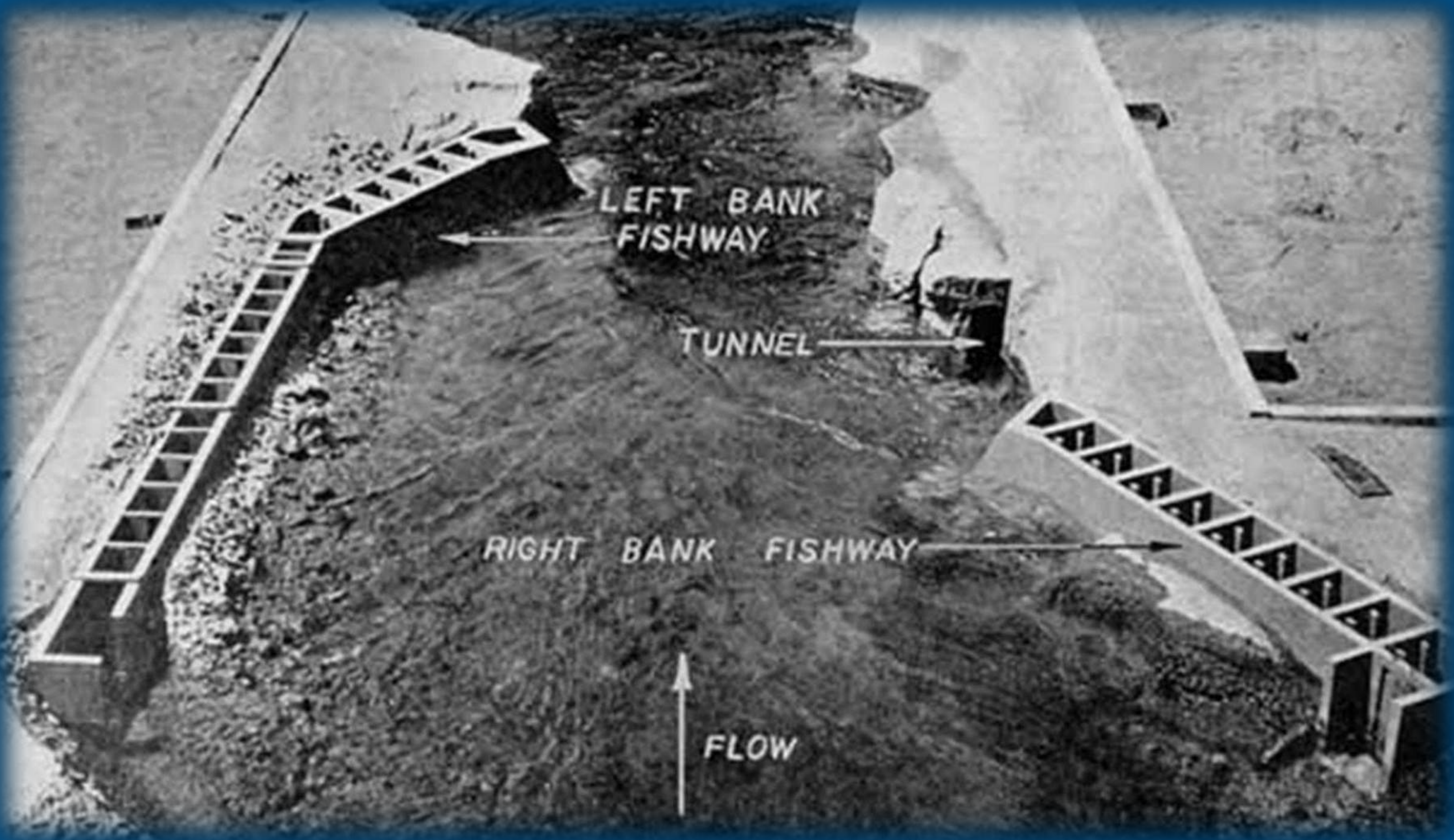
Fraser River
Big Bar Landslide
Fish Passage Mitigation

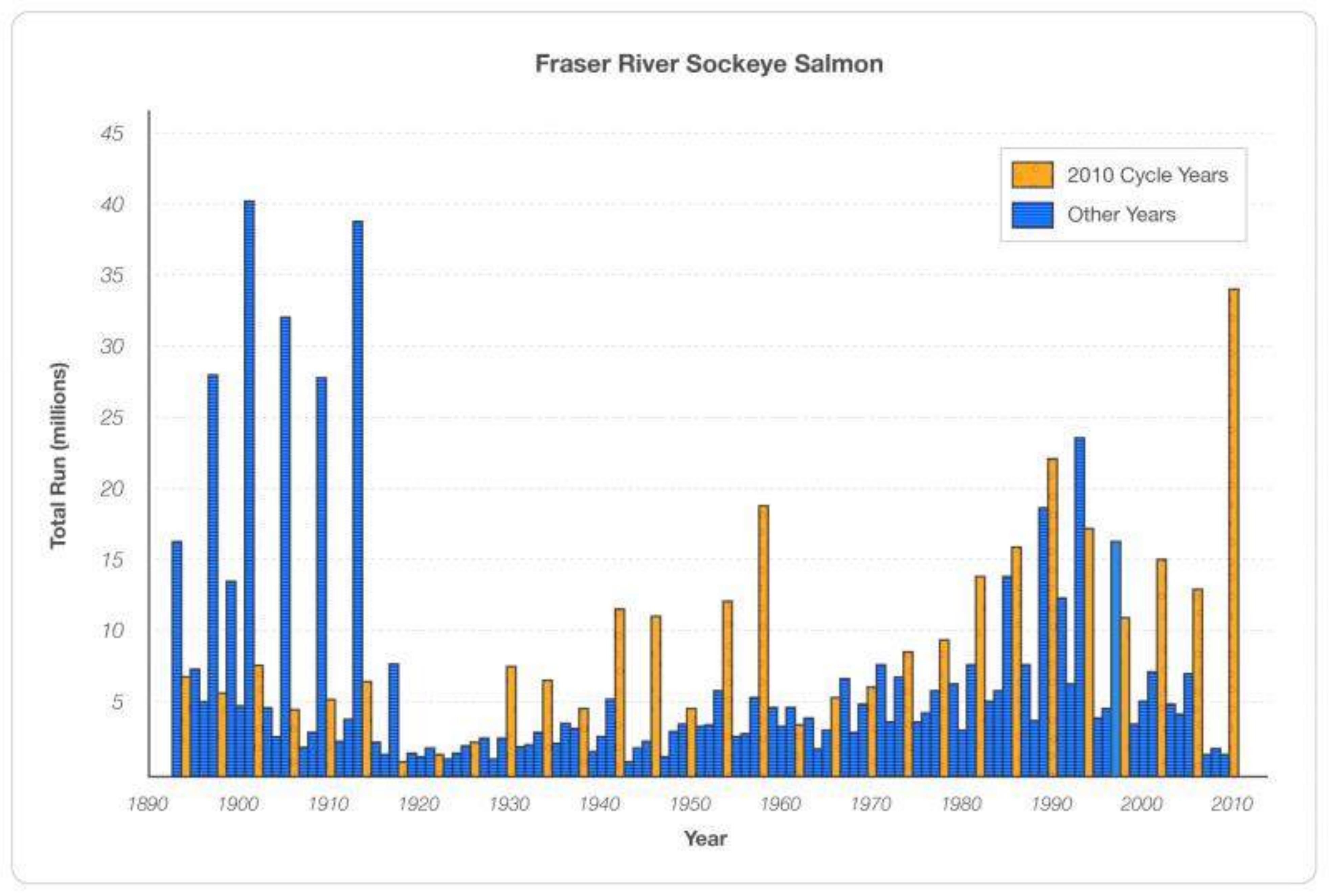
Barry Chilibeck, PEng
Northwest Hydraulic Consultants

Wednesday March 27 2024
SRF 2024

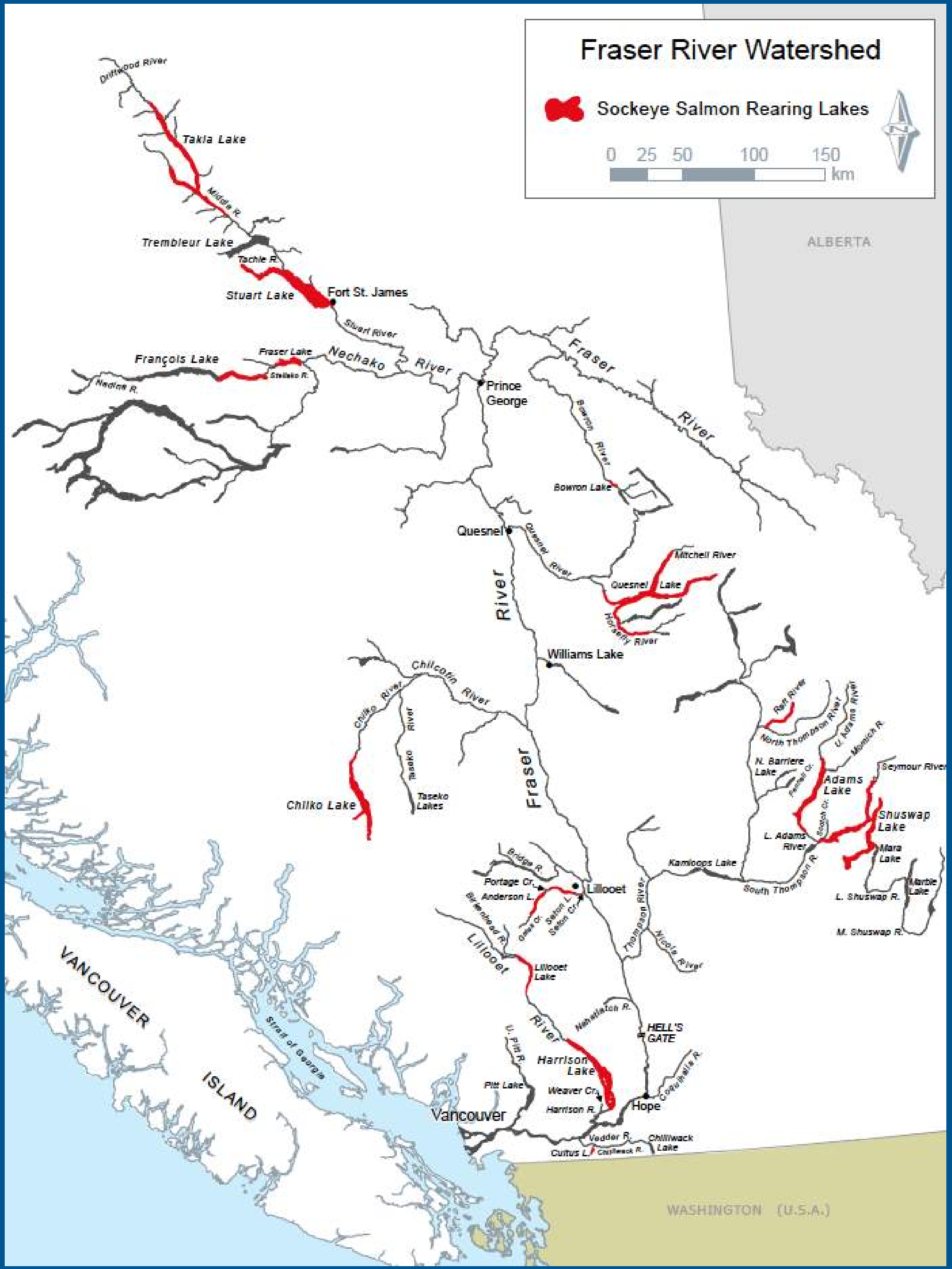


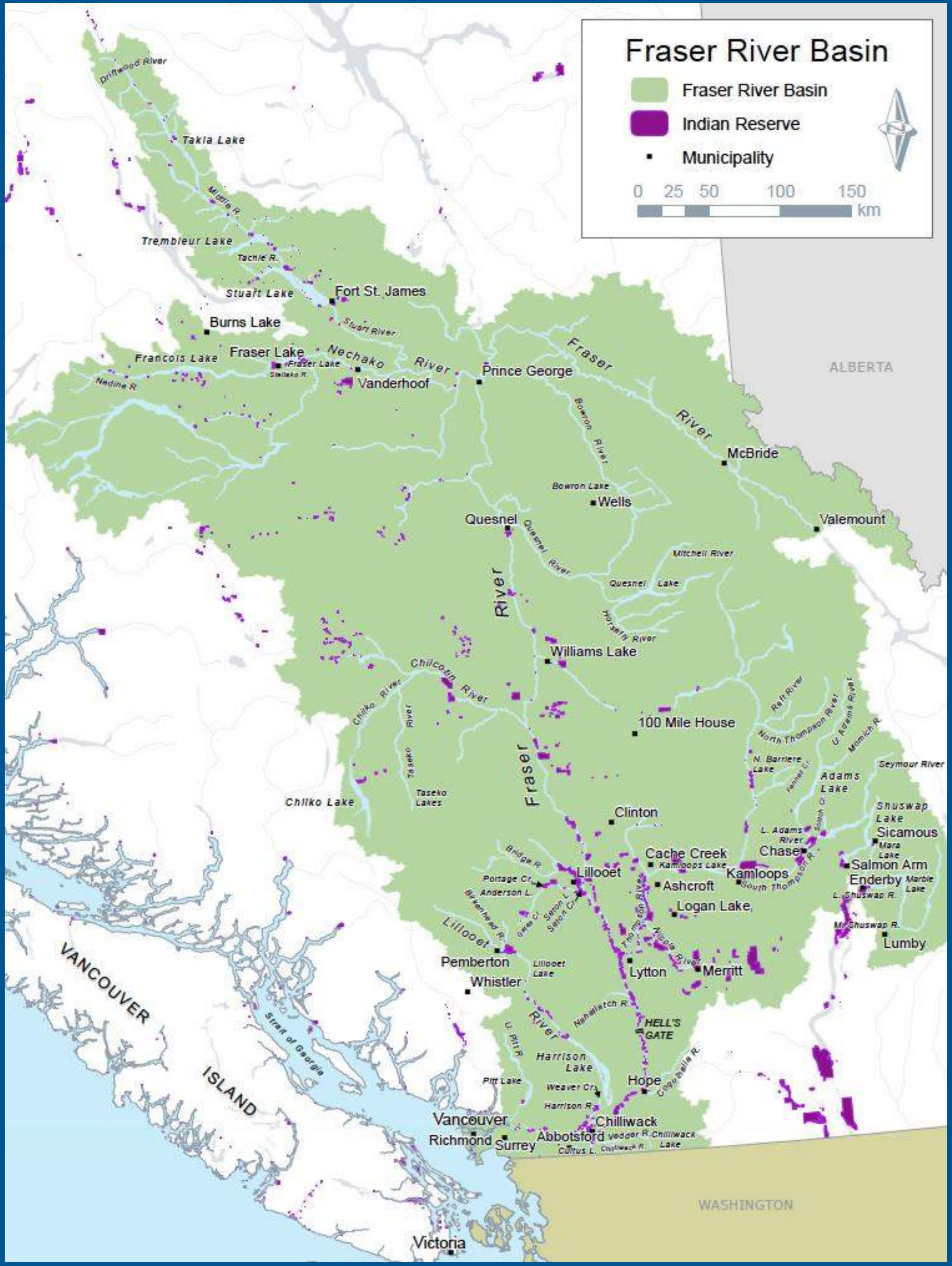

Clearing Rock Slide at Hells Gate, Frazer River
Rock moved 76,850 cu. yds. Drilled 9,634 Feet

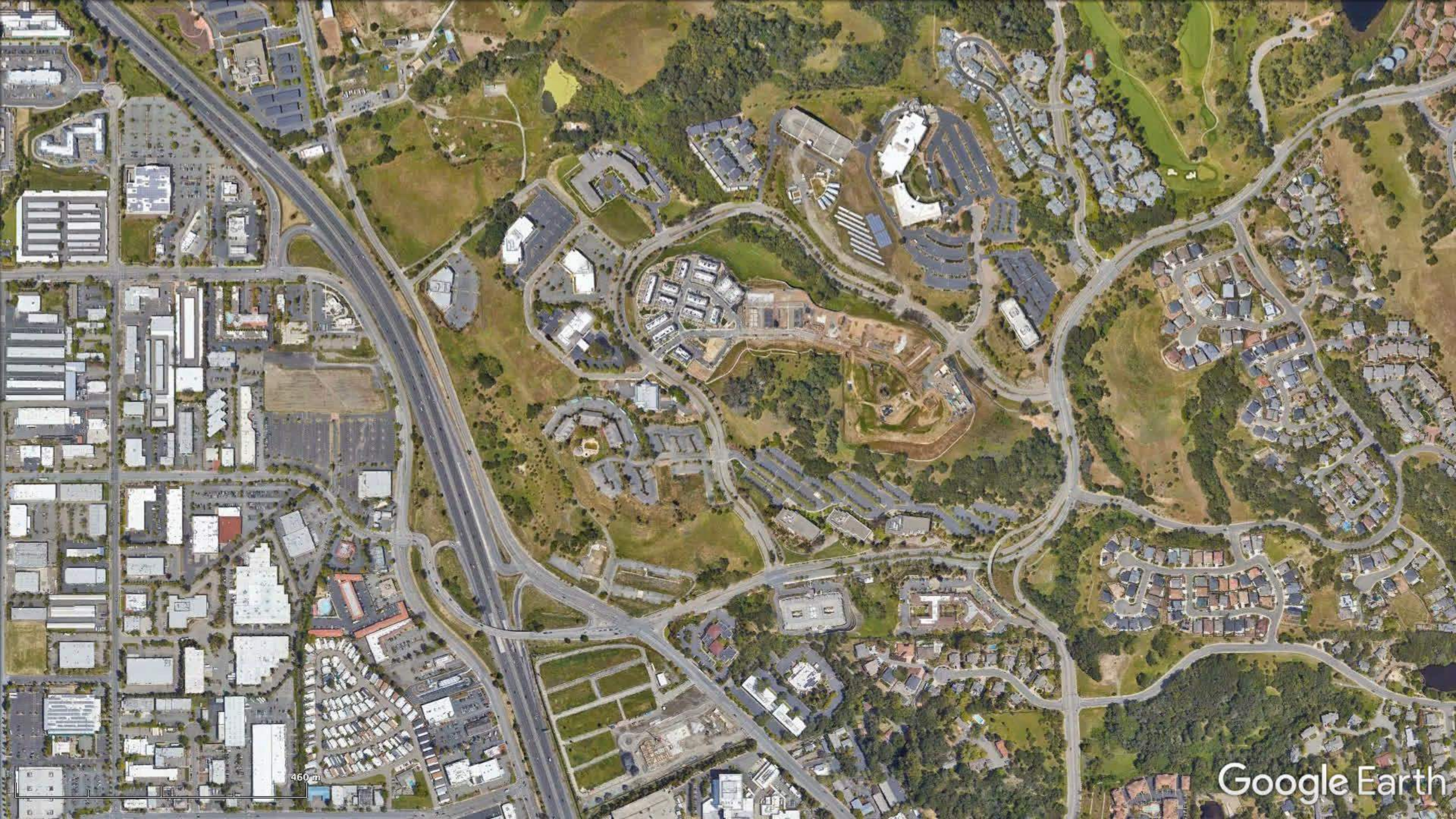

LEFT BANK
FISHWAY
TUNNEL
RIGHT BANK FISHWAY
FLOW



Fraser River Sockeye Salmon
2010 Cycle Years
Other Years
Total Run (millions)
45
40
35
30
25
20
15
10
5
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year

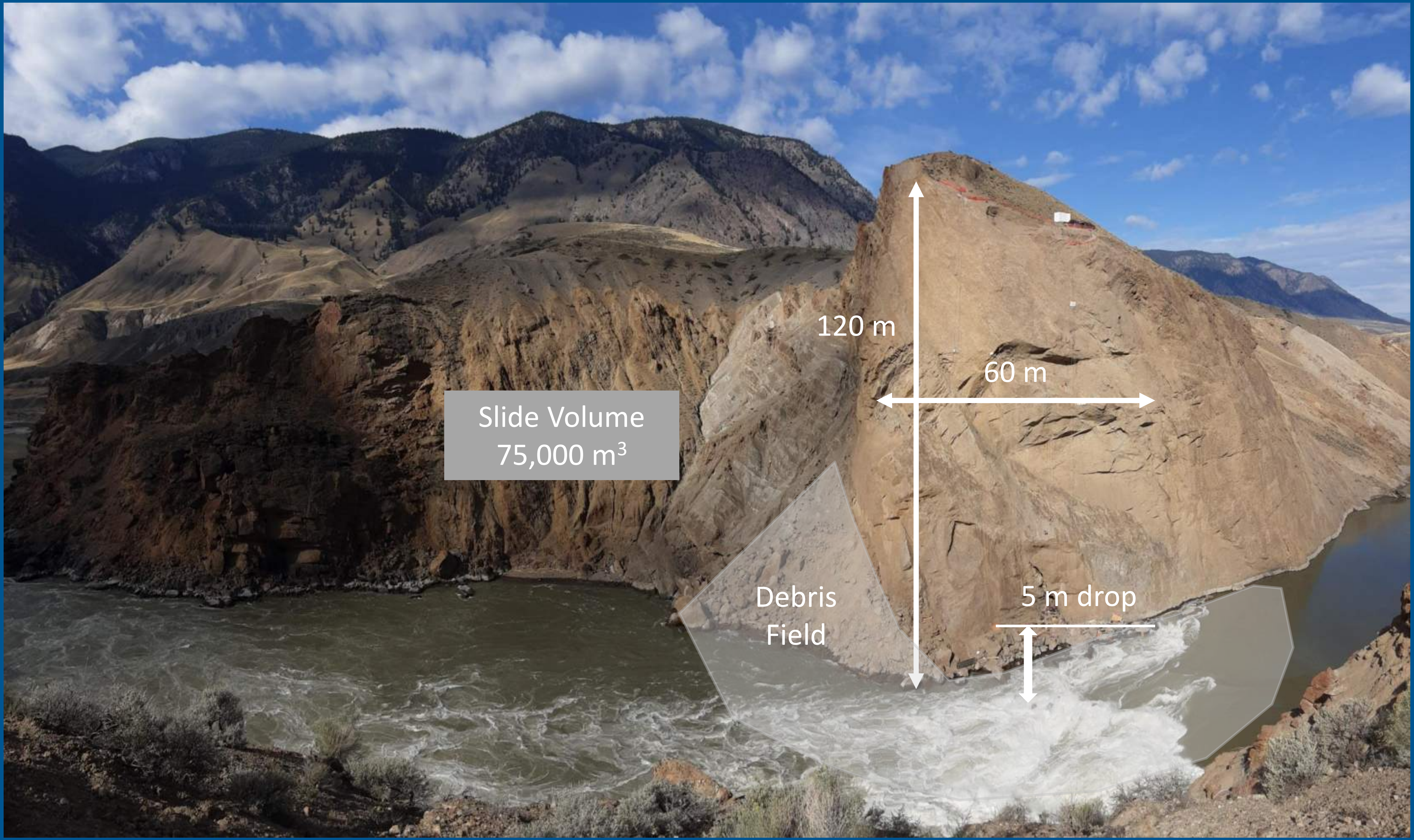

Fraser River Watershed
Sockeye Salmon Rearing Lakes
0 25 50 100 150
km
ALBERTA
Driftwood River
Takla Lake
Middle R.
Trembleur Lake
Tachie R.
Stuart Lake
Fort St. James
Stuart River
François Lake
Fraser Lake
Stellako R.
Nadina R.
Nechako
River
Prince George
Fraser
River
Bowron River
Bowron Lake
Quesnel
Quesnel River
Quesnel Lake
Mitchell River
Horsefly River
River
Williams Lake
Chilcotin River
Chilko River
Taseko River
Chilko Lake
Taseko Lakes
Fraser
Raft River
North Thompson River
U. Adams River
Momich R.
N. Barriere Lake
Adams Lake
Seymour River
Shuswap Lake
L. Adams River
Mara Lake
Kamloops Lake
South Thompson R.
L. Shuswap R.
M. Shuswap R.
Marble Lake
Bridge R.
Portage Cr.
Anderson L.
Birkenhead R.
Lillooet
Thompson River
Nicola River
Lillooet
Lillooet Lake
River
Nahatlatch R.
HELL'S GATE
U. Pitt R.
Harrison Lake
Pitt Lake
Weaver Cr.
Harrison R.
Hope
Coquihalla R.
Vancouver
Vedder R.
Chilliwack Lake
Cultus L.
Chilliwack R.
VANCOUVER
ISLAND
Strait of Georgia
WASHINGTON (U.S.A.)


Fraser River Basin
Fraser River Basin
Indian Reserve
Municipality
0 25 50 100 150
km
ALBERTA
Driftwood River
Takla Lake
Middle R.
Trembleur Lake
Tachie R.
Stuart Lake
Fort St. James
Stuart River
Burns Lake
Francois Lake
Fraser Lake
Nechako
River
Vanderhoof
Prince George
Fraser
River
McBride
Valemount
Bowron Lake
Wells
Quesnel
Quesnel River
Mitchell River
Quesnel Lake
Horsefly River
River
Williams Lake
Chilcotin River
Chilko River
Chilko Lake
Taseko Lakes
100 Mile House
Fraser
Clinton
Raft River
North Thompson River
Adams Lake
Seymour River
Shuswap Lake
Sicamous
Chase
Cache Creek
Kamloops Lake
Kamloops
Ashcroft
Logan Lake
Salmon Arm
Enderby
Lumby
Lillooet
Bridge R.
Portage Cr.
Anderson L.
Lillooet
Pemberton
Whistler
Lillooet Lake
Lytton
Merritt
HELL'S GATE
Harrison Lake
Pitt Lake
Weaver Cr.
Harrison R.
Hope
Chilliwack
Vancouver
Richmond
Surrey
Abbotsford
Cultus L.
Chilliwack Lake
VANCOUVER
ISLAND
Strait of Georgia
Victoria
WASHINGTON


460 m
Google Earth

Pre-slide Fall 2017

Post-slide Summer 2019



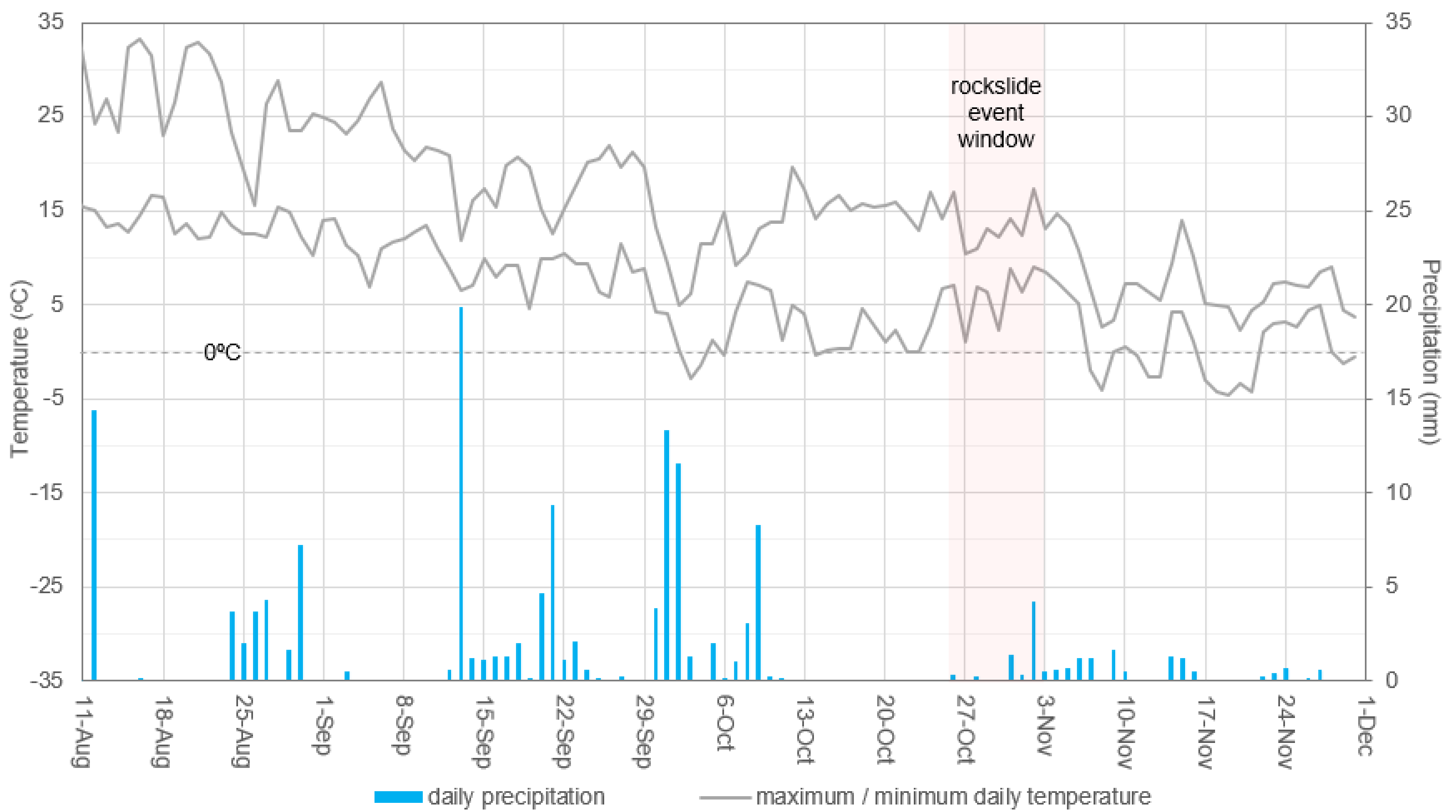
120 m
60 m
Slide Volume
75,000 m3
Debris
Field
5 m drop

When did this occur?

October 26th 2018

November 2nd 2018

Why did this occur?



Notes:
1. Daily maxiumum and minimum temperature measured at Lillooet weather station (elevation: 239.50 m.asl)
2. Daily preciptation at Big Bar rockslide site, based on interpolation between precipitation data measured between local Natural Resources Canada weather stations.

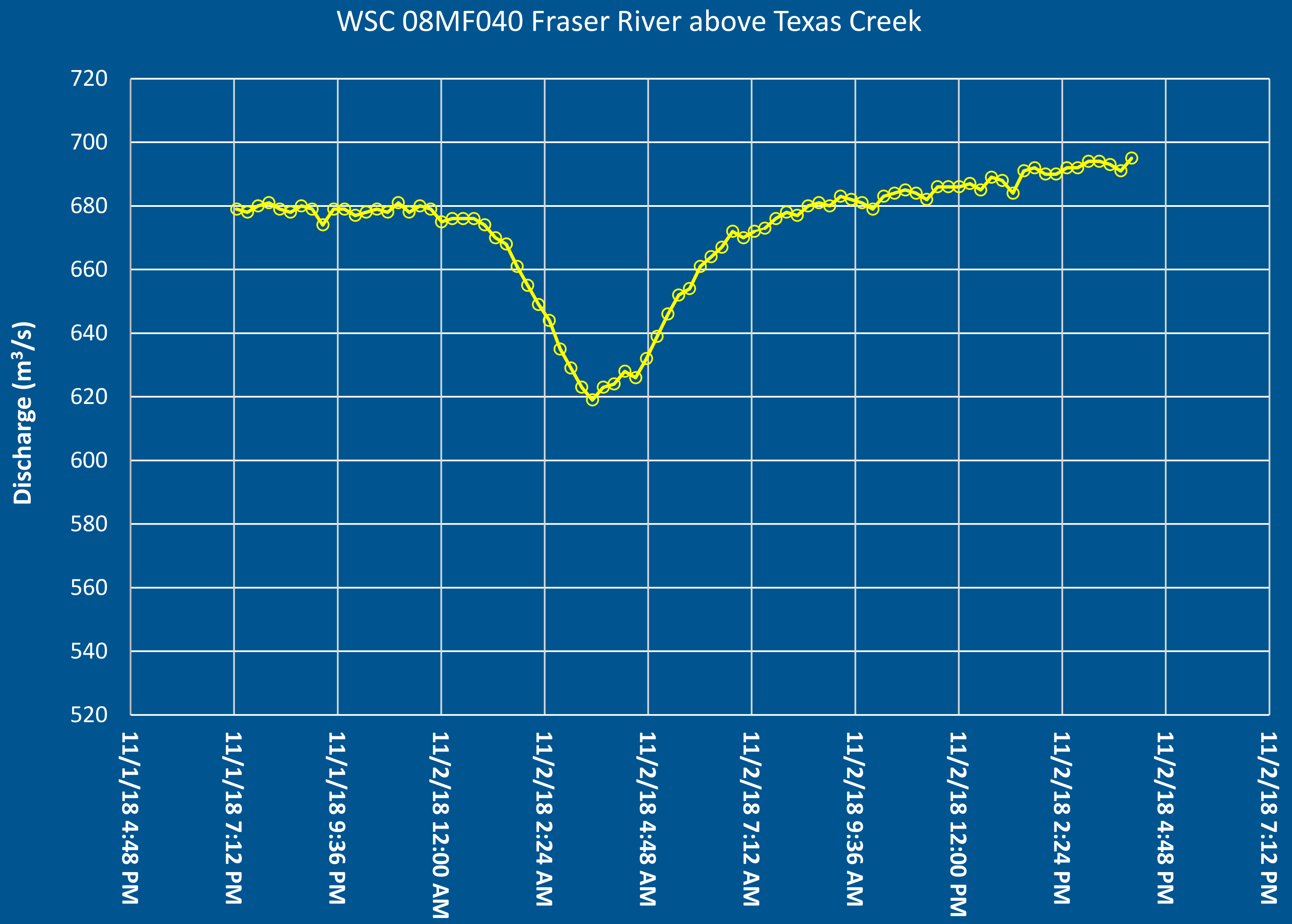
Big Bar Slide Timing

760,000 m^3 stored water behind the slide

4 m/s kinematic velocity at 600 m^3/s

Slide occurred at 1900 h PST on Nov 1st 2018

* 616 ac-ft
  9.7 fps
  21,200 cfs



Initial Emergency Response

Federal Government: salmon and oceans

- DFO – Fisheries and Oceans Canada
- CCG – Canadian Coast Guard

Provincial Government:

- FLNRORD – Water, Land, Flooding, Wildfire

Indigenous Groups:

- Upper Fraser Fisheries Conservation Alliance, High Bar First Nation and others

Initial Site Assessment

Fish Monitoring and Transport

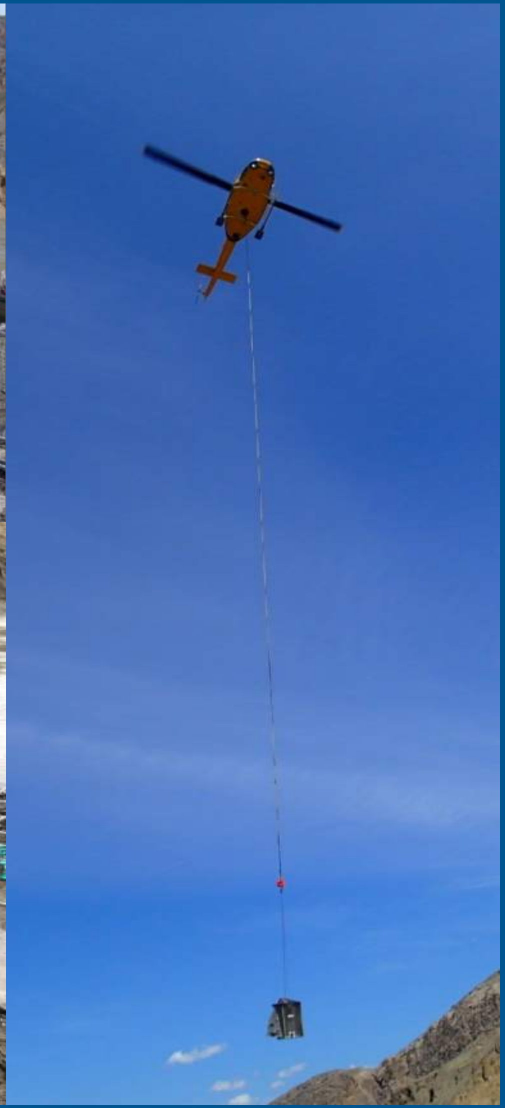
Seining and Heli-Transport

51,000 Sockeye

8,500 Chinook

500 Pink

3 Coho



Helicopter Transport Above the Slide

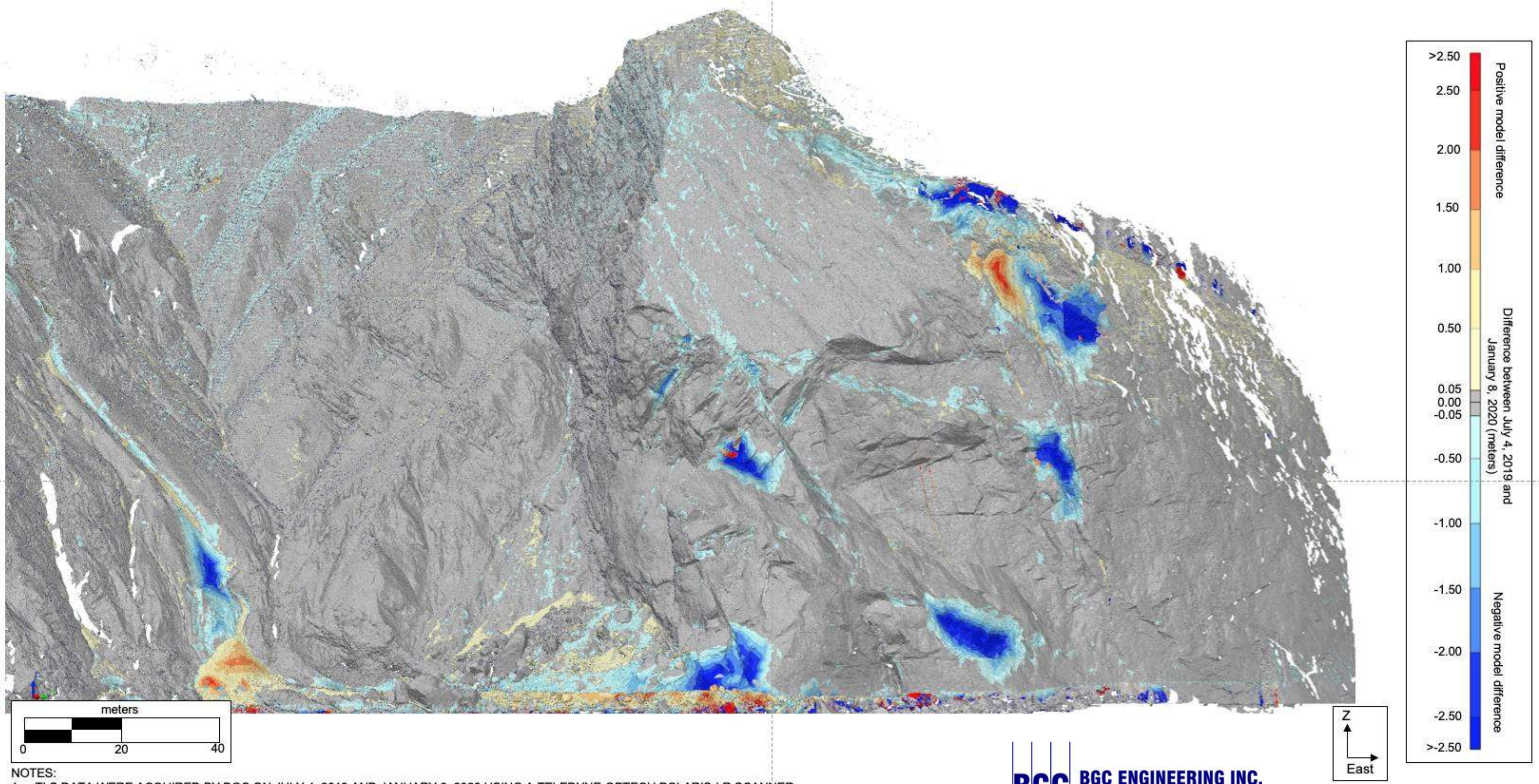
- 50 to 65% tagged fish resumed upstream migration after release
- 40% Chinook and 30% Sockeye fell back over the slide
- Multiple transits above the slide were recorded

<u>Reasons for fall back behaviour:</u>

- Capture and handling stress
- Water temperature
- Fish condition

Site Access and Rock Scaling

Site Access and Rock Scaling

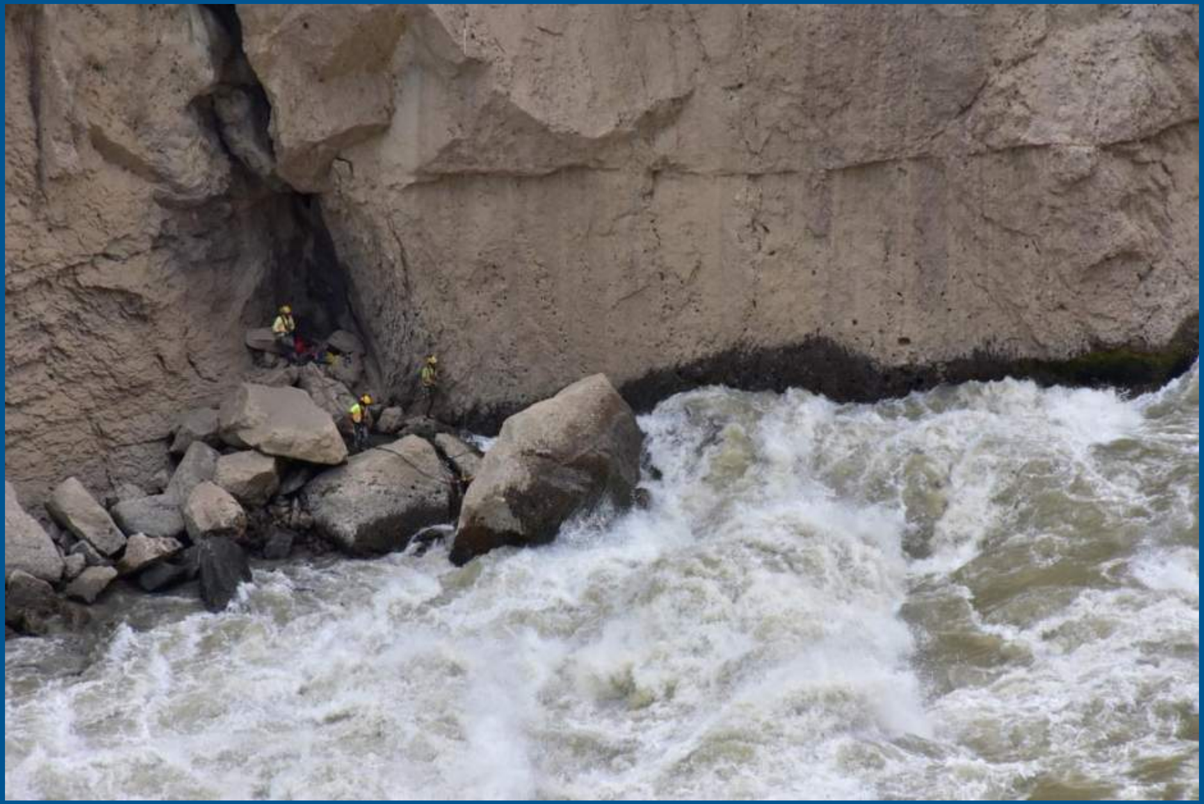


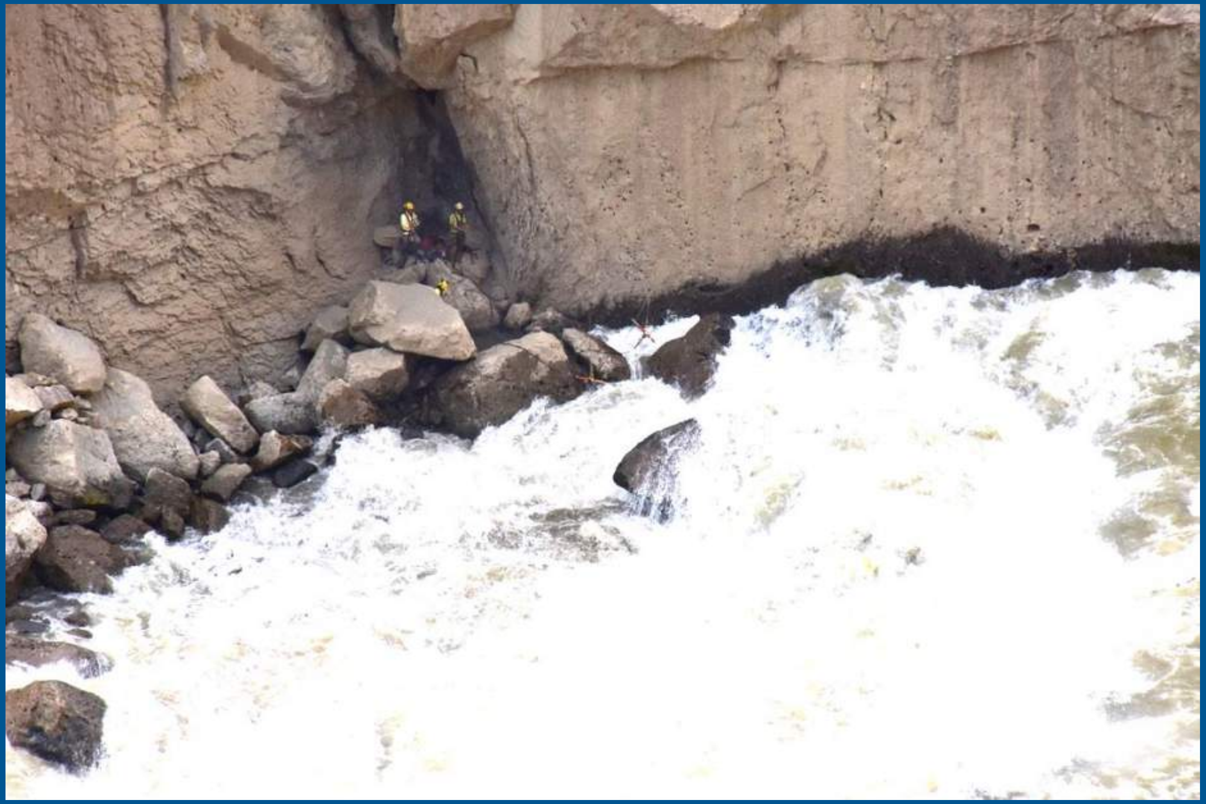
NOTES:

1. TLS DATA WERE ACQUIRED BY BGC ON JULY 4, 2019 AND JANUARY 8, 2020 USING A TELEDYNE-OPTECH POLARIS-LR SCANNER.
2. CHANGE DETECTION RESULTS ARE OVERLAIN ON JANUARY 8, 2020 TLS DATA AND ARE SHOWN WITH A LIMIT OF DETECTION FROM -0.05 M TO +0.05 M.
3. THIS FIGURE IS INTENDED AS A VISUAL REPRESENTATION AND NOT PROVIDED TO MATCH A STANDARD ENGINEERING SCALE.

Rock Manipulation for Fish Passage

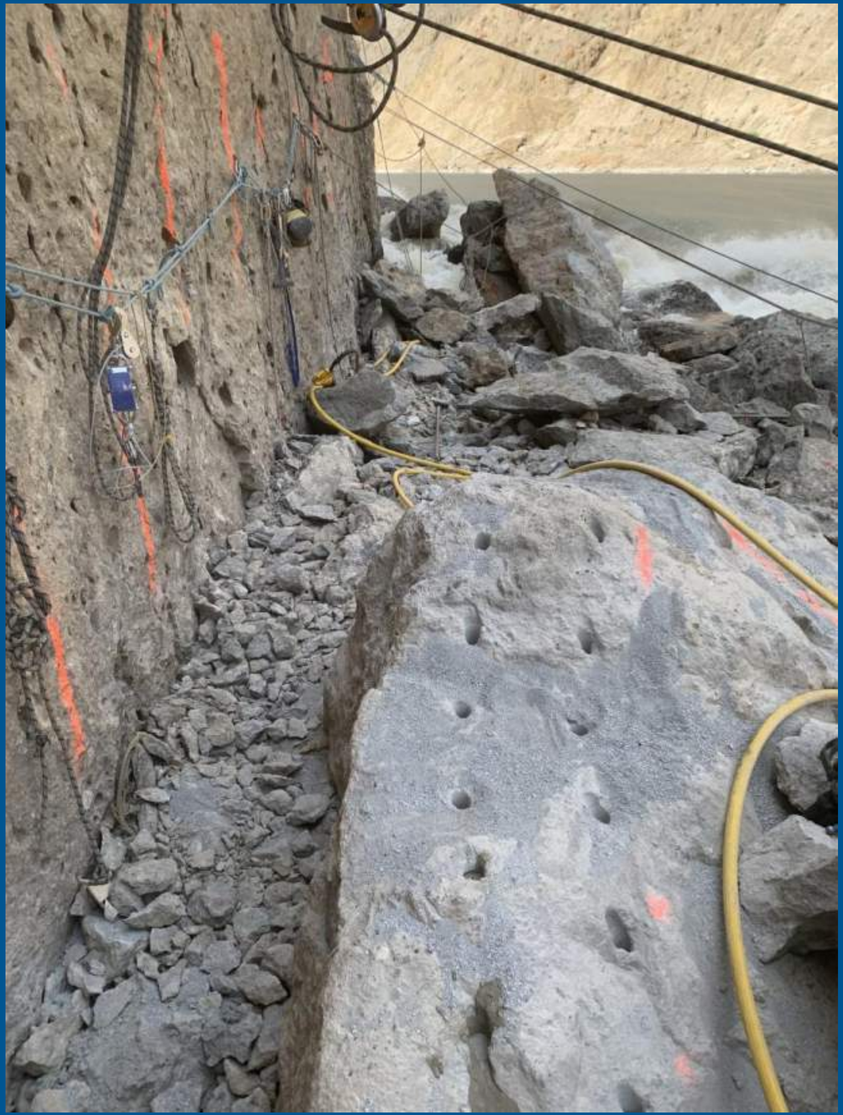
Not much room to start with….

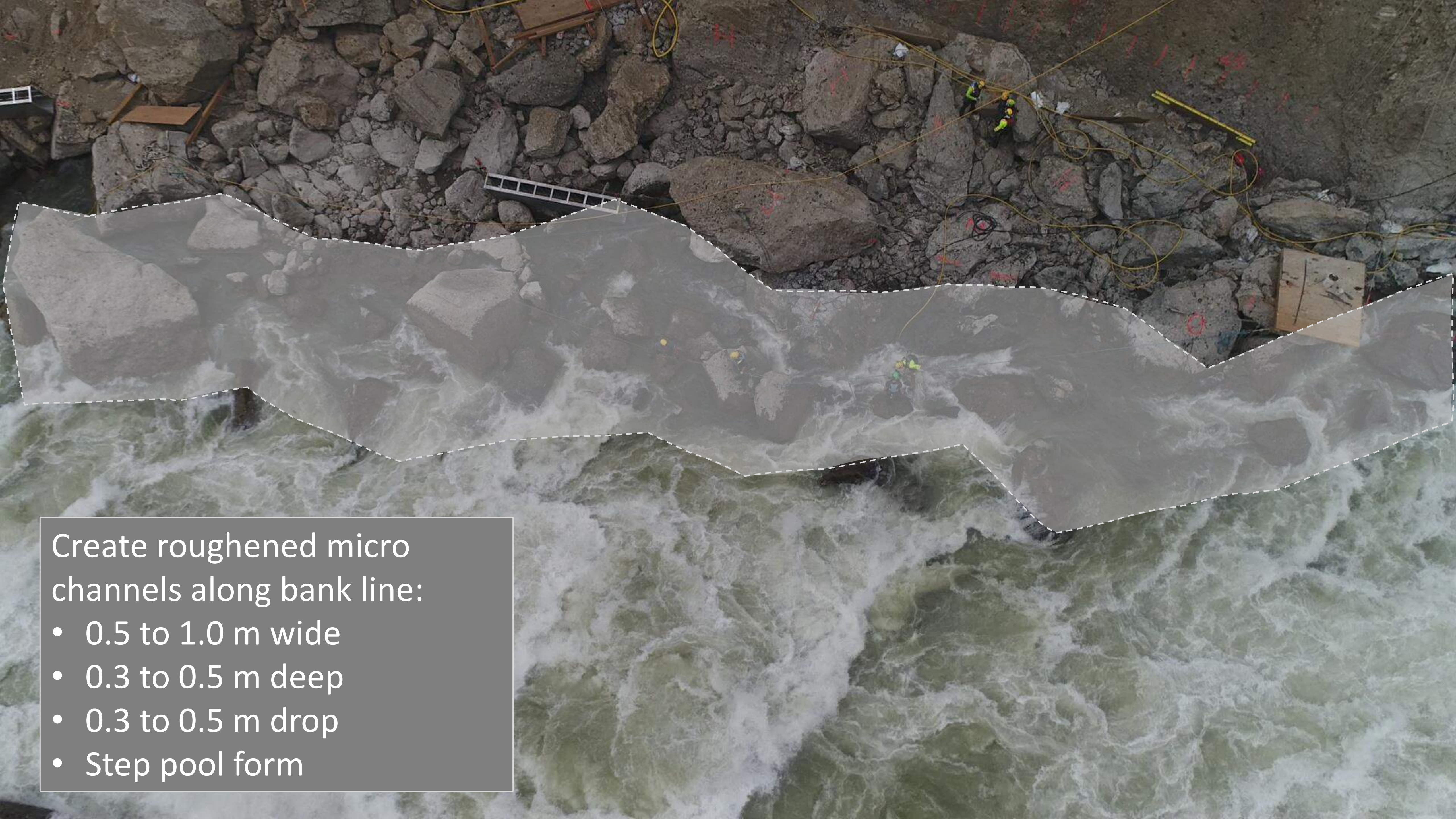




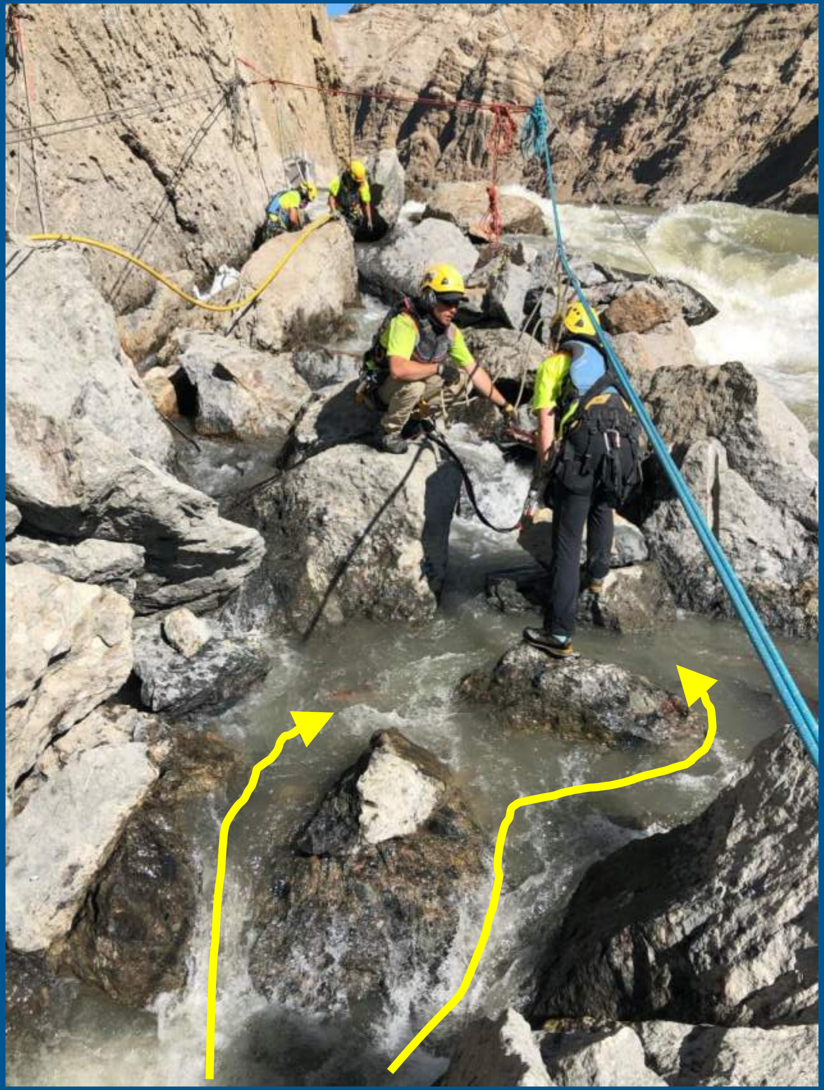
“Old Fashioned” Work

Rock Breaking and Expanding Grout



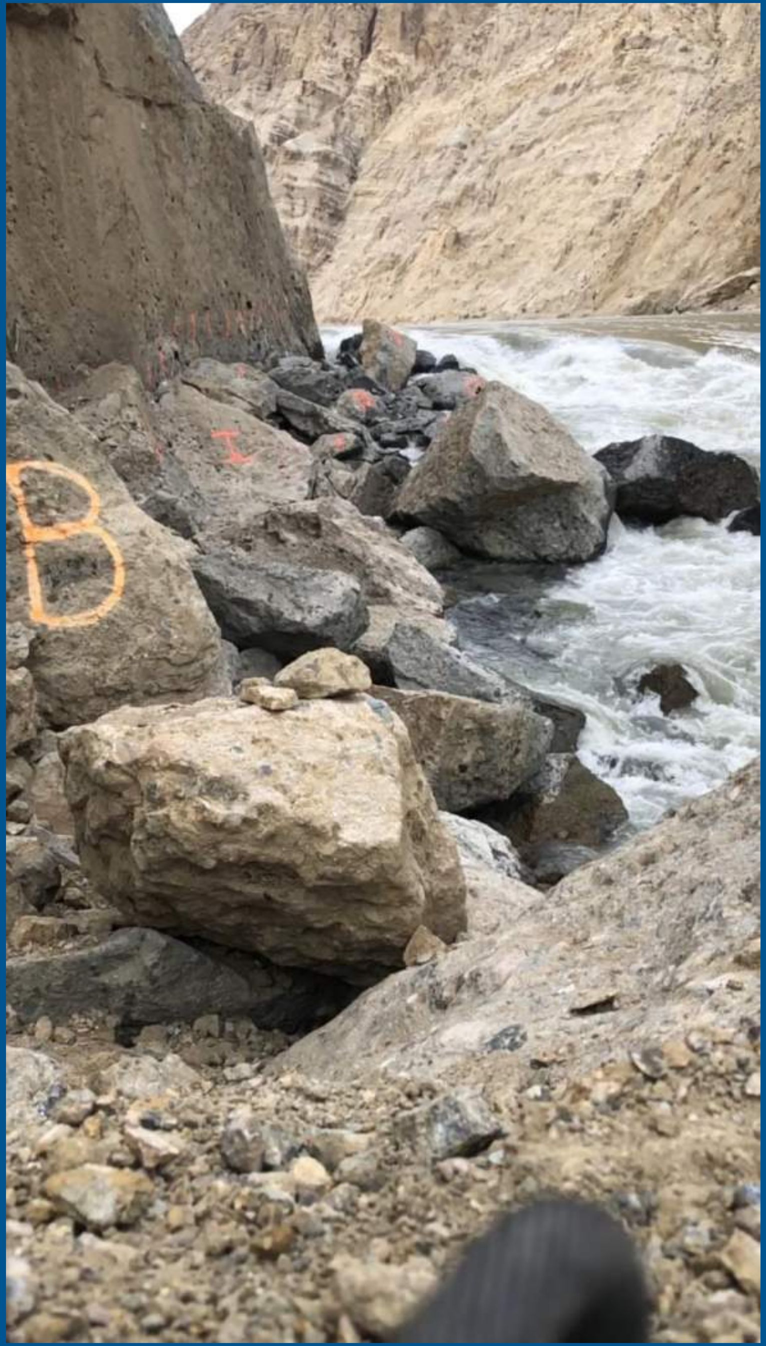

Create roughened micro
channels along bank line:
• 0.5 to 1.0 m wide
• 0.3 to 0.5 m deep
• 0.3 to 0.5 m drop
• Step pool form

Rock Manipulation for Fish Passage



Rock Manipulation for Fish Passage

Rock “Manipulation” for Fish Passage



Monitoring and Assessment

Daily video and still imaging

Real-time upstream and downstream water level measurements

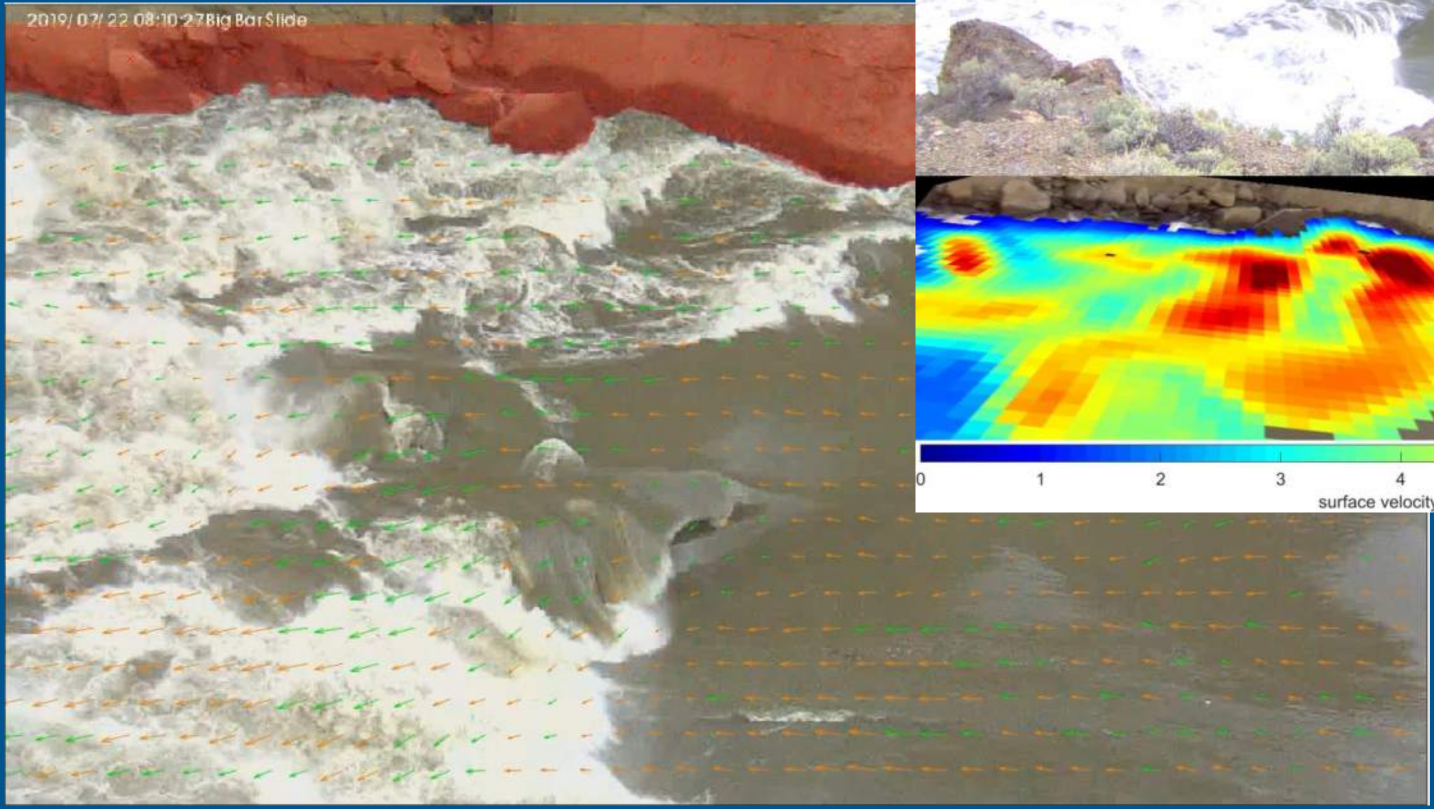
RTK UAV imaging

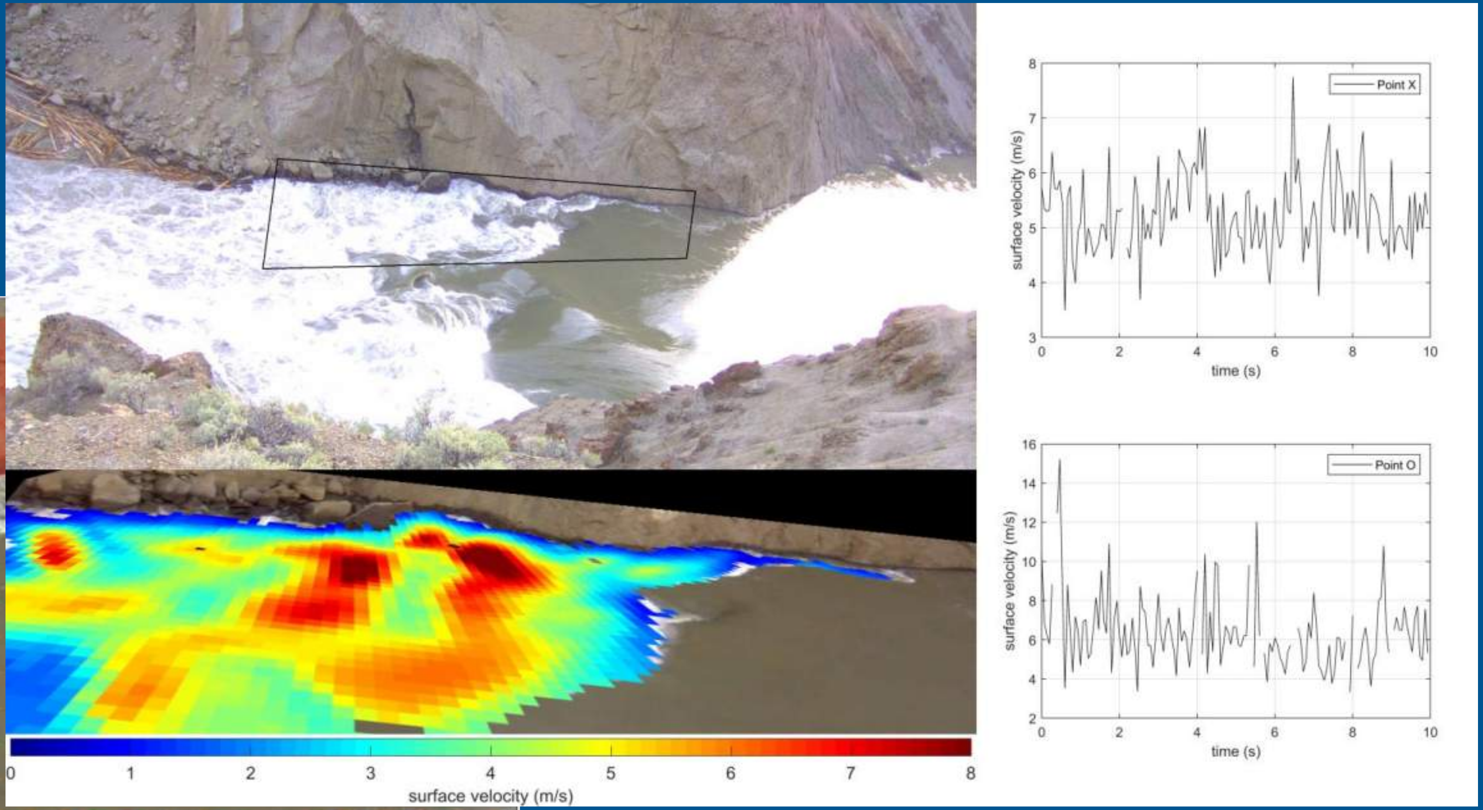
Terrestrial LIDAR

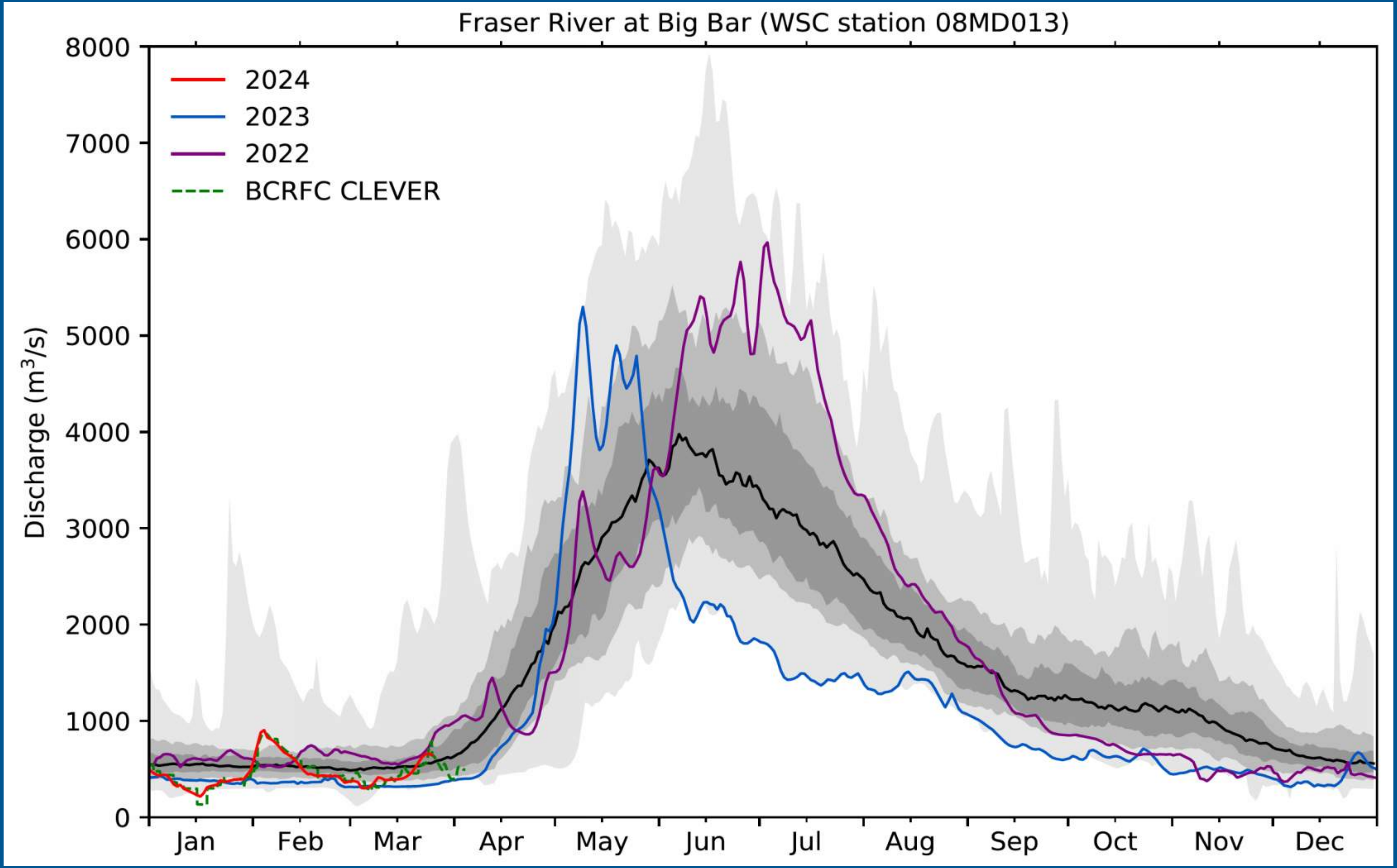
Re-established *WSC 08MD013* Fraser River at Big Bar

Hydroclimate Station

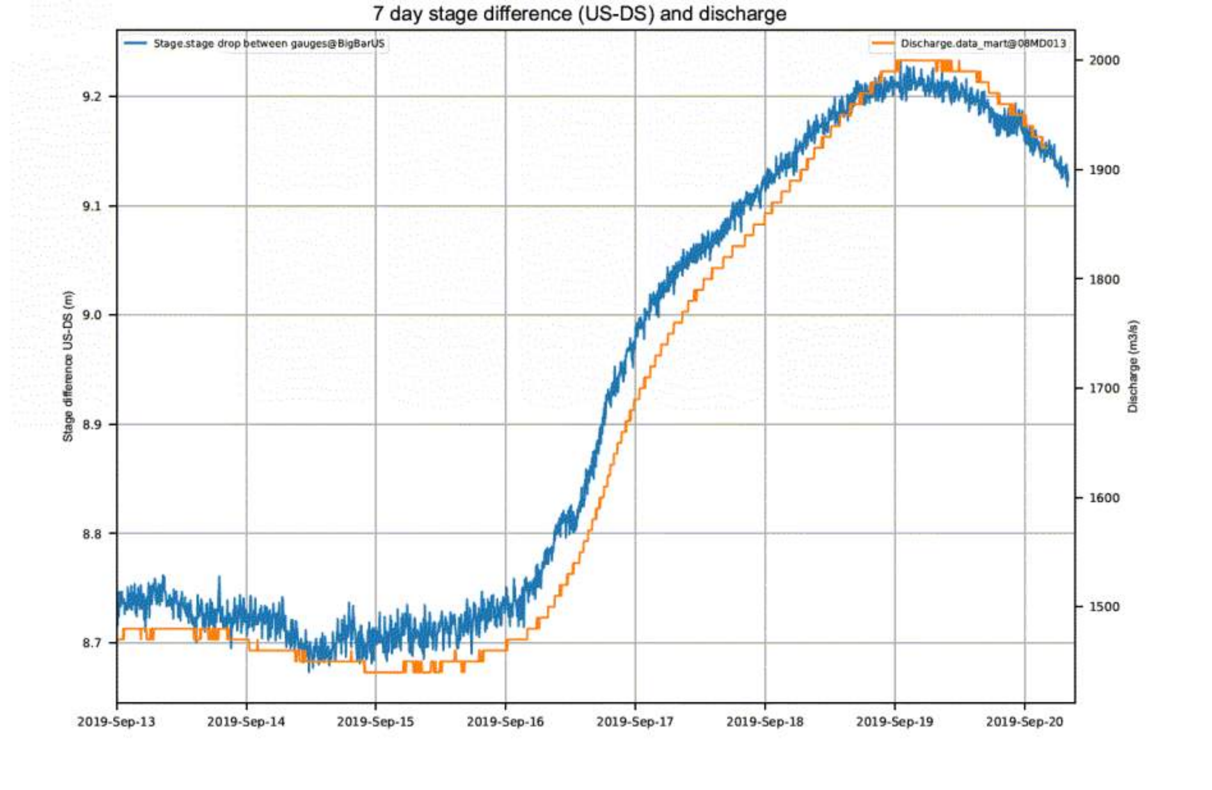
Particle Image Velocimetry

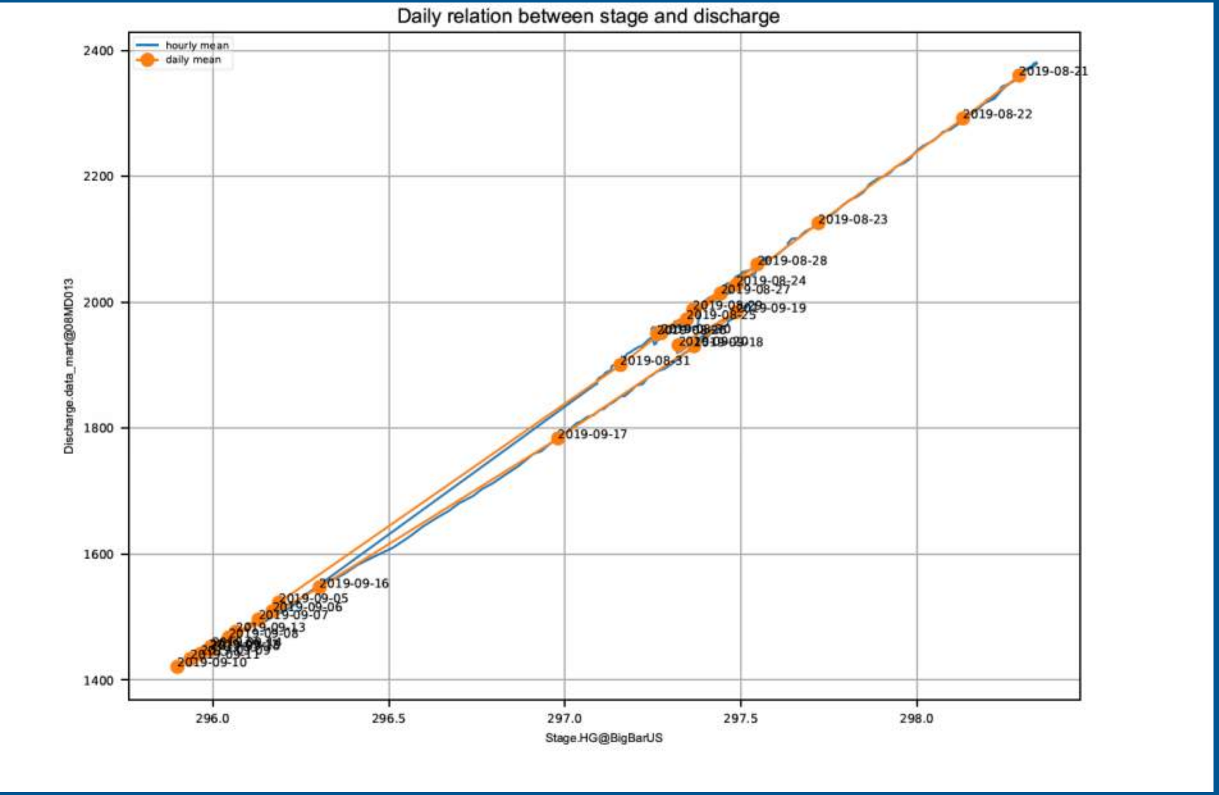





Fraser River at Big Bar (WSC station 08MD013)
Discharge (m3/s)
2024
2023
2022
BCRFC CLEVER
8000
7000
6000
5000
4000
3000
2000
1000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Big Bar Hydrometrics





Jul 17th 2019
2,800 m^3/s
99 kcfs

Nov 22th 2019

2,290 m^3/s

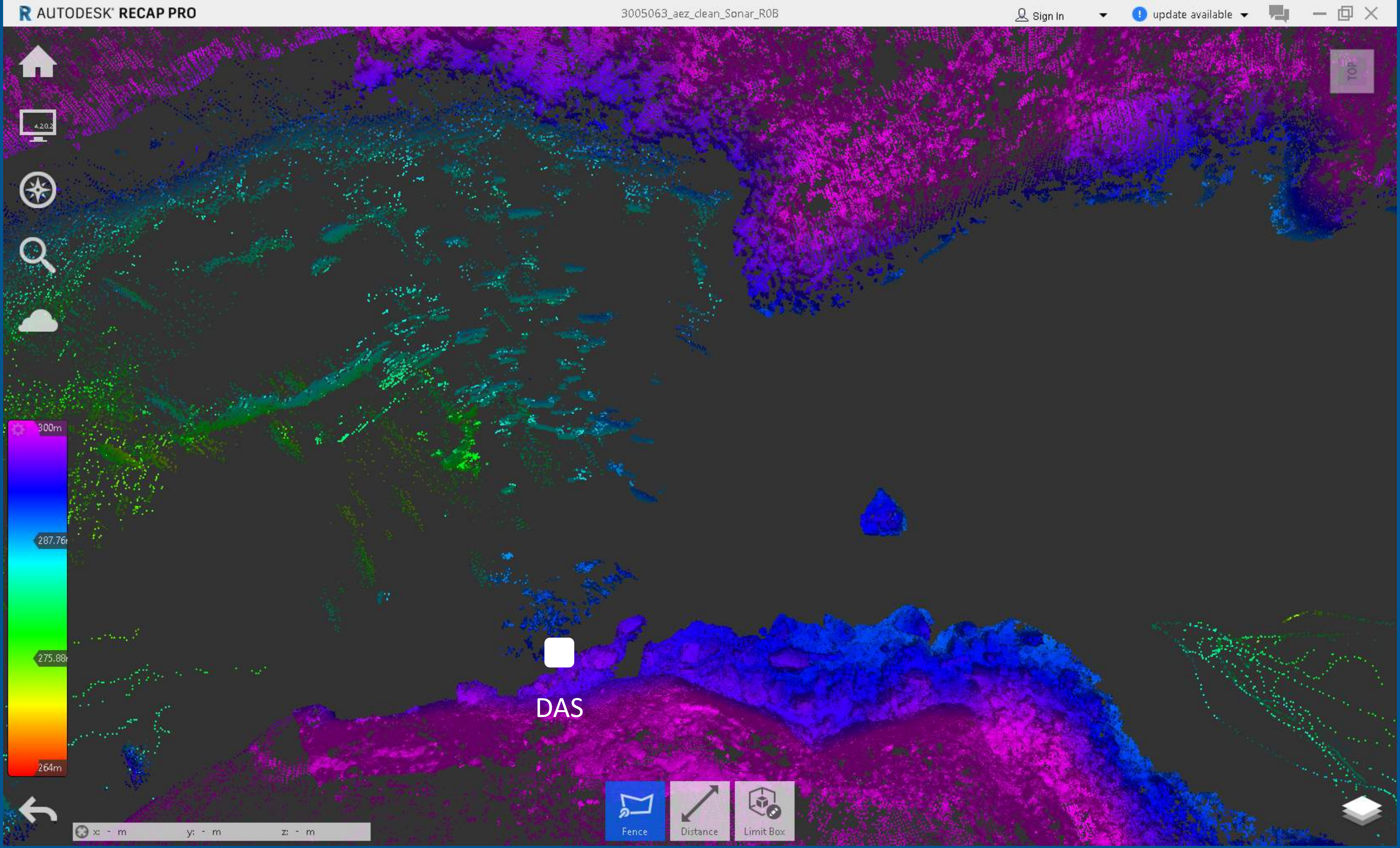
81 kcfs

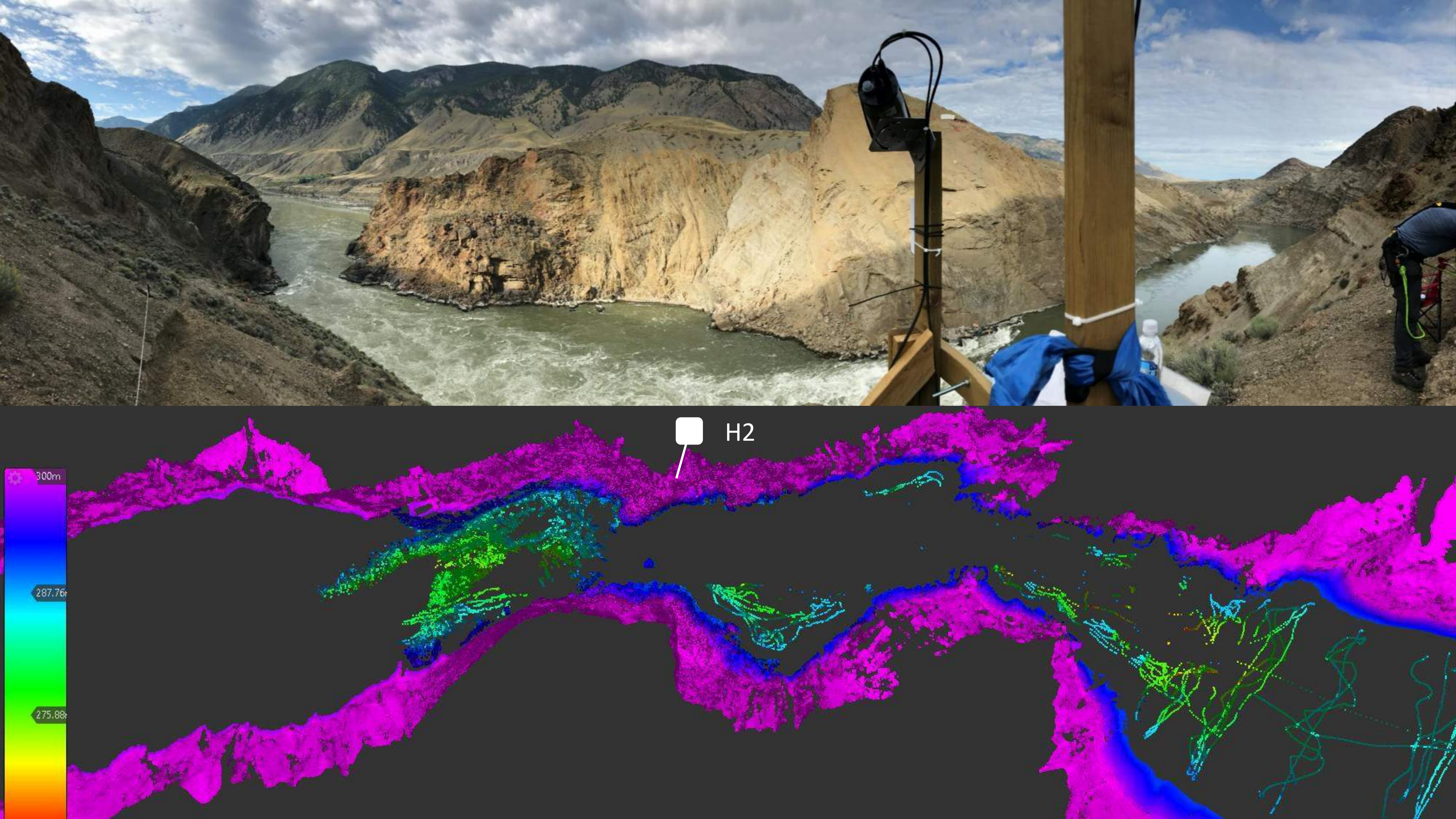
Jan 16th 2020
536 m^3/s
19 kcfs

Bathymetry

Bathymetry data below high water to assess slide rock fill

Challenges of safe access, aeration and limits of technology


AUTODESK RECAP PRO
3005063_aez_clean_Sonar_R0B
Sign In
update available
300m
287.76
275.88
264m
DAS
Fence
Distance
Limit Box
TOP


H2
300m
287.76
275.88

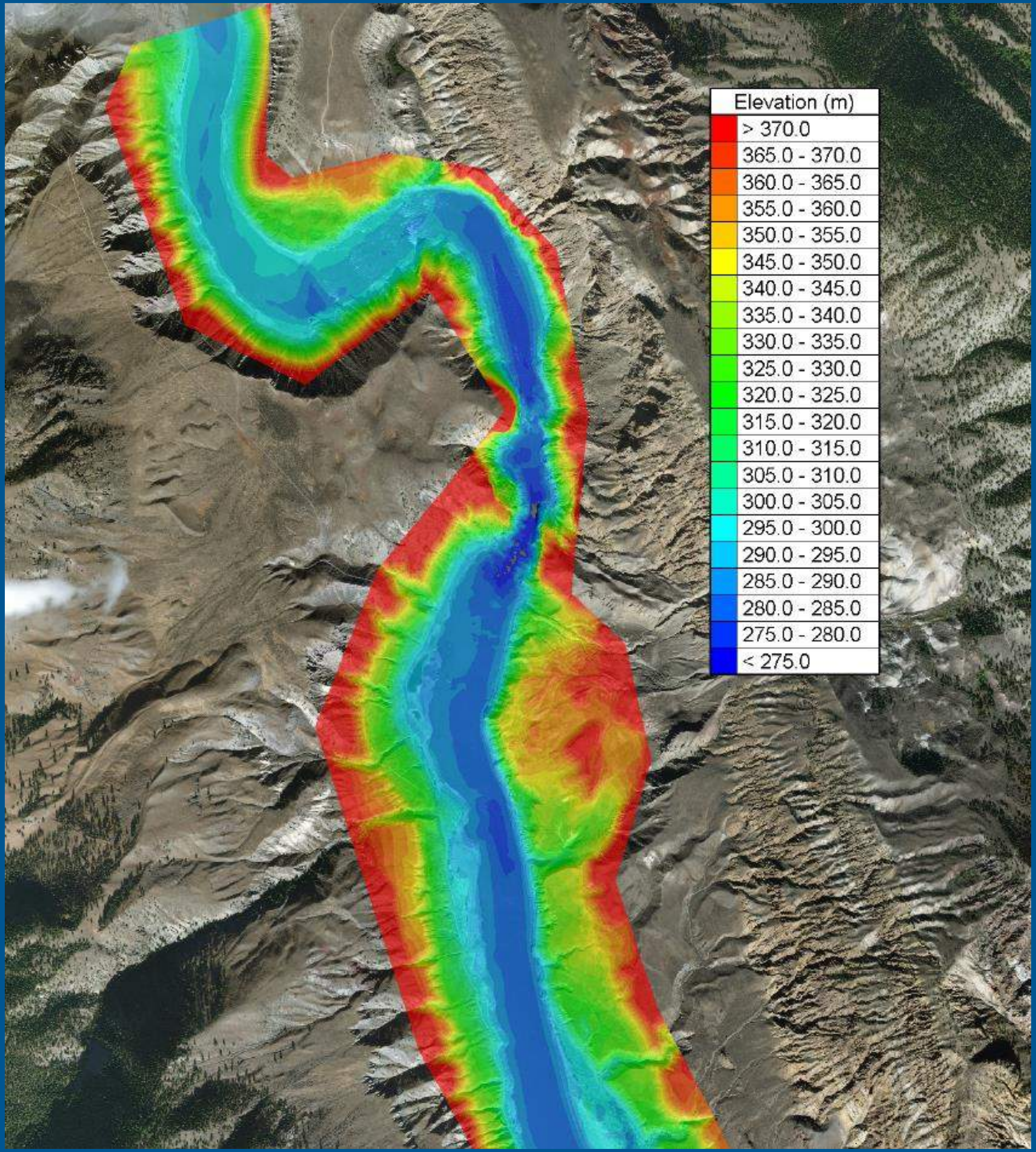
Hydraulic Modelling

Compiled a preliminary DEM

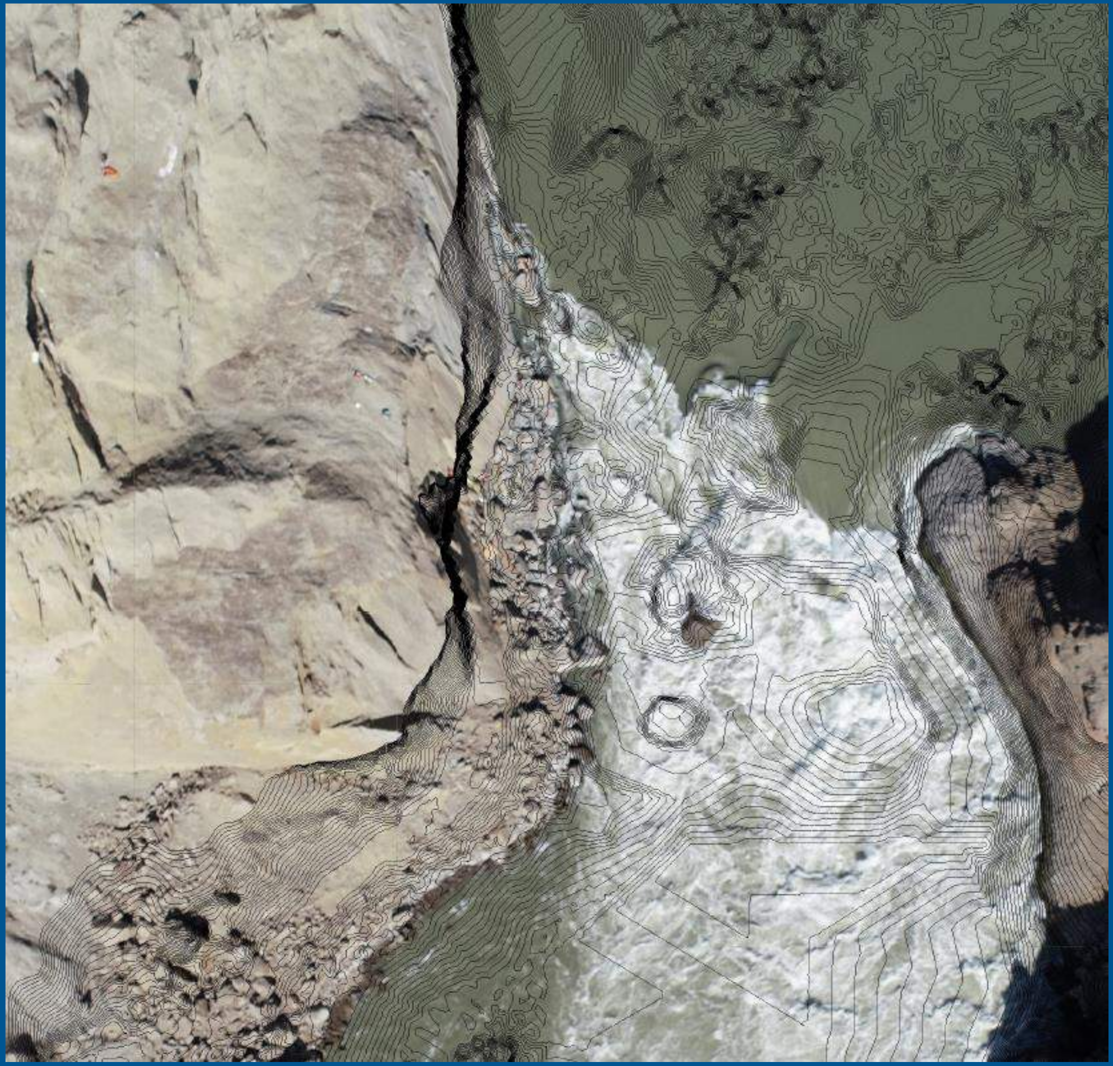
Value of a Geomatics Engineer

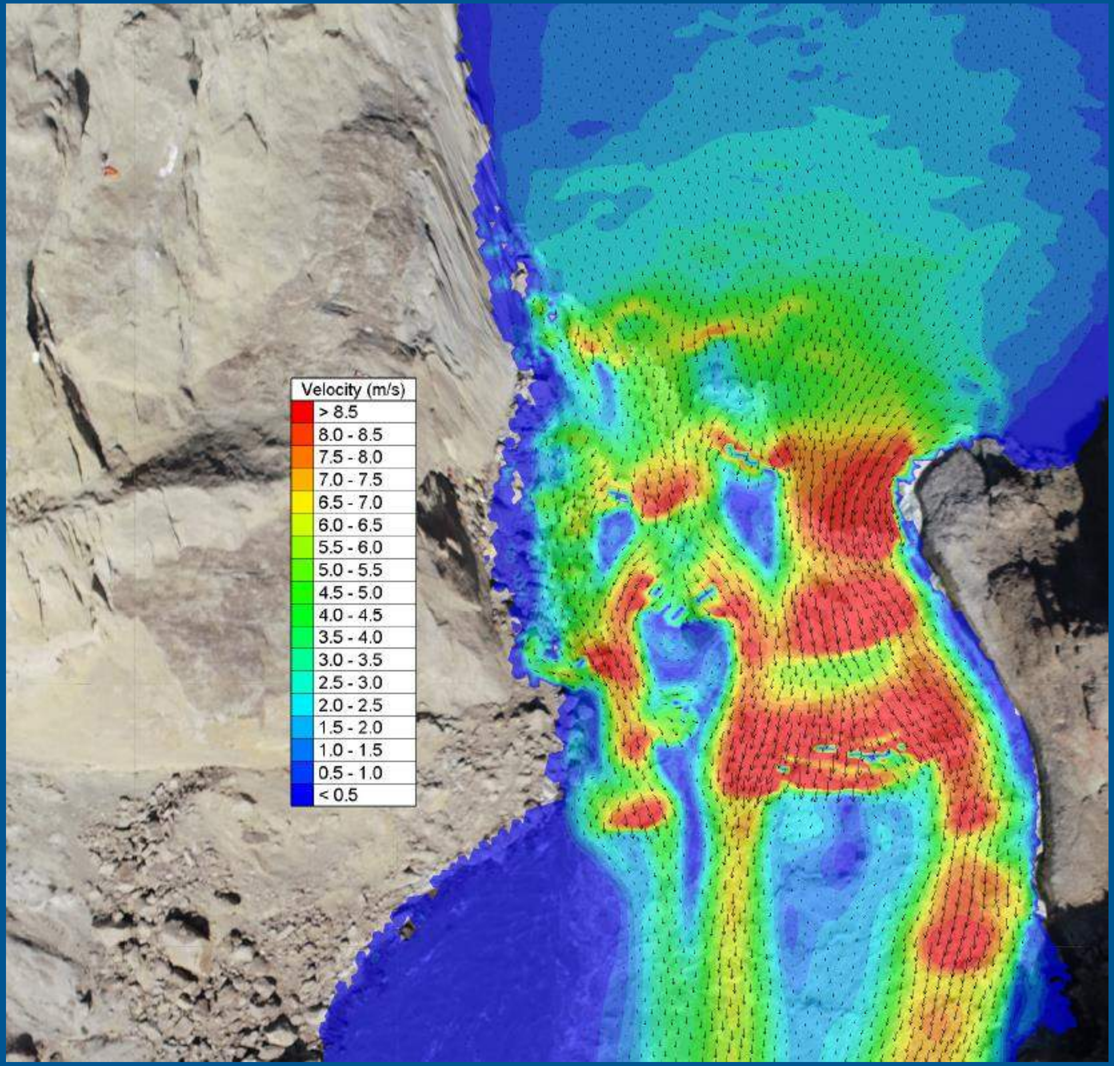
TELEMAC 2D hydraulic modelling to look at effects of rock removal

- large-scale side rock removal
- Key large boulders
- Slide crest

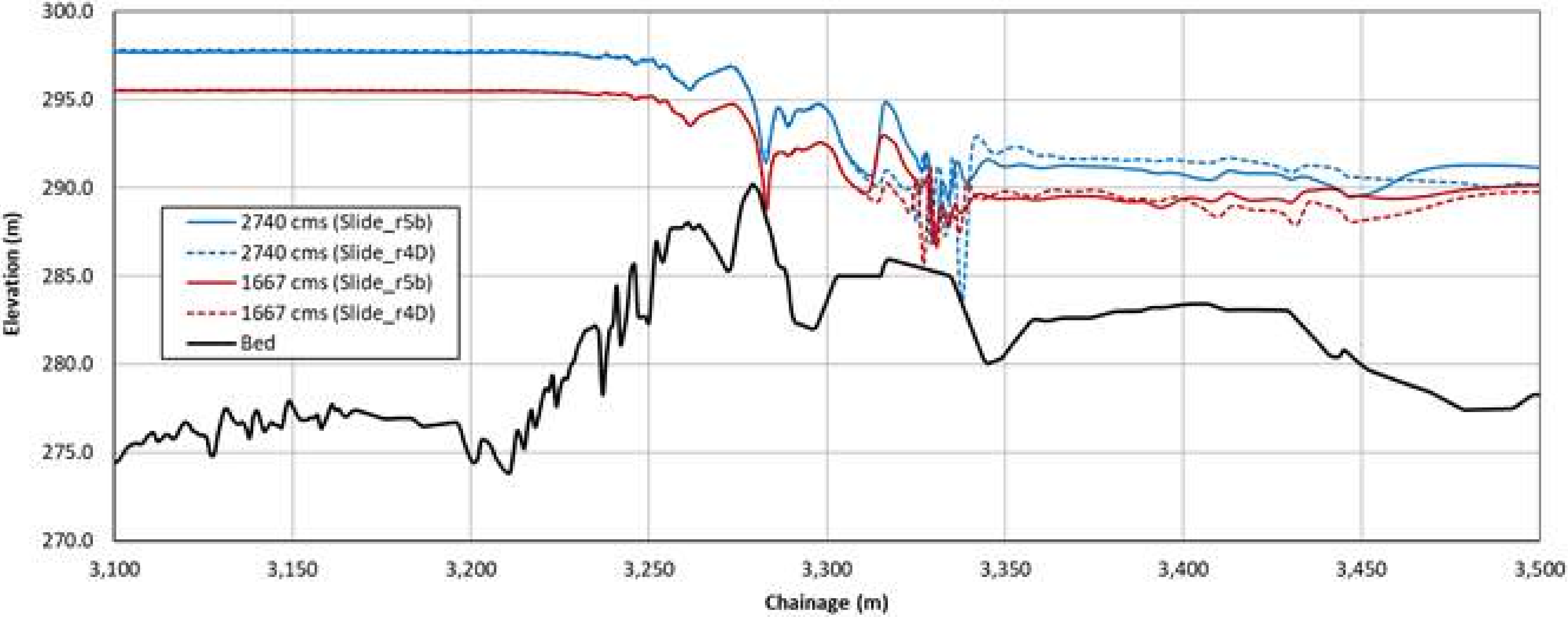


Hydraulic Modeling





Slide Hydraulics



But what were the Fish telling us?

Observed Fish Movement

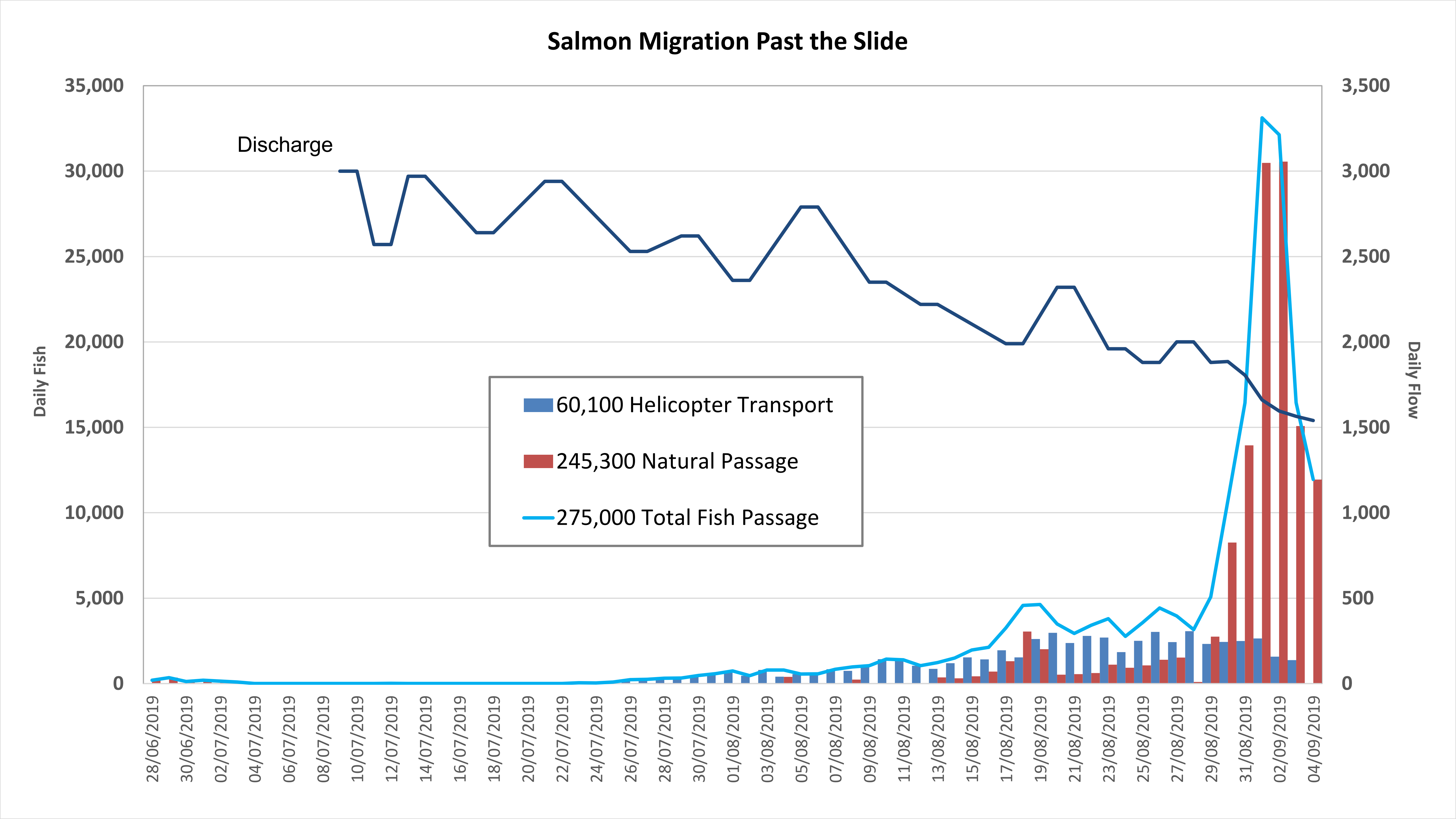
Active
- Cycling
- Resting

Milling
- Zombie Mode

Fall-back

Dispersal

The fish were not happy fish…



Salmon Migration Past the Slide
Discharge
60,100 Helicopter Transport
245,300 Natural Passage
275,000 Total Fish Passage
Daily Fish
Daily Flow
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
3,500
3,000
2,500
2,000
1,500
1,000
500
0
28/06/2019
30/06/2019
02/07/2019
04/07/2019
06/07/2019
08/07/2019
10/07/2019
12/07/2019
14/07/2019
16/07/2019
18/07/2019
20/07/2019
22/07/2019
24/07/2019
26/07/2019
28/07/2019
30/07/2019
01/08/2019
03/08/2019
05/08/2019
07/08/2019
09/08/2019
11/08/2019
13/08/2019
15/08/2019
17/08/2019
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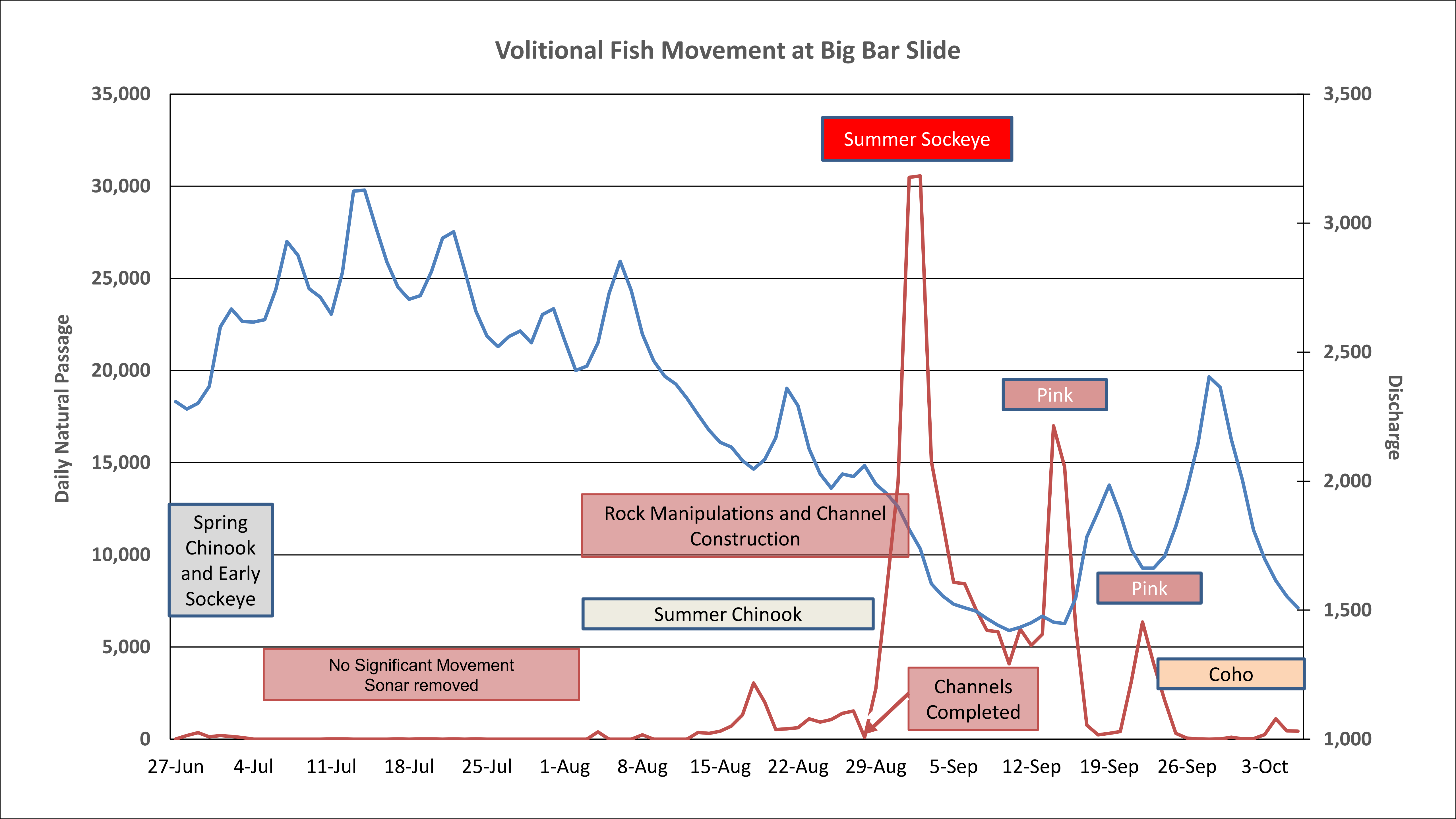
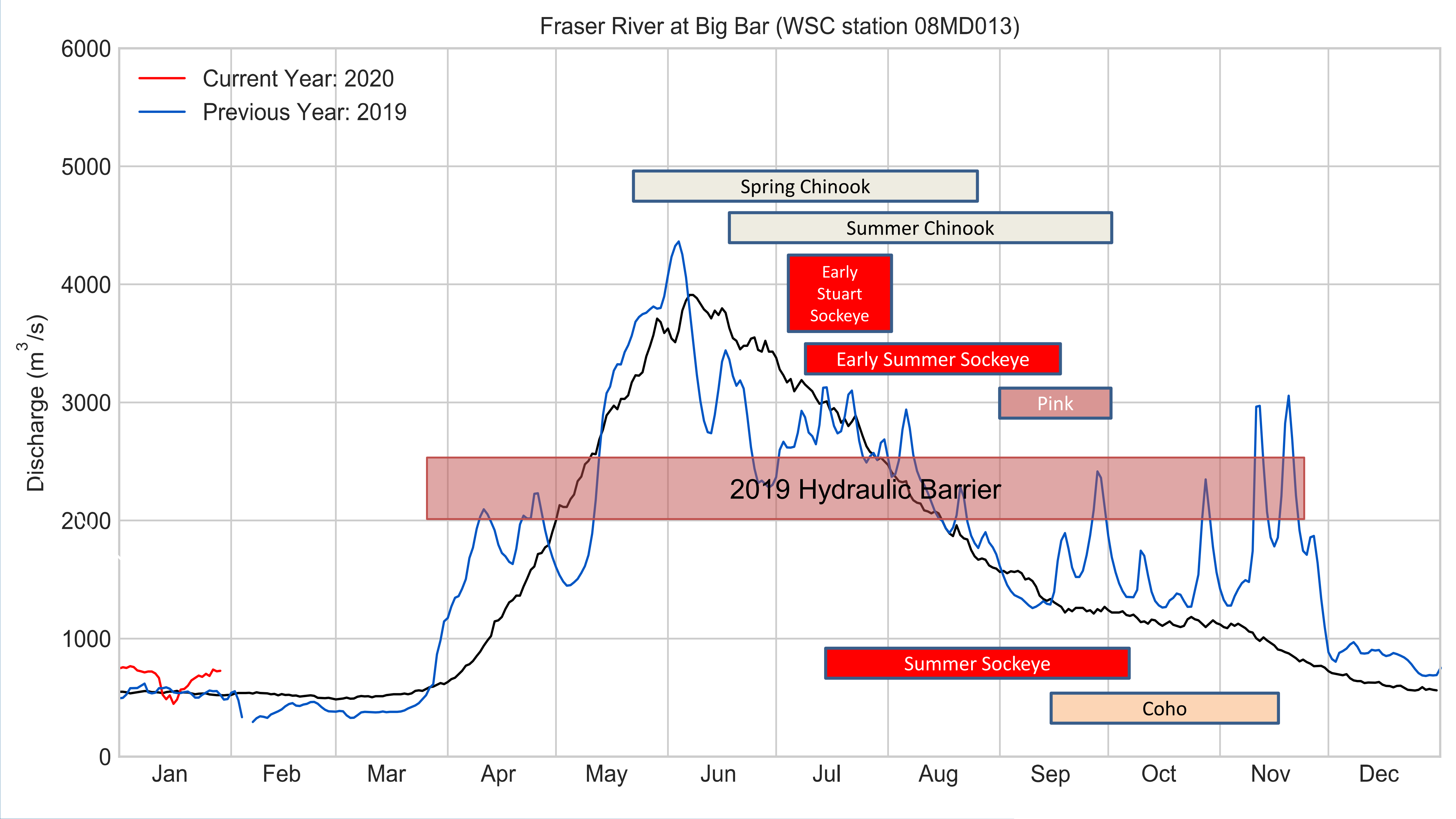
02/09/2019
04/09/2019



Volitional Fish Movement at Big Bar Slide
Daily Natural Passage
Discharge
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
3,500
3,000
2,500
2,000
1,500
1,000
27-Jun
4-Jul
11-Jul
18-Jul
25-Jul
1-Aug
8-Aug
15-Aug
22-Aug
29-Aug
5-Sep
12-Sep
19-Sep
26-Sep
3-Oct
Summer Sockeye
Pink
Pink
Coho
Spring Chinook and Early Sockeye
Rock Manipulations and Channel Construction
Summer Chinook
No Significant Movement
Sonar removed
Channels Completed



Fraser River at Big Bar (WSC station 08MD013)
Current Year: 2020
Previous Year: 2019
Discharge (m^3/s)
6000
5000
4000
3000
2000
1000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Spring Chinook
Summer Chinook
Early Stuart Sockeye
Early Summer Sockeye
Pink
2019 Hydraulic Barrier
Summer Sockeye
Coho

Significant Losses of Fish to Spawning Grounds

Spring Chinook

- Many rivers with 0 to 10 spawners, few with 50 or more

Early Stuart Sockeye

- 26,000 entered the Fraser Canyon
- Less than 100 fish on the spawning grounds

Summer Chinook

- Better than spring runs
- Some rivers with 2,000 fish

Impacts beyond the Fraser River

It is not likely possible to remove all the rock in the river.

Volitional fish movement is now a function of Fraser River hydrology and freshet timing.

There is a meaningful chance of extinction for:

- Early Stuart Sockeye
- Mid Fraser and Upper Fraser Spring Chinook.

Massive negative implications to Fraser Salmon.

Bookend Mitigation Options

Action:		Reaction:
Don’t remove additional slide rock	→	Prepare site and build a technical fishway
Remove industry-accessible rock and reduce the size of the slide impact	→	Maximize natural fish passage and minimize fishway structure need
Remove all the rock to completely mitigate impact of slide on river hydraulics	→	Completely restore natural volitional passage

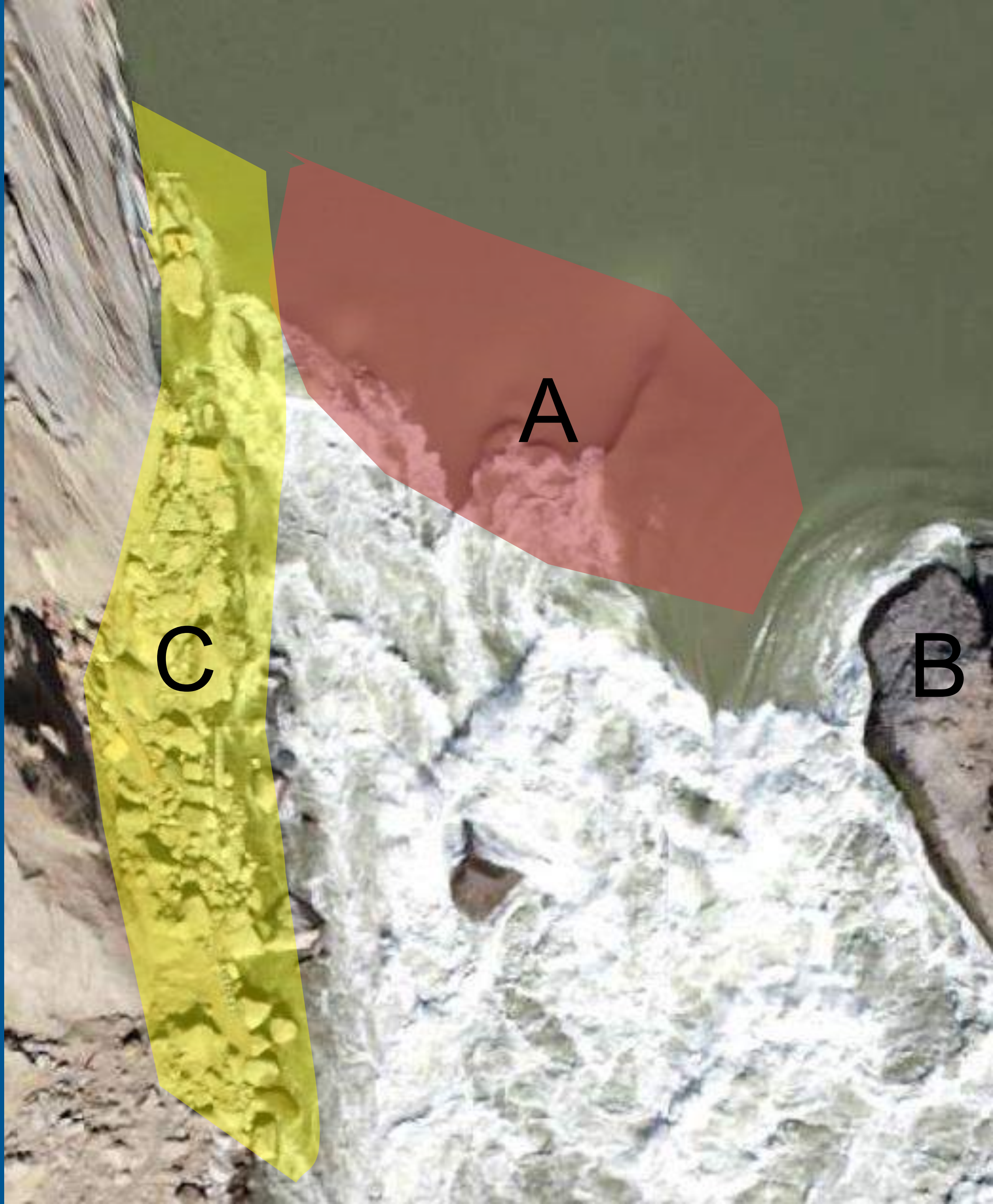
2020 Winter Work Program

Mobilizing to remove rock during seasonal low flows

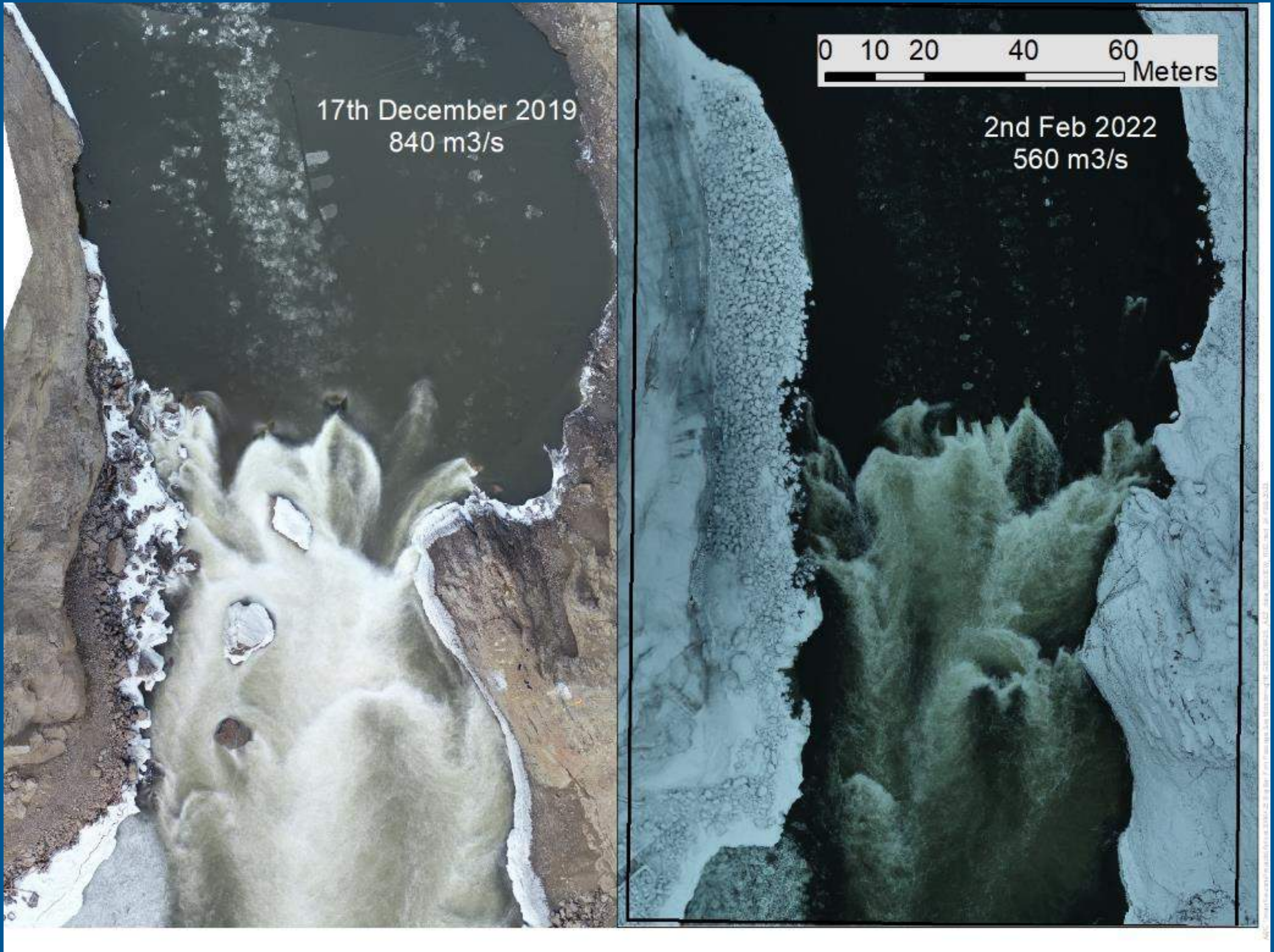
A. Remove Slide crest

B. Remove East toe

C. Modify West Bank



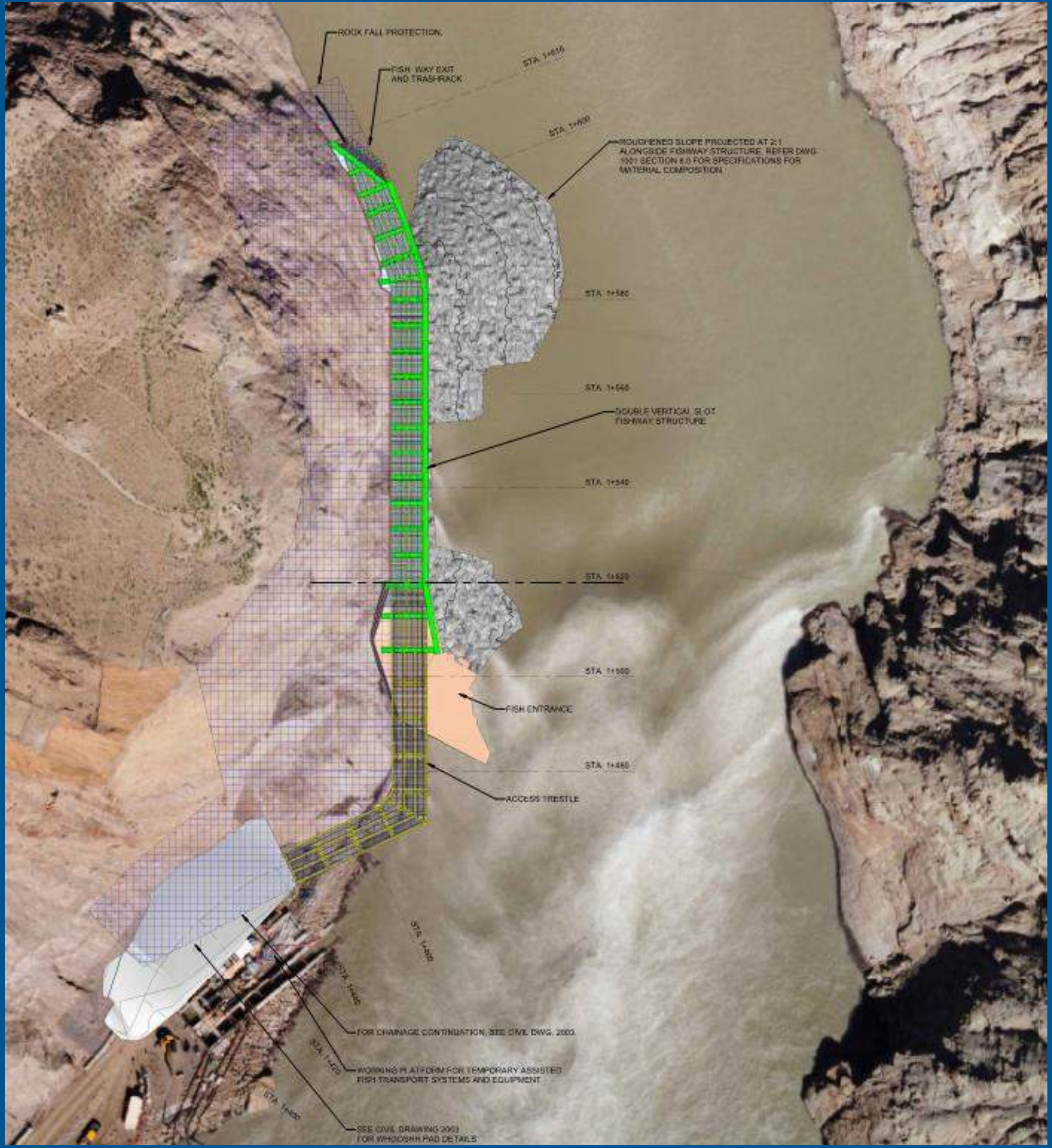
Work completed: 2020 East Toe Removal



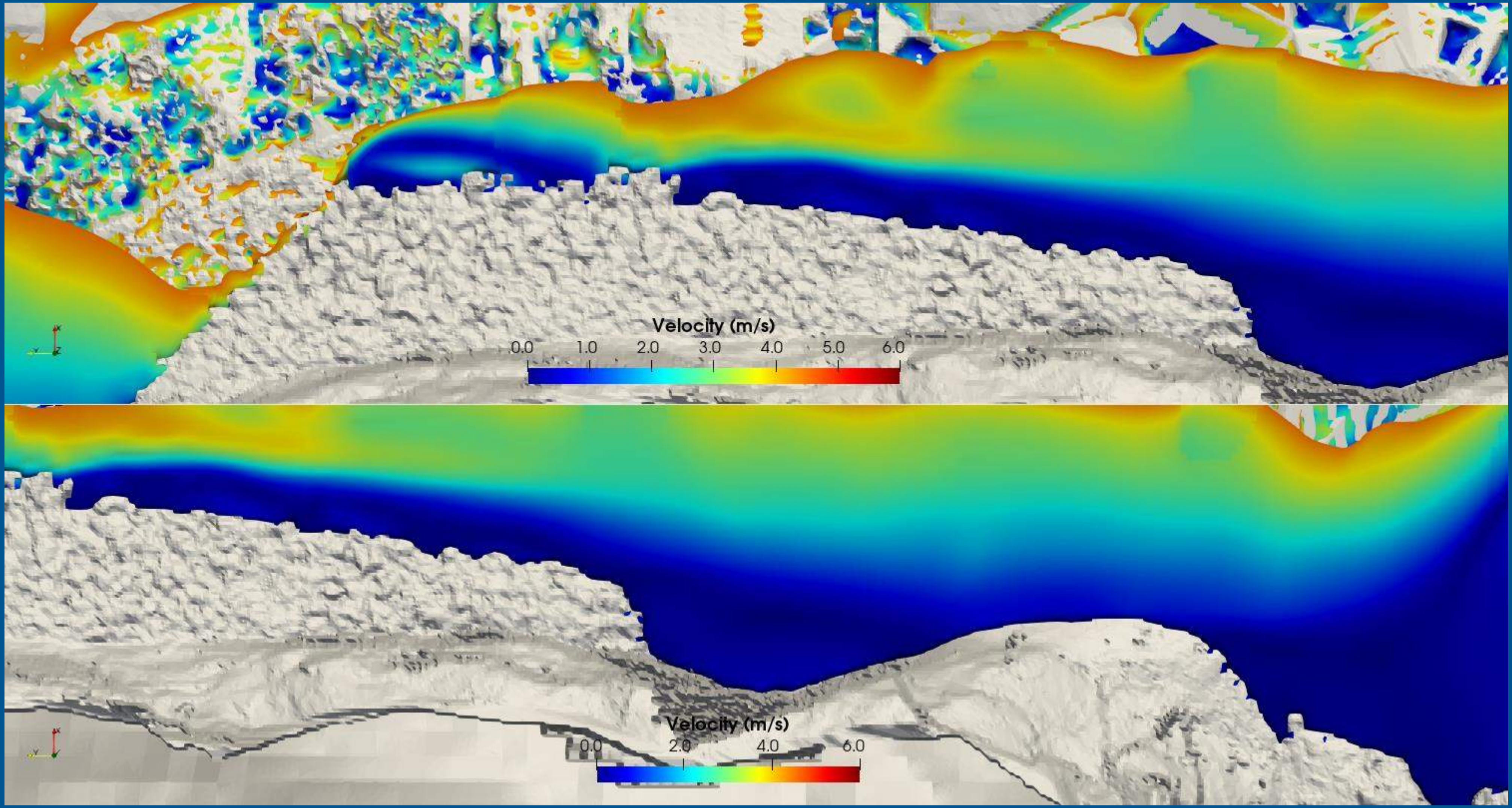
17th December 2019
840 m3/s
0 10 20 40 60
Meters
2nd Feb 2022
560 m3/s

Fish Passage Planning

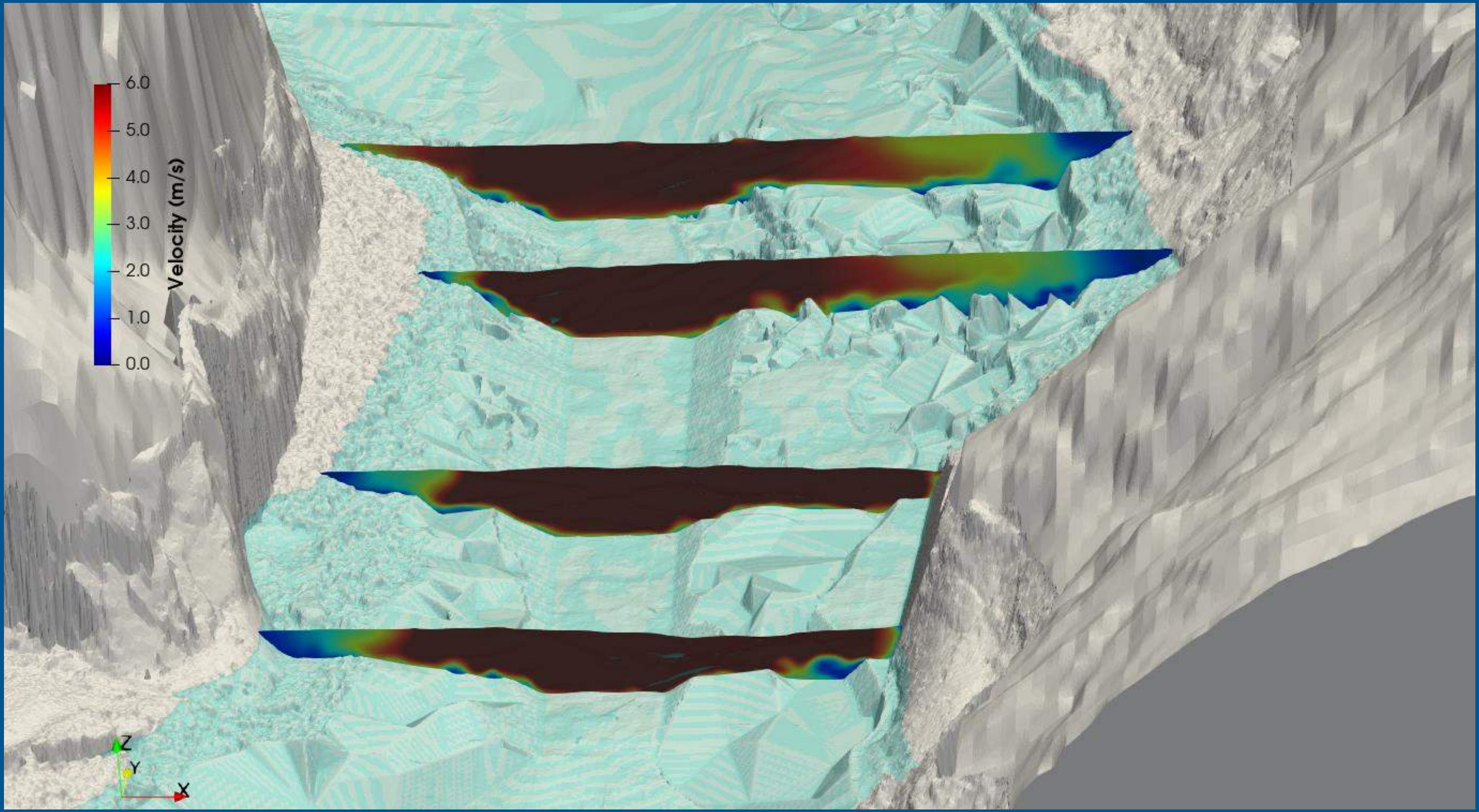
1. Volitional (non-directive)
   - In-River Roughened Slope
   - Technical Vertical Slot Fishway
2. Non-volitional / Assisted
   - Whoosh Trail
   - Fish Passage during construction



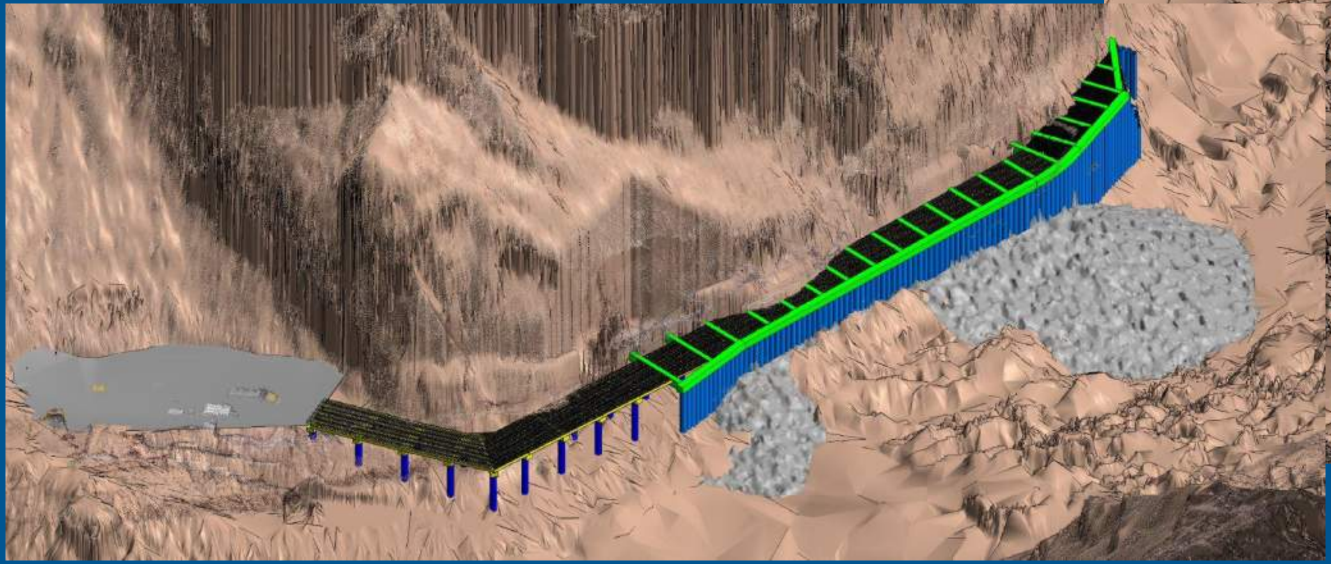
MOD 4 – 3,500 cms

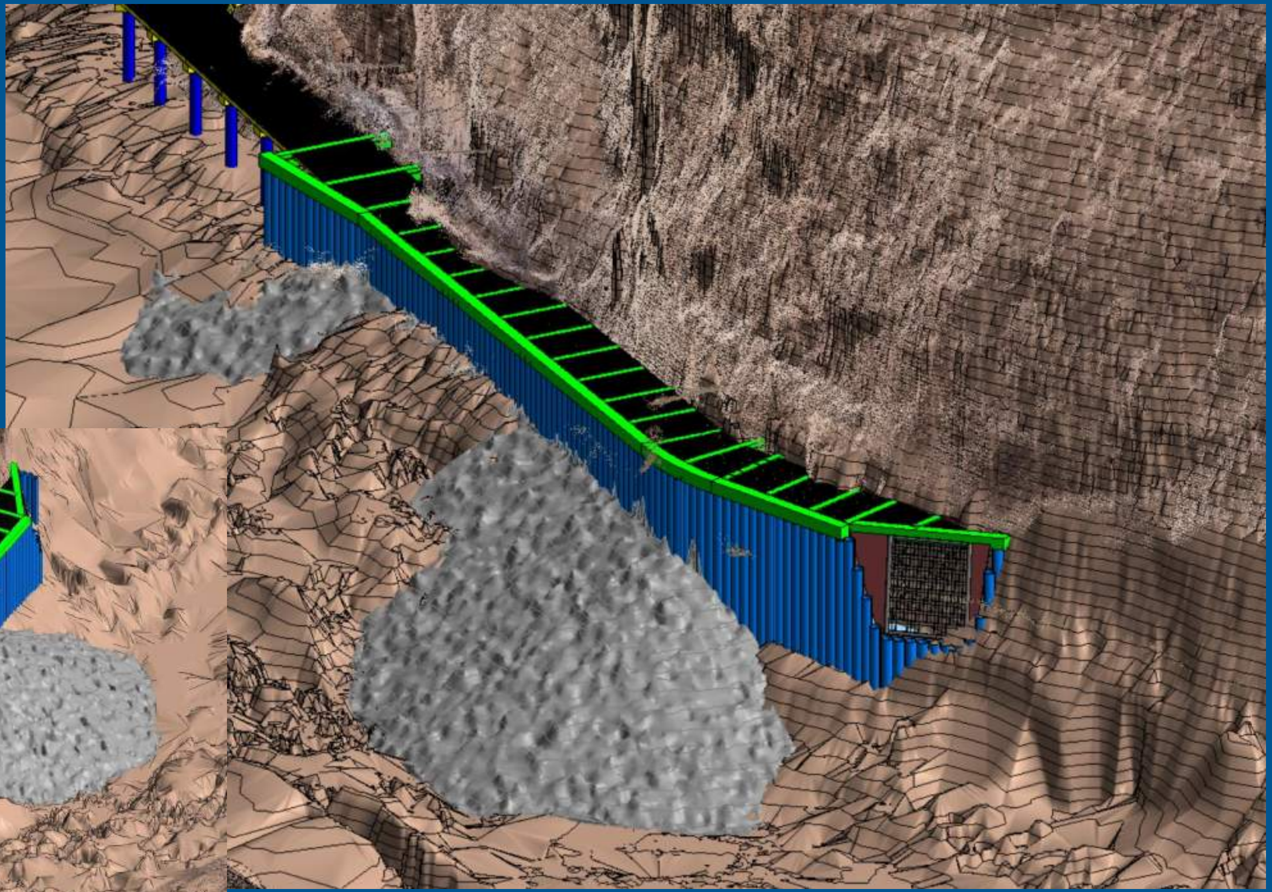


MOD 4 - 3,500 cms



Planned Vertical Slot Fishway



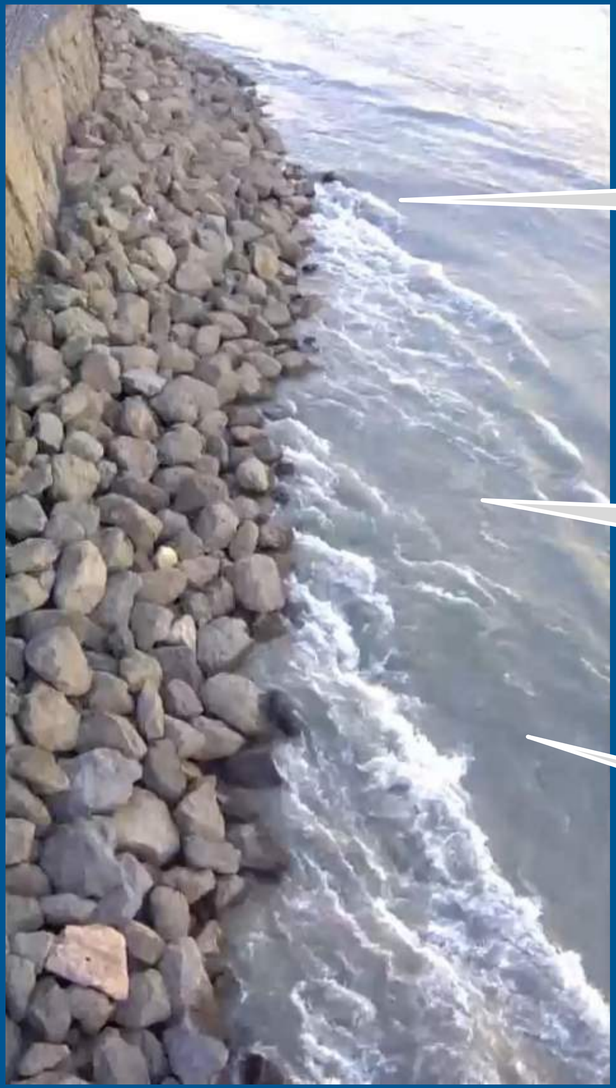


Work completed: 2021 Bench

2020 flow conditions at 2,500 m^3/s

2021 NLFW build

2022 at 2,500 m^3/s zoomed in



Small vertical hydraulic separations

NLF roughness creates slower hindered flow zone along edge

distributed hydraulic drop over length of NLF

2022 at 2500 m^3/s zoomed in

Work completed: River rock removal with ‘fingers’

Current Conditions

GIF


Total Counted: 1127
Since Oct 27, 2022
Remained In place: 1097
Moved: 29
New: 1
Green = Remained in place
Black = Moved
Red = New
October 27, 2022
Discharge: ~ 600 m3/s

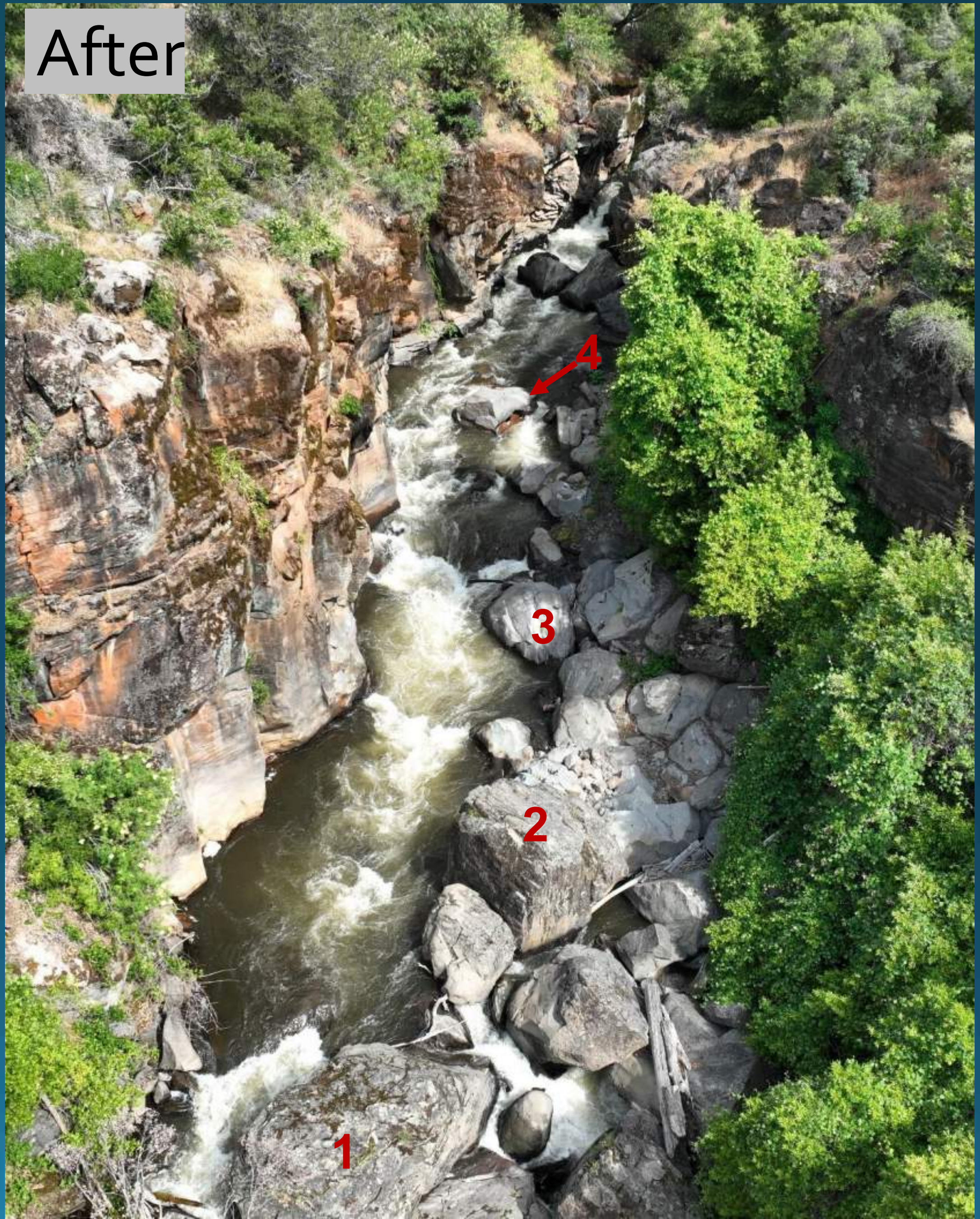
NLF Project Spotlight:

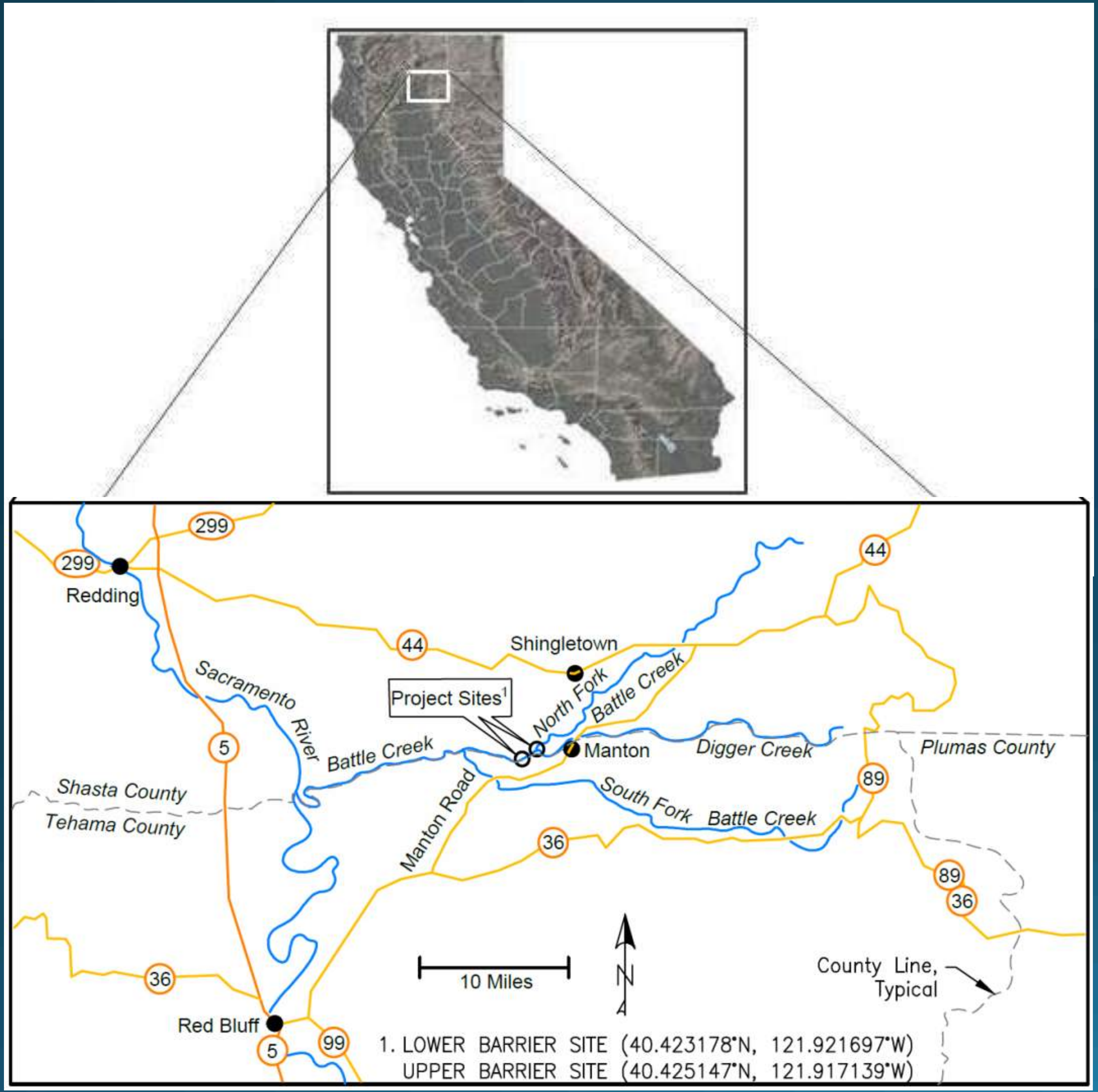
North Fork Battle Creek, Eagle Canyon Natural Barrier Modification Manton, CA

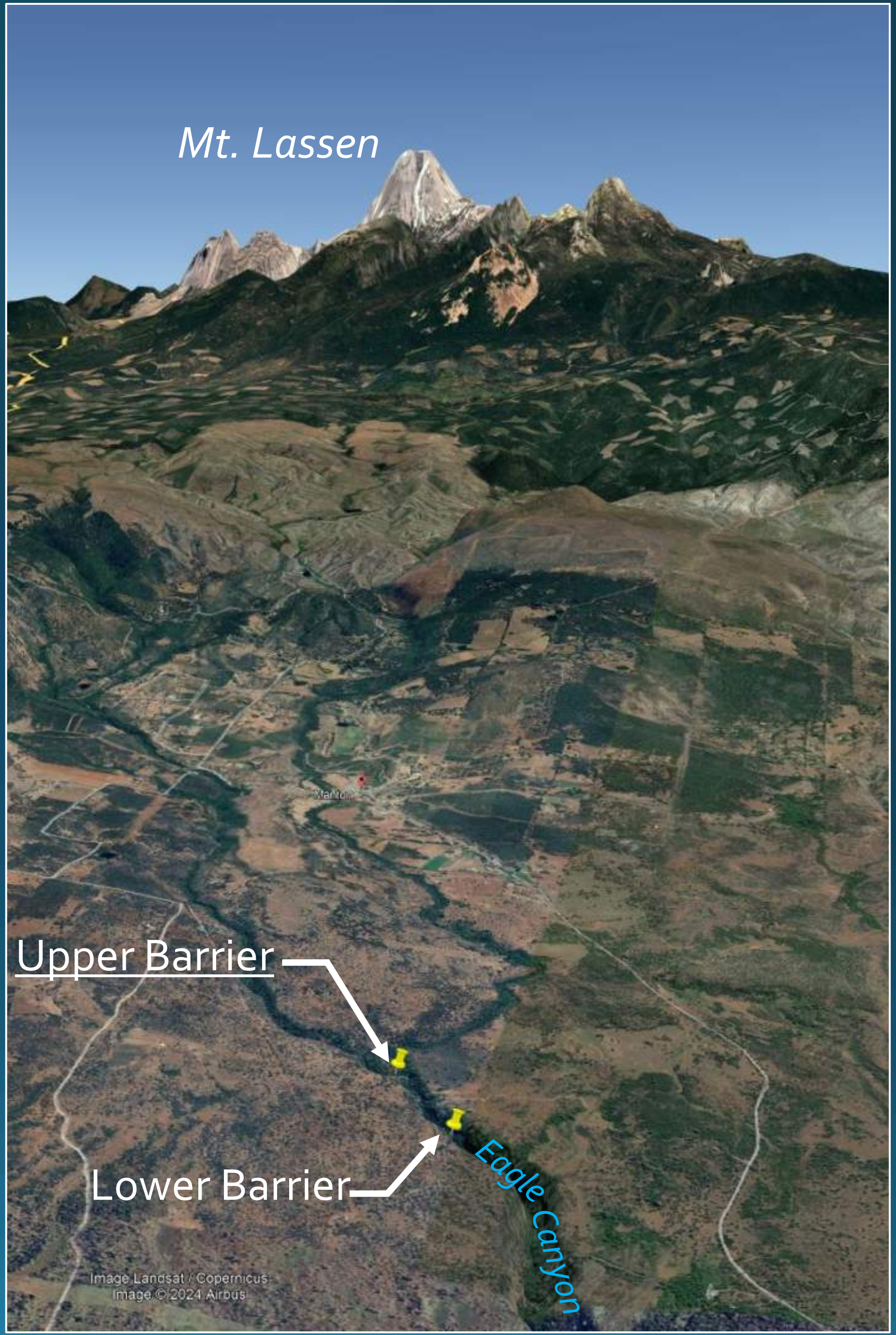
By: Michael Love

3/27/2024

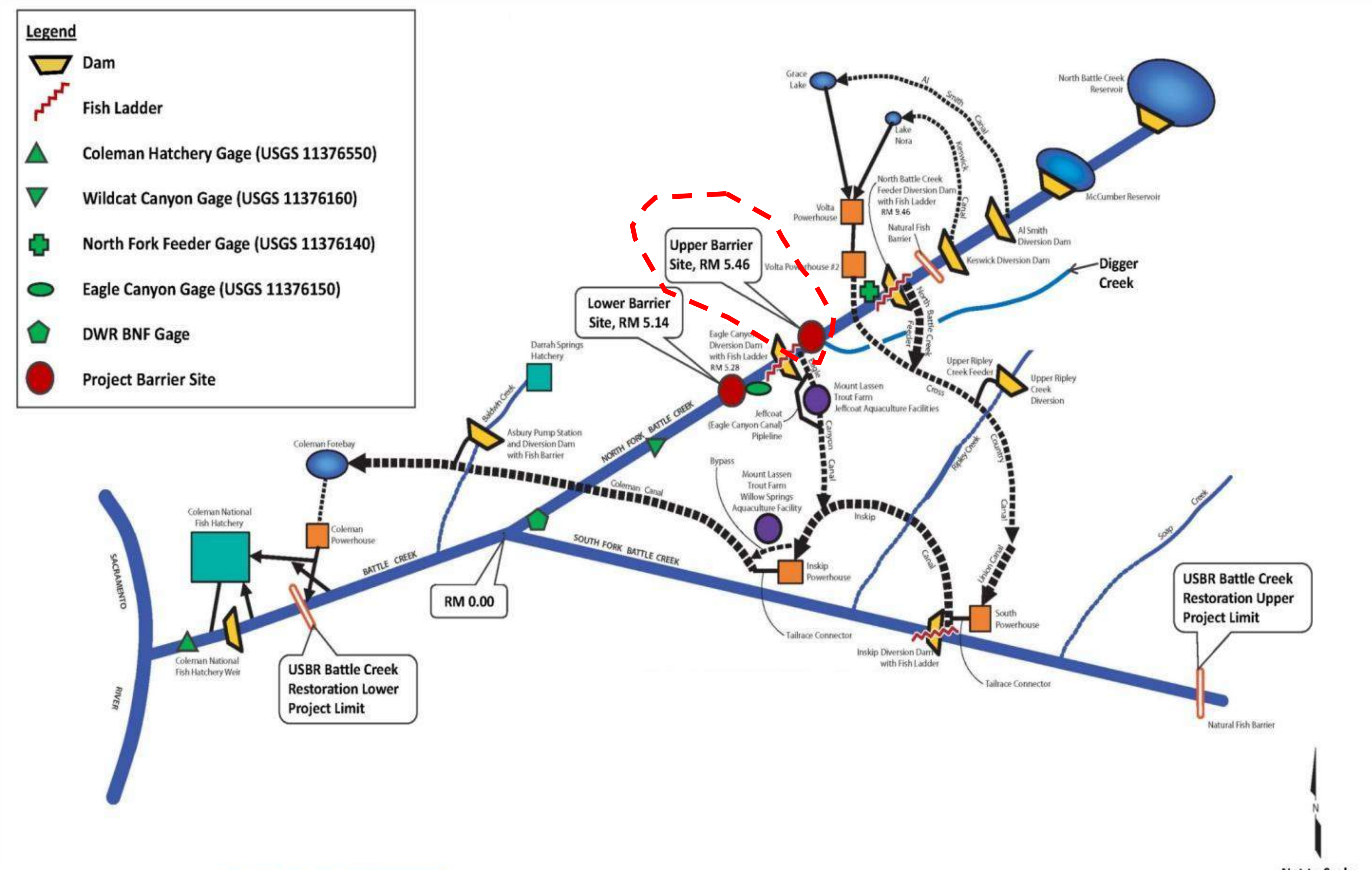
Eagle Canyon Upper Barrier Modifications




299
299
Redding
44
44
Shingletown
Sacramento River
North Fork Battle Creek
Project Sites[1]
Battle Creek
Manton
Digger Creek
Plumas County
5
Shasta County
Tehama County
Manton Road
South Fork Battle Creek
89
36
89
36
36
10 Miles
N
County Line, Typical
Red Bluff
5
99
1. LOWER BARRIER SITE (40.423178°N, 121.921697°W)
UPPER BARRIER SITE (40.425147°N, 121.917139°W)


Mt. Lassen
Upper Barrier
Lower Barrier
Eagle Canyon
Image Landsat / Copernicus
Image © 2024 Airbus

Battle Creek Hydropower Schematic with Lower and Upper Barriers

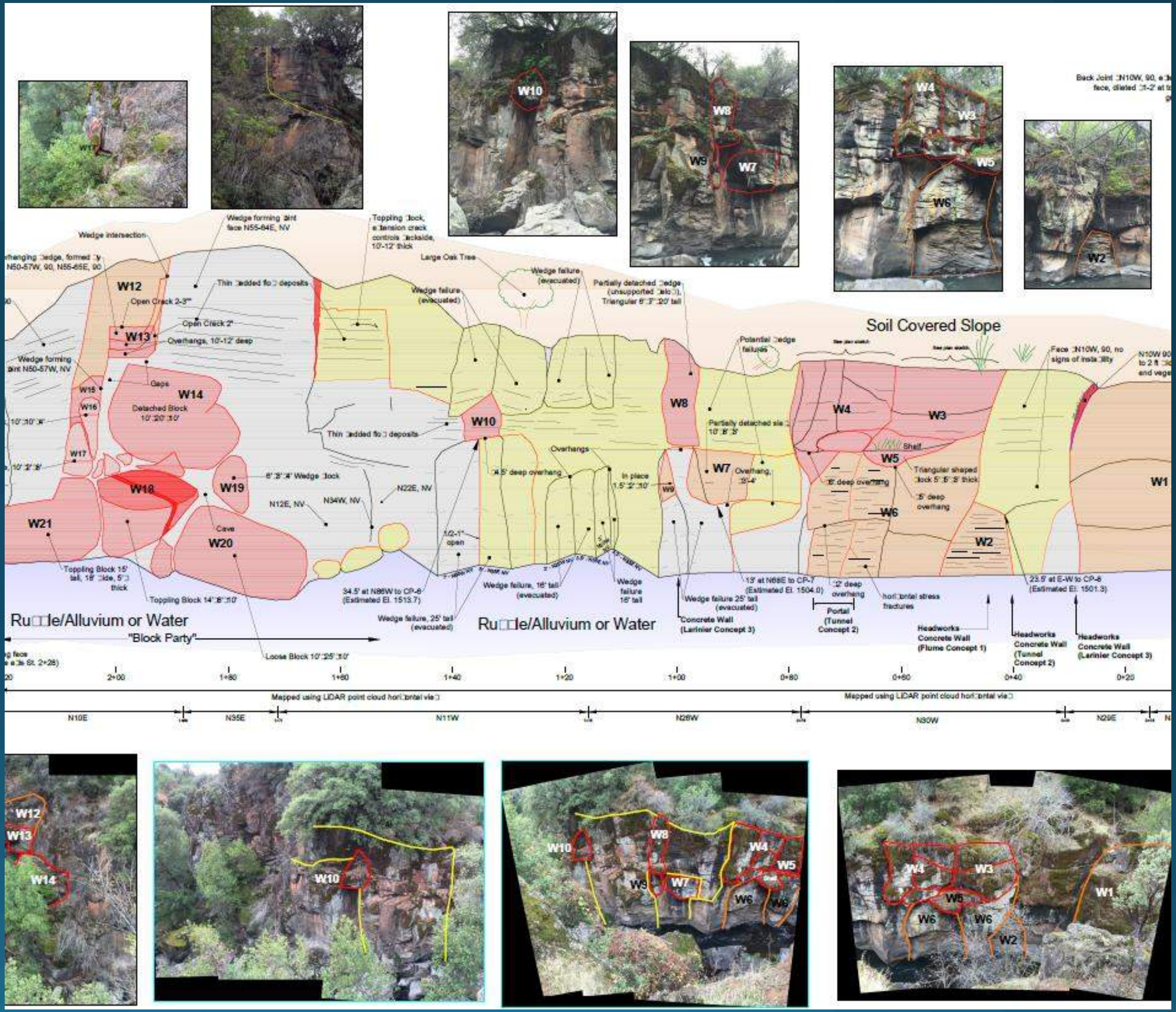


Based on map obtained from USBR (2015): http://www.battle-creek.net/restoration.html

Design Overview

Site Characterizations

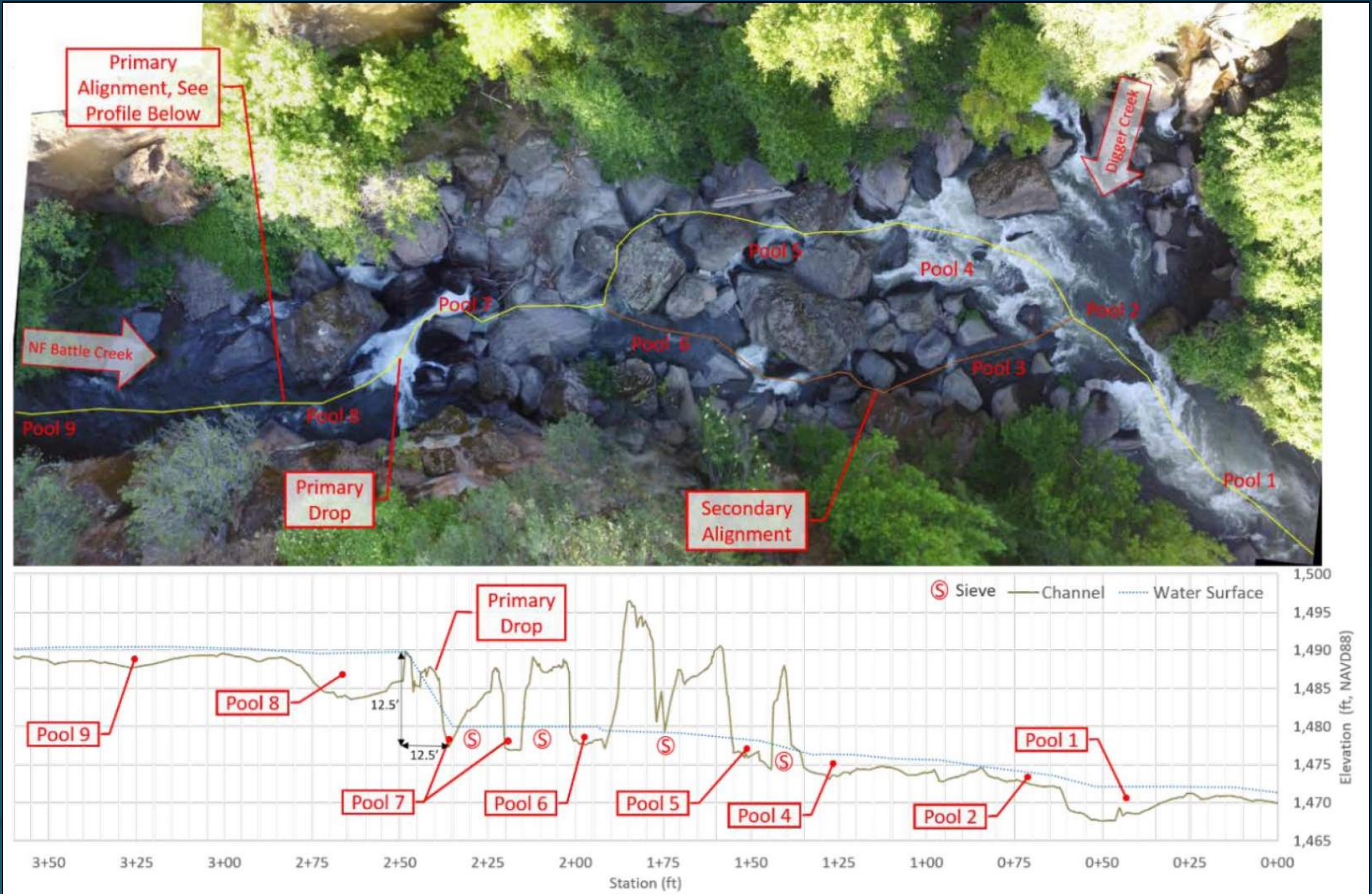
- Survey (total station, sonar, laser scan)
- Geotechnical investigation
- Boulder mapping
- Flow lines mapping
- Sieve mapping
- Pressure transducers
- Timelapse cameras
- Flow measurements



Geologic Mapping of Canyon Wall
By Cotton, Shires and Associates

Scan point cloud

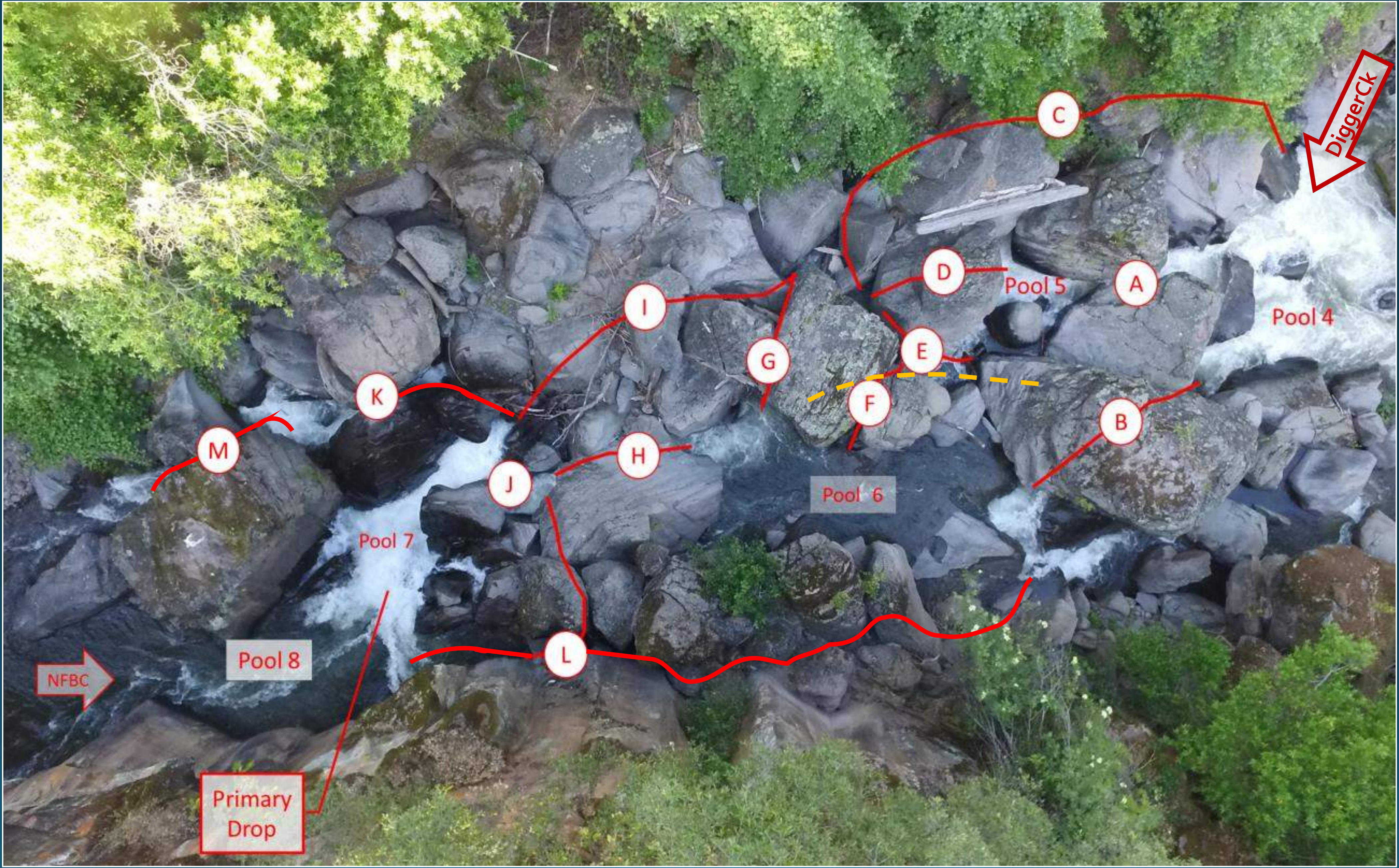
Upper Barrier Site Profile



Primary Drop

- 12.5 ft
- No pool below

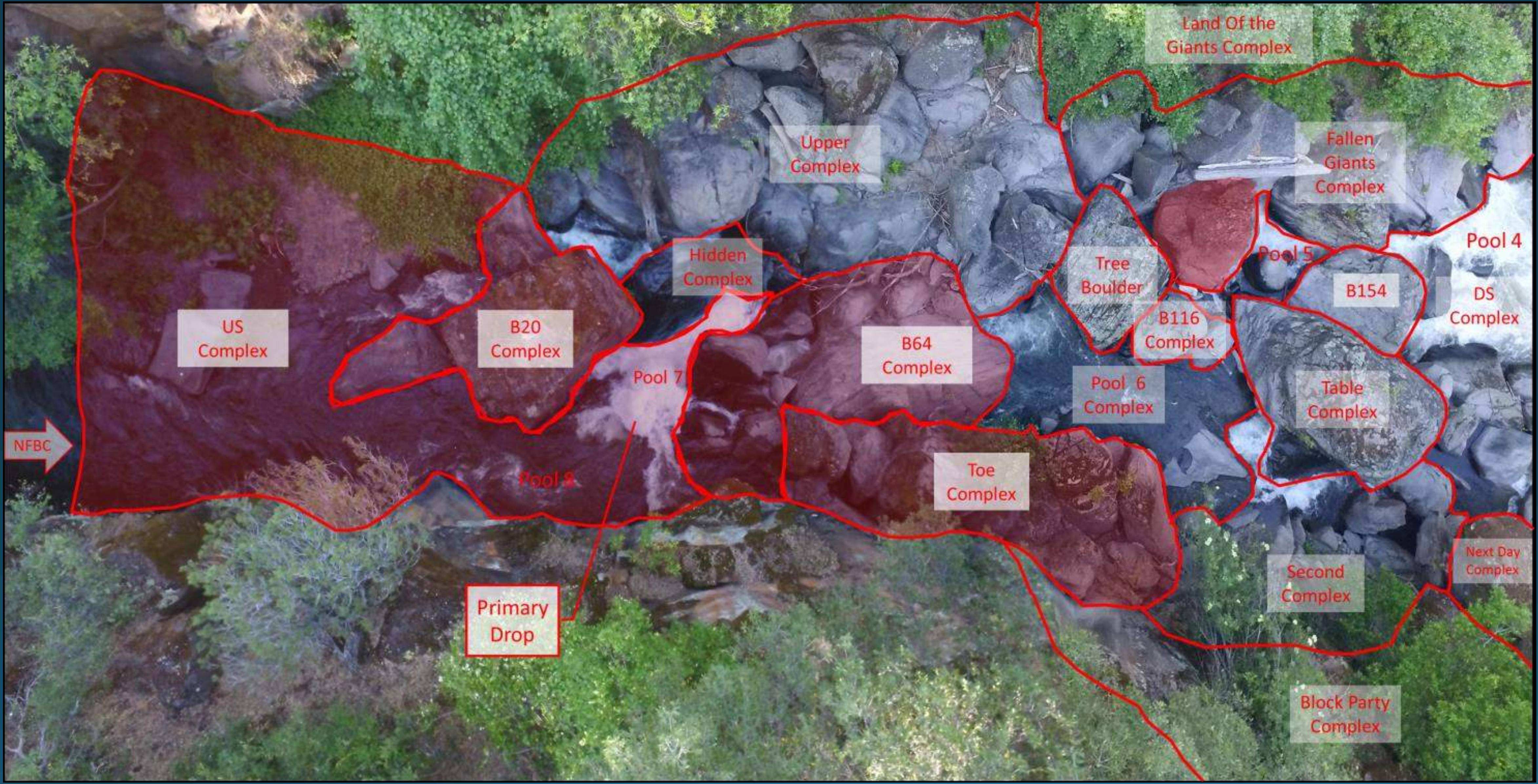
Upper Barrier Site Flow Paths thru Sieves



Primary Drop

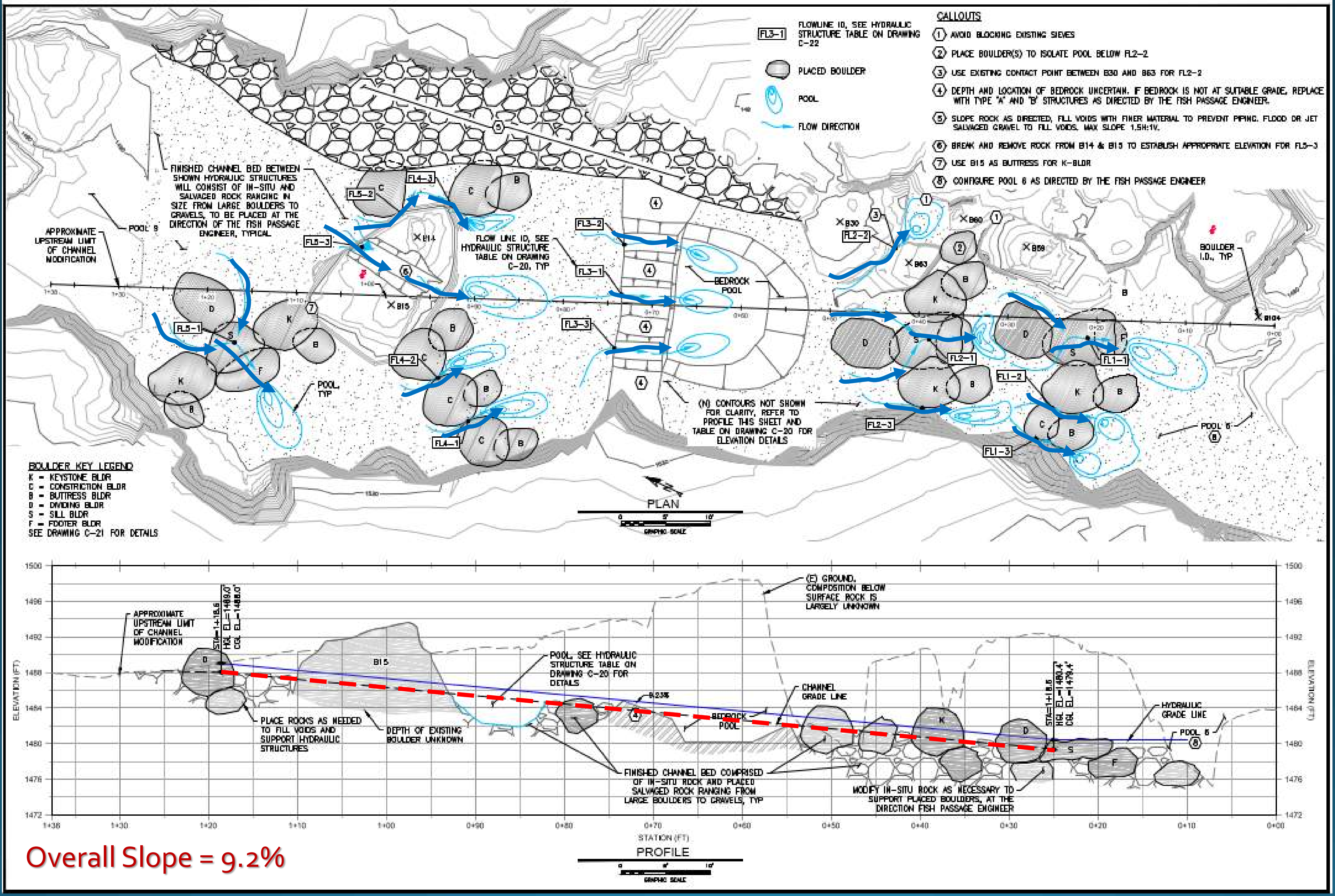
- 12.5 ft
- No pool

Upper Barrier Site
Boulders and Bedrock to be Removed



Channel Reconstruction

Conceptual Layout



Reconstruct Channel with Boulder Controls and Bedrock Modifications

2D Hydraulic Simulation

coupled with

Fish Energetics and Routing

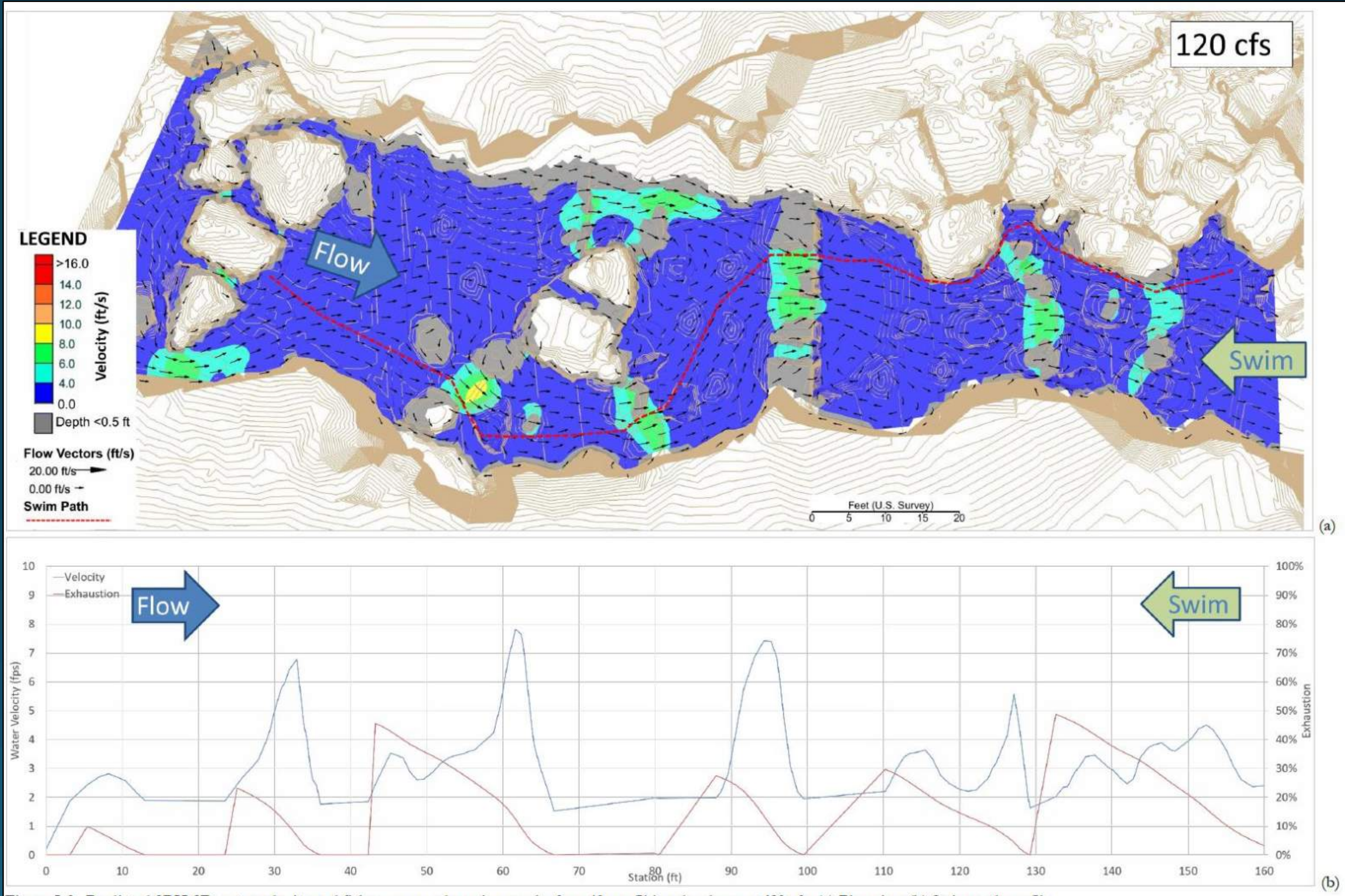


Figure 5-3. Predicted SRH-2D water velocity and fish passage exhaustion results for a 40 cm Chinook salmon at 120 cfs. (a) Plan view (b) Swim path profile.

Implementation

2021

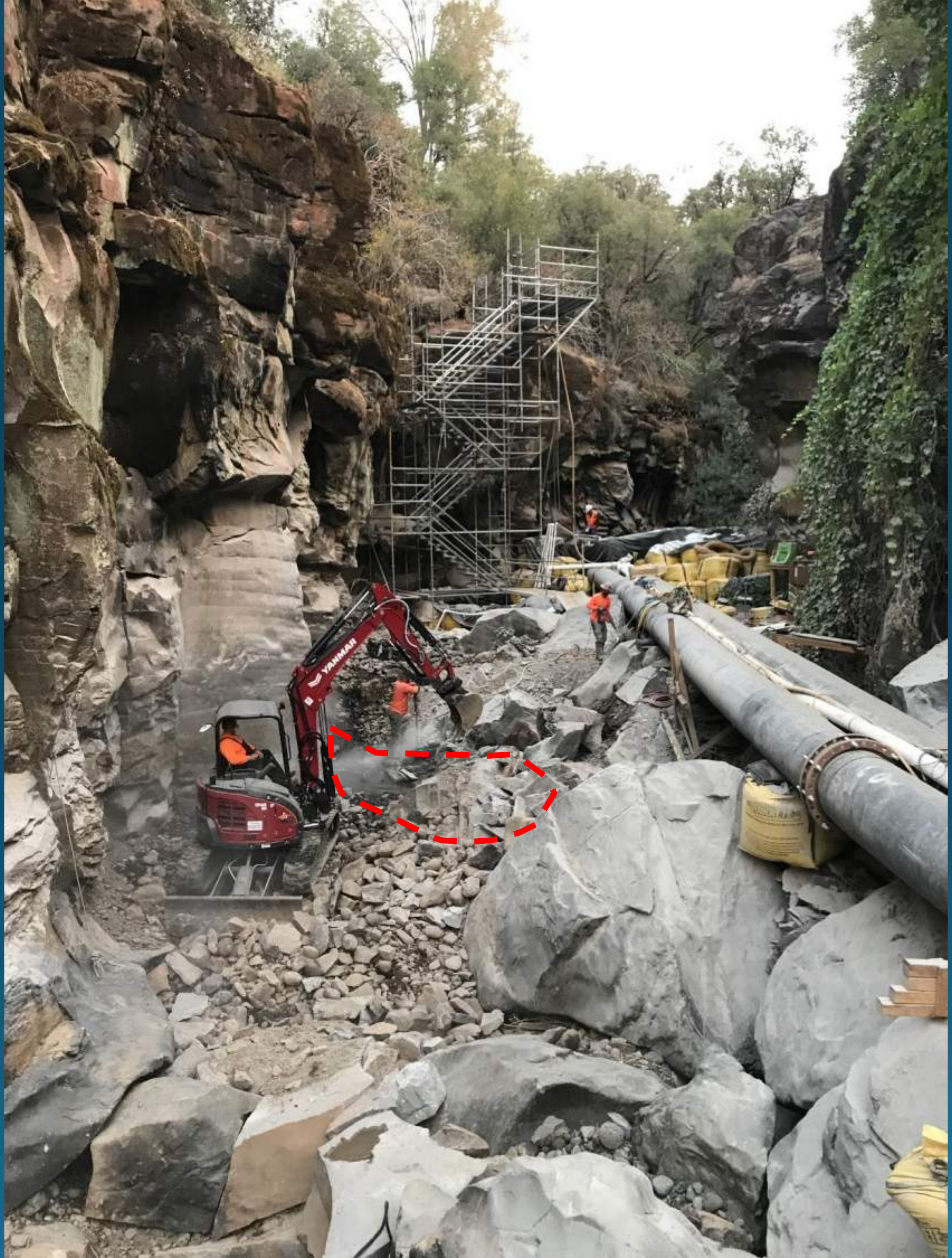

SRC
QUIKRETE

Lesson: Label what you know

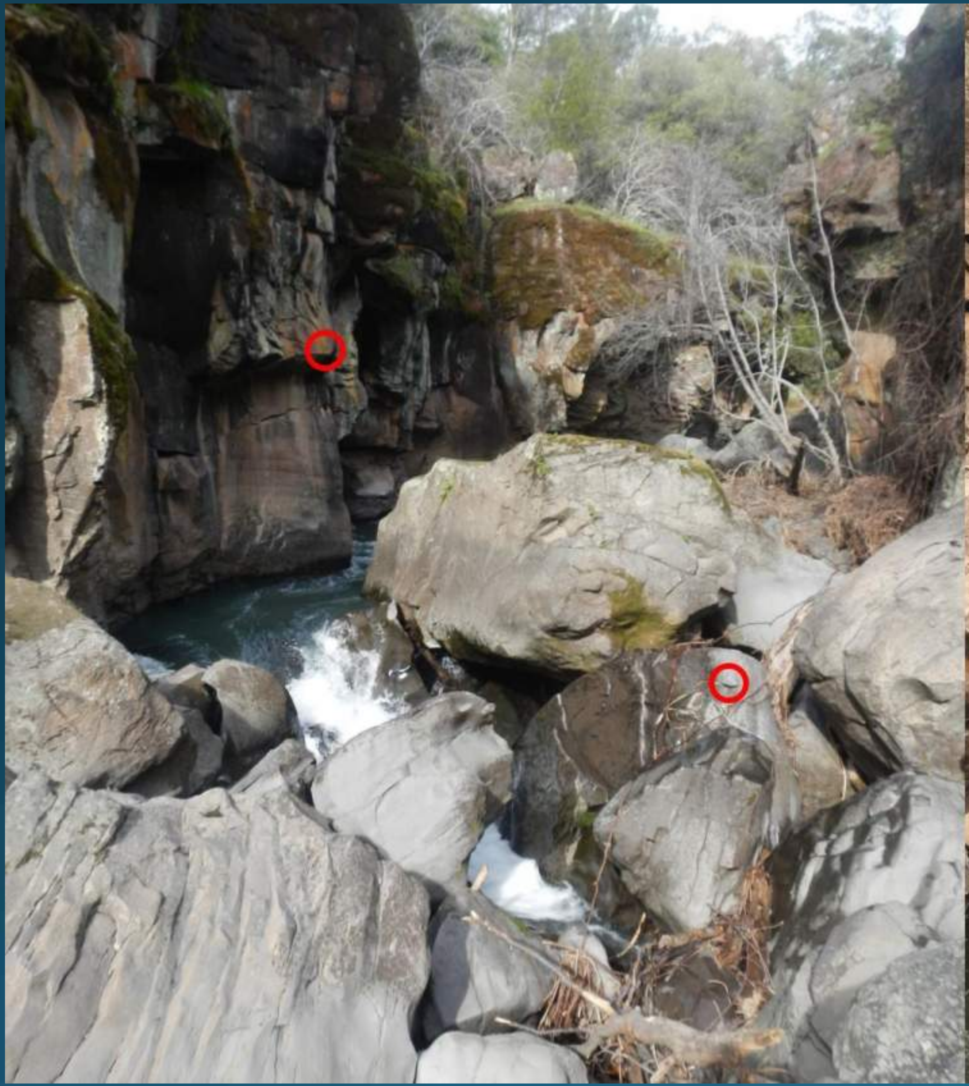
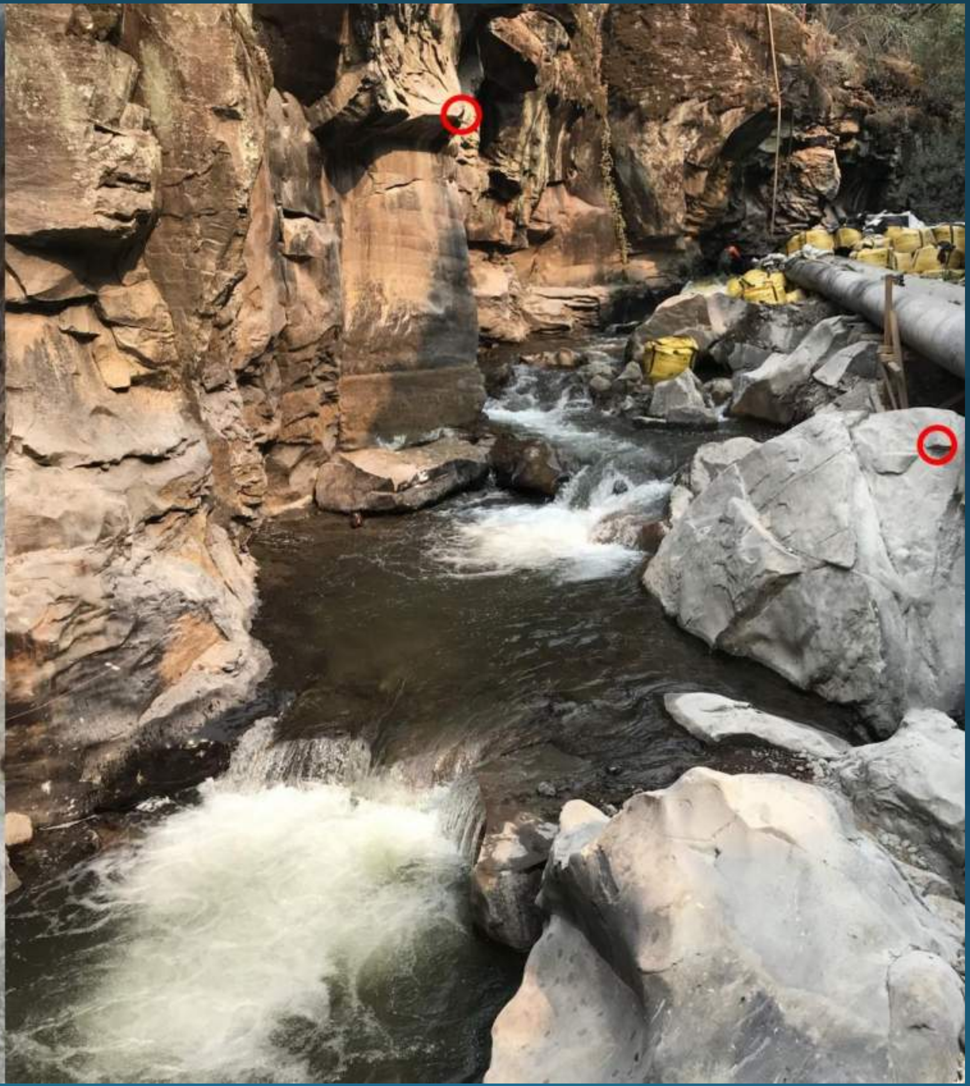

July 2, 2021
July 15, 2021
July 20, 2021

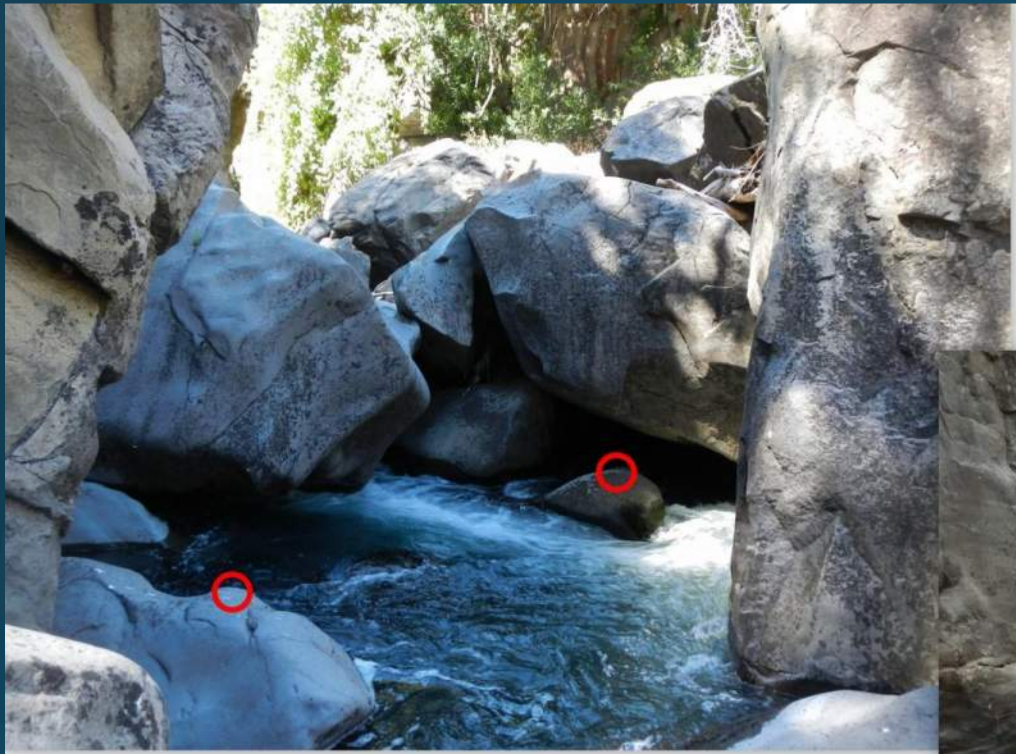
1,800 tons of rock removed
(3,600,000 lbs)


Battle Creek

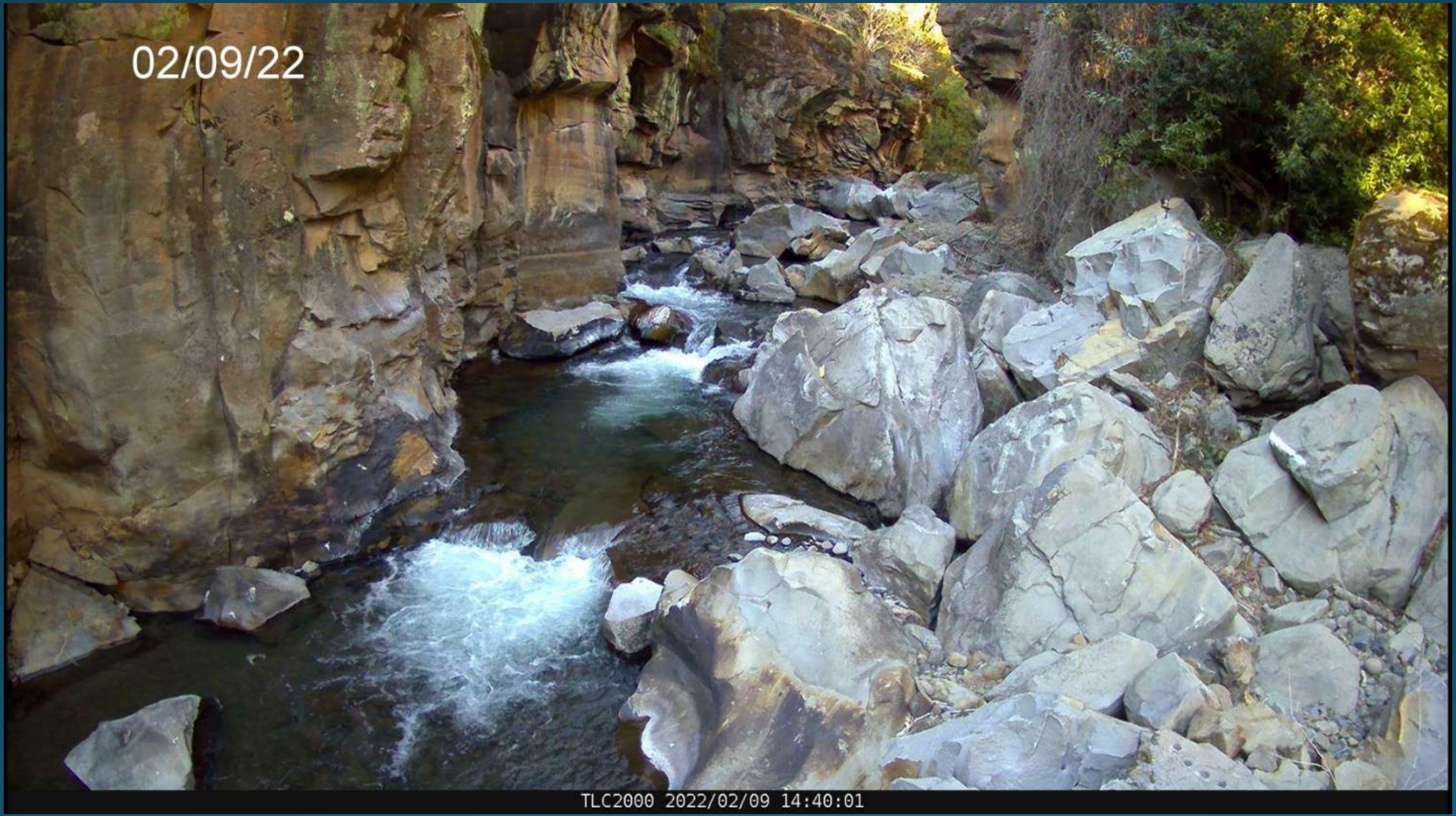

YANMAR

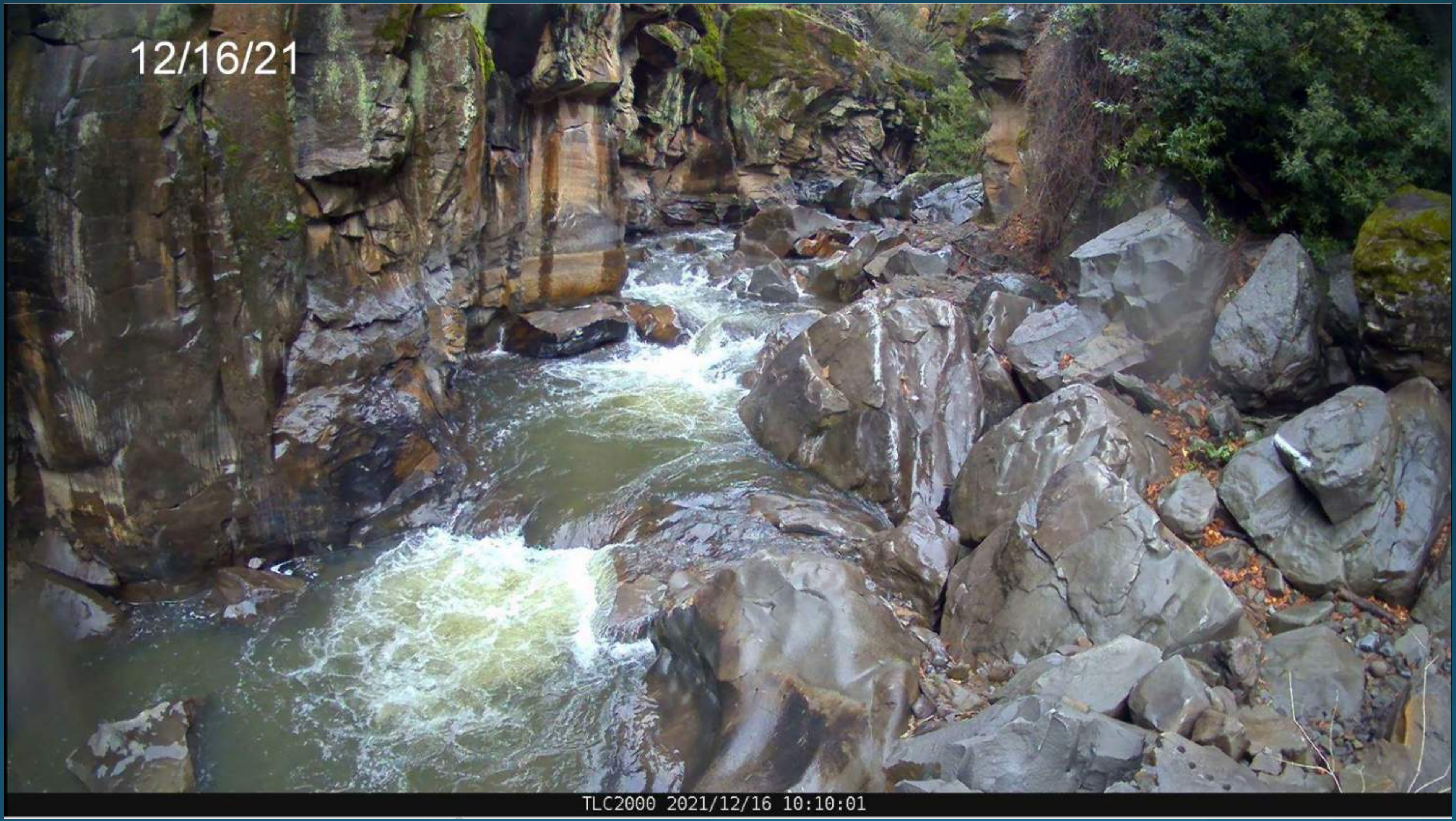
Implementation: Final Outcome

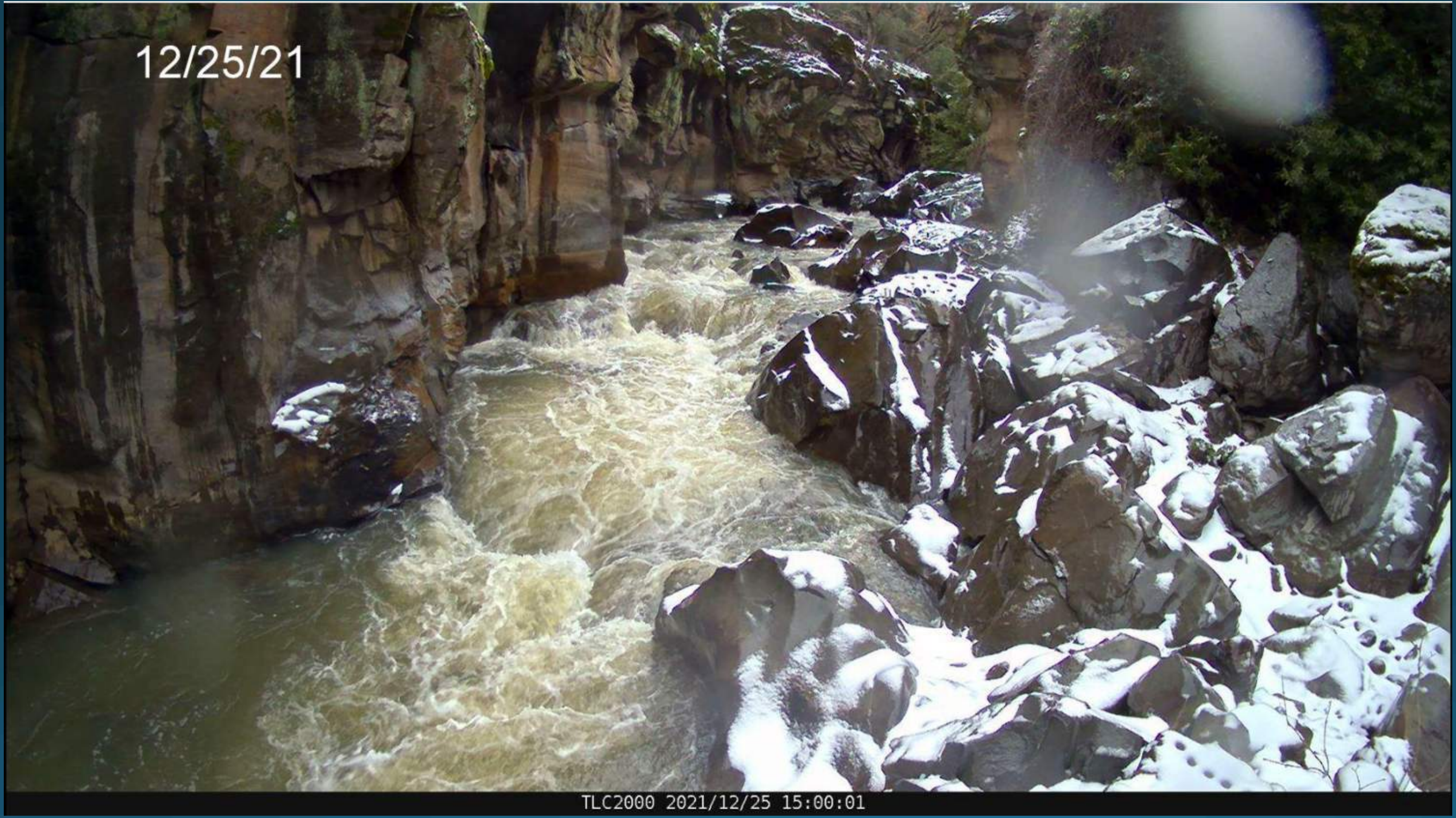






June 12, 2023
Project Reach


02/09/22
TLC2000 2022/02/09 14:40:01


12/16/21
TLC2000 2021/12/16 10:10:01


12/25/21
TLC2000 2021/12/25 15:00:01

Eagle Canyon Team

U.S. FISH & WILDLIFE SERVICE — DEPARTMENT OF THE INTERIOR

CALIFORNIA TROUT — KEEPER OF THE STREAMS

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

RESOURCE CONSERVATION DISTRICT OF TEHAMA COUNTY

PG&E

Landowners:
David Gamon & April Gamon
John Gamon & Donnette Thayer

AquaTerra CONSULTING

Michael Love & Associates — Hydrologic Solutions

TEHAMA ENVIRONMENTAL SOLUTIONS, INC. — Environmental Consulting • Habitat Restoration

NV5 — BEYOND ENGINEERING

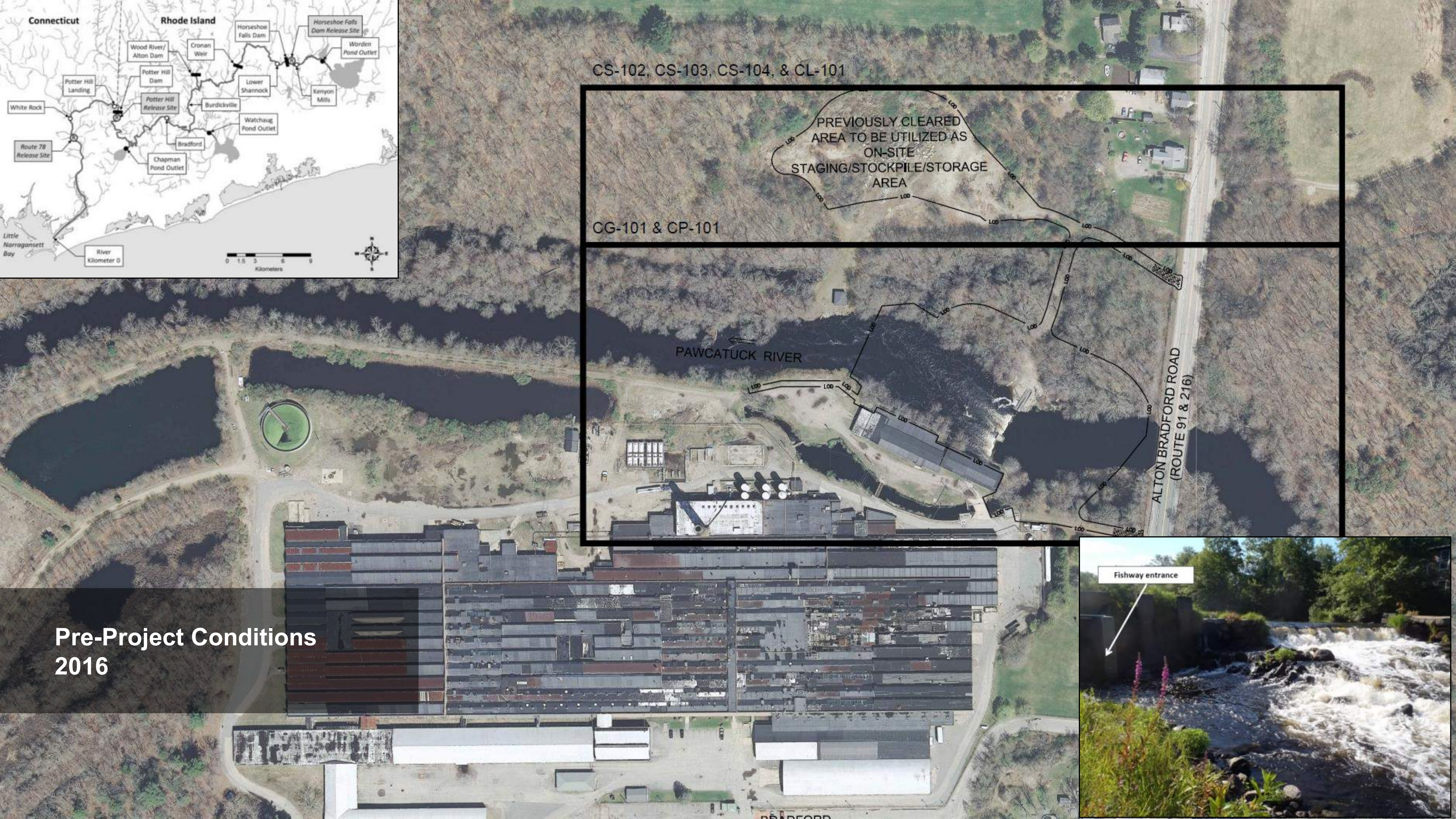
SYBLON REID — General Engineering Contractors — Providing Solutions to Difficult Projects

COTTON, SHIRES AND ASSOCIATES, INC. — CONSULTING ENGINEERS AND GEOLOGISTS

NLF Project Spotlight:

Pawcatuck River NLF at the Bradford Dam
Westerly, Rhode Island
Jesus Morales USFWS

3/262024



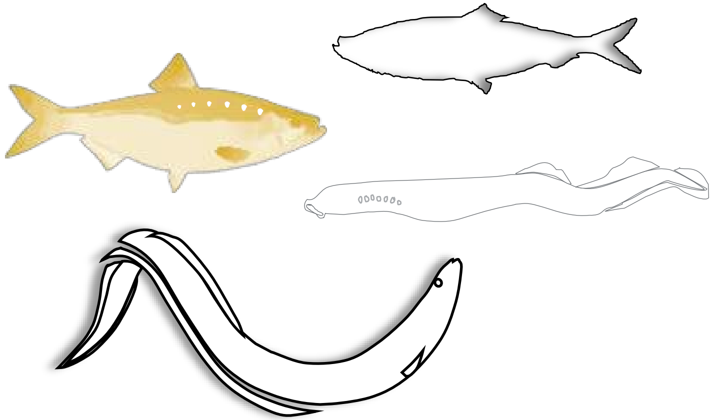
Pre-Project Conditions 2016

KEY CONSIDERATIONS AND PROJECT GOALS

01 Need to maintain unnatural pool elevation upstream of the dam for recreation

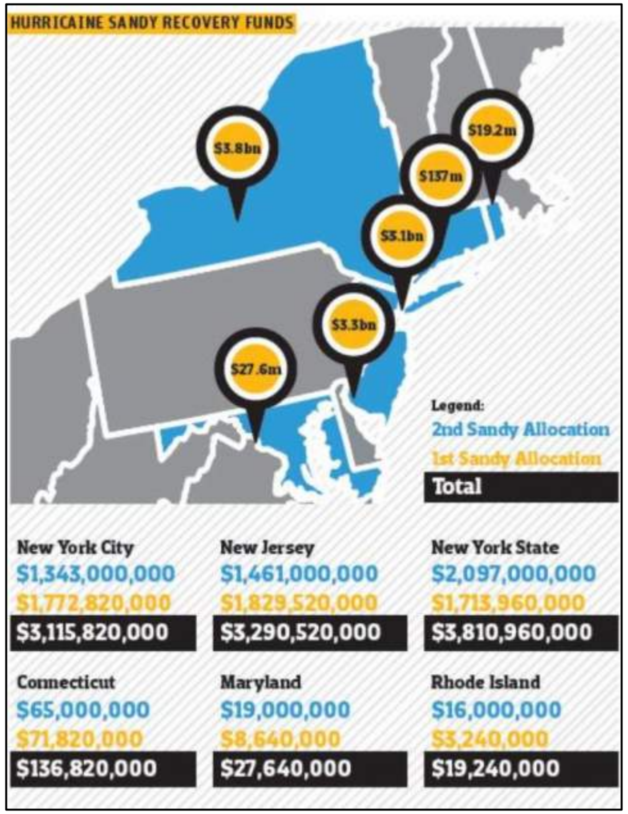
02 Need for slope stabilization and protection of the upstream bridge footers and abutments

03 Need to provide routes of passage for native migratory fish over a range of fish passage design flows



Bradford Dam NLF in Westerly, Rhode Island

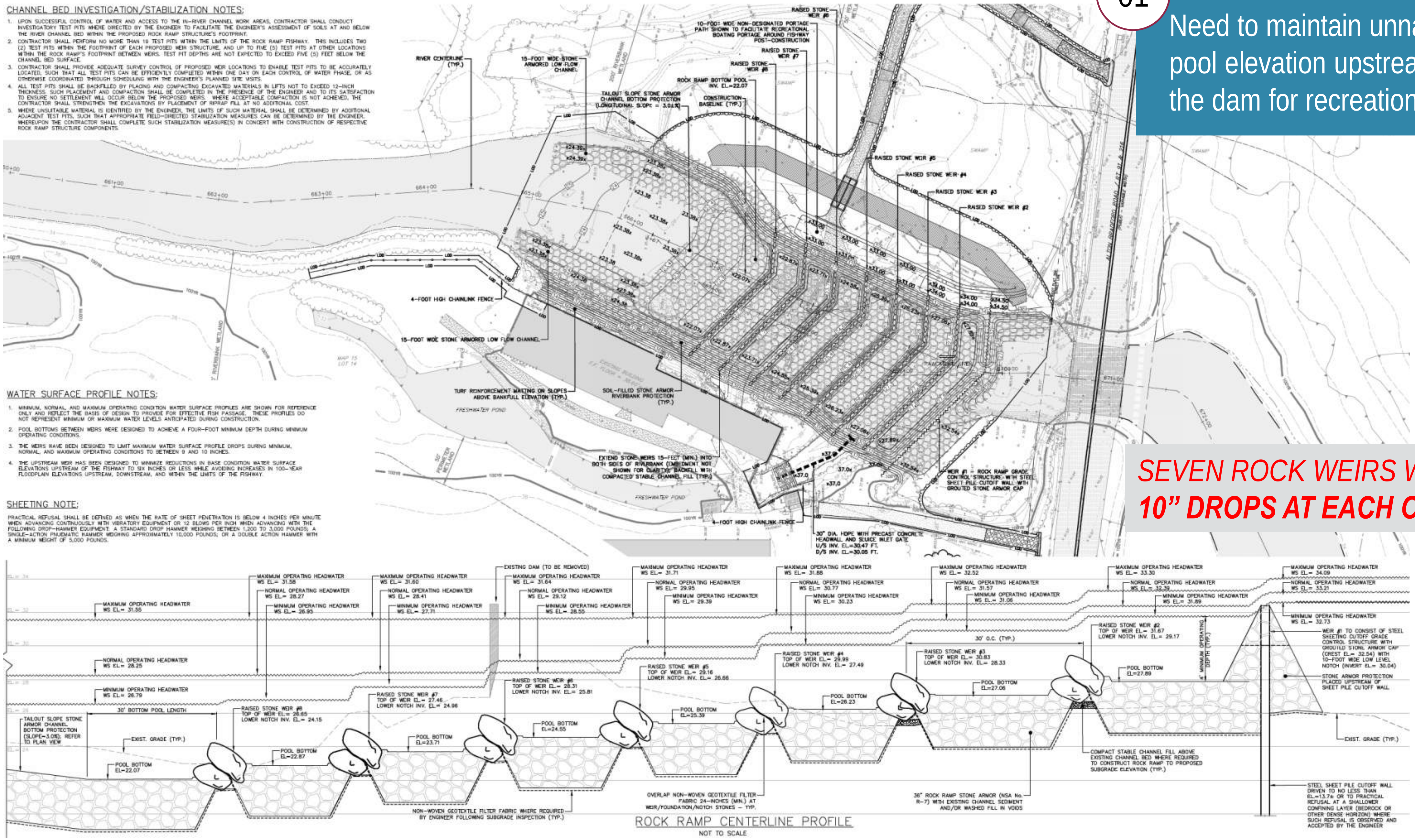
- **Purpose and Objectives**
  - Removal of Dam and Old Denil Fish Ladder
  - NLF Construction for Native Migratory Fish Species
  - Low-flow Channel Construction and Slope Stabilization
- **Key Features**
  - Pool & Weir NLF
  - Dimensions:
    - Length = 210 FT
    - Overall Slope = 2.8%
    - Width = 160 FT
  - Multiple distinct routes of passage at varying elevations and hydraulic conditions
  - Adequate submergence depth at each weir notch and energy dissipation at the pools for the full range of fish passage design flows



Proposed Conditions

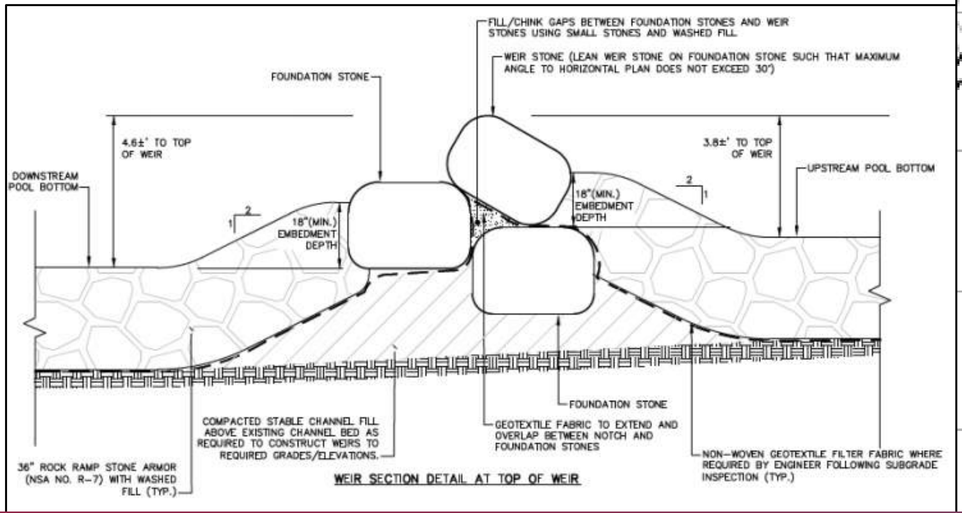
01

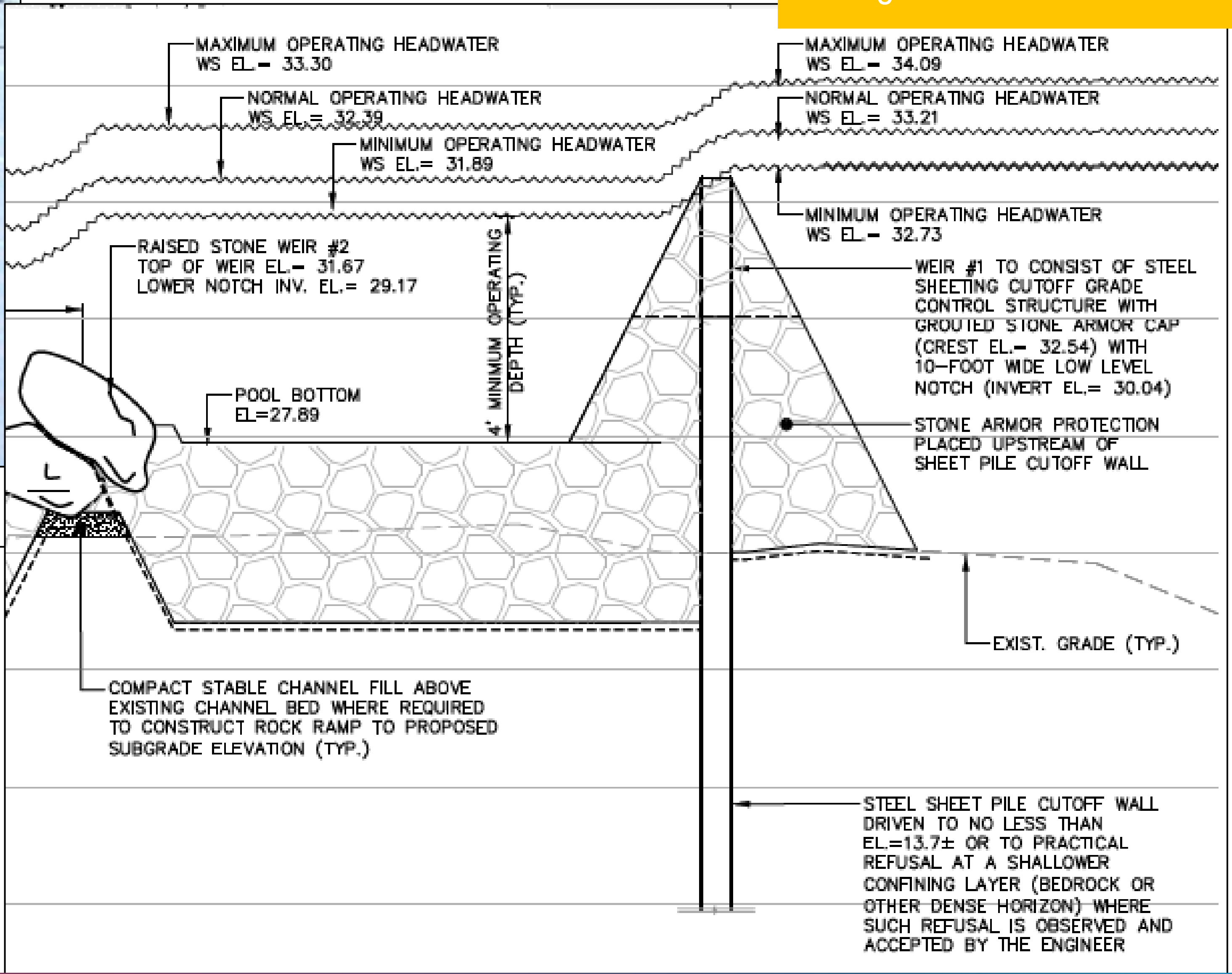
Need to maintain unnatural pool elevation upstream of the dam for recreation



SEVEN ROCK WEIRS WITH
10” DROPS AT EACH ONE

02 Need for slope stabilization and protection of the upstream bridge footers and abutments

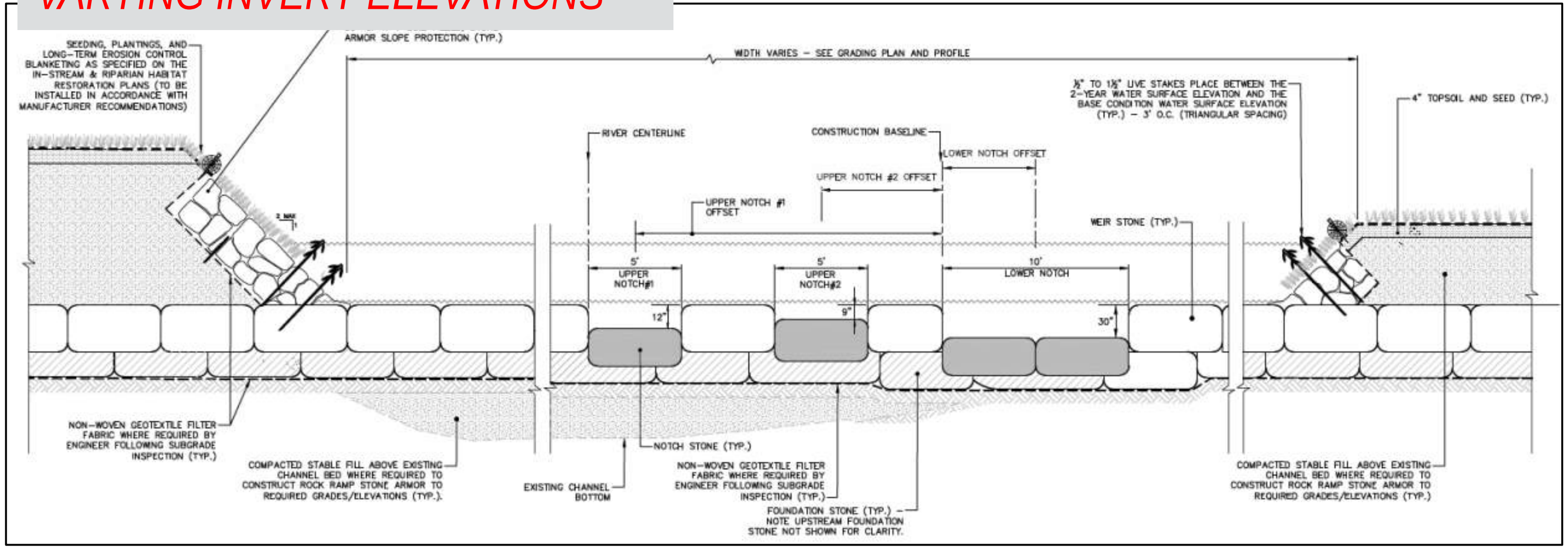


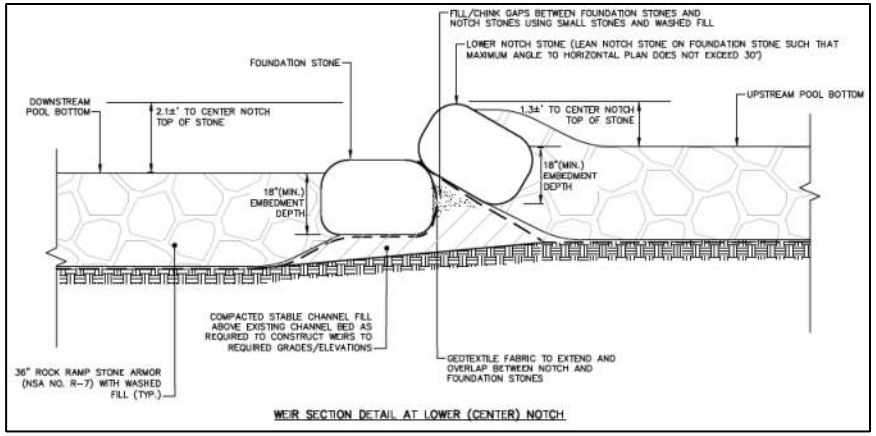


03

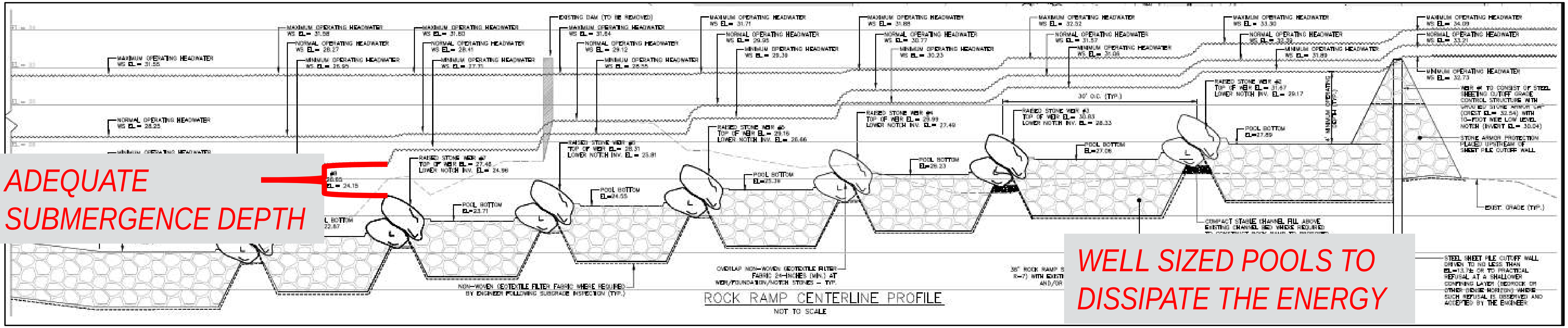
Need to provide routes of passage for native migratory fish over a range of fish passage design flows

THREE ROUTES OF PASSAGE AT VARYING INVERT ELEVATIONS



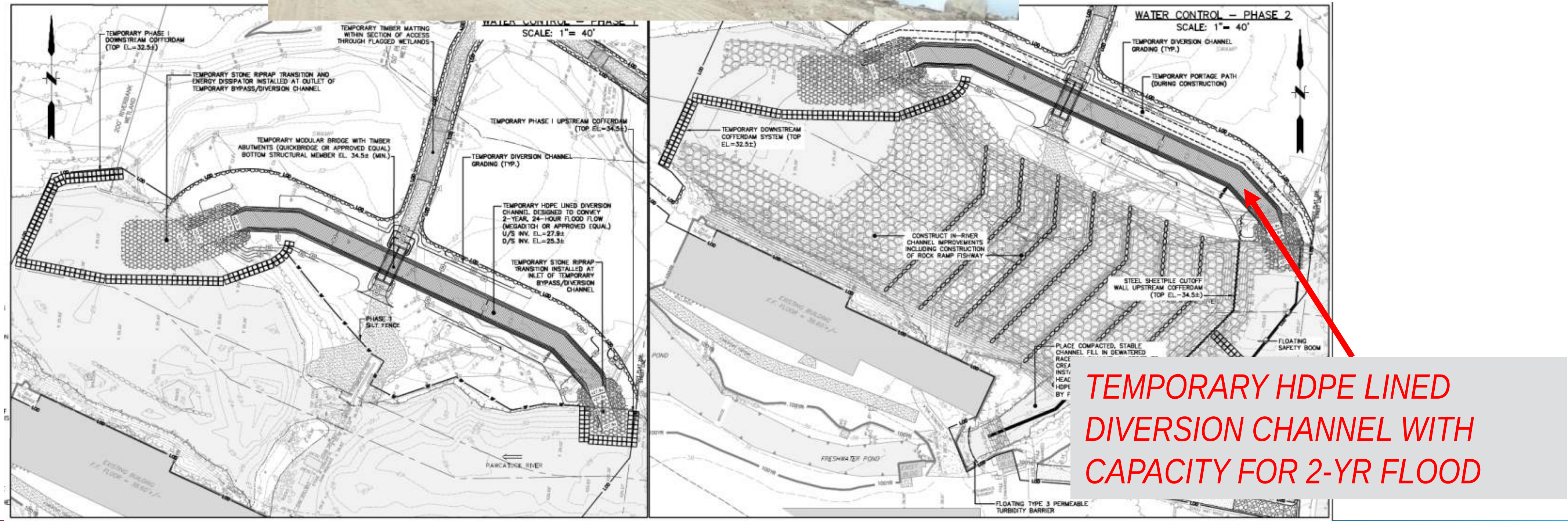


ADEQUATE SUBMERGENCE DEPTH



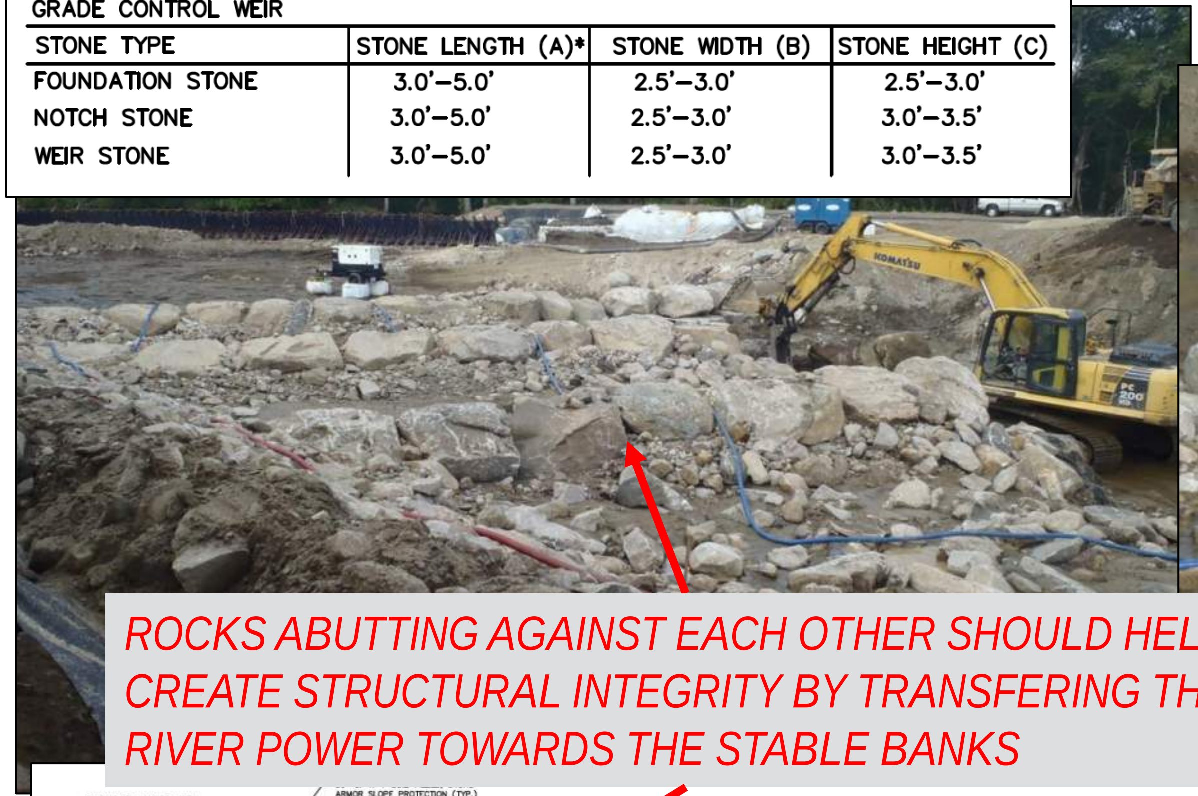
WELL SIZED POOLS TO DISSIPATE THE ENERGY

WATER MANAGEMENT PLAN



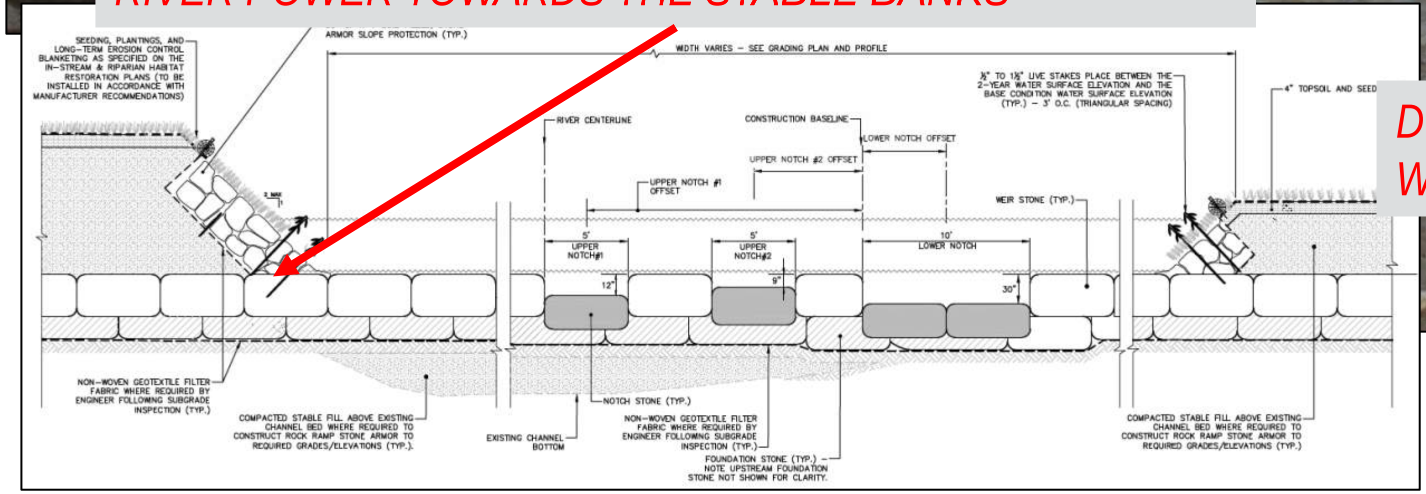
ROCKS WEIRS CONSTRUCTION

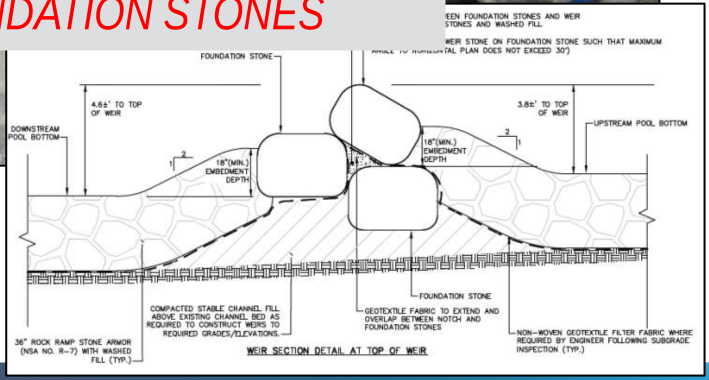
GRADE CONTROL WEIR			
STONE TYPE	STONE LENGTH (A)*	STONE WIDTH (B)	STONE HEIGHT (C)
FOUNDATION STONE	3.0'–5.0'	2.5'–3.0'	2.5'–3.0'
NOTCH STONE	3.0'–5.0'	2.5'–3.0'	3.0'–3.5'
WEIR STONE	3.0'–5.0'	2.5'–3.0'	3.0'–3.5'



ROCKS ABUTTING AGAINST EACH OTHER SHOULD HELP CREATE STRUCTURAL INTEGRITY BY TRANSFERING THE RIVER POWER TOWARDS THE STABLE BANKS

DOWNSTREAM SIDE OF WEIR WITH LARGE, WELL EMBEDED FOUNDATION STONES

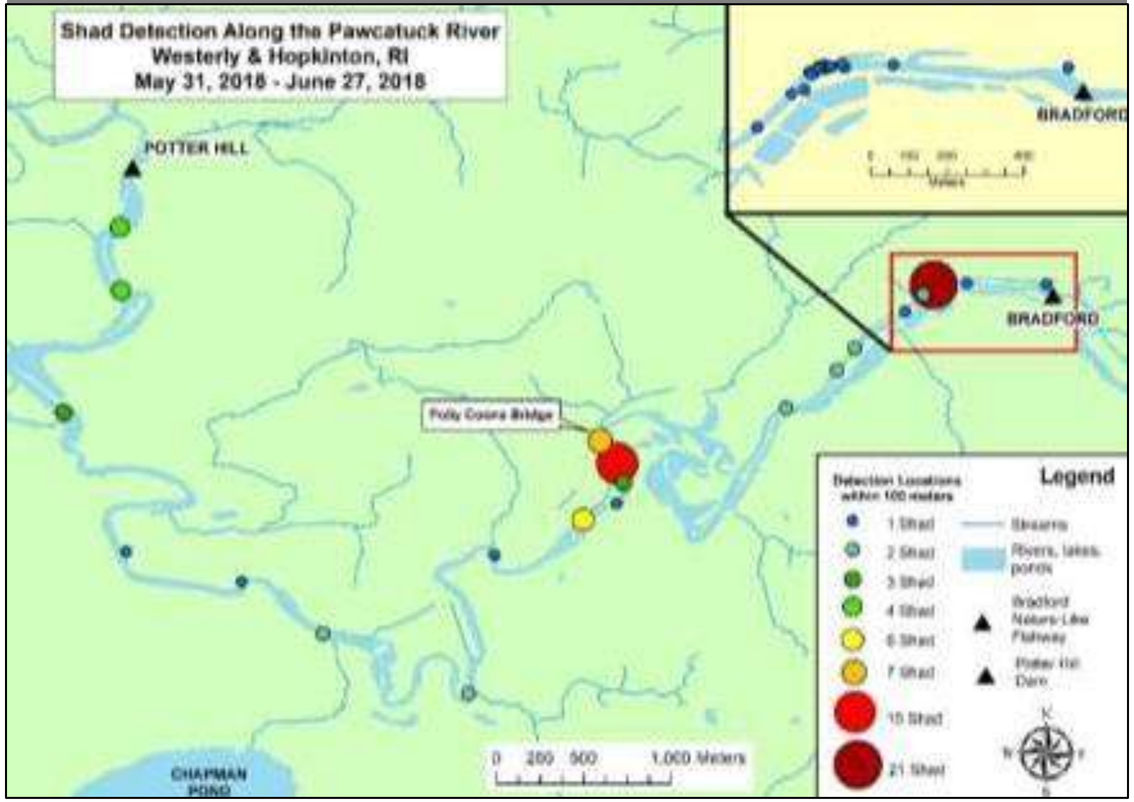




BRADFORD NATURE-LIKE FISHWAY

FINAL COST: $1.8 MILLION

2018 & 2019 American Shad and Alewife Biological Performance Evaluation



Passage Performance of Alewife and American Shad in the Pawcatuck River, Rhode Island

Prepared by:

Alex Haro, Ph.D.
U.S. Geological Survey, Leetown Science Center
S.O. Conte Anadromous Fish Research Laboratory
Turners Falls, Massachusetts

USGS science for a changing world

Memorandum prepared for the U. S. Fish and Wildlife Service, Coastal and Partners Program, 50 Bend Road, Charlestown, Rhode Island

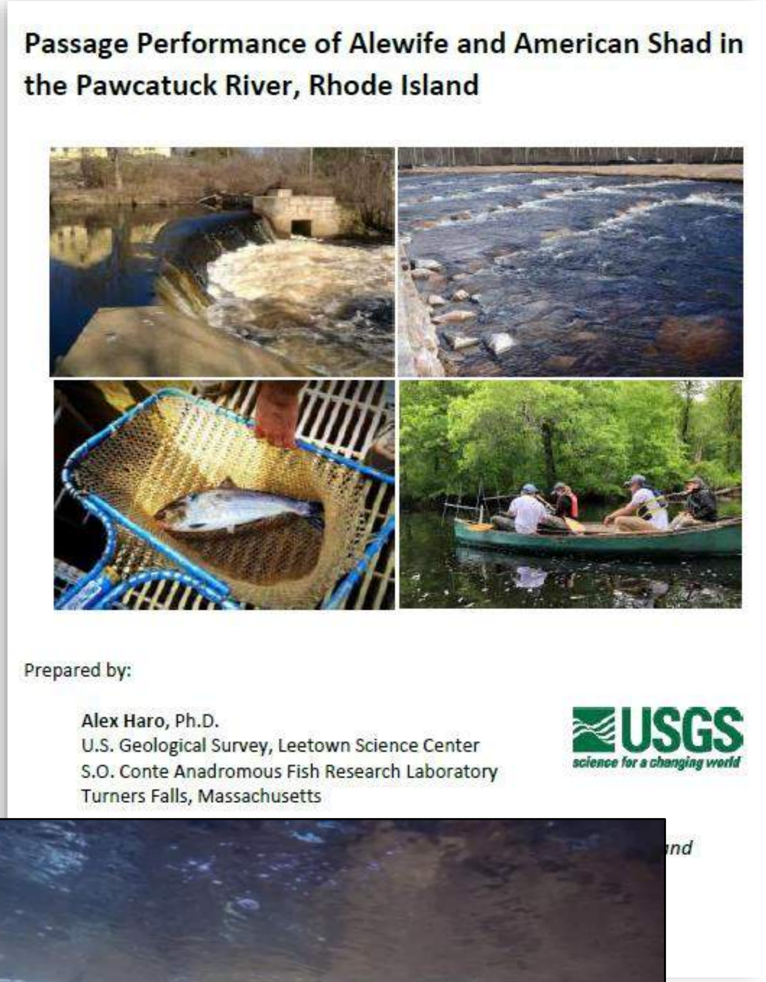
20 July 2020

2018 & 2019 American Shad and Alewife Biological Performance Evaluation

Table 6: Number of radio tagged Alewife and American Shad passing and failing to pass a site, and resultant proportion and 95% confidence interval, for 2018 and 2019.

Site	Pass/Fail Proportion	Alewife 2018 Releases Route 78	Alewife 2018 Releases Potter Hill Dam	Alewife 2018 Releases Horseshoe Falls Dam	Alewife 2019 Releases Route 78	Alewife 2019 Releases Potter Hill Dam	Alewife 2019 Releases Horseshoe Falls Dam	American Shad 2018 Releases Potter Hill Dam	American Shad 2019 Releases Potter Hill Dam
White Rock	N Pass	5			6				
	N Fail	0			0				
	Proportion Passed (95% CI)	**1.00**			**1.00**				
Potter Hill	N Pass	0			0				
	N Fail	1			6				
	Proportion Passed (95% CI)	**0.00**			**0.00**				
Bradford	N Pass		18			49		2	12
	N Fail		9			0		20	16
	Proportion Passed (95% CI)		**0.667** (0.529-0.864)			**1.00**		**0.091** (0.038-.309)	**0.429** (0.301-0.600)

Few American Shad ascended beyond the Bradford site; only one fish ascended as far as below the Lower Shannock site. Consistent congregations of American Shad below the Bradford site in deeper, slower moving reaches suggest that although they can pass Bradford, most American Shad do not do so. It may be possible that American Shad cease migrating below Bradford to spawn in the reach between Bradford and Potter Hill Dam. Analysis of stationary radio receiver data below Bradford indicated that many American Shad in these holding areas ascend to below the Bradford NLF passage structure at night, primarily in the early morning hours, which may be indicative of spawning activity in this location.


Passage Performance of Alewife and American Shad in the Pawcatuck River, Rhode Island

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NLF Project Spotlight:

Santa Paula Fishway
Santa Paula Creek, Santa Paula, CA

Mike Garello, PE and Marcin Whitman, PE

3/262024

Santa Paula Fishway at the USACE Flood Control Inlet

Project Objectives and Key Features

- Purpose and Objectives
  - Provide fish passage for ESA Southern California Steelhead
  - Provide hardened, stable, and durable profile control at inlet to USACE Flood Control Channel Sedimentation Basin
  - Project was necessitated by previous channel straightening and headcutting
- Key Features
  - Hardened technical fishway – pool and chute
  - 58 feet wide, 250 feet long, gradient of 7.5%
  - Inset into 250-foot-wide grouted rip rap inlet apron
  - Unit discharge of 160 cfs/ft (0.01 APE, peak discharge of 40,000 cfs) and 20 cfs/ft (0.05 PCE mean daily flow, 1,200 cfs)


9,270 feet
Fishway
Flood Control Channel (FCC)
Overview of Project Area
• Hydraulic Capacity 28,000 cfs
• Allowable deposition 120,000 cuy
Santa Paula Creek
Dike Rd
Grant Line St
Culbertson St
N 14th St
Encino Pl
Citrus St
Ernest Dr
N 13th St
Richmond Rd
Say Rd
Mariposa Dr
Harvard Blvd
E Telegraph Rd
Santa Paula Fwy
Santa Paula St

Pre-Project Conditions
2001

A DEEP HEADCUT FORMS AT THE FCC INLET AFTER CONSTRUCTION

Key Considerations, Challenges, and Risks

01 Inlet to Essential Flood Control Infrastructure

- Essential flood control facility
- Maintenance and sediment removals are already costly – fish passage costs not a part of the original plan

02 Steep Gradient 7 to 10% w/ Underlying Hardpan

- Steep inlet gradient
- High levels of hydraulic force – velocity, shear, stream power
- Discontinuous channel substrate
- Transition from low gradient non-uniform channel to stabilized channel with uniform geometry

03 Rapid Response Time - Compliance with ESA

- Original funding cap at $1M
- Short implementation timeline
- Lack of early engagement with CDFW and NMFS
- Lack of clarity regarding fish passage expectations

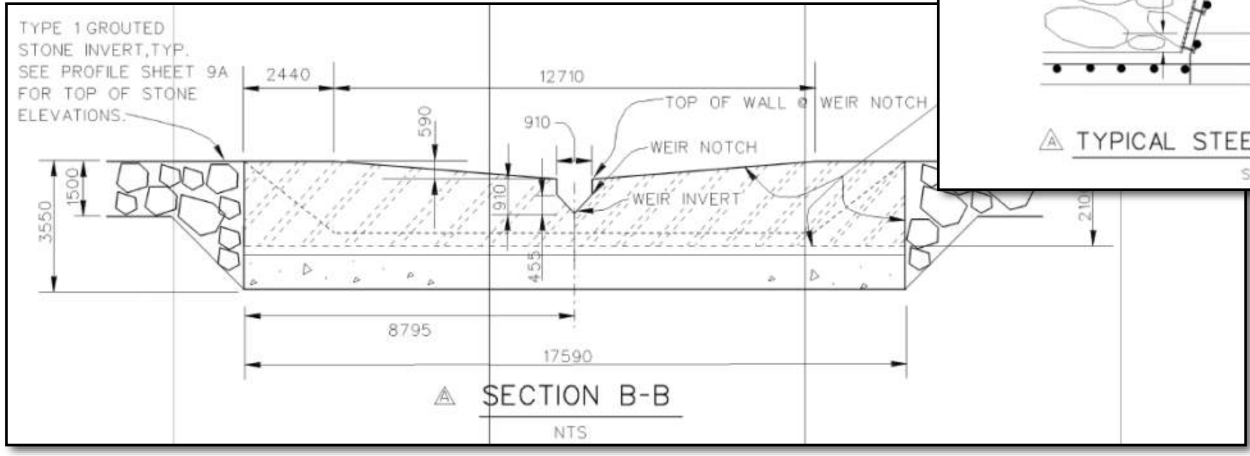
04 Flashy Hydrologic and Fluvial Watershed

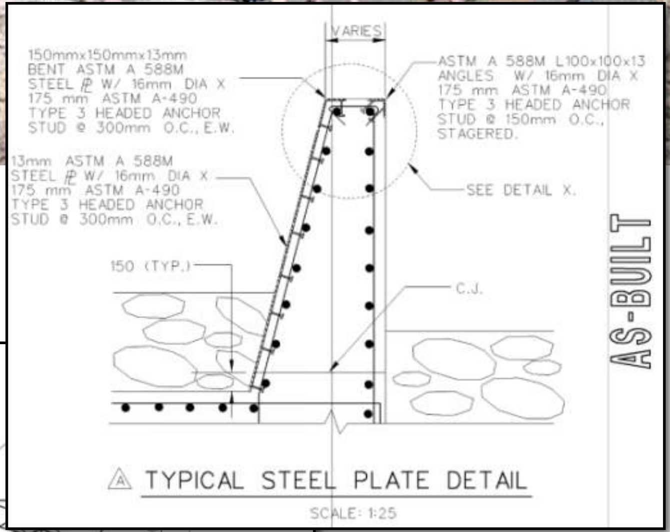
- Project did not take into consideration watershed level geomorphic context, geology, or existing river processes
- Flashy hydrologic response typical of Southern California watersheds

- *Is this a suitable environment for an NLF?*

Initial Solution

- Lack of adequate communication and consultation with CDFW, NOAA resulting in unclear fish passage expectations
- *USACE originally designed a small technical fishway (10 cfs)*
- *After engagement with CDFW, NOAA, and constrained with $1M construction cost cap, USACE designed and constructed a highly engineered technical fishway…*
  - o 17 Steel Reinforced Weirs
  - o Weir Length 57.75 ft
  - o Weir Thickness 18-in
  - o Design Hydraulic Drop 1-ft
  - o 1-D/S Bed Stabilizer
  - o Total Vertical Height 16-ft






2002
Post-Project Conditions
2002
USACE CONSTRUCTS A HEAVILY REINFORCED TECHNICAL FISHWAY

GRADIENT TRANSITIONS UPSTREAM AND DOWNSTREAM OF THE FCC INLET

Post-Project Conditions
2002

BEDLOAD ACCUMULATION AT THE FISHWAY EXIT CREATES HYDRAULIC FLANKING

Post-Project Conditions
Early 2003

JUST AFTER CLEANING, SMALL HYDROLOGIC EVENTS MOBILIZE MATERIAL WHICH ACCUMULATES IN POOLS


Late 2003
Post-Project Conditions
Late 2003
BEDLOAD ACCUMULATION AT THE FISHWAY EXIT CREATES HYDRAULIC FLANKING


BEDLOAD DEPOSITS REMOVED FROM LADDER POOLS
2004
Post-Project Conditions
2004
ADDITIONAL CHANNEL INCISION AT THE FISHWAY ENTRANCE. ADDRESSED WITH A CONCRETE BED STABILIZER.
MAINTENANCE OF THE FISH LADDER PERSISTS.

THE EFFECTIVE 100-YEAR EVENT INFLICTS SIGNIFICANT DAMAGE TO THE FISH LADDER

Post-Project Conditions
2005

THE EFFECTIVE 100-YEAR EVENT INFLICTS SIGNIFICANT DAMAGE TO THE FISH LADDER

Post-Project Conditions
2005

2005

AFTER CLEAN-UP AND REPAIRS, THE FISH LADDER IS STILL FUNCTIONAL, BUT SEDIMENT MANAGEMENT ISSUES CONTINUE TO DEGRADE LADDER PERFORMANCE

2009 Feasibility Study

ALTERNATIVE FORMULATION AND EVALUATION. ROUND TWO…

A — **Like Modifications to the Existing Structure**

Repair with like design features. Longer to address toe degradation.

B — **Construct a Bypass Fishway along the FCC Inlet**

Design and construct a fishway around the inlet apron.

03 — **Demo and Replace with a Multi-Slope Nature-Like Fishway**

Two to Three 5% Gradient Slopes with transition structures

04 — **Demo and Replace with a Multi-Slope Nature-Like Fishway**

Single 3 to 4% Gradient

Selection Factors Based on:

- **Perceived Effectiveness**
- **Operation and Maintenance Effort**
- **Flexibility of Design**
- **Nature Like Characteristics**
- **Durability**
- **Capital Cost**

2009 Feasibility Study

LOW	MOD	HIGH
↓	—	↑

ALT	E1 Performance	E2 O&M	E3 Flexibility	E4 Natural	E5 Durability	E6 Capital Cost
A	—	—	↓	↓	—	↑ $ 3.4 M
B	↓	↓	↓	↓	—	— $ 4.8 M
03	—	↑	↑	—	—/↑	↓ $ 6.8 M
04	—	↑	—	↑	—/↑	↓ $ 5.0 M

2009 Feasibility Study

- In 2010 Alternative A was developed to a 100% level of design
- Funding and schedule restraints further limited the ability to implement the Alternative with the resources available
- Environmental and co-sponsor concerns favored a more comprehensive approach
- No action has taken place to date…

Lessons Learned

- Geomorphic and hydrologic context plays a critical role in structure selection and design
- Engage stakeholders and agency representatives early
- Provide sufficient time and effort for engagement and communication
- Funding and schedule constraints introduce significant project risk – plan accordingly


Metrolink Crossing


Metrolink 1:6 Scale Physical Model


I-5 Crossing

NLF Project Spotlight:

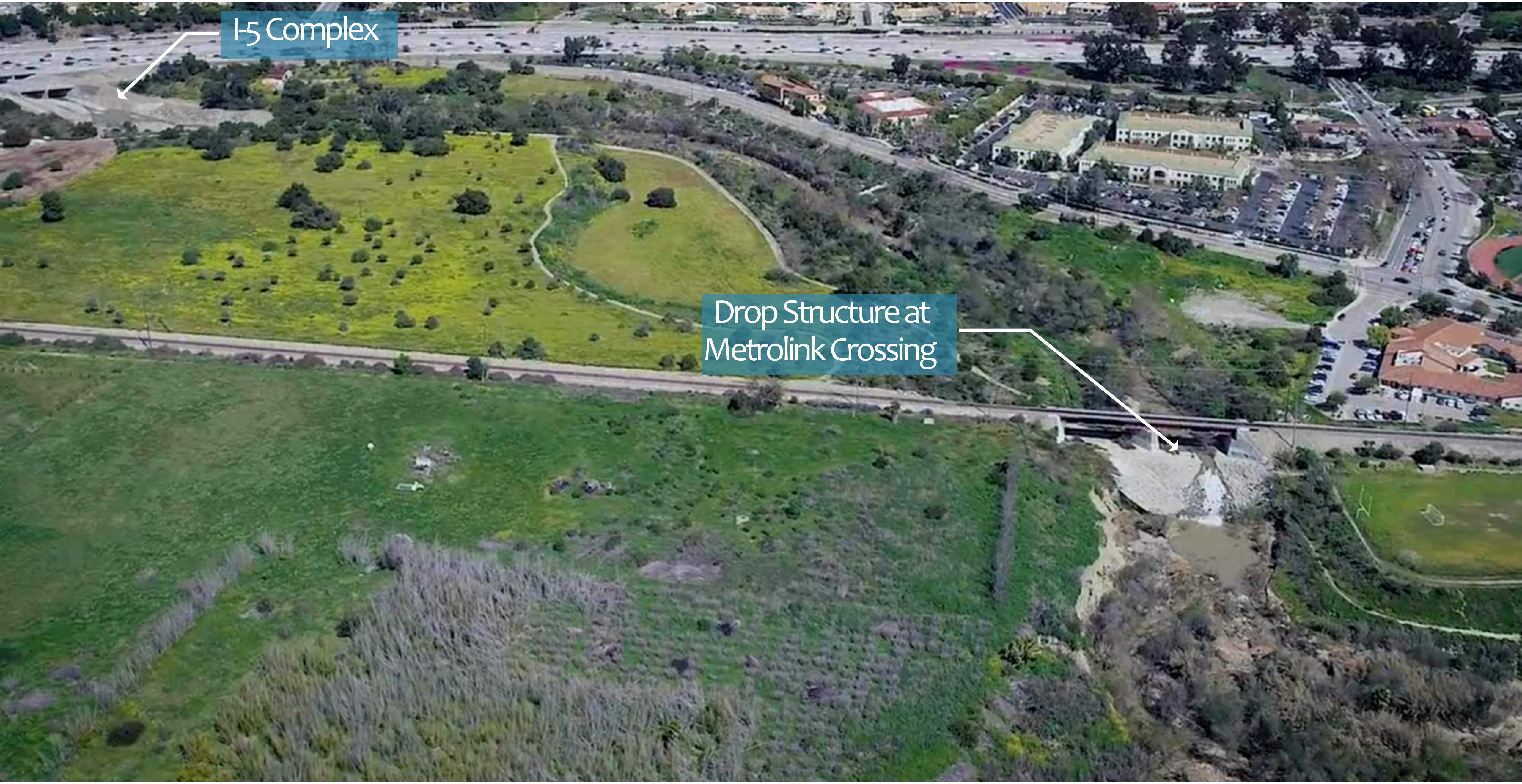
Trabuco Creek at I-5 and Metrolink
San Juan Capistrano, CA

AMERICAN FISHERIES SOCIETY BIOENGINEERING SECTION


I-5 1:8 Physical Model

3/27/2024

By: Michael Love

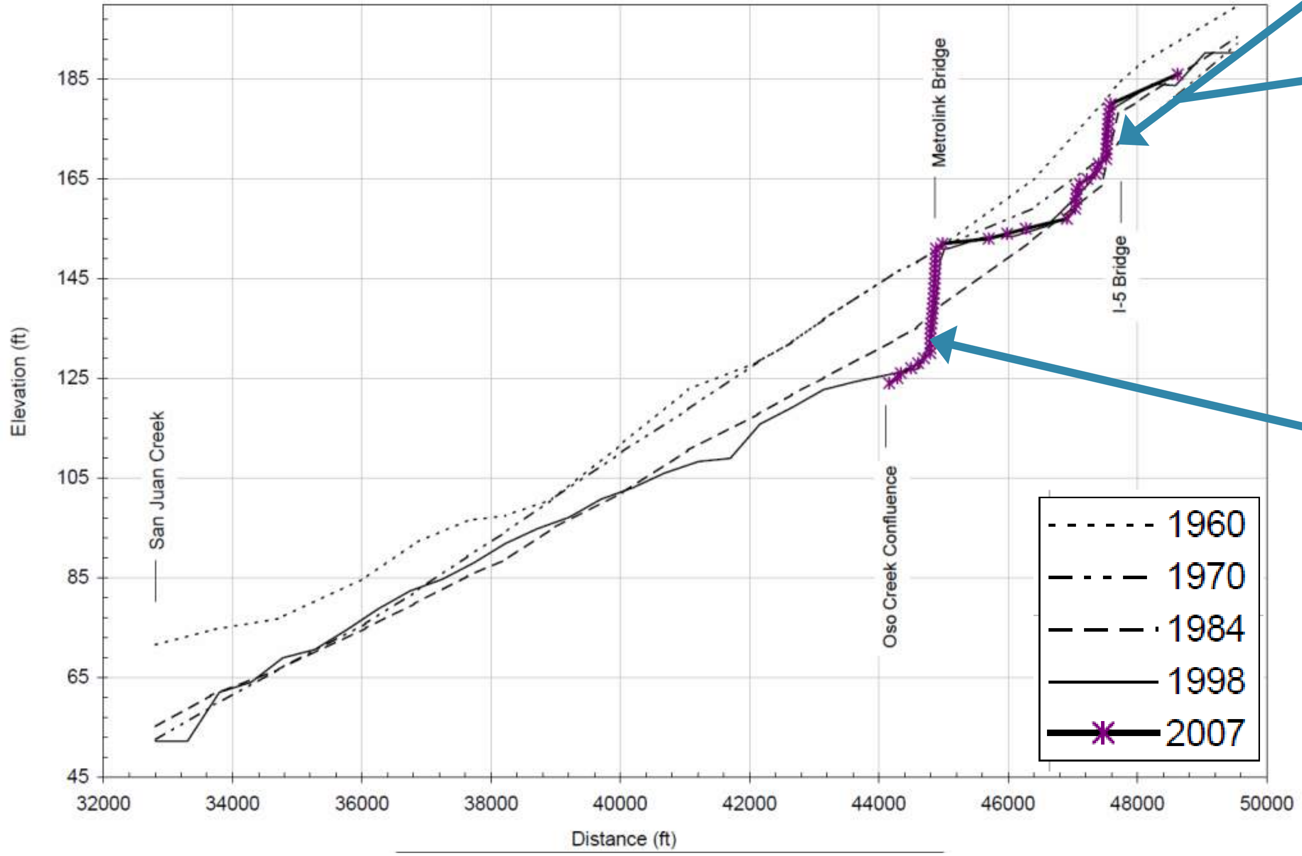

I-5 Complex
Drop Structure at Metrolink Crossing

Trabuco Creek Historical Incision and Knickpoints

- Up to 20 feet of vertical channel incision
- Drop thru I-5 Complex = 29 feet
- Drop across Metrolink Crossing = 24 feet
- Project Objective – Passage for Adult and Juvenile Steelhead


Camino Capistrano 1969


Camino Capistrano/I-5 Complex (4 bridges/19 lanes)

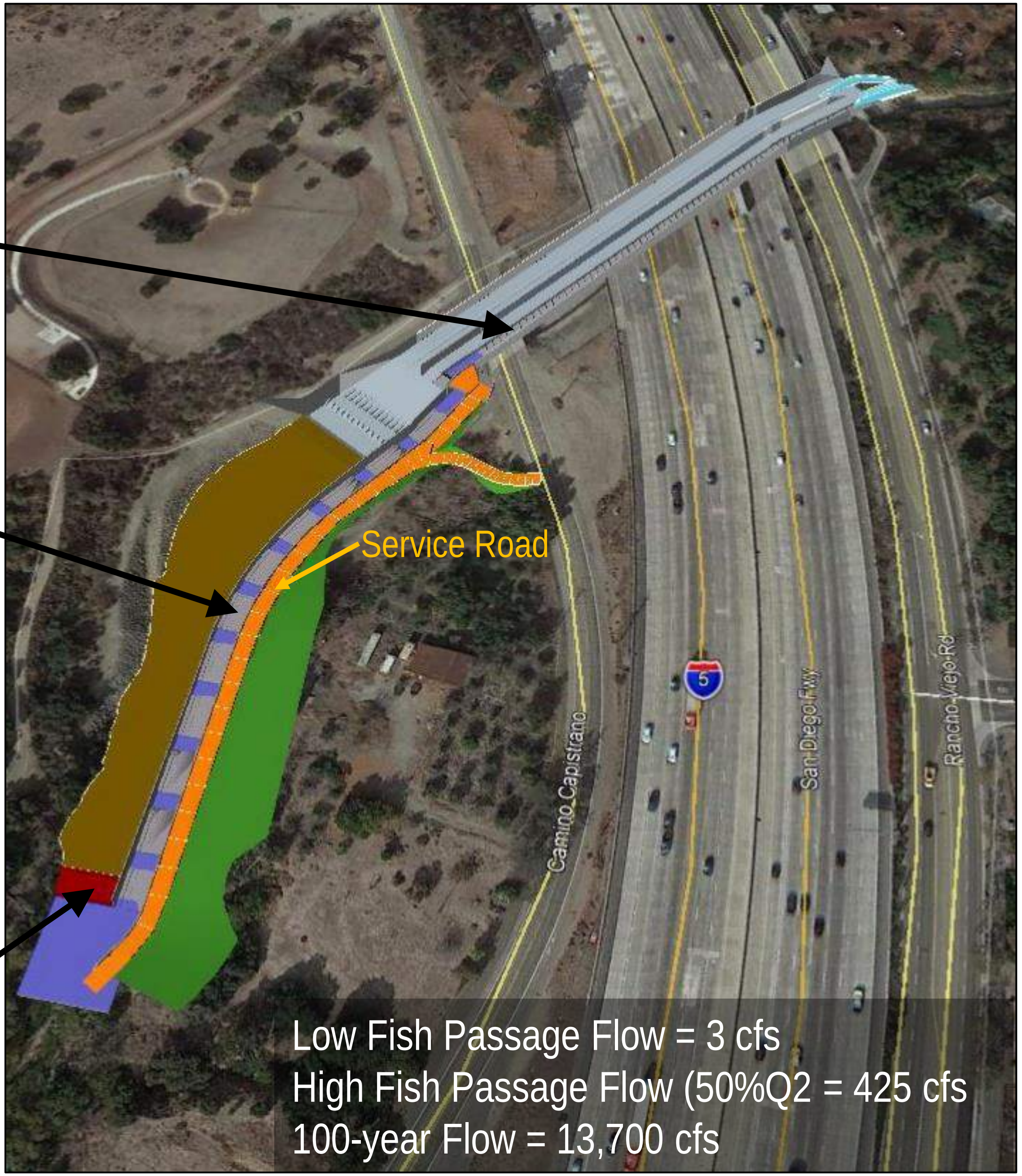



Metrolink Bridge & Utility Crossing

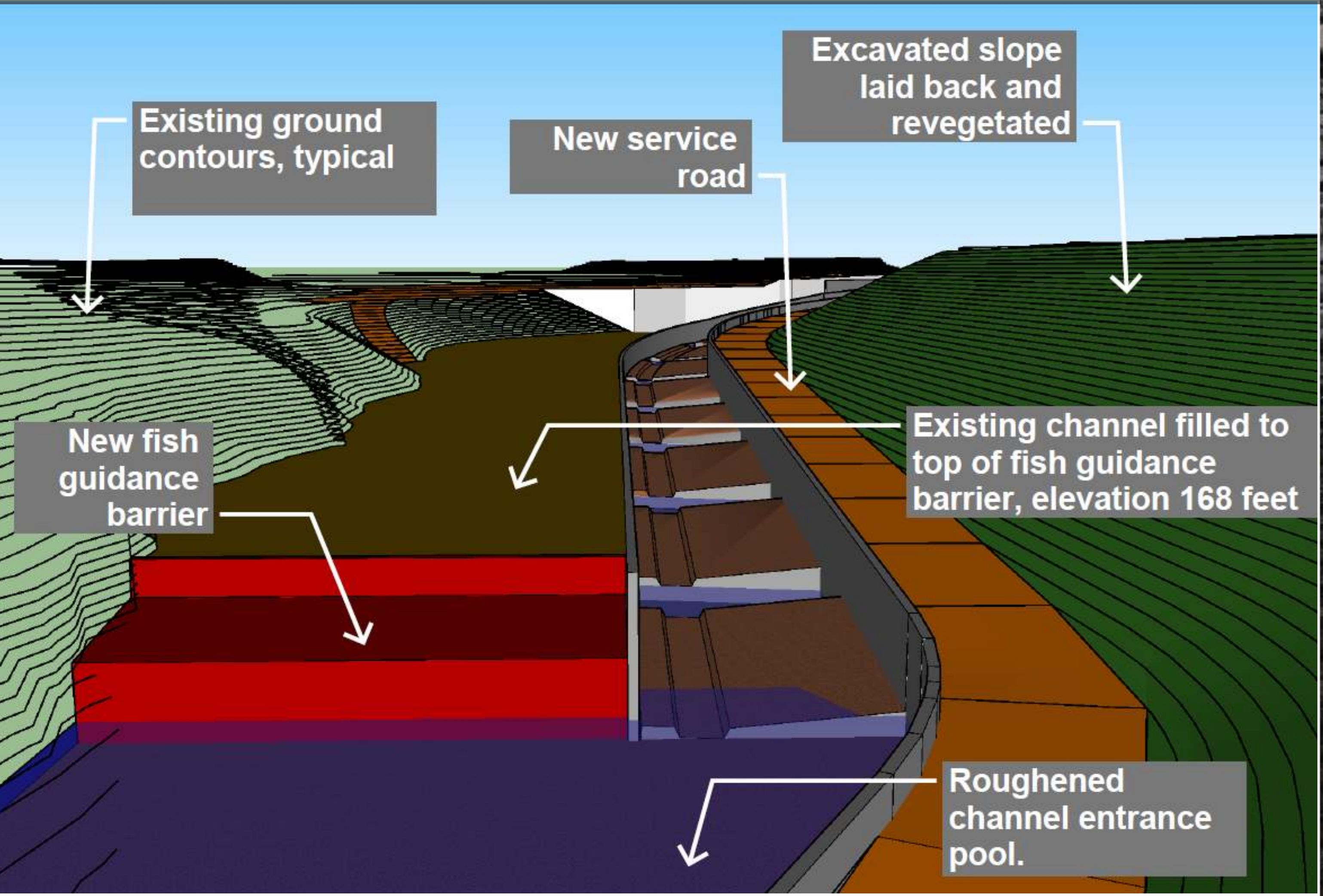
I-5 Complex Selected Project

Key Fish Passage Components (Upstream to Downstream)

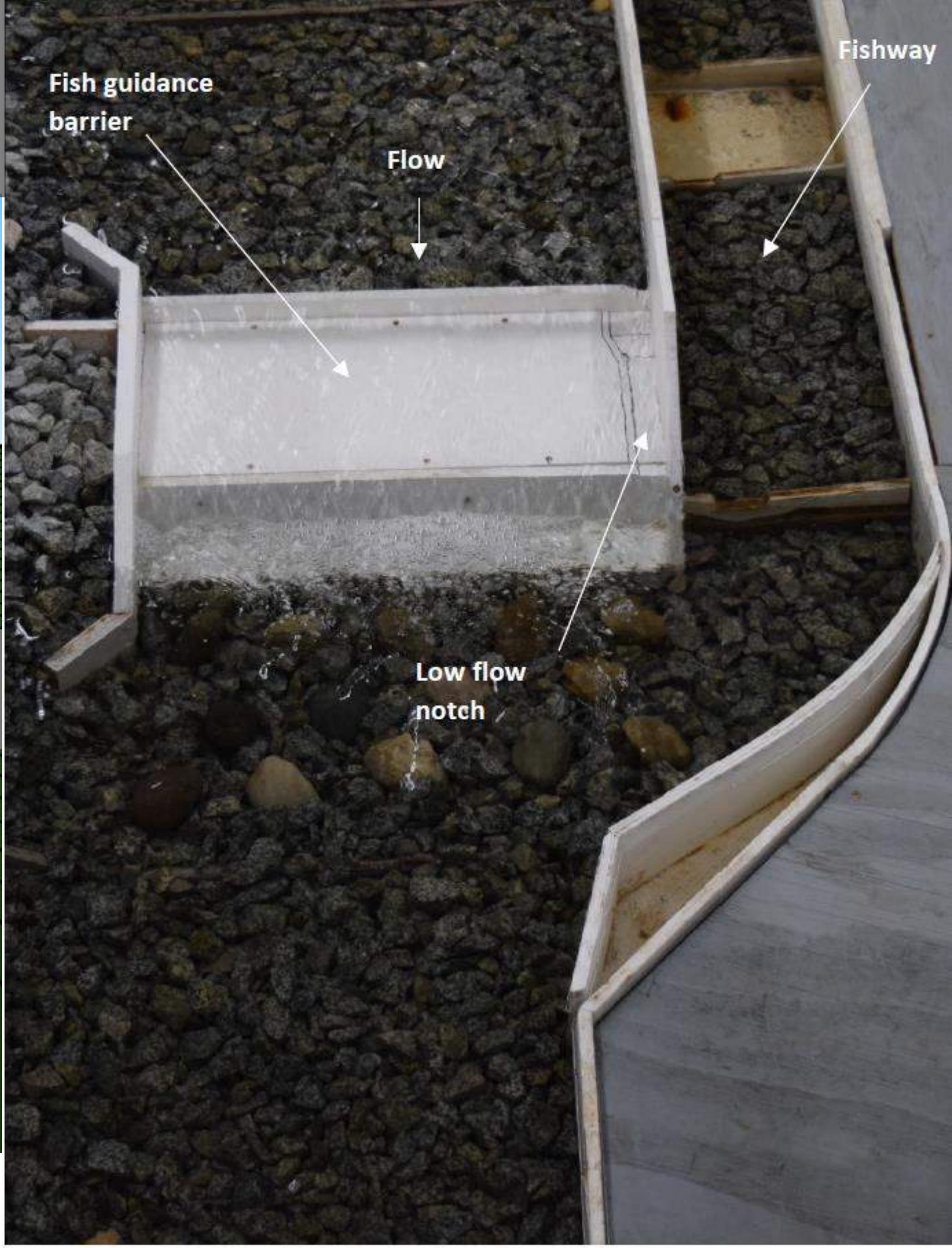
1. **Transport Channel with Corner Baffles**
   - 12 ft Wide x 3.5 ft Deep
   - 0.87% Slope
   - Length = 670 ft
2. **NLF in Concrete Bypass Channel**
   - Flow Control: Orifice at Fishway Exit
   - Type: Chutes and Pools Roughened Channel
   - Length = 637 feet
   - Width = 20 ft
   - Head Drop (Entrance-Exit) = 21 feet
   - Overall Slope = 3.3%
   - Boulder Chute Slope = 4.5%
   - Drop between Pools = 1.9 feet
   - Qhp Flow in NLF = 89 cfs (21%)
3. **Fish Guidance Barrier at NLF Entrance**
   - 10.5 ft tall with sloping apron



Fishway Entrance and Guidance Barrier



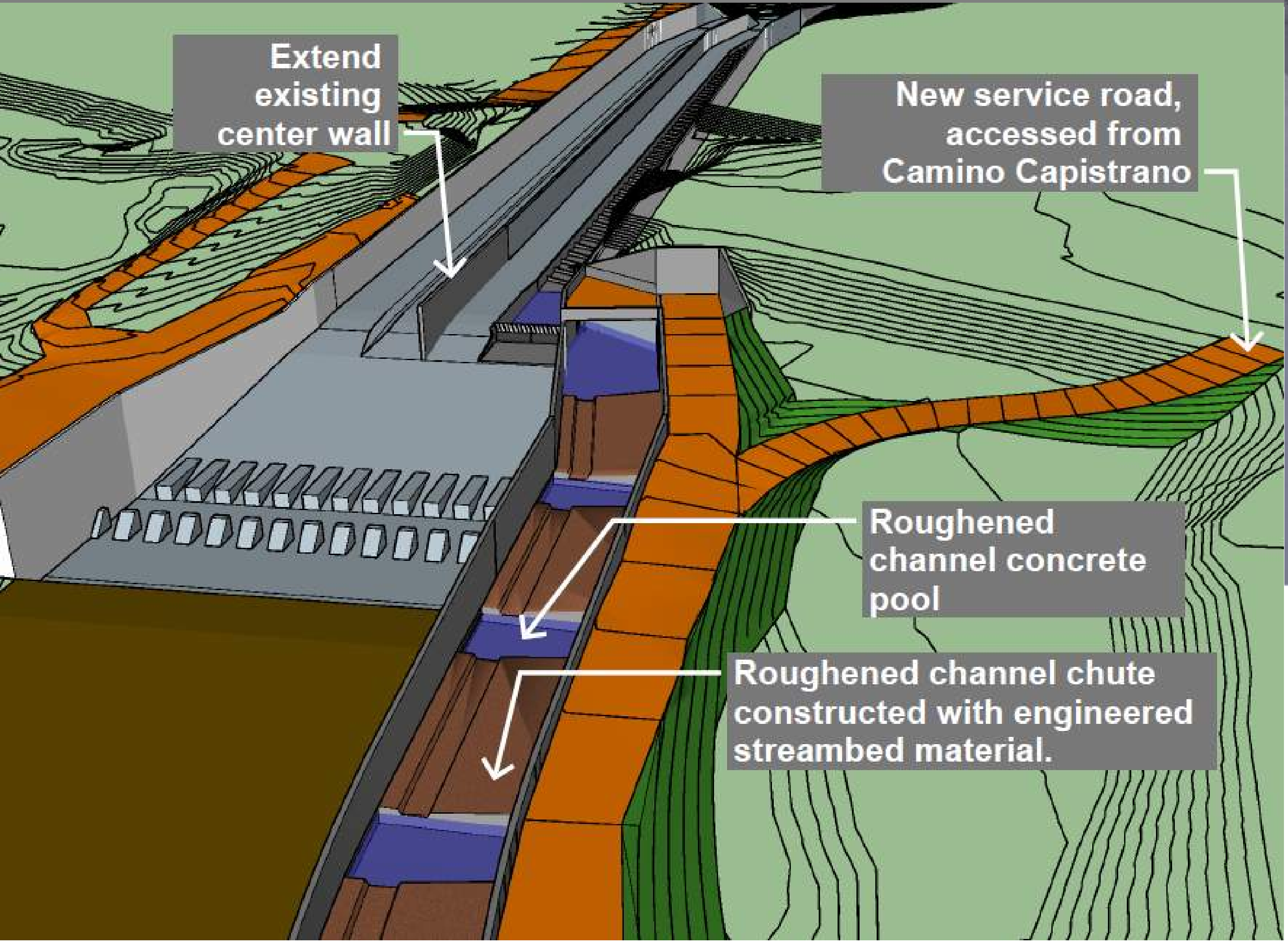
3D Rendering



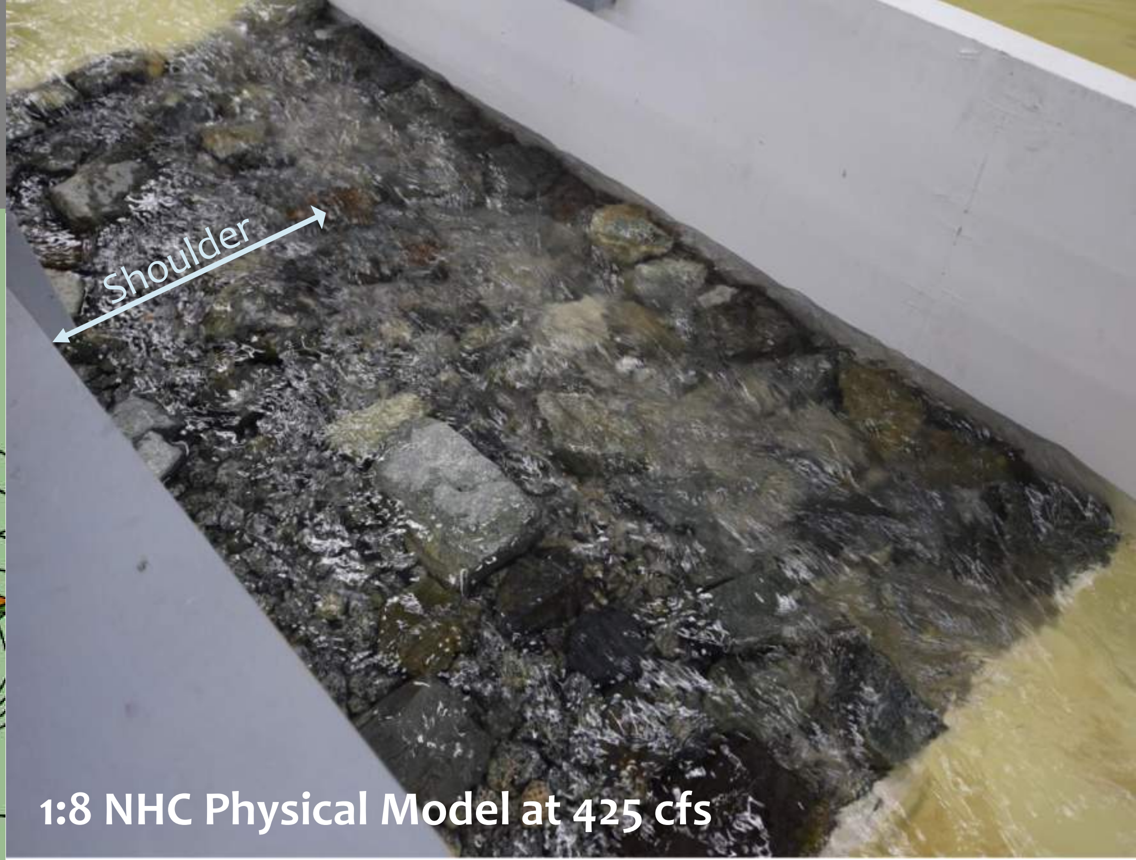
1:25 NHC Physical Model

Photo 2. Flow patterns at the fish guidance barrier and fishway entrance at 425 cfs.

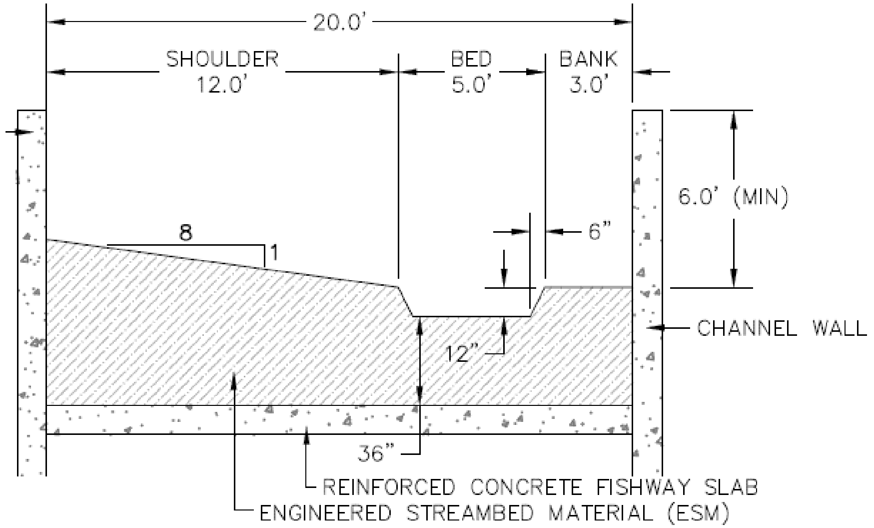
Chutes and Pools Roughened Channel



3D Rendering

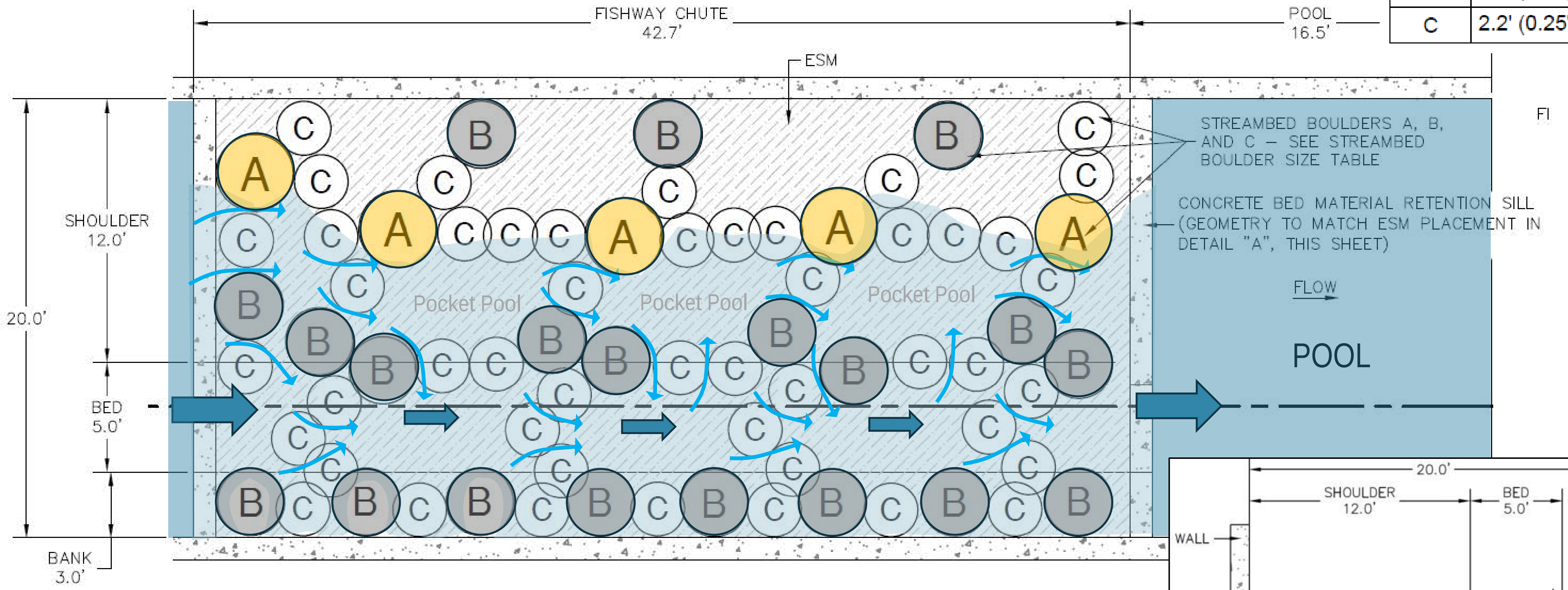


1:8 NHC Physical Model at 425 cfs

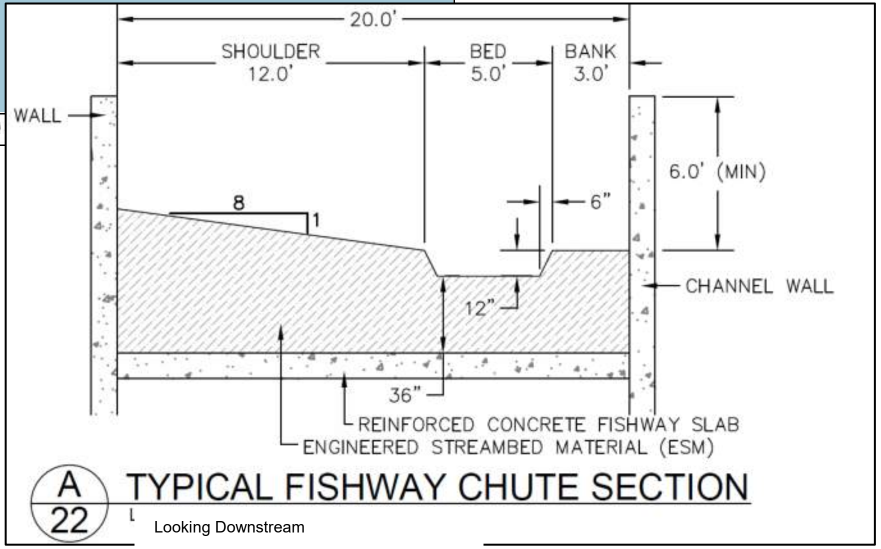


Rock Placement Plan for Chutes

STREAMBED BOULDER SIZE TABLE		
	SIZE	PROTRUDE
A	3.6' (0.4'±)	~1.4'
B	3.0' (0.4±)	~1.0'
C	2.2' (0.25'±)	~0.65'



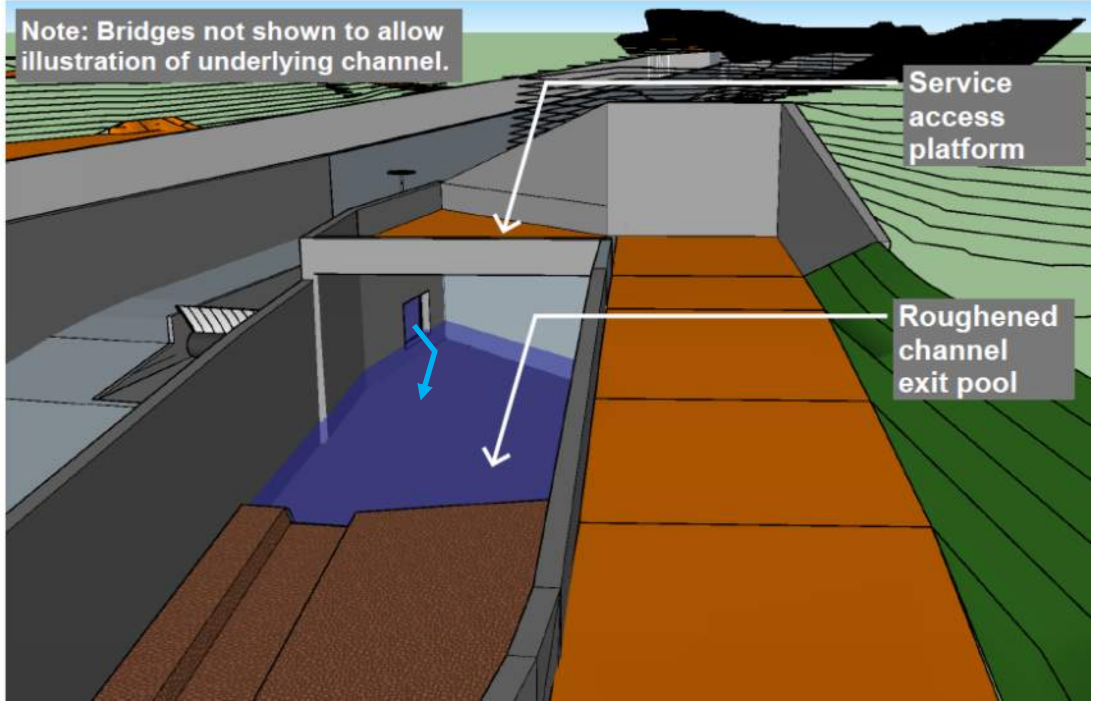
Rock Chute Plan



Shoulder provides variable depth and velocity zones over wide range of fish passage flows

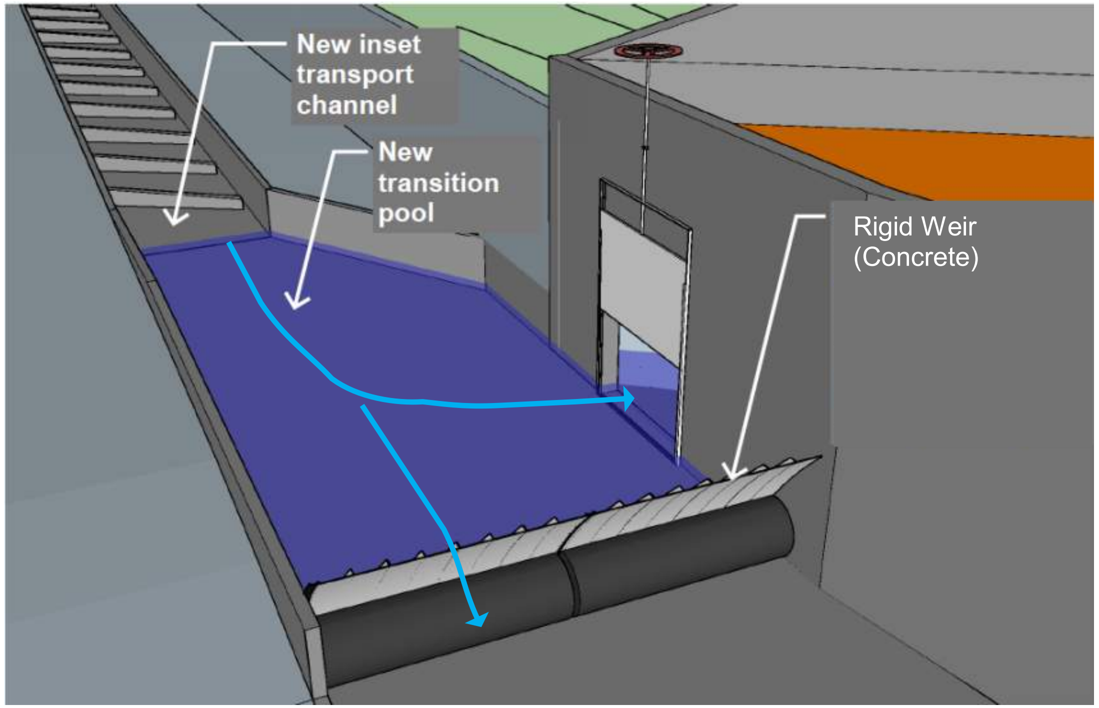
Baffled Transport Channel

Fishway Exit Pool Downstream of Orifice




1:8 NHC Physical Model

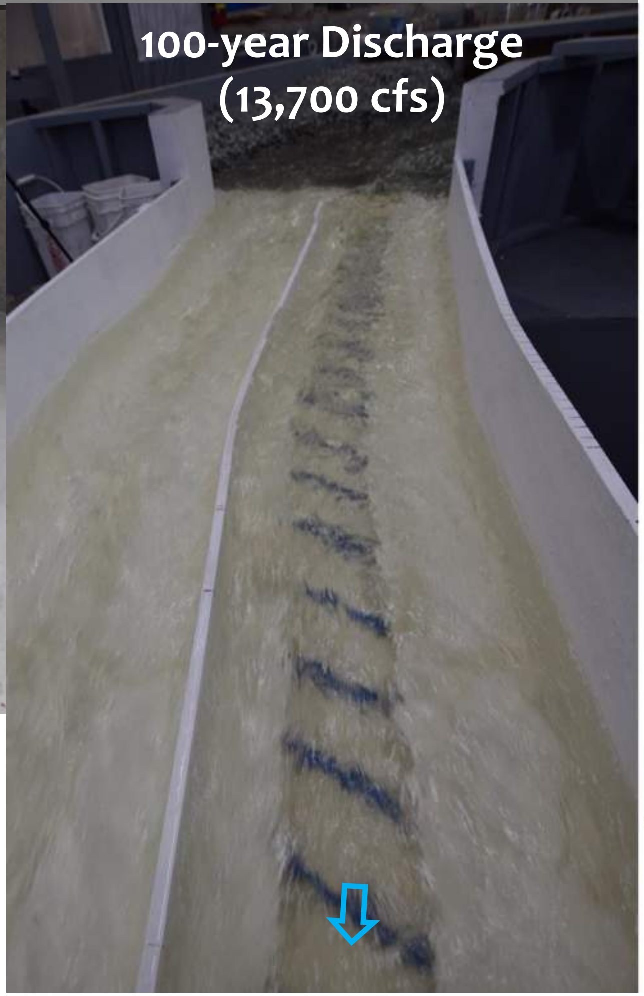

1:8 NHC Physical Model
Sedimentation Patterns



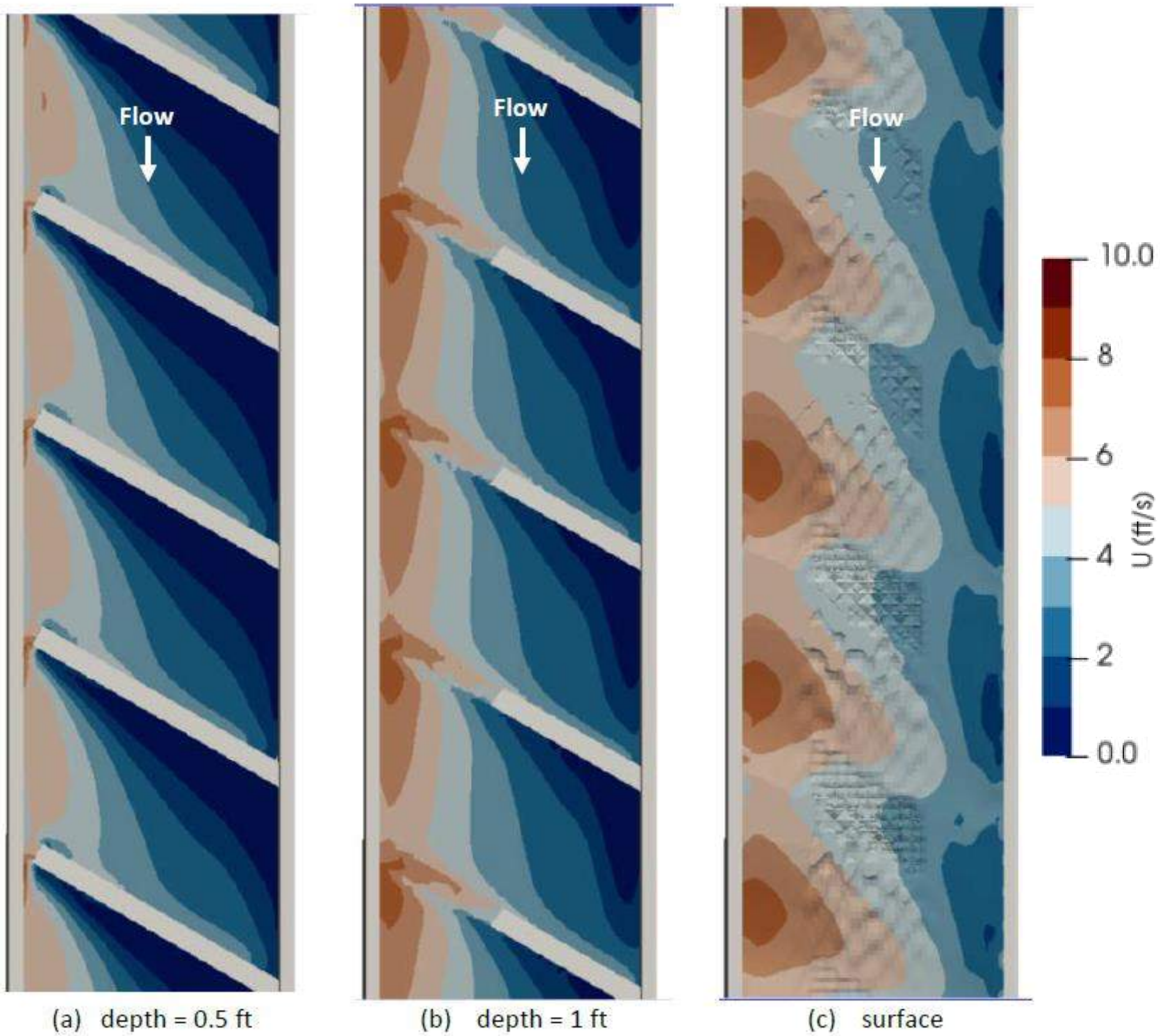
Transition Pool and Orifice at Fishway Exit

Baffled Transport Channel

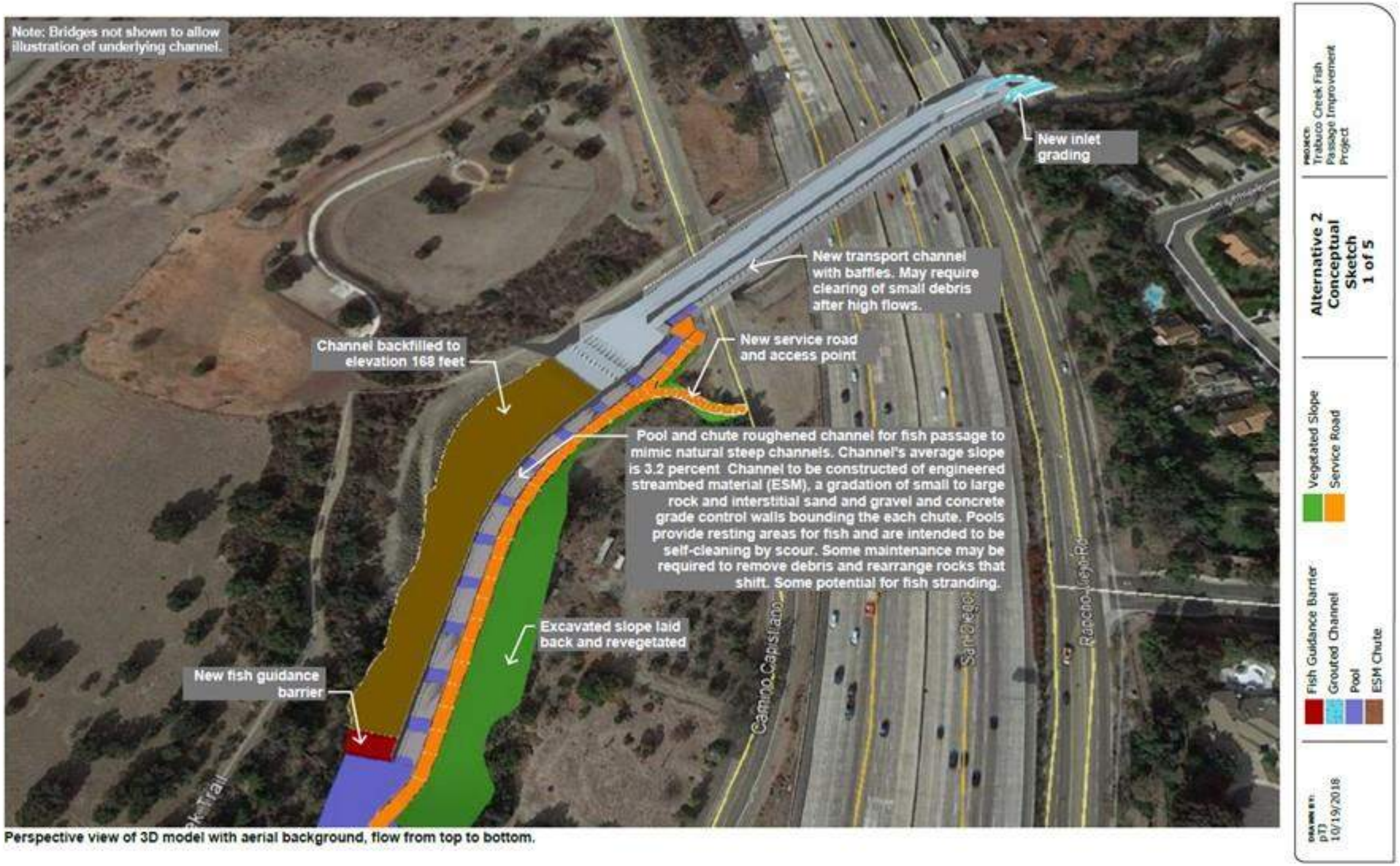
Example of a Baffled Transport Channel



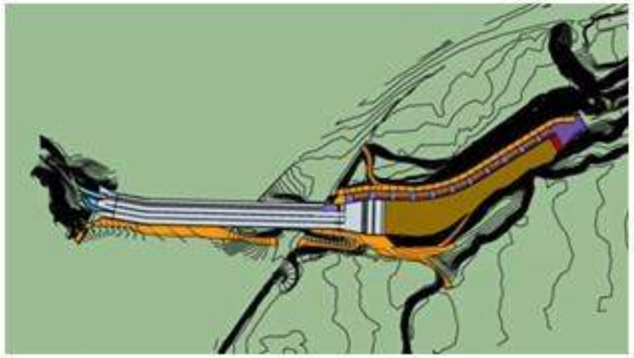
1:25 NHC Physical Model



CFD (3D) Modeling – Velocities in horizontal planes at various depths (206 cfs)



Perspective view of 3D model with aerial background, flow from top to bottom.



https://vimeo.com/797822371

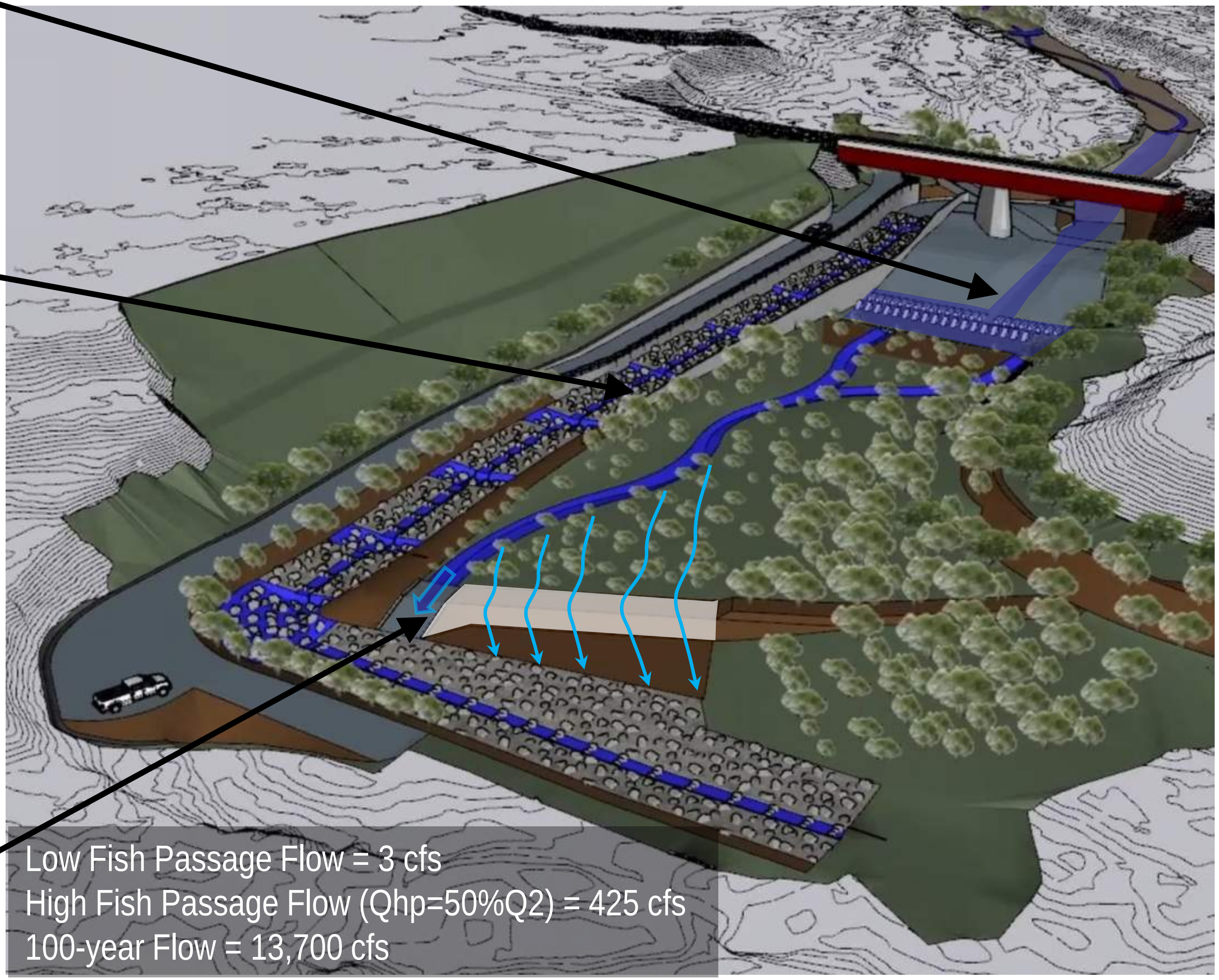
I-5 fish passage
3D animation

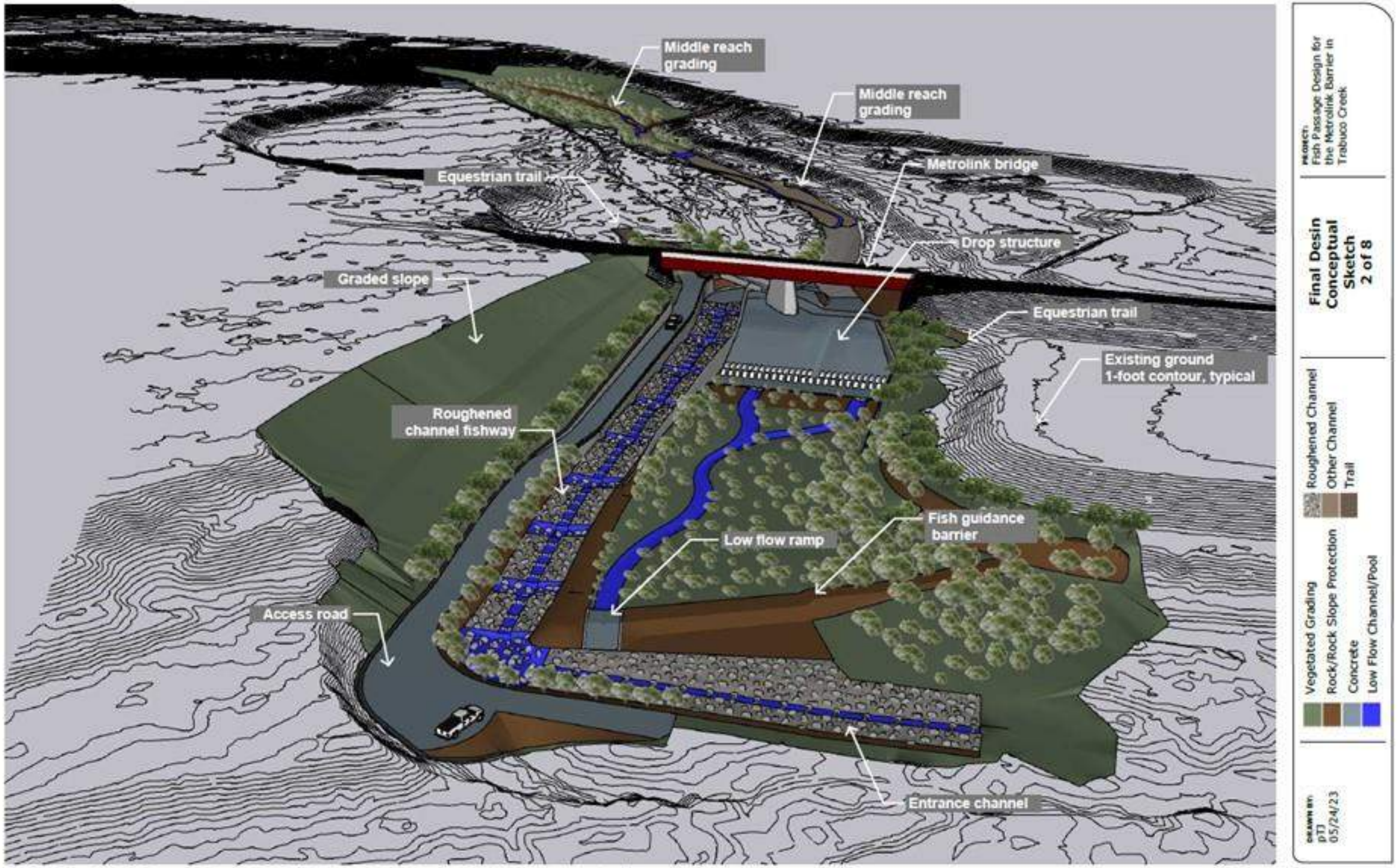
Metrolink Crossing Downstream of I-5 Complex

Metrolink NLF Project

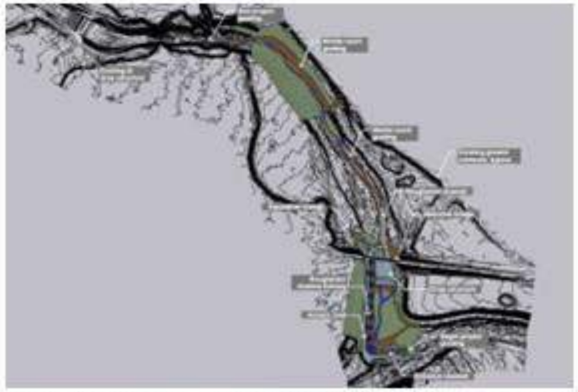
Key Fish Passage Components (Upstream to Downstream)

1. **Drop Structure with Out-Migrant Channel**
   - Head Drop = 14 ft
   - Concentrates Flow for Downstream Passage
2. **NLF Bypass Channel**
   - Fishway Exit Channel: 90º to Flow
   - Chutes and Pools Roughened Channel with Asymmetrical Cross Section
   - Head Drop (Entrance-Exit) = 26 feet
   - Length = 686 feet
   - Width = 30 ft
   - Overall Slope = 3.8%
   - Boulder Chute Slope = 5.75%
   - Drop between Pools = 2.5 feet
   - Qhp Flow in NLF = 212 cfs (50%)
3. **Fish Guidance Barrier at NLF Entrance**
   - Low Flow Ramp & Stacked Boulder Weir





Perspective view of 3D rendering showing the proposed project and existing contours, looking upstream



https://vimeo.com/829935448?share=copy

Metrolink fish passage 3D animation

Interstate 5 Bridge Array and Metrolink Railroad Bridge Fish Passage Barriers – Trabuco Creek, Orange County CA

Hydraulic Fishway Solutions
Status: 90% Design

Project Team
Engineering: NHC, Mike Love & Assoc., Gannett Fleming
Permitting: Stillwater Sciences
Project Lead: California Trout

Project partners/stakeholders include: California Department of Fish and Wildlife, National Marine Fisheries Service/NOAA, U.S. Fish & Wildlife Service, Orange County Public Works, Orange County Flood Control District, City of San Juan Capistrano, Acjachemen, California Department of Transportation, Southern California Regional Rail Authority, Moulton Niguel Water District, Highpointe Inc, and private landowners

Funders: CA Dept of Fish and Wildlife, National Fish and Wildlife Foundation, Wildlife Conservation Board

Project Partners

NOAA FISHERIES

CALIFORNIA TROUT
KEEPER OF THE STREAMS

WCB
State of California
Wildlife Conservation Board

CALIFORNIA
DEPARTMENT OF FISH & WILDLIFE

Michael Love & Associates
Hydrologic Solutions

nhc
northwest hydraulic consultants

GANNETT FLEMING
Excellence Delivered As Promised

Stillwater Sciences

NLF Project Spotlight:

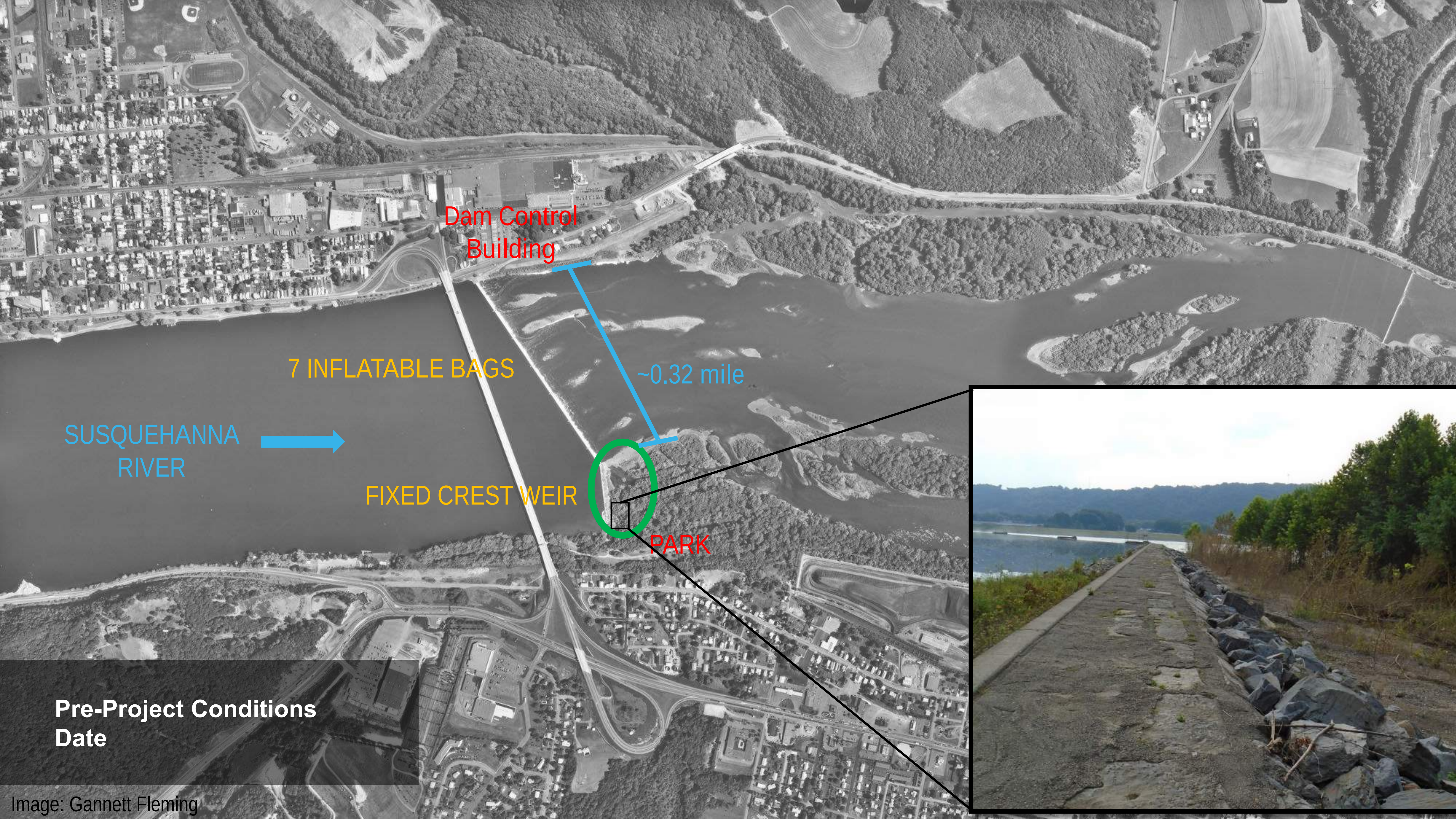
Shikellamy NLF
Shamokin Dam, PA

By: Tyler Kreider

3/27/2024

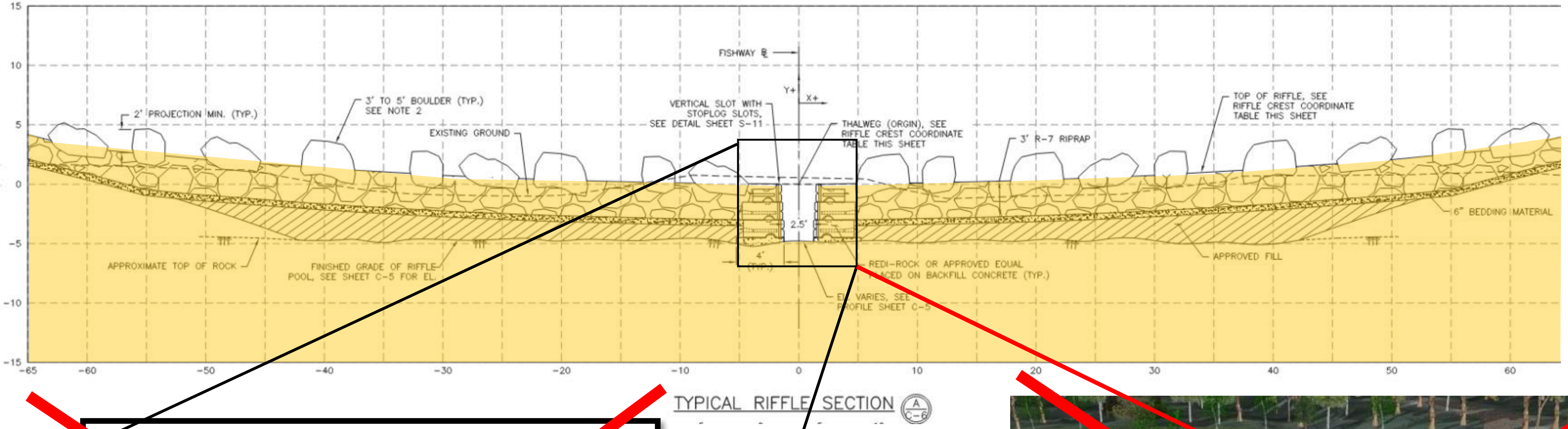
Shikellamy NLF

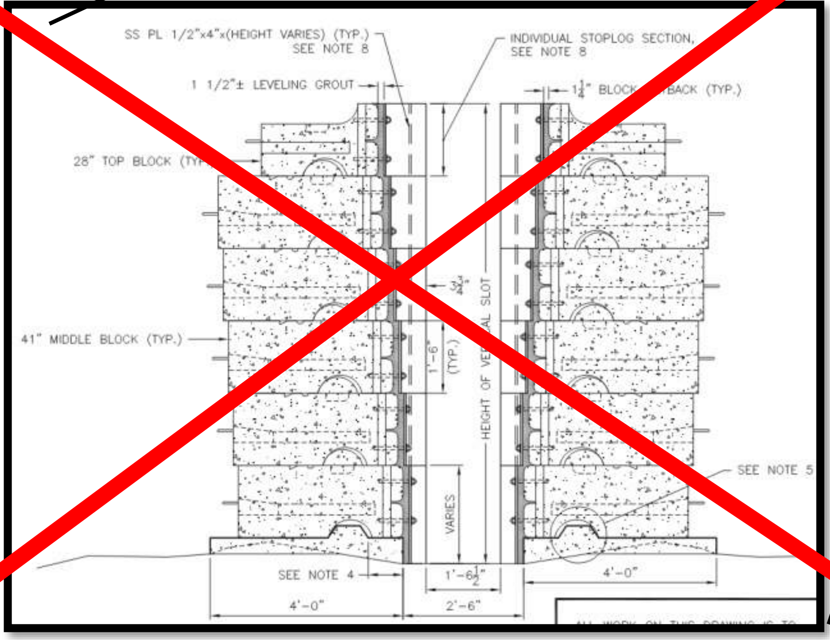
- Purpose and Objectives
  - Allow American Shad & River Herring passage at the dam
  - Provide passage when the dam was inflated
  - Maintain vehicle access to dam and emergency boat launch
- Key Features
  - NLF Type: Roughened Channel Bypass
  - Length: 700 feet Width: 120 feet Head: 8 feet
  - Overall slope: 1.3-1.5% Riffle Slope: 2.2-2.4%
  - Design NLF Flow: 950 cfs,
  - Operating range: 95%-5% exc. flow during fish passage season (~2,700-46,000 cfs river flow)



Pre-Project Conditions
Date

Image: Gannett Fleming



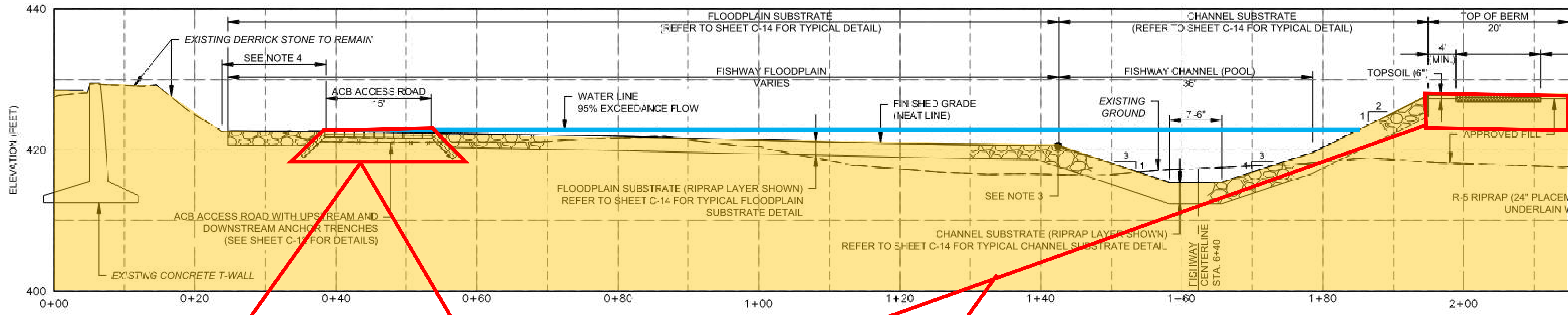


Key Challenge: Right-sizing design criteria

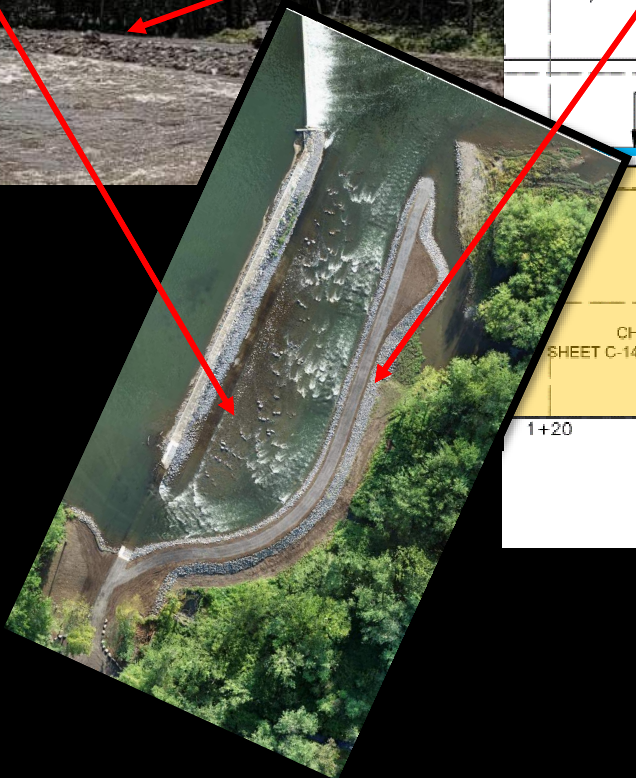
Challenges & Solutions

- Wetlands → kept NLF up near dam
- Attraction ("detraction") flow → keep NLF entrance as close to dam as feasible
- Access road → ACB road in floodplain

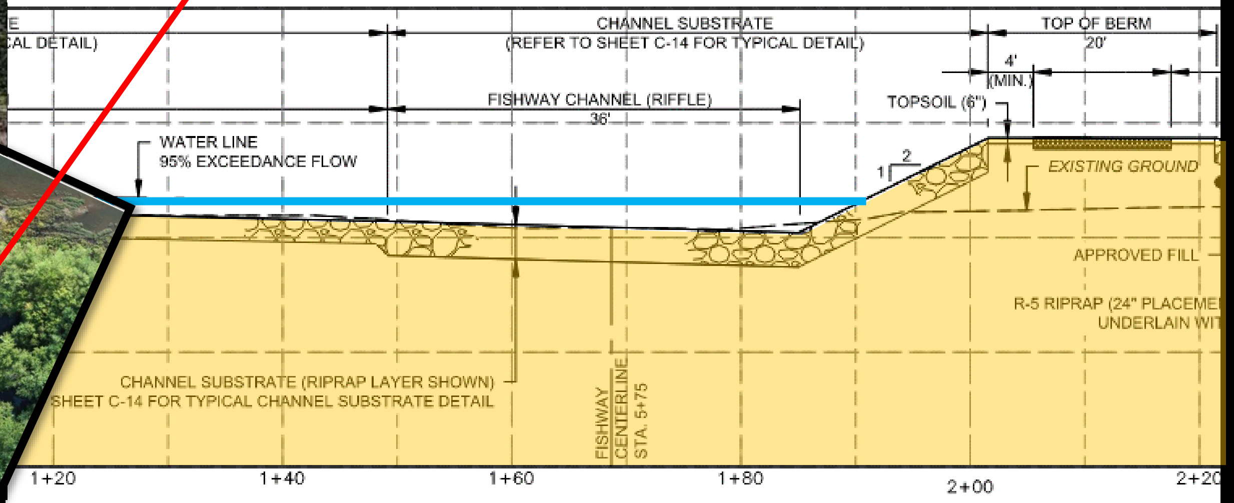
Photos courtesy of KC Construction



POOL Cross Section



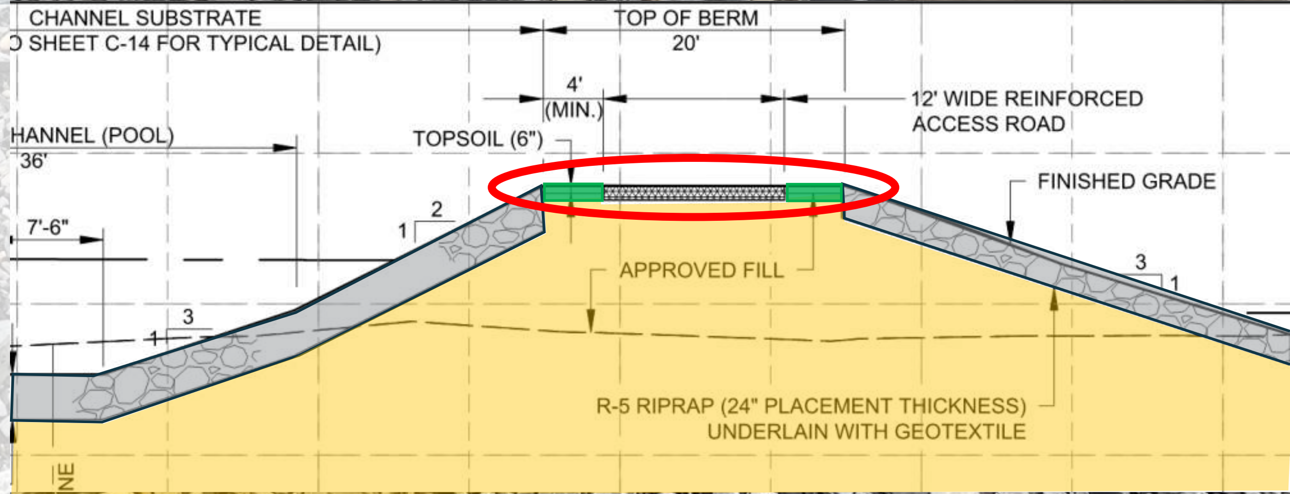
Key Challenge: River Access



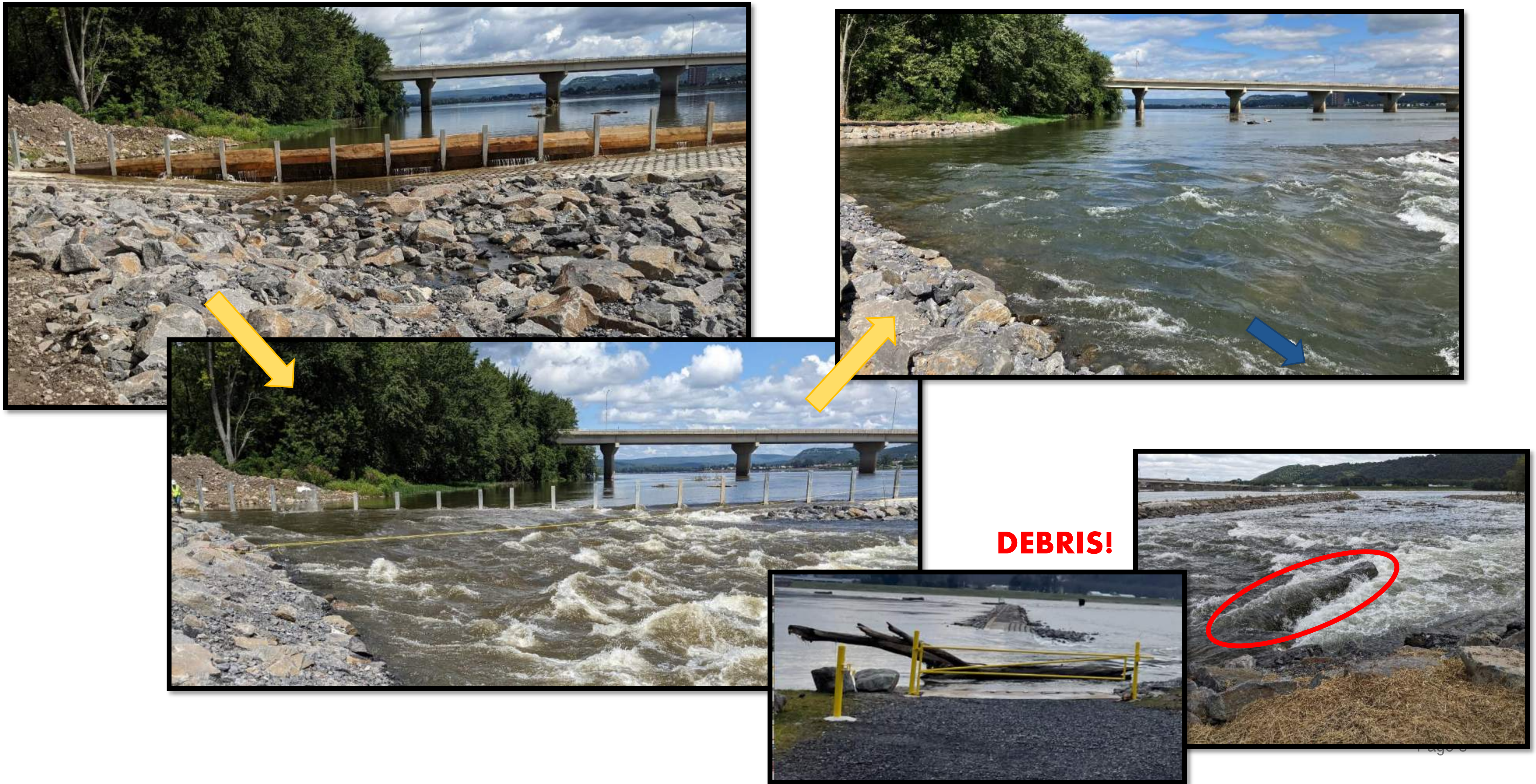
RIFFLE Cross Section

Lessons Learned:

- Tie-ins are critical
- Failure at the weakest member = soil
- Reminder that flood flow vectors don't match "typical" flow vectors



Key Challenge: Watering up & Maintenance



Shikellamy NLF – Questions?

NLF Project Spotlight:

James Creek
Mendocino County, CA
Mike Garello, PE

3/26/2024

James Creek

Project Objectives and Key Features

- Purpose and Objectives
  - Mitigate channel incision associated with encroachment of state highway road embankment spoils
  - Provide Passage to Chinook Salmon, Coho Salmon, and steelhead trout
  - Restore access to more than 3 miles of upstream habitat
- Key Features
  - Channel spanning, step pool roughened channel
  - 250 feet long, varies 25 to 50 feet wide, gradient of 6.5 %
  - 0.1 APE (100-year peak discharge) = 2,160 cfs
  - 0.5 APE (2-year peak discharge) = 630 cfs

Pre-Project Conditions
2011

Pre-Project Conditions
2011

Key Considerations, Challenges, and Risks

01 Delayed Build Due to Funding Constraints

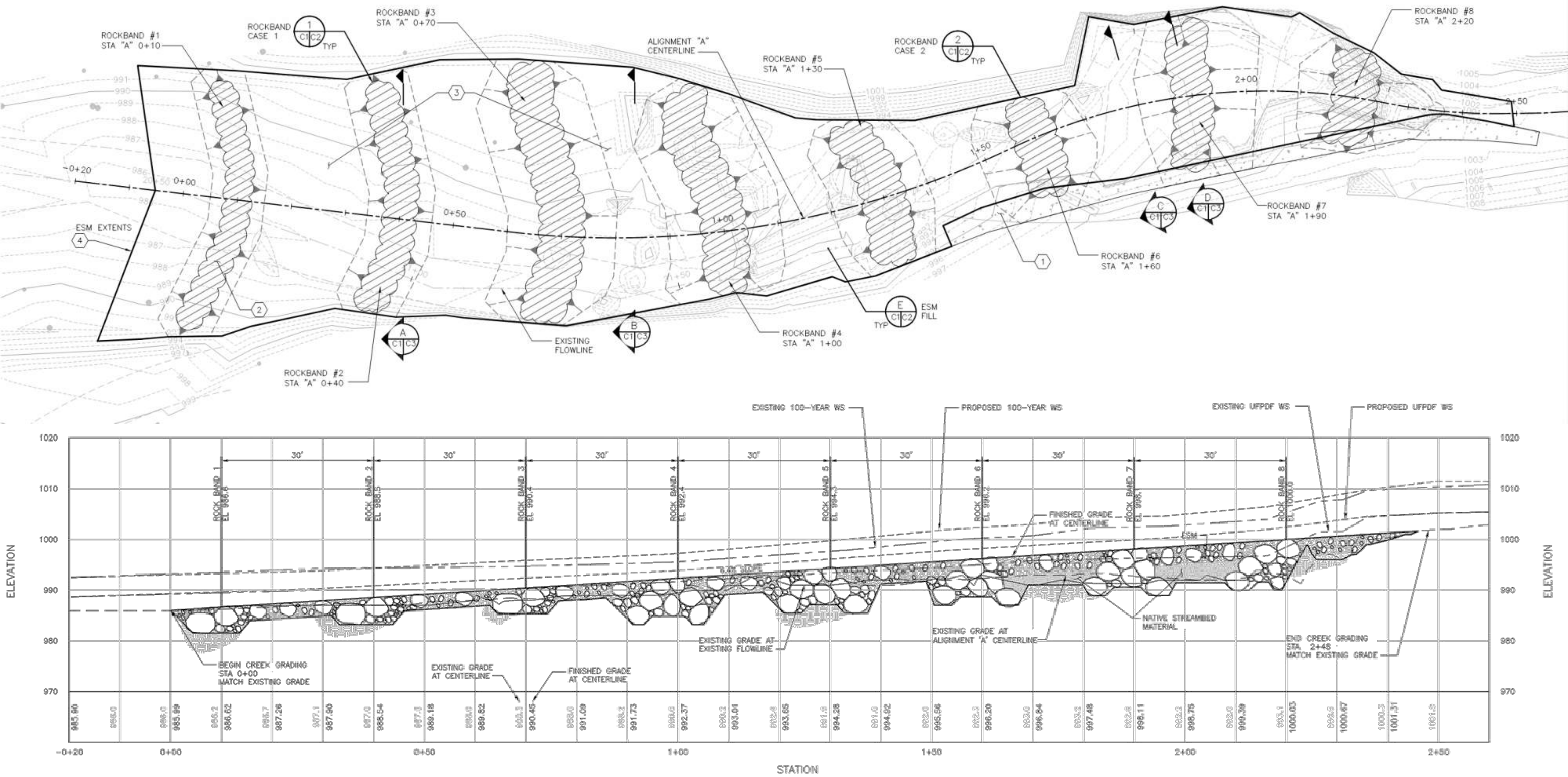
- Original designer advanced the project to a 100% level of definition in 2015
- Was to be constructed in one phase.
- Construction was delayed until additional funding could be obtained
- Risk of losing institutional project knowledge if designer is no longer involved in construction
- Design engineer not present during construction to relay design intent

02 Remote Site with Limited Access

- Limited access for geotechnical investigations
- Extent and nature of bedrock not fully defined
- Pioneered access of construction equipment to site - additional time and temporary construction impacts
- ~2,600 tons of quarried stone 28”-60” diameter
- ~2,500 tons of gravel & engineered streambed material 20” minus

03 Two-Phased Construction Process

- Pacific Watershed Associates proposed to perform construction over two seasons
- Winter flow events may mobilize channel-stored coarse sediment
- Risk if bedload mobilizing event doesn’t occur during winter reduces cost benefits
- Two episodes of disturbance vs. one - - increase in construction equipment/labor costs



Proposed Design Plan and Profile

Delayed Construction

- Additional funding made available through CDFW Fisheries Restoration Grant Program (FRGP)
- Pacific Watershed Associates were hired to construct the project in 2016
- Proposed construction over two seasons as a potential cost saving strategy

Benefits

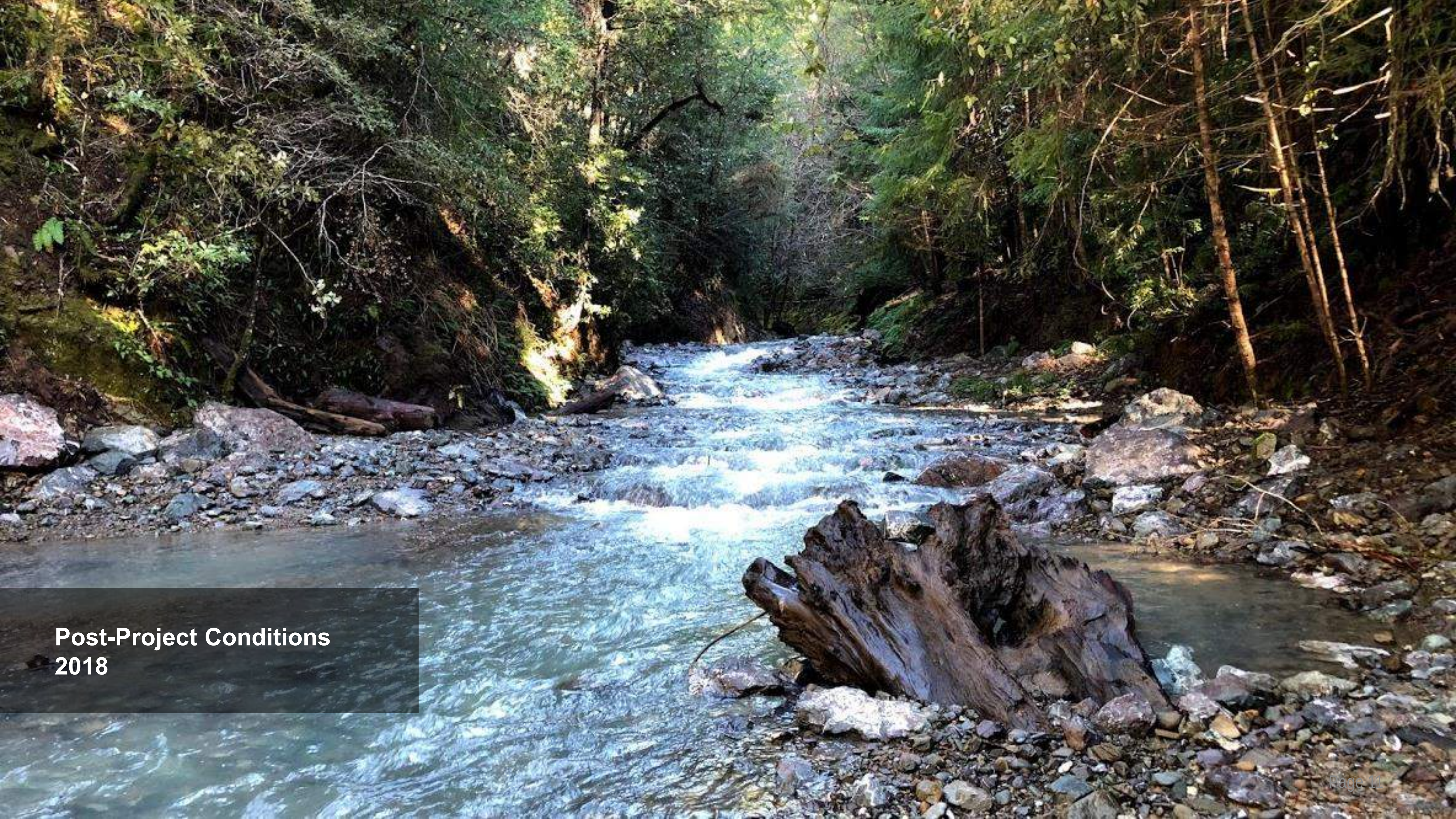
- Reduce construction costs,
- Allow adaptive management during construction,
- Limit the amount of imported alluvium required to construct the project
- Reduce imported gravel costs by up to 50%.
- Reduce transportation-related impacts.
- Reduce risk of introducing non-native species.
- Allow design to “settle in” and adapt design in Phase II if shortcomings are observed.
- Sequester up to 1,000 CY of excess channel-stored sediment.

Risks

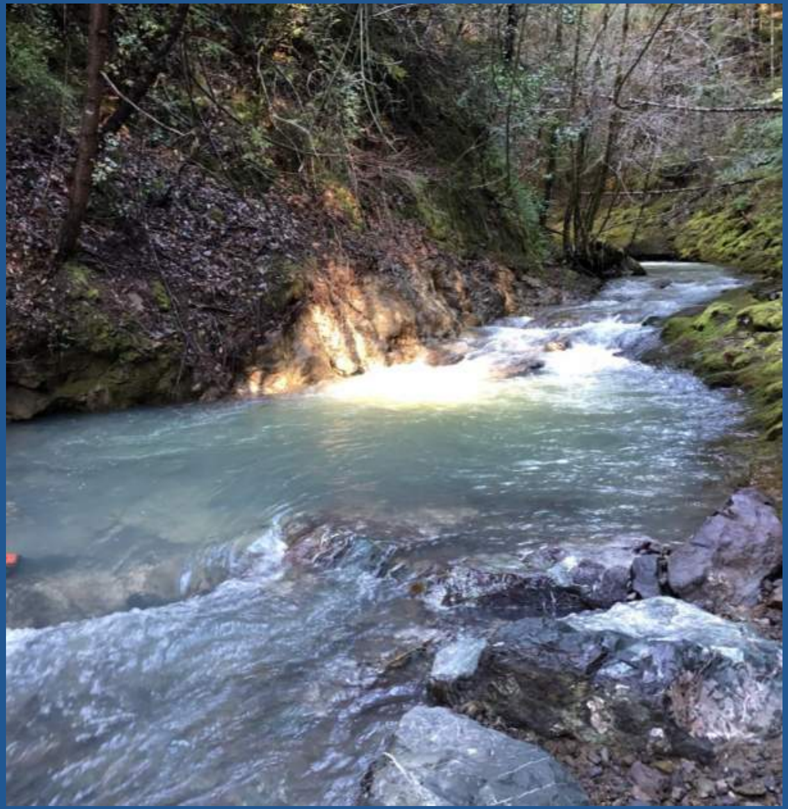
- No bedload mobilizing event during winter reduces cost benefits.
- Slight increase in construction equipment/labor costs.
- Potentially restrict access by steelhead for one winter.
- Two episodes of disturbance vs. one.

Two-Phase Construction Strategy: Phase 1 Construction

Two-Phase Construction Strategy: After Phase 1


Post-Project Conditions
2018

Two-Phase Construction Strategy: After Phase 2



Lessons Learned

- Construction methodology is critical and there are more ways than one to successfully construct a project
- Use of qualified contractors experienced in similar in-water work provides value and is an asset throughout construction
- Address potential dewatering challenges in the design process
- Interstitial gaps between placed rock can be addressed by hydraulicly placed sediment and streambed fill

AMERICAN FISHERIES SOCIETY
BIOENGINEERING SECTION