



Fish Passage Programs: Survey of Practice

Requested by
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Executive Summary

Background

Caltrans owns approximately 530 known barriers within the state highway system that block or impede passage of salmon and steelhead trout to their habitats. Remediation of barriers and effective new construction has been the goal of internal agency partnering meetings and communications throughout the state. The agency is seeking data that will allow for the comparison of procedures and costs related to various fish passage solutions.

To assist in this information-gathering effort, CTC & Associates conducted a survey of other West Coast state and federal transportation and wildlife agencies, academic researchers and consultants to gather information about fish passage programs. The survey addressed the use of full-span and partial, or hydraulic, solutions; planning and development processes; implementation; and long-term monitoring and maintenance of fish passage facilities. Publications provided by survey respondents and the results of a limited literature search supplemented survey findings.

Summary of Findings

Survey of Practice

An online survey solicited information about fish passage programs from 23 fish passage experts. Potential respondents were drawn from state departments of transportation (DOTs) in California, Oregon and Washington; departments of fish and wildlife (DFWs) in those states; and Federal Highway Administration's (FHWA's) Western Federal Lands Highway Division and National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS). Fish passage experts from two consulting firms and two universities completed the list of potential respondents. The survey received 11 responses from 13 of the 23 potential respondents. (Three Washington State DOT respondents collaborated on a single survey response.)

Below is a summary of key findings from the survey results in these topic areas:

- Program background.
- Project development.
- Species benefits.
- Construction and implementation.
- Monitoring and maintenance.

Refer to the **Detailed Findings** section of this report for a comprehensive review of survey responses.

Program Background

All agencies responding to the survey reported that full remediation of barriers for adult and juvenile salmon and steelhead is a goal of the respondent's program or agency. Washington and Oregon focus on full passage design, such as stream simulation or bridges, while Caltrans

uses primarily partial, or hydraulic, solutions with some full-span solutions. (A partial solution is typically a retrofit to a large culvert to include baffles, weirs or other velocity and depth controls to meet specific hydraulic criteria for fish passage.) Federal respondents encouraged full passage solutions. The following highlights key elements of respondents' fish passage programs and the varying emphasis on partial, or hydraulic, solutions.

California. Anadromous fish species are the focus of Caltrans' fish passage program and the subject of an annual report that must be submitted to the state Legislature. Among respondents, partial, or hydraulic, solutions are implemented most frequently in California. Thirty-two of the 39 barriers Caltrans has treated are partial solutions (hydraulic retrofits). California DFW's role is limited to the review and approval of fish passage designs, and the development of design guidelines and criteria for fish passage improvement. The agency formally monitors projects that are funded and constructed through Fisheries Restoration Grant Program (FRGP) grants.

Oregon. A state law passed in 2001 requires full passage solutions. Since passage of the 2001 law, funding provided through Oregon DOT's fish passage program replaces culverts in any condition to meet the stream simulation criteria identified in the state law. Projects funded outside of the fish passage program may pursue hydraulic criteria to meet passage requirements. While the Oregon DFW owns some barriers, most of the agency's work is associated with implementing fish passage requirements as other barrier owners implement fish passage projects.

Washington. Until recently, most fish passage projects in Washington were voluntary. The state is under a 2013 federal injunction related to tribal treaty rights that requires the state to remedy fish barriers with full passage stream simulation or bridges; partial/hydraulic solutions are not acceptable under this injunction. New or replacement structures must use what the Washington State DOT respondent described as a "geomorphic approach," which means that the solution involves a natural, self-maintaining bed such as stream simulation or a bridge.

Federal agencies. The FHWA respondent noted that when appropriate and acceptable, the agency executes partial/hydraulic designs and still tries to demonstrate 100 percent aquatic organism passage effectiveness. The NOAA respondent provided significant detail with regard to remediation solutions and performance standards, noting that inaccurate data associated with hydrological calculations and site assessment can result in the failure of many partial/hydraulic designs. (See page 14 of this report for the full NOAA response.)

Sedimentation and Water Quality

Oregon is the only state among the three West Coast states queried for this project that clearly seeks to address sedimentation and improve water quality as part of all fish passage projects. In Washington, the DOT "seek[s] to restore natural stream conditions/functions," while the Washington DFW respondent noted that his agency's approach is "to let the stream behave to the extent possible as it would without a crossing. One could argue water quality is improved by allowing such natural processes that typically result in more riparian [access], etc."

Plans and Estimated Costs

The use of standard plans and estimated costs is rare among respondents, with only the FHWA respondent indicating that his agency has standard plans for the range of potential solutions to

fish barriers (see [Appendix C](#)). The California agencies use manuals for design guidance, but as one of the Caltrans respondents noted, more are needed and in development.

Project Development

All but one of the responding agencies reported some degree of streamlining for the permitting associated with fish passage remediation project review and approval. Only Oregon DFW's respondent replied entirely in the negative, noting that his agency only reviews projects proposed by others.

Both FHWA and NOAA apply a streamlined process to the permitting of fish passage remediation projects. When they are available, FHWA uses memoranda of agreement or understanding. The NOAA respondent noted that some agencies have developed programmatic Endangered Species Act consultation pathways that do not require a biological assessment.

For Caltrans, documentation-related and permitting efficiencies exist in the few instances when funding is provided through the FRGP, but there is no streamlined process for projects that Caltrans develops internally. Oregon DOT maintains a programmatic consultation with NOAA's NMFS. Certain categories of projects can be completed with notifications; roughened channels and hydraulic projects require review and approval by FHWA and NMFS.

Coordinating Fish Passage Solutions

All respondents participate in a coordination process to identify, assess and prioritize fish passage solutions. Respondents from the three states described a statewide—and sometimes regional—approach. In California, Caltrans partners with California DFW to organize Fish Passage Advisory Committees (FishPACs) throughout the state. Biologists, engineers and other experts participating in FishPACs work to improve science and data, come to agreement on priorities, and allow for a regional assessment of fish passage priorities. In Oregon, Oregon DFW manages statewide fish passage prioritization. In Washington, the state DOT contracts with the state's DFW to identify barriers and assess upstream habitat. Washington DFW's coordination is fairly extensive, providing training, technical assistance and design services to the public and a variety of crossing owners.

Species Benefits

All respondent programs provide access to salmon and steelhead species. Once that access has been provided for, agency programs are more likely to provide access to other aquatic species than to terrestrial species. While all agency programs provide access to more than salmon and steelhead species, they differ on the breadth of an expanded program focus. Some agencies opt for a more expansive approach that provides connectivity to all species, while other respondents reported a more targeted focus on regulated species.

A wide range of aquatic and terrestrial species have benefited from respondents' full-span fish passage remediation projects. (A table on page 25 of this Preliminary Investigation summarizes survey responses.) Only the Oregon and NOAA respondents do not add in costs to address terrestrial species permeability on salmon and steelhead barrier remediation projects. None of the remaining respondents were able to identify specific costs, but some did describe how design considerations are made for terrestrial species.

One of the Caltrans respondents noted that design considerations for terrestrial species' access to a fish crossing are often made when developing a remediation project. Other respondents

reported less frequent consideration of terrestrial species, with the FHWA respondent reporting that on rare occasions additional culvert crossings are added at minimal cost; California DFW will sometimes include costs for terrestrial access.

In Washington, the DFW and DOT will consider the specific needs of certain terrestrial species or expand a project depending on the site and local safety or ecological concerns. The Washington DFW respondent believes his agency's focus on stream simulation and bridges that provide fish passage provides some terrestrial benefit.

Construction and Implementation

Responding agencies employ a range of activities and practices that help to ensure the proper implementation of fish passage remediation projects. Among the effective practices cited by respondents are preconstruction meetings, inspections by properly trained staff and other in-person site monitoring, and the monitoring of reports.

All respondents described additional coordination or oversight associated with implementing complex hydraulic solutions. Some spell out the additional coordination in conditional documents for inspections and approvals (California DFW), while others use preconsultation for complicated projects (Oregon DOT) or site visits by hydraulic engineers or biologists (Washington State DOT).

When asked about the participation of specialists—a fish passage engineer or biologist—to provide oversight or monitoring during the implementation of fish passage projects, only the NOAA and Oregon DFW respondents indicated that this type of specialist did not participate in monitoring or oversight. The table on page 28 of this Preliminary Investigation provides details of other agencies' practices.

Monitoring and Maintenance

Full-Span Solutions

Respondents were asked about the long-term costs and staff time associated with monitoring and maintenance of full-span solutions. Four agencies—Caltrans, FHWA, Oregon DFW and Washington State DOT—do not have specific cost data available. The following highlights other agencies' responses.

- California DFW only formally monitors projects that were funded and constructed using a FRGP grant. All California FRGP projects receive implementation monitoring via site visits during construction and using information provided by the grantee.
- A qualified biologist from Oregon DOT makes annual site visits that involve taking photos and conducting a best professional judgment analysis over a five-year monitoring period; the estimated cost for the five-year monitoring period is \$2,000.
- Washington DFW reported very minimal costs for monitoring and maintenance.
- Washington State DOT monitors fish passage corrections for performance at years 1, 5 and 10, at minimum. This process takes a couple of hours per visit.

Partial, or Hydraulic, Solutions

Agencies lacking maintenance and monitoring data for full-span solutions also lack that data for partial solutions. The following highlights selected respondent practices.

- California DFW recommends conducting an inspection once per year, at a minimum, before the fish passage season, or up to four inspections per year depending on the fishway. Typically, time and costs will be higher for fishway maintenance of partial solutions, primarily for the timely removal of debris and sediment that affects fishway performance.
- Washington State DOT contracts with Washington DFW to conduct inspections. In the 2017-2019 biennium, this inspection activity required staff time of about 0.15 FTE (full-time equivalent), or \$27,000 per year, for inspection of 97 sites. As with full-span solutions, performance monitoring for partial solutions is conducted at years 1, 5 and 10, at minimum.
- The Washington DFW respondent advised that routine inspections should occur several times per year to ensure fish passage is maintained. He noted that “these types of designs are prone to debris problems and typically require frequent repairs to continue providing fish passage in a reliable manner.”
 - Inspection time is estimated to be at least 80 hours per year, with a minimum of 80 additional hours required to perform basic maintenance such as gravel and debris removal.
 - The inspection and maintenance needed for partial solutions may range from \$5,000 to \$25,000 per year. The cost per site varies depending on site conditions and needs.

Maintenance and Inspection of Hydraulic Facilities

The frequency with which respondents initiated small maintenance projects to remove sediment and address scour at hydraulic fish passage facilities varied. The Caltrans respondents estimated that small maintenance projects are conducted every few years, while the California DFW undertakes small maintenance projects multiple times each year. Oregon DOT initiates this type of maintenance annually, and Washington DFW every two years. While FHWA does not own the structures and does not incur costs, the agency is often involved in projects that repair fish passage culverts.

None of the responding agencies include cost estimates and staff hours to fund long-term maintenance when planning partial solution fish passage remediation projects. California DFW's fish passage grant program funds construction of fish passage but not maintenance. For Caltrans, maintenance costs for partial solutions are not planned for and are based on circumstance and need. Oregon DOT funds its monitoring and maintenance of partial solutions separately with funds from the agency's Statewide Transportation Improvement Program. The Washington State DOT respondent noted that his agency does not typically implement partial corrections.

Survey responses indicated no consensus with regard to the frequency with which agencies inspect hydraulic facilities, with only the Oregon and Washington State DOT respondents reporting annual inspections.

Gaps in Findings

Two of the three states queried for this project are subject to a state law or federal injunction that limits those states' implementation of partial, or hydraulic, solutions. While respondents from these states (Oregon and Washington) responded to survey questions related to partial solutions, they may not have the same depth of experience with partial solutions that is associated with their implementation of full passage designs. An examination of other states' fish passage programs may identify more information related to the partial, or hydraulic, solutions most often used in California.

One of the primary goals of the project panel is an examination of the long-term costs and staff time associated with maintaining full-span and partial solutions. Not all respondents were able to provide this data. An examination of state practices beyond the West Coast may uncover more maintenance-related cost data that could be relevant for Caltrans' review of its fish passage program.

Next Steps

Moving forward, Caltrans could consider the following:

- Consulting with fish passage experts in Oregon and Washington to learn more about those states' implementation of full-span solutions and assess how that experience might relate to current and future practices in California.
- Reviewing in detail the design guidance and template plans provided by survey respondents.
- Consulting with the NOAA respondent to learn more about the challenges associated with hydrological calculations and site assessment for partial/hydraulic designs.
- Expanding review of fish passage programs beyond the West Coast to examine other states' activities, experience and research associated with remediating fish barriers. Examples of other state-related research include:
 - A 2014 fish passage cost–benefit analysis conducted for the Wisconsin Department of Natural Resources (see <https://www.lafollette.wisc.edu/images/publications/cba/2014-culvert.pdf>).
 - A 2009 Minnesota DOT report that examined statewide fish passage concerns related to culvert road crossings and performed a cost comparison between conventional and alternative culvert designs (see <https://www.lrrb.org/pdf/200920.pdf>).

Detailed Findings

Survey of Practice

Survey Approach

Twenty-three fish passage experts with experience specific to the West Coast were selected to receive an online survey that addressed topics related to fish passage. The survey sought information about the goals and practices associated with the respondent agencies' fish passage programs, project development, species benefits, construction and implementation of fish passage solutions, and the monitoring and maintenance of fish passage facilities.

Potential respondents from state and federal agencies were drawn from state departments of transportation (DOTs) in California, Oregon and Washington; departments of fish and wildlife (DFWs) in those states; and Federal Highway Administration (FHWA) and National Oceanic and Atmospheric Administration (NOAA). Fish passage experts from two consulting firms and two universities completed the list of potential respondents.

[Appendix A](#) provides the full text of the survey questions.

Summary of Survey Results

The survey received 11 responses from 13 of the 23 potential respondents. (Three Washington State DOT respondents collaborated on a single survey response.) Responding agencies included:

- California DFW (two responses).
- Caltrans (two responses).
- FHWA (Western Federal Lands Highway Division).
- NOAA (National Marine Fisheries Service).
- Oregon DOT (two responses).
- Oregon DFW.
- Washington DFW.
- Washington State DOT.

See [Appendix B](#) of this Preliminary Investigation for the full text of survey responses.

The following summarizes survey results in five topic areas:

- Program background.
- Project development.
- Species benefits.
- Construction and implementation.
- Monitoring and maintenance.

Program Background

Respondents were asked about their agencies' goals, decision-making processes and engineering practices for implementing remediation solutions. The following summarizes survey responses in these topic areas:

- Agency goals.
- Factors affecting selection of a grade or velocity control solution.
- Use of partial, or hydraulic, solutions.
- Cost and benefit determination for grade and velocity control solutions.
- Sedimentation and water quality.
- Plans and estimated costs.

Agency Goals

Full remediation of barriers for adult and juvenile salmon and steelhead is a goal of all responding agencies. (One of the two Caltrans respondents noted that rather than pursuing full remediation, Caltrans inventories, prioritizes and constructs high-priority barriers associated with other programmed projects.)

The following describes the program focus in each of the three West Coast states queried for this project:

California. Anadromous fish species are the focus of Caltrans' fish passage program and the subject of an annual report that must be submitted to the state Legislature "describing the status of the department's progress in locating, assessing and remediating barriers to fish passage, as defined." However, as one of the Caltrans respondents noted, "There are many nonanadromous crossings that should also be inventoried and prioritized."

California DFW's role is limited to the review and approval of fish passage designs (including Caltrans projects), and the development of design guidelines and criteria for fish passage improvement. California DFW only formally monitors projects that are funded and constructed through Fisheries Restoration Grant Program (FRGP) grants. The agency monitors implementation of passage projects constructed under its grant program for compliance with plans and design standards, and also monitors post-project effectiveness of the structure for meeting passage at design flows and for needed maintenance. The agency also conducts post-project monitoring for validation that assesses whether fish are using the structure and the structure is providing the biological services needed.

Oregon. Oregon state law requires full passage solutions. A law passed in 2001 and the associated rules outline requirements for meeting the law's hydraulic criteria. Funding provided through Oregon DOT's fish passage program replaces culverts in any condition to meet the requirements of the state fish passage law. Other projects that trigger the state law are required to provide full fish passage. While the Oregon DFW owns some barriers, most of the agency's work is associated with implementing fish passage requirements as other barrier owners implement fish passage projects.

Washington. Until recently, most fish passage projects in Washington were voluntary. As the Washington State DOT's web site indicates, "A federal court injunction, issued March

2013, requires the state to significantly increase the effort for removing state-owned culverts that block habitat for salmon and steelhead by 2030.” The state has 978 culverts that apply to this injunction, with 806 of them having “significant habitat.” The Washington State DOT respondent highlighted this in his survey responses, noting that “[w]e are currently operating much of our fish passage program in compliance with a federal injunction related to tribal treaty rights. This leads us to emphasize tribal coordination and the use of stream simulation and bridges as the typical design methods.”

See Related Resources below for more information about respondents’ fish passage programs.

Related Resources

California

2015 Fish Passage Annual Report: Report to the Legislature, Division of Environmental Analysis, Caltrans, October 2016.

<http://www.dot.ca.gov/docs/2016FishPassageAnnualReport.pdf>

This 2015 edition of the annual report required by the Legislature “provides fish passage assessment and remediation information for locations which Caltrans is responsible. This is in accordance with Streets and Highways Code, Section 156.1.”

Oregon

Fish Passage, Oregon Department of Fish and Wildlife, undated.

<http://www.dfw.state.or.us/fish/passage/>

This web site provides a wealth of information about fish passage practices in Oregon. Among the topics addressed are recent pilot repair projects, an approach to fish passage mitigation banking, priority lists and a diagram of the fish passage process.

House Bill 3002, 71st Oregon Legislative Assembly, 2001 Regular Session.

http://www.dfw.state.or.us/fish/passage/docs/HB_3002.pdf

This is the full text of the 2001 state law affecting Oregon’s treatment of fish passage. The Oregon DFW’s web site provides this background of the bill:

On August 8th, 2001, Governor Kitzhaber signed HB 3002 into law. One of the main objectives of HB 3002 was to craft legislation that combined the existing statutes into one meaningful piece of legislation, was reasonable for owners/operators, benefited fish that migrate for lifecycle needs, and had enough flexibility for the Commission to waive passage requirements under appropriate circumstances. Doing this in a way that encouraged cooperation and minimized the burden to owners and operators of artificial obstructions, while maintaining the authority of the Commission to enforce its laws, proved to require a great deal of creativity and flexibility. HB 3002 is intended to complement, not to abrogate, any related authority under other state and federal laws.

Oregon Revised Statutes § 509.580 to 509.595, General Protective Regulations, Fish Passage; Fishways; Screening Devices; Hatcheries Near Dams, 2015 Edition.

http://www.dfw.state.or.us/fish/passage/docs/ORS_509_Fish_Passage_Statutes.pdf

These regulations governing fish passage in Oregon include the following comment:

Note: 509.580 to 509.595 were enacted into law by the Legislative Assembly but were not added to or made a part of ORS chapter 509 or any series therein by legislative action. See Preface to Oregon Revised Statutes for further explanation.

Division 412, Fish Passage, Oregon Administrative Rules, Oregon Department of Fish and Wildlife, December 2016.

<http://www.dfw.state.or.us/OARs/412.pdf>

These administrative rules govern Oregon DFW's handling of fish passage.

Washington

Federal Court Injunction Related to Fish Passage, Washington State Department of Transportation, 2017.

<https://www.wsdot.wa.gov/Projects/FishPassage/CourtInjunction.htm>

From the web site: A federal court injunction, issued March 2013, requires the state to significantly increase the effort for removing state-owned culverts that block habitat for salmon and steelhead by 2030.

The U.S. District Court injunction affects:

- Washington State Department of Transportation.
- Washington State Department of Natural Resources.
- Washington State Department of Fish and Wildlife.
- Washington State Parks and Recreation Commission.

WSDOT has 978¹ culverts that apply to this injunction, with 806¹ of them having significant habitat.

¹ This number is subject to change as new information is collected regarding these culverts.

The injunction will require the state to maintain and monitor culverts for fish passage.

WSDOT Fish Barrier Correction: Moving Forward, Connecting Habitat, Washington State Department of Transportation, July 2017.

<https://www.wsdot.wa.gov/NR/rdonlyres/878FC8F2-B15D-49ED-BE85-229D4989C0E9/0/FishPassageFolioforWeb.pdf>

This brochure provides a brief description of the court case and the DOT's efforts in response.

WSDOT Fish Passage Performance Report, Stream Restoration Program, Washington State Department of Transportation, June 2016.

<http://www.wsdot.wa.gov/publications/fulltext/projects/FishPassage/2016FishPassageAnnualReport.pdf>

From the executive summary: Statewide there are 3,685 fish bearing highway crossings and 1,989 are fish passage barriers. 1,530 of these barriers block a significant amount of upstream habitat (> 200 meters).

To date, WSDOT has completed 301 fish passage barrier corrections, allowing access to approximately 954 miles of potential upstream habitat for fish. Twelve fish passage projects were completed in 2015, opening up 46 miles of potential upstream habitat. Two of the projects upgraded the crossing to meet current fish passage standards even though the site was not previously identified as a fish passage barrier. Five of the projects corrected Federal Court Injunction barrier culverts.

Twenty fish passage projects are planned for completion in 2016; all are injunction barrier corrections. Three of the fish passage projects are a part of a larger transportation project. These projects will open up over 93 miles of potential fish habitat.

Factors Affecting Selection of a Grade or Velocity Control Solution

Respondents were asked about the factors, other than cost, that help determine implementation of a grade or velocity control solution. The wide range of factors provided by respondents is reflected in the table below in these categories:

- Administrative.
- Construction.
- Impacts.
- Maintenance.
- Site.
- Species.

Factors Considered When Implementing a Grade or Velocity Control Solution		
Factor Category	Description	Agency
Administrative	Court decision	Washington DFW
	Project operation and management	NOAA
	Support of funding decision-makers	Caltrans
	Ownership; upstream property ownership	Caltrans; Oregon DOT
	Water rights	NOAA
Construction	Design flow requirements	NOAA
	Hydrology; hydrology methods used to develop structural design discharges and fish passage design flows	Oregon DOT; NOAA
Impacts	Cultural impacts	Caltrans
	Environmental impacts	Caltrans
	Potential impacts to other infrastructure	NOAA
Maintenance	Structure maintenance	NOAA
Site	Access	Caltrans
	Bank stability	NOAA
	Length of upstream habitat	California DFW
	Low-flow risk	FHWA
	Potential for improvement	California DFW

Factors Considered When Implementing a Grade or Velocity Control Solution		
Factor Category	Description	Agency
Site	Profile degradation	FHWA
	Reach-scale ¹ sediment transport characteristics	NOAA
	Scour depth	FHWA
	Severity of fish passage impediment	California DFW
	Site constraints	Washington State DOT
	Stream morphology	Oregon DOT
	Upstream and downstream channel condition and evolution; upstream or downstream controls	NOAA; Oregon DOT
	Vulnerability of stream to head cut	Oregon DOT
Species	Aquatic habitat conditions	California DFW
	Fish species affected	California DFW; Oregon DOT
	Importance of the barrier to native migratory fish	Oregon DOT

1 As defined in an October 2010 FHWA Hydraulic Engineering Circular: A reach-scale categorization allows streams to be categorized based on relative positions within the watershed and sediment transport characteristics (see page 54 of <https://www.fhwa.dot.gov/engineering/hydraulics/pubs/11008/hif11008.pdf>).

Use of Partial, or Hydraulic, Solutions

Partial, or hydraulic, solutions are implemented most frequently by Caltrans. (A partial solution is typically a retrofit to a large culvert to include baffles, weirs or other velocity and depth controls to meet specific hydraulic criteria for fish passage.) Legislation or court order requires the use of full solutions for many fish passage projects in Oregon and Washington.

State Practices

In California, 32 of the 39 barriers Caltrans has treated are partial solutions (hydraulic retrofits). The goal of the California DFW for the adult fish life stage is “all or significant portion adhering to fish passage criteria for the anticipated fish migration flow range.”

Since passage of the 2001 law, Oregon DOT’s fish passage program has focused on culvert replacements to meet stream simulation criteria. The fish passage program is funded separately from culvert repairs and culvert infrastructure projects; projects funded outside of the fish passage program may pursue hydraulic criteria to meet passage requirements.

The state of Washington is under a federal injunction to remedy fish barriers with full passage stream simulation or bridges; partial/hydraulic solutions are not acceptable under this injunction. The Washington State DOT respondent noted that the agency rarely uses a hydraulic correction, instead following the stream crossing design methodology published by Washington DFW. The Washington DFW respondent noted that “engineered solutions are legal in

Washington, however, new/replacement structures must use a 'geomorphic approach,' meaning something with a natural, self-maintaining bed such as stream simulation or a bridge." (Washington DFW's Water Crossing Design Guidelines describe the geomorphic approach to design; see page 18 of this Preliminary Investigation for a citation for this publication.)

Federal Practices

The FHWA respondent noted that when appropriate and acceptable, the agency does execute partial/hydraulic designs and still tries to demonstrate 100 percent aquatic organism passage (AOP) effectiveness. The NOAA respondent provided significant detail with regard to remediation solutions and performance standards, noting that inaccurate data associated with hydrological calculations and site assessment can result in the failure of many partial/hydraulic designs. Below is the NOAA respondent's complete survey response:

For larger-scale projects (such as high head dams), there is typically a performance standard, irrespective of solution type. Post-construction monitoring is conducted to ensure the project meets the standard. The question of the "appropriateness" of the solution is determined by the relative confidence of the agency, supported by past monitoring of similar projects along the West Coast and Pacific Northwest, that the design will achieve the required performance standard. Passage performance standards in the Pacific Northwest are often in the range of 95 to 99 percent efficiency.

For small-scale projects, such as irrigation diversions, road crossings or fishways, where monitoring for performance standards is often cost-prohibitive and efficiency is not well documented, designs that are the most compatible with existing or modified infrastructure and channel morphology determine what is "appropriate." Since monitoring is seldom conducted at this scale, the closer the solution can mimic the natural channel, the greater confidence the agency has that passage exists and has been maximized. Hydraulic designs for small-scale projects also suffer from large error bounds in hydrology, which are typically unaccounted for in fish passage designs. Some places in California have +/- 100 percent error in calculated hydrology. This error is rarely addressed adequately in fish passage designs for small-scale projects. Many hydraulic projects fail, not due to engineering methods, but due to the fact that calculated hydrology did not actually provide the frequency and duration of passage as was intended. Another typical mode of failure for hydraulic/grade control designs is that geomorphic site conditions were not properly assessed; this is true for any type of design, hydraulic or otherwise.

Small-scale projects that have funding to conduct monitoring and make post-construction modifications to project designs to stay within compliance of performance standards may benefit from developing and implementing project designs based on post-construction measurement of passage efficiency.

Cost and Benefit Determination for Grade and Velocity Control Solutions

Respondents were asked if they considered the cost of the proposed solution as well as the anticipated benefits when considering grade and velocity control solutions. The table below summarizes survey responses.

Determining Costs and Benefits for Grade and Velocity Control Solutions		
Practice	Agency	Comment
Consider Costs and Benefits	California DFW	The agency uses “conceptual-level cost estimates” of varying alternatives after determining the habitat extent and condition above the barrier.
		Among the criteria used by the agency to prioritize passage are species, length of habitat and cost.
	Caltrans	Cost estimates for alternatives are developed and the benefit is qualitatively determined.
	Oregon DOT	The agency determines the anticipated benefits to provide full passage at the lowest cost possible.
		Agency decisions have more to do with the condition of the infrastructure and ability to meet hydraulic criteria than cost. Full passage is difficult to achieve with most existing infrastructure, and most culverts have to be upsized significantly to meet the state’s hydraulic criteria.
Washington DFW	Benefits are not the foremost consideration if the “fix” is seen as reducing the owner’s motivation to replace the crossing with a stream simulation culvert or a bridge.	
Do Not Consider Costs and Benefits	FHWA, NOAA, Oregon DFW, Washington State DOT	N/A

Sedimentation and Water Quality

Oregon is the only state among the three West Coast states queried for this project that clearly seeks to address sedimentation and improve water quality as part of all fish passage projects. The table below summarizes the frequency with which respondents’ agencies address water quality. (In a few cases, respondents from the same agency provided differing responses.)

Frequency of Addressing Sedimentation and Water Quality	
Frequency	Agency
Always	California DFW, FHWA, Oregon DFW, Oregon DOT, Washington DFW
Often	California DFW, Caltrans, NOAA, Washington State DOT
Occasionally	Caltrans

When Water Quality is Addressed

Several respondents described efforts to improve water quality, with the California respondents providing the most detailed responses:

- One of the Caltrans respondents noted that “some of the fish barriers overlap with designated impaired water bodies. A few projects have been initiated to treat both fish as well as sediment issues in TMDL [total maximum daily load] areas.”

(The U.S. Environmental Protection Agency provides this definition of TMDL:

A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant.)

- A California DFW respondent noted that “it is important to consider the range of sediment sizes that may transport as a result of grade control changes and balance the need to maintain water quality impacts from fine sediment with retention of grade and sediment that are good for spawning and other habitat functions over the long term.” The other California DFW respondent provided this list of issues to consider:
 - Standards and engineering review for passage plans and associated water bypass fish screening plans.
 - Best management practices (BMPs) to control sediment and pollutant discharge while fish passage construction occurs.
 - BMPs for post-project disturbed sediment controls.
 - Provisions for riparian planting.
 - Provisions for project and post-project monitoring.

In Oregon, water quality is considered when presented with new impervious surface, removing bridge scuppers and treating water before entering a water body. In Washington, the DOT “seek[s] to restore natural stream conditions/functions,” while the Washington DFW respondent noted that his agency’s approach is “to let the stream behave to the extent possible as it would without a crossing. One could argue water quality is improved by allowing such natural processes that typically result in more riparian [access], etc.”

The NOAA respondent noted that water quality is addressed “whenever project operations or structures directly influence water quality.”

Plans and Estimated Costs

The use of standard plans and estimated costs is rare among respondents, with only the FHWA respondent indicating that his agency has standard plans for the range of potential solutions to fish barriers. (FHWA also estimates costs for each project.) Sample drawings provided by the FHWA respondent appear in [Appendix C](#).

Caltrans does have some standard plans (standard details are available in the agency’s fish passage design manual) but more are needed and in development. California DFW does not have standard plans and costs, instead using the California Salmonid Stream Habitat Restoration Manual for design guidance and typical designs. California DFW also refers back to costs of similar projects when evaluating passage proposals submitted through its grants program.

See Related Resources below for the publications cited by respondents and other plan- or construction-related publications.

Related Resources

California

Fish Passage Design for Roadway Crossings: An Engineering Document Providing Fish Passage Design Guidance for Caltrans Projects, Caltrans, May 2007.

<http://www.dot.ca.gov/design/manuals/fpm.html>

(Use this web site to access individual PDF files for each chapter and appendix included in the manual.)

From the web site: This guide is intended to provide detailed instructions to assist designers in generating projects that will achieve resource agency goals for fish passage within a state highway project context.

Developed in conformance with both state (California Department of Fish and Game) and Federal (National Oceanic and Atmospheric Administration Fisheries Service, Southwest Region) criteria, "Fish Passage Design for Road Crossings" provides worksheets, flow charts, design examples and other design aids to assist the designer in achieving permit achievable projects.

California Salmonid Stream Habitat Restoration Manual, 4th Edition, California Department of Fish and Wildlife, 2010.

<http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp>

(Use this web site to access all portions of the two-part manual. See particularly Fish Passage Design and Implementation, Part XII, in Volume 2.)

From the web site: This manual describes many methods and techniques used with varying degrees of success by habitat restoration specialists. The methods and techniques described here represent only a starting point for project design and implementation. They are not a surrogate for, nor should they be used in lieu of, a project design that has been developed and implemented according to the unique physical and biological characteristics of the site-specific landscape.

Oregon

Factors for Improved Fish Passage Waterway Construction, David N. Sillars, Hamid Moradkhani, Nicholas Tymvios and Trevor Smith, Oregon Department of Transportation and Federal Highway Administration, June 2011.

http://www.oregon.gov/ODOT/Programs/ResearchDocuments/SPR_654_Waterway.pdf

From the abstract: This report discusses work of a research project designed to discover factors that are key to successful long-term implementation of fish passageways, especially focused on the construction process. Areas of inquiry postulated in this study are that failures experienced in actual installations may be due to inadequate range and/or mix of soil and rock material gradation; unexpected water velocity, especially during high flows; inadequate mixing of rock and soil materials during construction; and inadequate compaction of rock and soil materials during construction. This report suggests that several factors may be especially important considerations in fish passage success. These factors are the relationship of downstream slope to structure slope, well-graded fine soil materials in the channel fill (improved by choice of fill source), and frequent site visits. Improving fish passages for cost-efficient fish movement is a priority for government agencies such as Oregon Department of Transportation (ODOT) and Oregon Transportation Research and Education Consortium (OTREC).

Washington

Water Crossing Design Guidelines, Washington Department of Fish and Wildlife, 2013.
<http://wdfw.wa.gov/publications/01501/wdfw01501.pdf>

From Chapter 1: These guidelines promote a water crossing selection and design process intended to have the least effect on the natural processes that create and support the stream structure in which fish live and migrate. The geomorphic approach to design is generally based on readily-measured characteristics of the natural channel in the adjacent reaches. This is in contrast to the once prevalent hydraulic culvert design method (*Chapter 6*) which uses criteria independent of channel conditions.

“Fish Passage Design Aids Wildlife Crossing in Washington State—State of the Practice,” Jon K. Peterson and Kelly McAllister, *TRB 93rd Annual Meeting Compendium of Papers*, Paper #14-2246, 2014.

<http://docs.trb.org/prp/14-2246.pdf>

From the abstract: Since 1991, the Washington State Department of Transportation (WSDOT) has partnered with the Washington Department of Fish and Wildlife (WDFW) to help sustain & restore aquatic ecosystems by improving fish passage & natural stream functions at road crossings through a statewide program for Washington highways. In the past 22 years, WSDOT has transitioned its program from culvert retrofits to total replacement of fish passage barrier culverts. Historically, WSDOT’s culvert projects & retrofits were designed for fish use using the hydraulic method based on the swimming abilities of fish. The collaboration with WDFW has led WSDOT to utilize the “stream simulation” design approach, where feasible, to correct a fish passage barrier. The principle of stream simulation is that if fish can move through a natural channel, they can also move through a man-made crossing that simulates the stream channel. WSDOT has placed motion triggered wildlife cameras near its stream simulation designed culverts around the state and discovered that these newer fish passage structures were very attractive to wildlife, especially deer. Highlighted in this paper are two stream simulation designed culverts on the east & west side of Washington state and also featured is the first WSDOT combination habitat connectivity & fish passage project constructed in this past year in the south central part of the state. The authors’ observations from hundreds of camera images are that a combination of dry bank, adequate illumination, shallow water & lower stream velocities through stream simulation structures provide attractive conditions for wildlife to pass through.

“I-90 Snoqualmie Pass East Project’s Design Engineering Challenges of Integrating Transportation Needs with Landscape-Level Connectivity and Transportation Corridor-Crossing Objectives in Washington State,” Randy Giles, Scott Golbek, Amanda Sullivan and Jerry Wood, *Transportation Research Record 2158*, pages 113-121, 2010.

Citation at <http://dx.doi.org/10.3141/2158-14>

From the abstract: The Washington State Department of Transportation’s (WSDOT) I-90 Snoqualmie Pass East Project has presented WSDOT engineers with many unique design challenges when integrating the ecological needs of the area with the transportation objectives of the project. ... To identify areas where investments in ecological connectivity should be made, WSDOT worked with dozens of agencies that manage land resources in the project area to design bridges and culverts that improve wildlife and aquatic connections. Integrating ecological objectives presented many design engineering challenges because of the project area’s unfavorable construction conditions. Trade-offs and compromises between WSDOT and land resource managers were needed to find suitable solutions to problems. Issues that required compromises included eliminating scour

issues while maximizing restoration areas; improving ground conditions for foundations without impacts to wetlands, endangered species, and footprint; creating habitat connections while treating stormwater; and designing bridges for clearance and connecting habitat.

Federal Agencies

No Name Creek, Western Federal Lands Highway Division, Federal Highway Administration, undated.

See [Appendix C](#).

This template set of plans provided by the FHWA survey respondent is what the agency typically provides for AOP culverts. The plans include:

- AOP culvert plan and profile.
- Culvert elevations.
- Simulated stream culvert interior treatment.
- Large culvert reinforced concrete collar details.
- Channel improvements typical details.

Anadromous Salmonid Passage Facility Design, National Marine Fisheries Service, Northwest Region, National Oceanic and Atmospheric Administration, July 2011.

http://www.westcoast.fisheries.noaa.gov/publications/hydropower/fish_passage_design_criteria.pdf

From the foreword: The following document provides criteria, rationale, guidelines, and definitions for the purpose of designing proper fish passage facilities for the safe, timely, and efficient upstream and downstream passage of anadromous salmonids at impediments created by artificial structures, natural barriers (where provision of fish passage is consistent with management objectives), or altered instream hydraulic conditions. This document provides fishway facility design standards for the National Marine Fisheries Service [NMFS], and is to be used for actions pertaining to the various authorities and jurisdictions of NMFS, including Section 18 of the Federal Power Act (FPA), the Endangered Species Act (ESA), and the Magnuson-Stevens Fishery Conservation and Management Act (MSA) in the Northwest Region (NWR).

Project Development

All but one of the responding agencies reported some type of process that streamlines the permitting associated with fish passage remediation project review and approval. Only Oregon DFW's respondent replied entirely in the negative, noting that his agency only reviews projects proposed by others.

For Caltrans, documentation-related and permitting efficiencies exist in the few instances when funding is provided through the FRGP, but there is no streamlined process for projects that Caltrans develops internally. Most Caltrans projects fall under standard permitting. Similarly, a California DFW respondent reported that some smaller open-channel fish passage projects funded by FRGP can be conducted under the FRGP programmatic California Environmental Quality Act (CEQA) and associated U.S. Army Corps of Engineers (USACE) regional general permit.

Both FHWA and NOAA apply a streamlined process to the permitting of fish passage remediation projects. When they are available, FHWA uses memoranda of agreement or understanding. The NOAA respondent noted that some agencies have developed programmatic Endangered Species Act consultation pathways that do not require a biological assessment.

The four topic areas below are examined in greater detail in the following:

- Permits and permitting partners.
- The review process.
- Coordinating fish passage solutions.
- Stakeholders in fish passage programs.

Permits and Permitting Partners

Most respondents provided some level of detail with regard to the types of permits associated with fish passage projects and the partners with which their agencies work to process some of those permits.

California. Caltrans' permitting activities consider the following:

- California Endangered Species Act (CESA) (consultation under Section 2080.1).¹
- California Wild and Scenic Rivers Act.
- Clean Water Act Section 401 (water quality certification).
- Clean Water Act Section 404 (wetlands and waters of the U.S.).
- Coastal Development Permit.
- Endangered Species Act (Section 7, Interagency Cooperation).¹
- Lake and Streambed Alteration agreements (with California DFW).
- Other state or local permit.

¹ From the California DFW web site (see <https://www.wildlife.ca.gov/Conservation/CESA>): If a species is listed by both the federal Endangered Species Act and the California Endangered Species Act (CESA), Fish and Game Code section 2080.1 allows an applicant who has obtained a federal incidental take statement (federal Section 7 consultation) or a federal incidental take permit (federal Section 10(a)(1)(B)) to request that the Director of CDFW find the federal documents consistent with CESA. If the federal documents are found to be consistent with CESA, a consistency determination (CD) is issued and no further authorization or approval is necessary under CESA.

California DFW's FRGP permitting process includes:

- CEQA (mitigated negative declaration).
- State Water Resources Control Board (Clean Water Act 401 water quality certification and wetlands program).
- Clean Water Act Section 404 (USACE regional general permit and associated NOAA and U.S. Fish and Wildlife Service permits).

Oregon. Oregon DOT maintains a programmatic consultation with NOAA's National Marine Fisheries Service (NMFS). Certain categories of projects can be completed with notifications; roughened channels and hydraulic projects require review and approval by FHWA and NMFS. The DOT and Oregon DFW are collaborating on a pilot project for culvert repair, with each repair requiring individual review and approval. Oregon DFW reviews each fish passage plan individually. As the Oregon DOT respondent noted, USACE and Oregon Department of State Lands regulate filling in and removal of streams and wetlands, and most of the agency's culvert projects require permits from these agencies.

Washington. Washington State DOT's primary permitting partners include Washington DFW, Washington State Department of Ecology, USACE, U.S. Fish and Wildlife Service, NOAA's NMFS and the contacts required in connection with Washington's State Environmental Policy Act (SEPA).

(SEPA is described as "a medium for citizens of the state to protect their environment." As the Washington DFW web site indicates, "[a]ny governmental action may be conditioned or denied pursuant to SEPA. Since the Washington Department of Fish and Wildlife (WDFW) issues permits, i.e., Hydraulic Project Approvals, Grass Carp Applications, and Shooting Preserve Permits, we may be the Lead Agency in reviewing an applicant's project or action before issuing our permit. This status is determined by rule in WAC 197-11-922 through WAC 197-11-946. All agencies must send their own SEPA required actions out for review.")

The Washington DFW respondent noted that "it is typically easier to get state and local permits in Washington for certain types of beneficial projects, such as improving fish passage."

The Review Process

The following summarizes respondents' descriptions of the process employed to review and develop fish passage projects.

California. Caltrans project biologists and engineers work with California DFW, NOAA's NMFS and other partners to scope the solution and develop design- and environmental-related documents. Caltrans staff members also check in with external permitting partners and finalize plans and environmental permitting.

One of the California DFW respondents noted that "ideally, as fish passage projects are initiated, C[alifornia]DFW engineering is engaged for technical support and ultimately final review and approval as the project moves through planning, design and permitting." The second California DFW respondent noted that "all passage projects need approval of design by CDFW or NOAA passage engineer, and CDFW biologist staff [is] often consulted in this review. CDFW regulatory staff write[s] Lake and Streambed Alteration agreements for passage projects that review and condition [a] project's environmental protections."

FHWA. FHWA staff members conduct site reviews with representatives from appropriate resource agencies in attendance. During these site reviews, bankfull width is discussed, and the design concept is negotiated. The concept design and design basis report is submitted to resource agencies for concurrence, and the agencies then apply for permits.

Oregon. The state DOT uses a project team project development process, with hydraulic engineers and biologists working together to meet passage requirements. NOAA’s NMFS and Oregon DFW provide review and approval of designs.

Washington. Primary fish passage regulation in Washington is conducted by Washington DFW fish biologists with the assistance of Washington State DOT engineers when warranted. The state DOT uses an “extensive multidisciplinary process that involves early coordination especially with tribes and W[ashington]DFW.”

Coordinating Fish Passage Solutions

All respondents participate in a coordination process to identify, assess and prioritize fish passage solutions. Respondents from the three states described a statewide—and sometimes regional—approach.

- **California.** Caltrans partners with California DFW to organize Fish Passage Advisory Committees (FishPACs) throughout the state. Biologists, engineers and other experts participating in FishPACs work to improve science and data, and come to agreement on priorities, and allow for a regional assessment of fish passage priorities.
- **Oregon.** Oregon DFW manages statewide fish passage prioritization. The agency may also identify needed fish passage projects and provide a cost share or technical assistance. Oregon DOT evaluates the cost and benefit of addressing the highest priority barriers and assesses the delivery capacity of projects identified by project delivery teams and regional construction offices.
- **Washington.** The state DOT contracts with the state’s DFW to identify barriers and assess upstream habitat. Priority is based largely on potential habitat but also includes other factors such as cost, partnerships and other planned work. The Washington DFW respondent noted that the agency’s coordination is fairly extensive, providing training, technical assistance and design services to the public and a variety of crossing owners. The agency routinely collaborates with tribes, individuals, nongovernmental organizations and government agencies at all levels.

In addition to these statewide efforts, one of the California DFW respondents noted that efforts to assess and prioritize projects are informed by methods described in the agency’s stream habitat restoration manual and the agency’s response to issues or complaints. (See page 17 of this Preliminary Investigation for a citation for this California DFW manual.)

Stakeholders in Fish Passage Programs

Respondents were asked about the stakeholders most often involved in their agencies’ fish passage programs. The table below summarizes the wide range of stakeholders identified in survey responses.

Stakeholders Commonly Involved in Fish Passage Programs		
Stakeholder Type	Description	Respondent Agency
Nonprofit Organizations	California Trout	Caltrans
	Coastal Conservancy	Caltrans

Stakeholders Commonly Involved in Fish Passage Programs

Stakeholder Type	Description	Respondent Agency
Nonprofit Organizations	Nonprofit organizations that facilitate fisheries restoration grant projects; fisheries-focused nongovernmental organizations	California DFW
	Philanthropic groups	Caltrans
	Watershed groups	Caltrans
Private Entities	Construction companies	California DFW
	Local and regional advocates	California DFW
	Private citizens; landowners; other barrier owners	California DFW, Caltrans, FHWA Oregon DFW, Oregon DOT, Washington State DOT
	Private fish passage engineers	California DFW
	Railroads	California DFW
	Water diverters	Oregon DFW
Public Agencies or Governments	Bonneville Power Administration (U.S. Department of Energy)	Washington DFW
	Bureau of Land Management	California DFW, FHWA
	California State Water Resources Control Board and regional water quality boards	Caltrans
	Counties	FHWA
	National and state fish and wildlife agencies	Caltrans, FHWA
	National Park Service	FHWA
	Natural Resources Conservation Service	Washington DFW
	Regulatory and resource agencies	Caltrans, FHWA, Oregon DOT
	Road management agencies	Oregon DFW
	State parks	Washington DFW
	Tribes	California DFW, Caltrans, Oregon DOT, Washington State DOT
	USACE	Caltrans
	U.S. Department of Defense	FHWA
U.S. Forest Service	California DFW, FHWA	

Species Benefits

Respondents were asked to describe the scope of their agencies' fish passage programs in benefiting species other than salmon and steelhead. Survey questions sought feedback on:

- General program focus.
- Expanded program focus.
- Species benefiting from remediation.
- Consideration of terrestrial species.

General Program Focus

All respondent programs provide access to salmon and steelhead species. Once that access has been provided for, agency programs are more likely to provide access to other aquatic species than to terrestrial species. The table below summarizes survey responses.

Fish Passage Programs' General Focus			
Agency	Provide Access to Salmon and Steelhead Species	Provide Access to Other Aquatic Species	Provide Access to Terrestrial Species
California DFW	X	X	X
Caltrans (Senior Fish Biologist)	X		
Caltrans (Senior Hydraulics Engineer)	X	X	X
FHWA	X	X	
NOAA	X	X	
Oregon DFW	X	X	X
Oregon DOT	X	X	
Washington DFW	X	X	
Washington State DOT	X	X	X

Expanded Program Focus

While all agency programs provide access to more than salmon and steelhead species, they differ on the breadth of program focus. Some agencies opt for a more expansive approach that provides connectivity to all species, while other respondents reported a more targeted focus on regulated species. The table below describes the expanded focus of respondents' fish passage programs. Note that responses highlight differences within states and agencies.

Expanded Focus of Respondents' Fish Passage Programs	
Sphere of Interest	Agency
Connectivity for All Species	California DFW, Oregon DFW, Washington DFW, Washington State DOT
Connectivity for Regulated Species¹	California DFW, Caltrans, FHWA, NOAA, Oregon DOT

1 Includes state and federal listed species and habitat.

Species Benefiting from Remediation

Respondents were asked about the species or habitats that have benefited from full-span fish passage remediation projects.

The Washington State DOT respondent noted that all aquatic species benefit from the agency's stream simulation/bridge approach to remediation, and agency monitoring shows that many terrestrial species use these culverts, including deer. Similarly, the Oregon DOT respondent noted that "many terrestrial and other aquatic species benefit from passage projects." The table below summarizes the particular species respondents reported as benefiting from full-span projects.

Species Benefiting from Respondents' Full-Span Remediation Projects		
Category	Species	Agency
Aquatic	Green sturgeon	NOAA
	Native migratory fish	Oregon DFW, Oregon DOT
	Pacific lamprey	California DFW, FHWA, NOAA, Oregon DFW
	Suckers	California DFW, Oregon DFW
	Tidewater goby	California DFW
	Trout; bull trout; coastal cutthroat trout; rainbow trout	California DFW, FHWA, NOAA
Terrestrial	Bats	Caltrans
	Bear	California DFW, Caltrans
	Deer	Caltrans, Washington State DOT
	Elk, mountain lion	California DFW
Terrestrial or Aquatic	Amphibians	California DFW, Caltrans, FHWA
	Invertebrates	Caltrans

Consideration of Terrestrial Species

Only the Oregon and NOAA respondents do not add in costs to address terrestrial species permeability on salmon and steelhead barrier remediation projects. None of the remaining respondents were able to identify specific costs, but some did describe how design considerations are made for terrestrial species.

One of the Caltrans respondents noted that design considerations for terrestrial species' access to a fish crossing are occasionally made when developing a remediation project. Other respondents reported less frequent consideration of terrestrial species, with the FHWA respondent reporting that on rare occasions additional culvert crossings are added at minimal cost; California DFW will sometimes include costs for terrestrial access.

In Washington, the DFW and DOT will consider the specific needs of certain terrestrial species or expand a project depending on the site and local safety or ecological concerns. The Washington DFW respondent believes his agency's focus on stream simulation and bridges that provide fish passage provides some terrestrial benefit.

Construction and Implementation

Respondents were asked to describe their agencies' practices when constructing and implementing fish passage solutions. Their responses are presented below in these topic areas:

- Ensuring proper implementation.
- Coordination for complex hydraulic solutions.
- Specialists' participation during implementation.
- Remediation and emergencies.

Ensuring Proper Implementation

Agencies identified a range of activities and practices that help to ensure the proper implementation of fish passage remediation projects. Among the effective practices cited in the table below, which summarizes survey responses, are preconstruction meetings, inspections by properly trained staff and other in-person site monitoring, and the monitoring of reports.

Activities and Practices to Ensure Proper Implementation		
State/Agency Type	Agency	Description of Activity or Practice
California	California DFW	<ul style="list-style-type: none">• Proper guidance for implementation, including construction BMPs.• Permit conditions that may include inspections by appropriate California DFW staff.• FRGP grants: The grantee and California DFW are tasked with implementation requirements and post-project monitoring and reporting in connection with permit compliance and construction standards.• Lake and Streambed Alteration agreements: DFW inspects for permit compliance.

Activities and Practices to Ensure Proper Implementation

State/Agency Type	Agency	Description of Activity or Practice
California	Caltrans	<ul style="list-style-type: none"> On the most successful projects, a resident engineer works in collaboration with a fish biologist or other staff member with appropriate expertise. Contract specifications may include permits that are conditioned to have specific staff with appropriate expertise on hand at key times.
Federal Agency	FHWA	<ul style="list-style-type: none"> Training for construction monitors. In-person site monitoring. Construction handoff reports.
	NOAA	<ul style="list-style-type: none"> Monitoring during construction as needed.
Oregon	Oregon DFW	<ul style="list-style-type: none"> Report monitoring.
	Oregon DOT	<ul style="list-style-type: none"> Development of proper specifications and plans. Project inspectors are on-site during construction. Project inspectors are trained. If necessary, the engineer of record will help inspect and direct the contractor on construction. Preconstruction meetings set expectations for the contractor. Agency biologists perform inspections during critical project implementation phases for programmatic consultation with NOAA's NMFS.
Washington	Washington DFW	The respondent noted that "we're weak in this area. We need to do a better job of monitoring outcomes."
	Washington State DOT	<ul style="list-style-type: none"> Contract specifications. Training for construction inspectors. Project coordination.

Coordination for Complex Hydraulic Solutions

The table below highlights the additional coordination or oversight provided by respondent agencies when complex hydraulic solutions are implemented.

Coordination Practices When Implementing Complex Hydraulic Solutions		
State/Agency Type	Agency	Description of Activity or Practice
California	California DFW	Ideally, coordination is established through written conditional documentation for inspections and approvals.
	Caltrans	Appropriate staff members are on hand during construction and layout of key hydraulic features.
Federal Agency	FHWA	Resource agencies and project partners help monitor construction.
	NOAA	NMFS engineers in Idaho, Oregon and Washington are on-site during complex implementations.
Oregon	Oregon DFW	The agency uses site inspections and reviews monitoring reports; efforts are made to adaptively manage, if necessary.
	Oregon DOT	Preconsultation is required with both NMFS and Oregon DFW for complicated projects.
Washington	Washington DFW	The agency has limited availability but tries to ensure the projects with the most risk and highest potential habitat value get the most attention throughout the process.
	Washington State DOT	Project sites are visited by hydraulic engineers and/or biologists as needed.

Specialists' Participation During Implementation

Respondents were asked about the participation of specialists—a fish passage engineer or biologist—to provide oversight or monitoring during the implementation of fish passage projects. Only the NOAA and Oregon DFW respondents indicated that this type of specialist did not participate in monitoring or oversight. The table below summarizes the remaining respondents' monitoring and oversight practices.

Specialists' Participation in Implementation-Related Monitoring and Oversight		
State/Agency Type	Agency	Description of Activity or Practice
California	California DFW	<ul style="list-style-type: none"> Project-specific permit conditions may include project monitoring and inspections by appropriate DFW staff.

Specialists' Participation in Implementation-Related Monitoring and Oversight		
State/Agency Type	Agency	Description of Activity or Practice
California	California DFW	<ul style="list-style-type: none"> • A biologist is required during fish relocation and channel dewatering activities. • An engineer is required to submit plans and may be required to be on-site or inspect a project to provide an as-built drawing.
	Caltrans	<ul style="list-style-type: none"> • Oversight requirements are included in contract specifications and permit conditions when appropriate.
Federal Agency	FHWA	<ul style="list-style-type: none"> • The agency requires monitoring by a construction engineer experienced with fish passage structures.
Oregon	Oregon DOT	<ul style="list-style-type: none"> • Biologists are present during critical project delivery milestones. • Channel construction is directed by agency hydraulic engineers and/or biologists.
Washington	Washington DFW	<ul style="list-style-type: none"> • The agency conducts a follow-up inspection when work is completed. <p>(The respondent noted that with an investment of more time, the agency “would likely end up with better quality outcomes.”)</p>
	Washington State DOT	<ul style="list-style-type: none"> • Specialists' participation is not strictly required in all cases but is often done to help ensure success.

Remediation and Emergencies

All agencies implement fish passage remediation projects when state or federal emergencies are declared or after the emergency has concluded.

Monitoring and Maintenance

Respondents provided information about their agencies' fish passage monitoring and maintenance activities in connection with:

- Full-span solutions.
- Partial, or hydraulic, solutions.
- Small maintenance projects.
- Funding long-term maintenance of partial solutions.
- Inspecting hydraulic facilities.

Full-Span Solutions

Respondents were asked about the long-term costs and staff time associated with monitoring and maintenance of full-span solutions. Four agencies—Caltrans, FHWA, Oregon DFW and Washington State DOT—do not have specific cost data available. The FHWA respondent noted that his agency does not own structures and therefore does not incur maintenance costs. Oregon DFW does not typically conduct long-term monitoring and maintenance, with the respondent noting that this is the structure owner's responsibility.

The following summarizes the maintenance and monitoring data provided by the remaining respondents:

- California DFW only formally monitors projects that were funded and constructed using a FRGP grant. All California FRGP projects receive implementation monitoring via site visits during construction and using information provided by the grantee.
- If grade control is needed, California DFW authorizes the cost for an annual inspection to evaluate fish passage performance. Associated maintenance costs depend on the outcome of the inspection and channel changes that could occur as the result of flood flows.
- A qualified biologist from Oregon DOT makes annual site visits that involve taking photos and conducting a best professional judgment analysis over a five-year monitoring period; the estimated cost for the five-year monitoring period is \$2,000.
- Washington DFW reported very minimal costs for monitoring and maintenance.
- Washington State DOT monitors fish passage corrections for performance at years 1, 5 and 10, at minimum. This process takes a couple of hours per visit. Maintenance crews may look at passage sites very briefly once or twice a year to examine the passage from a maintenance perspective.

Partial, or Hydraulic, Solutions

Respondents from two agencies—California DFW and Oregon DOT—conduct the same type of monitoring and maintenance for partial solutions as is conducted for full-span solutions. (A second respondent from California DFW offered a different perspective; see below.) Other agencies lacking maintenance and monitoring data for full-span solutions also lack that data for partial solutions.

California DFW recommends conducting an inspection once per year, at a minimum, before the fish passage season. More frequent inspections (four times per year) may be needed depending on the type of fishway. Associated maintenance costs depend on the outcome of the fishway performance and any changes that could occur as the result of flood flows. Typically, time and costs will be higher for fishway maintenance of partial solutions, primarily for the timely removal of debris and sediment that affects fishway performance.

Washington State DOT contracts with Washington DFW to inspect what the respondent calls an "older correction." In the 2017-2019 biennium, this inspection activity required staff time of about 0.15 FTE (full-time equivalent), or \$27,000 per year, for inspection of 97 sites. As with full-span solutions, performance monitoring for partial solutions is conducted at years 1, 5 and 10, at minimum.

The Washington DFW respondent noted that “hydraulic fish passage designs are highly variable in performance and maintenance needs. These types of designs are prone to debris problems and typically require frequent repairs to continue providing fish passage in a reliable manner. Unfortunately, oversight is inconsistent, so necessary inspections, maintenance and repairs are frequently not completed in a timely manner, if at all. Proper inspection and maintenance may range from \$5,000 to \$25,000 per year.”

The Washington DFW respondent also advised that routine inspections should occur several times per year to ensure fish passage is maintained. He estimated inspection time to be at least 80 hours per year, with a minimum of 80 additional hours required to perform basic maintenance such as gravel and debris removal.

Small Maintenance Projects

Respondents were asked how often their agencies initiated a small maintenance project to remove sediment and address scour or any other issues at an existing hydraulic fish passage facility.

- The Caltrans respondents estimated that small maintenance projects are conducted every few years on fish passage projects (perhaps every five years for projects that have a high bed load). The agency does not have current inspection reports for many locations and does not know how effectively these sites are functioning or if maintenance is required.
- California DFW undertakes small maintenance projects multiple times each year. California DFW commonly requests that maintenance occur on fish passage facilities before and during the fish migration season, which is mostly during the winter months. Typical maintenance removes debris and sediment affecting fish passage performance but sometimes may include velocity or profile control adjustments to address a long-term issue.
- Oregon DOT initiates this type of maintenance annually, and Washington DFW every two years. While FHWA does not own the structures and does not incur costs, the agency is often involved in projects that repair fish passage culverts.
- Washington State DOT maintains records on maintenance actions for about 1,500 barriers in the Puget Sound and Olympic Peninsula area. In 2013, the agency reported 12 maintenance activities in this area; in 2014, 20 maintenance activities; in 2015, 22 maintenance activities; and in 2016, 16 maintenance activities.

Funding Long-Term Maintenance of Partial Solutions

None of the responding agencies include cost estimates and staff hours to fund long-term maintenance when planning partial solution fish passage remediation projects. California DFW's fish passage grant program funds construction of fish passage but not maintenance. For Caltrans, maintenance costs for partial solutions are not planned for and are based on circumstance and need. Oregon DOT funds its monitoring and maintenance of partial solutions separately with funds from the agency's Statewide Transportation Improvement Program. The Washington State DOT respondent noted that his agency does not typically implement partial corrections.

Inspecting Hydraulic Facilities

Survey responses indicated no consensus with regard to the frequency with which agencies inspect hydraulic facilities, with only the Oregon and Washington State DOT respondents reporting annual inspections. The table below summarizes survey responses.

Inspection Frequency for Hydraulic Facilities	
Frequency	Agency
Annually	Oregon DOT, Washington State DOT
After major storm events	California DFW, ¹ Caltrans, ² Washington DFW
As required by permit conditions	FHWA
Periodically for known issues	Oregon DFW
When staff is working on other projects	Caltrans
When we can get around to it	California DFW, ¹ Caltrans

- 1 California DFW also inspects hydraulic facilities on the basis of specific requests and assists private, local, county and state road managers with some planned and opportunistic monitoring.
- 2 Caltrans inspects after major events that cause storm damage.

Appendix A: Survey Questions

The following survey was presented to potential respondents from West Coast state and federal agencies, universities and consulting firms expected to have experience with fish passage programs.

Fish Passage Solutions: Introduction

Please briefly describe your fish passage role.

Fish Passage Solutions: Engineering

1. Is the goal of your program/agency to fully remediate barriers for adult and juvenile salmon and steelhead at locations that you own or have jurisdiction over?
 - Yes (please respond to Question 1A).
 - No (please describe below the goal of your program; then skip to Question 2).
- 1A. Aside from costs, what are other factors that help determine implementation of a grade or velocity control solution?
2. What threshold of fish passage efficiency does your agency use to determine if a hydraulic/partial solution (i.e., grade, velocity control) is the appropriate solution for a barrier location?
3. For grade and velocity control solutions, do you determine the cost of the proposed solution as well as the anticipated benefits, such as relative percentage of salmon and steelhead that will likely be able to negotiate the facility and gain access to upstream habitat?
 - No.
 - Yes (please describe below how the cost and anticipated benefits are determined).
4. Is a goal of your agency to also address sedimentation and to improve water quality in the stream or watershed?
 - Always.
 - Often.
 - Occasionally.
 - Never.

If applicable, please describe when water quality is addressed.

5. Has your agency developed standard plans and estimated costs for the range of potential solutions to fish barriers (i.e., full-span and hydraulic/partial solutions)?
 - No.
 - Yes (please describe below these standard plans and estimated costs).
6. If available, please provide links below to standard plans and estimated costs for your agency's fish barrier solutions. Send any files not available online to Chris Kline at chris.kline@ctcandassociates.com.

Fish Passage Solutions: Project Permitting

1. Is there a process in place for streamlined permitting for fish passage remediation project review and approval?
 - Yes (please respond to Questions 1A and 1B).
 - No (please describe below how project designs and plans are coordinated and approved across agencies; then skip to Question 2).
- 1A. Which agencies and permits are included in the permitting process?
- 1B. Please describe the engineering and environmental review and approval process.
2. Does your agency participate in partnering toward identifying, assessing, prioritizing, planning and implementing successful fish passage solutions?
 - Yes (please respond to Question 3).
 - No (please skip to Question 4).
3. Please describe the coordination process for identifying, assessing and prioritizing road/stream crossings.
4. Please list below common, involved fish passage stakeholders.

Fish Passage Solutions: Species Benefits

1. Please indicate below the intent of your program by selecting all that apply.
 - To provide access to salmon and steelhead species.
 - To provide access to other aquatic species.
 - To provide access to other terrestrial species.
2. If your program provides access to more than salmon and steelhead species, on what do you focus?
 - Regulated species (e.g., state and federal listed species) and habitat.
 - Overall stewardship values of connectivity for all species.
3. Aside from salmon and steelhead, what are some of the other species or habitats that have benefited from full-span fish passage remediation projects that your state or agency has worked on?
4. Does your agency add in costs to also address terrestrial species permeability on salmon and steelhead barrier remediation projects?
 - No.
 - Yes (please provide these costs below, if available).

Fish Passage Solutions: Construction and Implementation

1. How does your agency ensure that fish passage remediation projects are properly implemented during construction?
2. Does your agency conduct additional coordination or oversight during the implementation of complex hydraulic solutions?
 - No.

- Yes (please describe below the additional coordination or oversight).
3. Does your agency require monitoring or oversight of either a fish passage engineer or biologist during implementation?
 - No.
 - Yes (please describe below the monitoring or oversight required).
 4. Does your agency implement fish passage remediation projects at known barrier locations when state or federal emergencies are declared?
 - No.
 - Yes.
 5. If your agency does not implement fish passage remediation projects when emergencies are declared, do you initiate a permanent restoration project to address fish passage remediation after the emergency has concluded?
 - N/A.
 - No.
 - Yes.

Fish Passage Solutions: Monitoring and Maintenance

1. What are typical long-term costs for monitoring and associated maintenance of full-span solutions?
 - 1A. Please estimate annual staff time needed for monitoring and maintenance of full-span solutions.
2. What are typical long-term costs for monitoring and associated maintenance of partial/hydraulic solutions (e.g., baffles and weirs)?
 - 2A. Please estimate annual staff time needed for monitoring and maintenance of partial/hydraulic solutions.
3. Approximately how often does your agency need to initiate a small maintenance project or effort to address issues (e.g., remove sediment, address scour or a damaged facility) at current hydraulic fish passage facilities?
 - Multiple times each year.
 - Annually.
 - Every two years.
 - Every three years.
 - Other (please specify).
4. During the planning of partial solution fish passage remediation projects, do you include cost estimates and staff hours that will be needed for long-term maintenance and monitoring of the facility after implementation?
 - Yes.
 - No (please describe below how you fund long-term maintenance of partial fish passage solutions if costs are not captured in project estimates).

5. When does your agency inspect the status of fish passage hydraulic facilities?

- After major storm events.
- Annually.
- When we can get around to it.
- Other (please specify).

Wrap-Up

Please use this space to provide any comments or additional information about your answers above.

Appendix B: Survey Results

The full text of each survey response is provided below. For reference, an abbreviated version of each question is included before the response; the full question text is available in [Appendix A](#). Responses have been edited for clarity. When a respondent skipped a section of the survey, those questions have been omitted.

State Agencies

California

California Department of Fish and Wildlife 1

Contact: Jonathan Mann, Senior Fish Passage Engineer, California Department of Fish and Wildlife, 916-445-2182, jonathan.mann@wildlife.ca.gov.

Fish Passage Solutions: Introduction

Fish passage role: Review and approve fish passage designs, including for Caltrans projects.

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** Yes.
- 1A. **Factors other than costs that determine grade or velocity solution:** Severity of fish passage impediment, other nearby fish passage impediments, adjacency and potential impacts to other infrastructure, aquatic habitat conditions and potential for improvement of such.
2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** Adult fish life stage = all or significant portion of adhering to fish passage criteria for the anticipated fish migration flow range.
3. **Determine costs and anticipated benefits for grade and velocity solutions?** Yes. Ideally using conceptual level cost estimates of varying alternatives to achieve fish passage after determining the habitat extent and condition above the barrier.
4. **Frequency of addressing sedimentation and improving water quality:** Often.
When water quality is addressed: It is important to consider the range of sediment sizes that may transport as a result of grade control changes and balance the need to maintain water quality impacts from fine sediment with retention of grade and sediment that are good for spawning and other habitat functions over the long term.
5. **Standard plans and costs?** Yes. Not necessarily “standard plans” but design guidance and typicals are covered in the [California] Salmonid Stream Habitat Restoration Manual, Vol. 2, 4th edition, Part XII, Fish Passage Design and Implementation.
6. **Links to standard plans and costs:** [See California Salmonid Stream Habitat Restoration Manual, 4th Edition, Vol. 2, Part XII, Fish Passage Design and Implementation, 2010.]
<http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp>

Fish Passage Solutions: Project Permitting

1. **Streamlined permitting process for remediation?** Yes.

- 1A. **Agencies and permits included in permitting process:** For CDFW [California Department of Fish and Wildlife], the permitting liaisons to Caltrans are there to help facilitate permitting of fish passage improvement projects for CESA [California Endangered Species Act] and DFG [Department of Fish and Game] code for lake and streambed alterations.
- 1B. **Engineering and environmental review and approval process:** Ideally, as fish passage projects are initiated CDFW engineering is engaged for technical support and ultimately final review and approval as the project moves through planning, design and permitting.
2. **Participation in partnering to implement solutions?** Yes.
3. **Coordination process:** Provide data and other technical support in regional and statewide programmatic fish passage efforts including participating in assessment, prioritization and remediation planning.
4. **Common, involved stakeholders:** Other than responsible natural resource governmental organizations: NGOs [non-governmental organizations] and especially nonprofit organizations that facilitate [F]isheries [R]estoration [G]rant projects. Local and regional interested advocates.

Fish Passage Solutions: Species Benefits

1. **Program intent:**
 - To provide access to salmon and steelhead species.
 - To provide access to other aquatic species.
 - To provide access to other terrestrial species.
2. **Expanded focus:** Regulated species (e.g., state and federal listed species) and habitat.
3. **Species and habitats benefiting from full-span remediation:** Pacific lamprey, tidewater goby, trout, frogs, salamanders, many different small and sometimes large terrestrial and partial-aquatic species (river otter, beaver, etc.).
4. **Add in costs to address terrestrial species?** Yes. If a fish passage improvement project meets the highest goal of full stream simulation design, terrestrial species connectivity can be achieved at the stream channel margins and the associated costs are then embedded in the fish passage project.

Fish Passage Solutions: Construction and Implementation

1. **How to ensure proper implementation during construction?** By first providing the proper guidance for implementation including construction BMPs [best management practices] and then also through permit conditions that may include inspections by appropriate CDFW staff.
2. **Additional coordination or oversight for complex solutions?** Yes. Ideally through established written conditional documentation for inspections and approvals.
3. **Monitoring or oversight by fish passage engineer or biologist?** Yes. Through project-specific permit conditions that may include project monitoring and inspections by appropriate CDFW staff.
4. **Implement remediation projects in response to emergency declarations?** No.
5. **If remediation projects are not implemented in response to emergency declarations, are permanent restoration projects initiated after the emergency?** N/A.

Fish Passage Solutions: Monitoring and Maintenance

1. **Long-term costs for monitoring and maintaining full-span solutions:** If grade control is needed costs for an inspection once per year [are] recommended from a fish passage performance perspective. Associated maintenance costs would depend on the outcome of the inspection and channel changes that could occur as the result of flood flows.
- 1A. **Annual staff time for monitoring and maintaining full-span solutions:** See above.
2. **Long-term costs for monitoring and maintaining partial/hydraulic solutions:** An inspection once per year at a minimum prior to the fish passage season is recommended, but more frequent (4x/year) inspections may be needed depending on the type of fishway [that] is implemented. Probably best to assume costs associated with inspections up to 4x [per] year. Associated maintenance costs would depend on the outcome of the fishway performance and any changes that could occur as the result of flood flows.
- 2A. **Annual staff time for monitoring and maintaining partial/hydraulic solutions:** Typically, time and costs will be higher for fishway maintenance, primarily to timely remove debris and sediment that affects the fishway performance.
3. **Frequency of small maintenance projects:** CDFW commonly requests maintenance occur on fish passage facilities before and during the fish migration season, which is mostly in the winter. Typical maintenance is to remove debris and sediment affecting fish passage performance, but sometimes it may include velocity or profile control adjustments for a long-term issue.
4. **Include cost estimates and staff hours for monitoring and maintenance in planning for partial solutions?** Yes.
5. **Frequency of inspection for hydraulic facilities:** When we get around to it.

Wrap-Up

Additional Comments: [No response.]

California Department of Fish and Wildlife 2

Contact: Allan Renger, Environmental Scientist Supervisor/Fisheries Biologist, Region 1, California Department of Fish and Wildlife, 707-725-7194, allan.renger@wildlife.ca.gov.

Fish Passage Solutions: Introduction

Fish passage role: My fish passage role is prioritizing Caltrans and other passage issues for treatment, leading fish habitat and biological survey relevant to fish passage, some monitoring of completed passage projects/fish, providing conditions to passage construction project permits.

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** Yes.
- 1A. **Factors other than costs that determine grade or velocity solution:** Fish species affected, length of upstream habitat.
2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** CDFW does not have established criteria that I know of. In these situations, CDFW biologist and engineering staff will communicate [and] weigh biological importance of species and life stage addressed or not addressed by a partial solution.

3. **Determine costs and anticipated benefits for grade and velocity solutions?** Yes. CDFW will use species, length of habitat and cost to prioritize passage.
4. **Frequency of addressing sedimentation and improving water quality:** Always.
When water quality is addressed: Standards and engineering review for passage plans and associated water bypass fish screening plans, BMPs to control sediment/pollutant discharge while fish passage construction occurs, BMPs for post-project disturbed sediment controls, [p]rovisions for riparian planting, [p]rovisions for project and post-project monitoring.
5. **Standard plans and costs?** Yes. We do not have standard plans or costs, but we reference cost of similar projects when evaluating passage proposals through to our grants program.
6. **Links to standard plans and costs:** [No response.]

Fish Passage Solutions: Project Permitting

1. **Streamlined permitting process for remediation?** Yes and no. Some smaller open-channel fish passage projects funded by CDFW Fisheries Restoration Grant Program [FRGP] can be conducted under FRGP programmatic CEQA [California Environmental Quality Act] and associated USACE [United States Army Corps of Engineers] regional general permit. Most Caltrans projects will fall under standard permitting.
- 1A. **Agencies and permits included in permitting process:** Projects that qualify under CDFW FRGP permitting have: CEQA Mitigated Neg Dec [mitigated negative declaration]; CDFW [Fish and Game Code Section] 1602, SWRCB 401 cert [State Water Resources Control Board Clean Water Act 401 water quality certification], USACE 404 regional general permit and associated NOAA USFWS ESA BO [National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, Endangered Species Act Biological Opinions].
- 1B. **Engineering and environmental review and approval process:** All passage projects need approval of design by CDFW or NOAA passage engineer, and CDFW biologist staff [is] often consulted in this review. CDFW regulatory staff write[s] Lake and Streambed Alteration agreements for passage projects that review and condition [a] project's environmental protections
2. **Participation in partnering to implement solutions?** Yes.
3. **Coordination process:** Identified by communication with the relevant private, local, county, state [or] fed[eral] road management entity or as issues [or] complaints arise. Assessed and prioritized by methods in the CDFW stream habitat restoration manual Flosi et al. [See California Salmonid Stream Habitat Restoration Manual, 4th Edition, 2010. <http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp>.]
4. **Common, involved stakeholders:** Private landowners, timberland land owners, cities, counties, Caltrans, state parks, railroads, USFS [U.S. Forest Service], BLM [Bureau of Land Management], Native American tribes, private fish passage engineers, construction companies, fisheries-focus[ed] NGOs.

Fish Passage Solutions: Species Benefits

1. **Program intent:**
 - To provide access to salmon and steelhead species.
 - To provide access to other aquatic species.
 - To provide access to other terrestrial species.
2. **Expanded focus:** Overall stewardship values of connectivity for all species.

3. **Species and habitats benefiting from full-span remediation:** Lamprey, coastal cutthroat trout, rainbow trout, Sacramento sucker, amphibians, deer, elk, bear, mountain lion.
4. **Add in costs to address terrestrial species?** Yes. Sometimes CDFW has required provisions for terrestrial animals that resulted in costs.

Fish Passage Solutions: Construction and Implementation

1. **How to ensure proper implementation during construction?** It depends. Under CDFW FRGP grants the grantee and CDFW have implementation and post-project monitoring and reporting roles for permit compliance and construction standards. Under LSAA [Lake and Streambed Alteration agreement] CDFW 1602 we can inspect a project for permit compliance. CDFW receives calls and investigates code violations. CDFW conducts some biological and facility post-project monitoring specific to passage projects. CDFW conducts general biological and habitat monitoring that provides data relevant to passage projects. Counties and Caltrans provide passage inspection reports, and CDFW notifies entities of issues we observe with passage structures.
2. **Additional coordination or oversight for complex solutions?** Yes. CDFW has conducted fish relocation in support of Caltrans projects. CDFW has engineering and construction Caltrans liaison positions.
3. **Monitoring or oversight by fish passage engineer or biologist?** Yes. A biologist is required during fish relocation [and] channel de-watering activities. An engineer will need to submit plans and as-built and may need to be on-site [or] inspect [a project] to provide an as-built [drawing].
4. **Implement remediation projects in response to emergency declarations?** Yes.
5. **If remediation projects are not implemented in response to emergency declarations, are permanent restoration projects initiated after the emergency?** N/A.

Fish Passage Solutions: Monitoring and Maintenance

1. **Long-term costs for monitoring and maintaining full-span solutions:** CDFW only formally monitors projects that were funded [or] constructed via a CDFW FRGP grant. CDFW monitors implementation of passage projects constructed under its grant programs for compliance with plans and design standards; monitors post-project effectiveness of the structure for meeting passage at design flows and maintenance issues; monitors post-project for validation: Do fish use the structure and is it providing the biological services needed?

All FRGP projects receive implementation monitoring via site visits during construction and information from the grantee and this is about \$2,000 to \$5,000.

A subset of FRGP projects [is] selected for effectiveness monitoring [for] about \$2,000 to \$5,000.

A subset of FRGP projects [is] selected for validation monitoring, and costs are dependent on monitoring technique and effort expended. Sometimes a site is monitored for multiple years [for] about \$2,000 to \$10,000.

- 1A. **Annual staff time for monitoring and maintaining full-span solutions:** All FRGP projects receive implementation monitoring via site visits during construction and information from the grantee and this is about three weeks.

A subset of FRGP projects [is] selected for effectiveness monitoring [for] about one to three weeks.

A subset of FRGP projects [is] selected for validation monitoring, and costs are dependent on monitoring technique and effort expended. Sometimes a site is monitored for multiple years [for] about two to 12 weeks.

2. **Long-term costs for monitoring and maintaining partial/hydraulic solutions:** CDFW only formally monitors projects that were funded [or] constructed via a CDFW Fisheries Restoration Grant Program grant. CDFW monitors implementation of passage projects constructed under its grant programs for compliance with plans and design standards; monitors post-project effectiveness of the structure for meeting passage at design flows and maintenance issues; monitors post-project for validation: Do fish use the structure and is it providing the biological services needed?

All FRGP projects receive implementation monitoring via site visits during construction and information from the grantee and this is about \$2,000 to \$5,000.

A subset of FRGP projects [is] selected for effectiveness monitoring [for] about \$2,000 to \$5,000.

A subset of FRGP projects [is] selected for validation monitoring and costs are dependent on monitoring technique and effort expended. Sometimes a site is monitored for multiple years [for] about \$2,000 to \$10,000.

- 2A. **Annual staff time for monitoring and maintaining partial/hydraulic solutions:** All FRGP projects receive implementation monitoring via site visits during construction and information from the grantee and this is about three weeks

A subset of FRGP projects [is] selected for effectiveness monitoring [for] about one to three weeks.

A subset of FRGP projects [is] selected for validation monitoring, and costs are dependent on monitoring technique and effort expended. Sometimes a site is monitored for multiple years [for] about two to 12 weeks.

3. **Frequency of small maintenance projects:** Multiple times per year.
4. **Include cost estimates and staff hours for monitoring and maintenance in planning for partial solutions?** No. Our grants program funds construction of fish passage but does not fund maintenance. That is the responsibility of the road manager/owner.
5. **Frequency of inspection for hydraulic facilities:** After major storm events. CDFW receives calls and also assists private, local, county [and] state road managers with some planned and opportunistic monitoring.

Wrap-Up

Additional Comments: [No response.]

Caltrans 1

Contact: Melinda Molnar, Senior Fish Biologist, Office of Biological Studies and Structures, Caltrans, 707-445-6627, melinda.molnar@dot.ca.gov.

Fish Passage Solutions: Introduction

Fish passage role: I am the biological lead for fish passage at Caltrans.

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** Yes.
- 1A. **Factors other than costs that determine grade or velocity solution:** Access, ownership, support of district [and] programming (funding) decision-makers.
2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** Of the 39 barriers that Caltrans has treated, 32 of those are partial solutions (hydraulic retrofits). The effectiveness of passing fish at the partial solutions is unknown.
3. **Determine costs and anticipated benefits for grade and velocity solutions?** No.
4. **Frequency of addressing sedimentation and improving water quality:** Occasionally.
When water quality is addressed: Some of the fish barriers overlap with designated impaired water bodies. A few projects have been initiated to treat both fish as well as sediment issues in TMDL [total maximum daily load] areas.
5. **Standard plans and costs?** No.
6. **Links to standard plans and costs:** [No response.]

Fish Passage Solutions: Project Permitting

1. **Streamlined permitting process for remediation?** No. In the few instances where grant funding has been obtained some document and permit efficiencies exist, but there is no streamline[d] process for projects that Caltrans develops internally.
- 1A. **Agencies and permits included in permitting process:** Lake and Streambed Alteration [Program] (CDFW); water quality certification ([Section] 401); wetlands/waters of the U.S. (Sect[ion] 404 [Clean Water Act]); federal Endangered Species [Act] (Sect[ion] 7); [California] Endangered Species Act, consistency for dual listing ([Section] 2080.1); and in some instances 4(f), Wild and Scenic [Rivers Program], Coastal Development Permit (CDP) or other state/local permit.
- 1B. **Engineering and environmental review and approval process:** Project biologists and engineers work with [California Department of Fish and] Wildlife, NMFS [National Marine Fisheries Service] and other partners to scope solution; project developed to 35 percent design and environmental document. Check in with external permitting partners. Finalize plans and environmental permitting.
2. **Participation in partnering to implement solutions?** Yes.
3. **Coordination process:** There are groups throughout the state that Caltrans organizes, in coordination with [California Department of Fish and] Wildlife, called Fish Passage Advisory Committees (FishPACs) where biologists, engineers and other experts work to improve science and data and come to agreement on priorities.
4. **Common, involved stakeholders:** [California Department of Fish and] Wildlife, National Marine Fisheries Service, U.S. Fish & Wildlife, Coastal Commission, Coastal Conservancy, California Trout, State Water Quality Control Board, [U.S.] Army Corps of Engineers.

Fish Passage Solutions: Species Benefits

1. **Program intent:**
 - To provide access to salmon and steelhead species.
2. **Expanded focus:** [No response.]
3. **Species and habitats benefiting from full-span remediation:** Other aquatic and terrestrial species. When we replace a culvert with a bridge we have also added bat habitat

to the bridge design.

4. **Add in costs to address terrestrial species?** No.

Fish Passage Solutions: Construction and Implementation

1. **How to ensure proper implementation during construction?** The hydraulic engineer and fish biologist often work with the resident engineer and contractor. When this doesn't happen, implementation is less successful, as is the effectiveness of the outcome.
2. **Additional coordination or oversight for complex solutions?** No.
3. **Monitoring or oversight by fish passage engineer or biologist?** Yes. When required by permit.
4. **Implement remediation projects in response to emergency declarations?** Yes.
5. **If remediation projects are not implemented in response to emergency declarations, are permanent restoration projects initiated after the emergency?** N/A.

Fish Passage Solutions: Monitoring and Maintenance

1. **Long-term costs for monitoring and maintaining full-span solutions:** We don't know.
- 1A. **Annual staff time for monitoring and maintaining full-span solutions:** We don't know.
2. **Long-term costs for monitoring and maintaining partial/hydraulic solutions:** We don't know.
- 2A. **Annual staff time for monitoring and maintaining partial/hydraulic solutions:** We don't know.
3. **Frequency of small maintenance projects:** Projects come up every few years, but many of the locations do not have current inspections and we don't know how effectively they're functioning or if maintenance projects need to be initiated.
4. **Include cost estimates and staff hours for monitoring and maintenance in planning for partial solutions?** This is an issue we are looking to address.
5. **Frequency of inspection for hydraulic facilities:** When we can get around to it.

Wrap-Up

Additional comments: [No response.]

Caltrans 2

Contact: Steve Thorne, Natural Resource Project Development/Senior Hydraulics Engineer, Caltrans, 530-225-3087, steve.thorne@dot.ca.gov.

Fish Passage Solutions: Introduction

Fish passage role: Original member of D2 FishPAC team, senior hydraulics engineer in charge of supervising Hydraulics branch. Current role includes assessments, evaluations, conceptual designs, final PS&E [plans, specifications and estimates], as well as developing and oversight of other engineers involved in hydraulic design for fish passage.

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** No. Inventory, prioritize and construct the highest priorities and locations that are within other

programmed projects.

- 1A. **Factors other than costs that determine grade or velocity solution:** Access from private property owners; environmental impacts, including cultural resources.
2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** It depends on the site context, but often the goal is to mimic the natural situation as much as practicable in a stream simulation.
3. **Determine costs and anticipated benefits for grade and velocity solutions?** Yes. Cost estimates for alternatives are developed and the benefit is qualitatively determined.
4. **Frequency of addressing sedimentation and improving water quality:** Often.
When water quality is addressed: [No response.]
5. **Standard plans and costs?** Yes. Some standard plans and details exist but more are needed and being worked on.
6. **Links to standard plans and costs:** It would take some effort to assemble this. Some standard details are in the Caltrans fish passage design manual [Fish Passage Design for Roadway Crossings: An Engineering Document Providing Fish Passage Design Guidance for Caltrans Projects]; see <http://www.dot.ca.gov/design/manuals/fpm.html>.

Fish Passage Solutions: Project Permitting

1. **Streamlined permitting process for remediation?** Yes.
- 1A. **Agencies and permits included in permitting process:** If funds are contributed from the FRGP, then environmental permitting is streamlined.
- 1B. **Engineering and environmental review and approval process:** [No response.]
2. **Participation in partnering to implement solutions?** Yes.
3. **Coordination process:** [No response.]
4. **Common, involved stakeholders:** Tribes, watershed groups, resource agencies, public agencies, private citizens, philanthropic groups.

Fish Passage Solutions: Species Benefits

1. **Program intent:**
 - To provide access to salmon and steelhead species.
 - To provide access to other aquatic species.
 - To provide access to other terrestrial species.
2. **Expanded focus:** Regulated species (e.g., state and federal listed species) and habitat.
3. **Species and habitats benefiting from full-span remediation:** Humans, deer, bear, amphibians, snails, mammals.
4. **Add in costs to address terrestrial species?** Yes. Often design considerations for access to the crossing [are] included.

Fish Passage Solutions: Construction and Implementation

1. **How to ensure proper implementation during construction?** A resident engineer is in control of the project and appropriate staff with expertise [is] called out. Sometimes permits are conditioned to have resource agency or staff with appropriate expertise on hand at key

times. This is in the contract specifications.

2. **Additional coordination or oversight for complex solutions?** Yes. Appropriate staff [is] on hand during construction and layout of key hydraulic features.
3. **Monitoring or oversight by fish passage engineer or biologist?** Yes. Contract specifications are included when appropriate.
4. **Implement remediation projects in response to emergency declarations?** Yes.
5. **If remediation projects are not implemented in response to emergency declarations, are permanent restoration projects initiated after the emergency?** N/A.

Fish Passage Solutions: Monitoring and Maintenance

1. **Long-term costs for monitoring and maintaining full-span solutions:** Relatively low.
- 1A. **Annual staff time for monitoring and maintaining full-span solutions:** Not known.
2. **Long-term costs for monitoring and maintaining partial/hydraulic solutions:** Not known.
- 2A. **Annual staff time for monitoring and maintaining partial/hydraulic solutions:** Not known.
3. **Frequency of small maintenance projects:** Other. Roughly 5 years on some that have high bed load such as Shotgun Creek on Sha-5.
4. **Include cost estimates and staff hours for monitoring and maintenance in planning for partial solutions?** No. This is an issue we are looking to address.
5. **Frequency of inspection for hydraulic facilities:** When staff [is] in the area working on other projects typically and after major events that cause storm damage.

Wrap-Up

Additional comments: Anadromous fish species are the focus (and required to be reported [under] SB-857) [California Senate Bill-857], but there are many non-anadromous crossings that should also be inventoried a[nd] prioritized.

Oregon

Oregon Department of Fish and Wildlife

Contact: Alan Ritchey, Program Manager, Fish Screening and Passage Program, Oregon Department of Fish and Wildlife, 503-947-6229, alan.d.ritchey@state.or.us.

Fish Passage Solutions: Introduction

Fish passage role: [No response.]

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** No. ODFW [Oregon Department of Fish and Wildlife] owns some barriers but most work is related to implementing fish passage requirements as other barrier owners implement projects.

- 1A. **Factors other than costs that determine grade or velocity solution:** [No response.]
2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** Conditions consistent with fish passage criteria.
3. **Determine costs and anticipated benefits for grade and velocity solutions?** No.
4. **Frequency of addressing sedimentation and improving water quality:** Always.
When water quality is addressed: [No response.]
5. **Standard plans and costs?** No.
6. **Links to standard plans and costs:** [No response.]

Fish Passage Solutions: Project Permitting

1. **Streamlined permitting process for remediation?** No. ODFW reviews projects proposed by others. Our authority is over fish passage.
- 1A. **Agencies and permits included in permitting process:** [No response.]
- 1B. **Engineering and environmental review and approval process:** [No. response.]
2. **Participation in partnering to implement solutions?** Yes.
3. **Coordination process:** ODFW manages a statewide fish passage prioritization. We also identify and sometimes cost share or provide technical assistance on fish passage projects.
4. **Common, involved stakeholders:** ODOT [Oregon Department of Transportation] and other road management agencies. Also work with water diverters. Partner with other resources to fund passage restoration projects.

Fish Passage Solutions: Species Benefits

1. **Program intent:**
 - To provide access to salmon and steelhead species.
 - To provide access to other aquatic species.
 - To provide access to other terrestrial species.
2. **Expanded focus:** Overall stewardship values of connectivity for all species.
3. **Species and habitats benefiting from full-span remediation:** All native migratory fish. Lamprey and suckers are common beneficiaries.
4. **Add in costs to address terrestrial species?** No.

Fish Passage Solutions: Construction and Implementation

1. **How to ensure proper implementation during construction?** Ongoing maintenance is a condition of the fish passage approval that ODFW issues. Monitoring reports may also be generated.
2. **Additional coordination or oversight for complex solutions?** Yes. Possible site inspections, review monitoring reports, work to adaptively manage, if necessary.
3. **Monitoring or oversight by fish passage engineer or biologist?** No.
4. **Implement remediation projects in response to emergency declarations?** Yes.
5. **If remediation projects are not implemented in response to emergency declarations,**

are permanent restoration projects initiated after the emergency? N/A.

Fish Passage Solutions: Monitoring and Maintenance

1. **Long-term costs for monitoring and maintaining full-span solutions:** ODFW does not typically conduct the long-term monitoring and maintenance. That is the owner's responsibility.
- 1A. **Annual staff time for monitoring and maintaining full-span solutions:** ODFW does not typically conduct the long-term monitoring and maintenance. That is the owner's responsibility.
2. **Long-term costs for monitoring and maintaining partial/hydraulic solutions:** ODFW does not typically conduct the long-term monitoring and maintenance. That is the owner's responsibility.
- 2A. **Annual staff time for monitoring and maintaining partial/hydraulic solutions:** ODFW does not typically conduct the long-term monitoring and maintenance. That is the owner's responsibility.
3. **Frequency of small maintenance projects:** ODFW does not typically conduct the long-term monitoring and maintenance. That is the owner's responsibility.
4. **Include cost estimates and staff hours for monitoring and maintenance in planning for partial solutions?** No. ODFW does not typically conduct the long-term monitoring and maintenance. That is the owner's responsibility.
5. **Frequency of inspection for hydraulic facilities:** This is not typically ODFW's responsibility but this may occur periodically at known issues or as needed to ensure fish passage is functioning.

Wrap-Up

Additional comments: ODFW is typically a regulator, not the operator. We have authority over fish passage and review work proposed by others. We do not own or have responsibility over that many culverts.

Oregon Department of Transportation 1

Contact: Robert Trevis, Program Lead, Culvert Engineering Program, Oregon Department of Transportation, 503-986-3860, robert.e.trevis@odot.state.or.us.

Fish Passage Solutions: Introduction

Fish passage role: Help set standards and provide help to region staff.

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** No. Depends on the funding source. ODOT's Bill Warncke, who responded to your survey, oversees the fish passage program funding [that] replaces culverts in any condition to meet state fish passage law. Other projects that trigger the state law are required to provide full fish passage.
- 1A. **Factors other than costs that determine grade or velocity solution:** Stream morphology, hydrology [and] any upstream or downstream controls and species.

2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** State law requires full passage.
3. **Determine costs and anticipated benefits for grade and velocity solutions?** Yes. We determine the anticipated benefits to provide full passage at the lowest cost possible in accordance with state regulatory agencies.
4. **Frequency of addressing sedimentation and improving water quality:** Always.
When water quality is addressed: New impervious surface, removing bridge scuppers and treating water before entering a water body.
5. **Standard plans and costs?** No.
6. **Links to standard plans and costs:** [No response.]

Fish Passage Solutions: Project Permitting

1. **Streamlined permitting process for remediation?** No. See Bill Warncke's answers through "Construction."
- 1A. **Agencies and permits included in permitting process:** See Bill Warncke's answers through "Construction."
- 1B. **Engineering and environmental review and approval process:** See Bill Warncke's answers through "Construction."
2. **Participation in partnering to implement solutions?** See Bill Warncke's answers through "Construction."
3. **Coordination process:** See Bill Warncke's answers through "Construction."
4. **Common, involved stakeholders:** See Bill Warncke's answers through "Construction."

Fish Passage Solutions: Species Benefits

1. **Program intent:** See Bill Warncke's answers through "Construction."
2. **Expanded focus:** See Bill Warncke's answers through "Construction."
3. **Species and habitats benefiting from full-span remediation:** See Bill Warncke's answers through "Construction."
4. **Add in costs to address terrestrial species?** See Bill Warncke's answers through "Construction."

Fish Passage Solutions: Construction and Implementation

1. **How to ensure proper implementation during construction?** Proper specifications, plans, preconstruction meetings and inspection. If necessary, the engineer of record will help inspect and direct the contractor on construction.
2. **Additional coordination or oversight for complex solutions?** [No response.]
3. **Monitoring or oversight by fish passage engineer or biologist?** Yes. See Bill's answers.
4. **Implement remediation projects in response to emergency declarations?** Yes. See Bill's answers.
5. **If remediation projects are not implemented in response to emergency declarations, are permanent restoration projects initiated after the emergency?** N/A.

Fish Passage Solutions: Monitoring and Maintenance

1. **Long-term costs for monitoring and maintaining full-span solutions:** Refer to Bill Warncke's answers to Questions 1 through 2A [and] 4 through 5.
- 1A. **Annual staff time for monitoring and maintaining full-span solutions:** [No response.]
2. **Long-term costs for monitoring and maintaining partial/hydraulic solutions:** [No response.]
- 2A. **Annual staff time for monitoring and maintaining partial/hydraulic solutions:** [No response.]
3. **Frequency of small maintenance projects:** Every two years.
4. **Include cost estimates and staff hours for monitoring and maintenance in planning for partial solutions?** [No response.]
5. **Frequency of inspection for hydraulic facilities:** [No response.]

Wrap-Up

Additional Comments: [No response.]

Oregon Department of Transportation 2

Contact: William Warncke, Geo-Environmental/Fish Passage Lead, Geo-Environmental Section, Oregon Department of Transportation, 503-986-3459, william.m.warncke@odot.state.or.us.

Fish Passage Solutions: Introduction

Fish passage role: I am ODOT's fish passage lead.

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** Yes.
- 1A. **Factors other than costs that determine grade or velocity solution:** Importance of the barrier to native migratory fish (NMF), upstream property ownership and vulnerability of stream to head cut.
2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** State fish passage rules outline requirements for meeting hydraulic criteria. Since passage of renewed fish passage law and implementing rules, ODOT's fish passage program has focused on culvert replacements to meet stream simulation criteria. This is a separate funding program from culvert repairs and culvert infrastructure projects. Nonfish passage funded project[s] may pursue hydraulic criteria to meet passage requirements.
3. **Determine costs and anticipated benefits for grade and velocity solutions?** Yes. The decision has more to do with the condition of the infrastructure and ability to meet hydraulic criteria. Theoretically meeting hydraulic criteria provides full passage—this is difficult to achieve with most existing infrastructure. Most culverts have to be upsized significantly to meet hydraulic criteria.
4. **Frequency of addressing sedimentation and improving water quality:** Always.
When water quality is addressed: [No response.]
5. **Standard plans and costs?** No.

6. **Links to standard plans and costs:** [No response.]

Fish Passage Solutions: Project Permitting

1. **Streamlined permitting process for remediation?** No.
- 1A. **Agencies and permits included in permitting process:** ODOT has a programmatic consultation with NMFS. Certain categories of projects can be completed with notifications. Roughened channels and hydraulic projects require review and approval by FHWA [Federal Highway Association] and NMFS. We have a pilot project with ODFW on culvert repair, but each repair has individual review and approval. ODFW reviews each fish passage plan individually. The Corp[s] [USACE] and Department of State Lands regulate removal and fill in streams and wetlands. Most culvert projects require permits from these agencies.
- 1B. **Engineering and environmental review and approval process:** ODOT has a project team project development process—hydraulic engineers and biologists work together to meet passage requirements. NMFS and ODFW provide review and approval of designs.
2. **Participation in partnering to implement solutions?** Yes.
3. **Coordination process:** ODFW provides a list of high-priority barriers across the state. ODOT evaluates cost/benefit of addressing highest priority barriers and delivery capacity of project delivery team and regional construction offices.
4. **Common, involved stakeholders:** Tribes, regulatory agencies, environmental groups, adjacent landowners.

Fish Passage Solutions: Species Benefits

1. **Program intent:**
 - To provide access to salmon and steelhead species.
 - To provide access to other aquatic species.
2. **Expanded focus:** Regulated species (e.g., state and federal listed species) and habitat.
3. **Species and habitats benefiting from full-span remediation:** Oregon's law requires passage for all native migratory fish. Many terrestrial and other aquatic species benefit from passage projects.
4. **Add in costs to address terrestrial species?** No.

Fish Passage Solutions: Construction and Implementation

1. **How to ensure proper implementation during construction?** Project inspectors are on-site during construction. Inspectors are trained. Precon[struction] meetings set expectations for the contractor. Agency biologists perform inspections during critical project implementation phases for programmatic consultation with NMFS.
2. **Additional coordination or oversight for complex solutions?** Yes. Preconsultation is required with both NMFS and ODFW for complicated projects.
3. **Monitoring or oversight by fish passage engineer or biologist?** Yes. As described above, biologists are present during critical project delivery milestones. Channel construction is directed by agency hydraulic engineers and/or biologists.
4. **Implement remediation projects in response to emergency declarations?** Yes.
5. **If remediation projects are not implemented in response to emergency declarations,**

are permanent restoration projects initiated after the emergency? Yes.

Fish Passage Solutions: Monitoring and Maintenance

1. **Long-term costs for monitoring and maintaining full-span solutions:** Quick site visit, photos and BPJ [best professional judgment] analysis by qualified biologist annually for five years at \$2,000 for [a] five-year monitoring period.
- 1A. **Annual staff time for monitoring and maintaining full-span solutions:** See above.
2. **Long-term costs for monitoring and maintaining partial/hydraulic solutions:** About the same as full-span solutions.
- 2A. **Annual staff time for monitoring and maintaining partial/hydraulic solutions:** See above.
3. **Frequency of small maintenance projects:** Annually.
4. **Include cost estimates and staff hours for monitoring and maintenance in planning for partial solutions?** No. Monitoring and maintenance are paid for separately from a skim off the STIP [State Transportation Improvement Program].
5. **Frequency of inspection for hydraulic facilities:** Annually.

Wrap-Up

Additional Comments: You are welcome to contact me for additional information.

Washington

Washington Department of Fish and Wildlife

Contact: Don Ponder, Engineer Section Manager, Habitat Restoration Division, Washington Department of Fish and Wildlife, 360-902-2547, donald.ponder@dfw.wa.gov.

Fish Passage Solutions: Introduction

Fish passage role: I lead a group of engineers focused on habitat protection and restoration in Washington, which includes extensive fish passage work statewide.

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** Yes.
- 1A. **Factors other than costs that determine grade or velocity solution:** Until recently, most fish passage projects in Washington were voluntary. A court decision has since compelled the state to fix some of its barriers within a set period of time.
2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** Engineered solutions are legal in Washington, however new/replacement structures must use a “geomorphic approach,” meaning something with a natural, self-maintaining bed, such as stream simulation or a bridge.
3. **Determine costs and anticipated benefits for grade and velocity solutions?** Yes. We generally are in favor of some benefit rather than none; however, not necessarily if the “fix” is seen as reducing the owner’s motivation to replace the crossing with a stream simulation culvert or a bridge.

4. **Frequency of addressing sedimentation and improving water quality:** Always.
When water quality is addressed: Our approach is to let the stream behave to the extent possible as it would without a crossing. One could argue water quality is improved by allowing such natural processes that typically result in more riparian [access], etc.
5. **Standard plans and costs?** No.
6. **Links to standard plans and costs:** [No response.]

Fish Passage Solutions: Project Permitting

1. **Streamlined permitting process for remediation?** Yes.
- 1A. **Agencies and permits included in permitting process:** It is typically easier to get state and local permits in Washington for certain types of beneficial projects, such as improving fish passage.
- 1B. **Engineering and environmental review and approval process:** Primary fish passage regulation in Washington is conducted by WDFW (my agency) by fish biologists with the assistance of our engineers when warranted.
2. **Participation in partnering to implement solutions?** Yes.
3. **Coordination process:** ODFW manages a statewide fish passage prioritization. We also identify and sometimes cost share or provide technical assistance on fish passage projects.
4. **Common, involved stakeholders:** ODOT and other road management agencies. Also work with water diverters. Partner with other resources to fund passage restoration projects.

Fish Passage Solutions: Species Benefits

1. **Program intent:**
 - To provide access to salmon and steelhead species.
 - To provide access to other aquatic species.
2. **Expanded focus:** Overall stewardship values of connectivity for all species.
3. **Species and habitats benefiting from full-span remediation:** As an engineer, I'll leave this question to be answered (better) by the biologists.
4. **Add in costs to address terrestrial species?** Yes. In some cases, we consider the specific needs of certain terrestrial species. However, typically we focus on fish with the belief that stream simulation and bridges will have some terrestrial benefit.

Fish Passage Solutions: Construction and Implementation

1. **How to ensure proper implementation during construction?** Frankly, we're weak in this area. We need to do a better job of monitoring outcomes.
2. **Additional coordination or oversight for complex solutions?** Yes. We have limited availability, so yes, we try to ensure the projects with the most risk and highest potential habitat value get the most attention throughout the process.
3. **Monitoring or oversight by fish passage engineer or biologist?** Yes. We do a follow-up inspection when the work is completed. However, if we invested more time we would likely end up with better quality outcomes.
4. **Implement remediation projects in response to emergency declarations?** No.

5. **If remediation projects are not implemented in response to emergency declarations, are permanent restoration projects initiated after the emergency?** Yes.

Fish Passage Solutions: Monitoring and Maintenance

1. **Long-term costs for monitoring and maintaining full-span solutions:** In terms of fish passage, monitoring and maintenance costs with full-spans should be very minimal. From a structural cost, the type of structure drives those costs. For example, painting a steel structure may be very expensive over water but concrete would not require painting.
 - 1A. **Annual staff time for monitoring and maintaining full-span solutions:** Annual costs may be 40 staff hours per year focused on bridge safety aspects.
2. **Long-term costs for monitoring and maintaining partial/hydraulic solutions:** Hydraulic fish passage designs are highly variable in performance and maintenance needs. These types of designs are prone to debris problems and typically require frequent repairs to continue providing fish passage in a reliable manner. Unfortunately, oversight is inconsistent, so necessary inspections, maintenance and repairs are frequently not completed in a timely manner, if at all. Proper inspection and maintenance may range from \$5,000 to \$25,000 per year.
 - 2A. **Annual staff time for monitoring and maintaining partial/hydraulic solutions:** Routine inspections should occur several times per year to ensure fish passage is maintained. I would estimate inspection time to be at least 80 hours per year. At least an additional 80 hours would be required to perform basic maintenance such as gravel and debris removal.
3. **Frequency of small maintenance projects:** Every two years.
4. **Include cost estimates and staff hours for monitoring and maintenance in planning for partial solutions?** [No response.]
5. **Frequency of inspection for hydraulic facilities:** After major storm events.

Wrap-Up

Additional comments: [No response.]

Washington State Department of Transportation

Contacts: Paul Wagner, Biology Branch Manager, Environmental Services, Washington State Department of Transportation, 360-705-7406, wagnerp@wsdot.wa.gov.

Mark Barber, Stream Restoration Program Manager, Environmental Services, Washington State Department of Transportation, 360-705-7518, barberm@wsdot.wa.gov.

Dean Moon, Fish Passage Program Manager, Environmental Services, Washington State Department of Transportation, 360-705-7130, moondr@wsdot.wa.gov.

[Note: These three Washington State Department of Transportation (WSDOT) fish passage experts coordinated their responses in one survey below.]

Fish Passage Solutions: Introduction

Fish passage role: Manage WSDOT's fish passage program and policy.

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** Yes.
- 1A. **Factors other than costs that determine grade or velocity solution:** Site constraints.
2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** We rarely use a hydraulic correction, but follow the stream crossing design methodology published by Washington State Department of Fish and Wildlife.
3. **Determine costs and anticipated benefits for grade and velocity solutions?** No.
4. **Frequency of addressing sedimentation and improving water quality:** Often.
When water quality is addressed: We seek to restore natural stream conditions/functions.
5. **Standard plans and costs?** No.
6. **Links to standard plans and costs:** [No response.]

Fish Passage Solutions: Project Permitting

1. **Streamlined permitting process for remediation?** Yes.
- 1A. **Agencies and permits included in permitting process:** Primary: WDFW [Washington Department of Fish and Wildlife], Washington Department of Ecology, COE [USACE], USFWS, NMFS, SEPA [State Environmental Policy Act].
- 1B. **Engineering and environmental review and approval process:** We have an extensive multidisciplinary process that involves early coordination esp[ecially] with tribes and WDFW.
2. **Participation in partnering to implement solutions?** Yes.
3. **Coordination process:** We contract with WDFW to [identify] barriers and assess upstream habitat. Priority is based largely on potential habitat, but also includes other factors such as cost, partnerships and other planned work.
4. **Common, involved stakeholders:** Tribes, agencies, adjacent landowners, other barrier owners.

Fish Passage Solutions: Species Benefits

1. **Program intent:**
 - To provide access to salmon and steelhead species.
 - To provide access to other aquatic species.
 - To provide access to other terrestrial species.
2. **Expanded focus:** Overall stewardship values of connectivity for all species.
3. **Species and habitats benefiting from full-span remediation:** All aquatic species benefit from stream simulation/bridge approach. Our monitoring also shows that many terrestrial species use these culverts too, including deer.
4. **Add in costs to address terrestrial species?** Yes. In general, the benefits are provided by the stream simulation or bridge design; in some situations a bit more is justified depending on the site and local safety/ecological concerns.

Fish Passage Solutions: Construction and Implementation

1. **How to ensure proper implementation during construction?** Contract specifications, training of construction inspectors, project coordination.
2. **Additional coordination or oversight for complex solutions?** Yes. Projects are visited by hydraulic engineers and/or biologists as needed.
3. **Monitoring or oversight by fish passage engineer or biologist?** Not strictly required in all cases, but is often done by staff to help ensure success.
4. **Implement remediation projects in response to emergency declarations?** Yes.
5. **If remediation projects are not implemented in response to emergency declarations, are permanent restoration projects initiated after the emergency?** Yes.

Fish Passage Solutions: Monitoring and Maintenance

1. **Long-term costs for monitoring and maintaining full-span solutions:** We do not have that number readily available.
- 1A. **Annual staff time for monitoring and maintaining full-span solutions:** We monitor our fish passage corrections for performance at years 1, 5 and 10 at a minimum. This work takes a couple hours per visit. Maintenance probably looks at these once or twice a year very briefly to see that they look OK from their standpoint.
2. **Long-term costs for monitoring and maintaining partial/hydraulic solutions:** We contract with WDFW to inspect these types of older corrections. In the [2017-2019] biennium, this amounted to about 0.15 FTE [full-time equivalent] (\$27,000 /year) for inspection of 97 sites.
- 2A. **Annual staff time for monitoring and maintaining partial/hydraulic solutions:** See above.
3. **Frequency of small maintenance projects:** We have about 1,500 barriers in the Puget Sound and Olympic Peninsula area [in] our records for these types of maintenance actions. For this area in 2013 we reported 12 maintenance activities. In 2014, 20; in 2015, 22; in 2016, 16.
4. **Include cost estimates and staff hours for monitoring and maintenance in planning for partial solutions?** No. We really don't typically do partial corrections.
5. **Frequency of inspection for hydraulic facilities:** Annually.

Wrap-Up

We are currently operating much of our fish passage program in compliance with a federal injunction related to tribal treaty rights. This leads us to emphasize tribal coordination and the use of stream simulation and bridges as the typical design methods.

More info[rmation] here: <http://www.wsdot.wa.gov/Projects/FishPassage/default.htm>.

Federal Agencies

Federal Highway Administration

Contact: Sven Leon, Hydraulics Team Leader, Western Federal Lands Highway Division, Federal Highway Administration, 360-619-7767, sven.leon@dot.gov.

Fish Passage Solutions: Introduction

Fish passage role: Design fish passage structures for federal lands access road projects in Alaska, Washington, Oregon, Idaho, Montana and Wyoming.

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** Yes.
- 1A. **Factors other than costs that determine grade or velocity solution:** Low-flow risk, scour depth and profile degradation.
2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** When appropriate and acceptable, we also do hydraulic/partial designs. We still try to demonstrate 100 percent AOP [aquatic organism passage] effectiveness.
3. **Determine costs and anticipated benefits for grade and velocity solutions?** No.
4. **Frequency of addressing sedimentation and improving water quality:** Always.
When water quality is addressed: [No response.]
5. **Standard plans and costs?** Yes. We have standard plans. We estimate costs for each project.
6. **Links to standard plans and costs:** I will email drawings to Chris. [See [Appendix C.](#)]

Fish Passage Solutions: Project Permitting

1. **Streamlined permitting process for remediation?** Yes.
- 1A. **Agencies and permits included in permitting process:** When available, we use MOAs [memoranda of agreement] and MOUs [memoranda of understanding].
- 1B. **Engineering and environmental review and approval process:** Site review conducted by us with resource agencies attending. Bankfull width is discussed and design concept negotiated. Concept design and design basis report submitted to resource agencies for concurrence. Then apply for permits.
2. **Participation in partnering to implement solutions?** Yes.
3. **Coordination process:** New projects: We help review possible crossings for unknown fish passage needs and priorities.
4. **Common, involved stakeholders:** Tribes, resource agencies, FS [U.S. Forest Service], USFWS, BLM, NPS [National Park Service], DOD [U.S. Department of Defense], state DOT and counties.

Fish Passage Solutions: Species Benefits

1. **Program intent:**
 - To provide access to salmon and steelhead species.

- To provide access to other aquatic species.
2. **Expanded focus:** Regulated species (e.g., state and federal listed species) and habitat.
 3. **Species and habitats benefiting from full-span remediation:** Lamprey, bull trout, cutthroat trout, frogs.
 4. **Add in costs to address terrestrial species?** Yes. Rarely, may add additional culvert crossings. Cost is minimal.

Fish Passage Solutions: Construction and Implementation

1. **How to ensure proper implementation during construction?** We have training for construction monitors, construction handoff reports, and monitor sites ourselves.
2. **Additional coordination or oversight for complex solutions?** Yes. Resource agencies and project partners will also help monitor construction.
3. **Monitoring or oversight by fish passage engineer or biologist?** Yes. We require monitoring by construction engineers experienced with fish passage structures.
4. **Implement remediation projects in response to emergency declarations?** Yes.
5. **If remediation projects are not implemented in response to emergency declarations, are permanent restoration projects initiated after the emergency?** Yes.

Fish Passage Solutions: Monitoring and Maintenance

1. **Long-term costs for monitoring and maintaining full-span solutions:** We do not own the structures and do not incur costs. Scour and profile degradation can make full-riprap-lined, open-bottom culverts fish barriers.
- 1A. **Annual staff time for monitoring and maintaining full-span solutions:** We do not own the structures and do not incur costs. Scour and profile degradation can make full-riprap-lined, open-bottom culverts fish barriers.
2. **Long-term costs for monitoring and maintaining partial/hydraulic solutions:** We do not own the structures and do not incur costs. Scour and profile degradation can make full-riprap-lined, open-bottom culverts fish barriers.
- 2A. **Annual staff time for monitoring and maintaining partial/hydraulic solutions:** We do not own the structures and do not incur costs. Scour and profile degradation can make full-riprap-lined, open-bottom culverts fish barriers.
3. **Frequency of small maintenance projects:** Other. We do not own the structures and do not incur costs. We often do projects that repair fish passage culverts.
4. **Include cost estimates and staff hours for monitoring and maintenance in planning for partial solutions?** We do not own the structures and do not incur costs.
5. **Frequency of inspection for hydraulic facilities:** We do not own the structures and do not incur costs.

Wrap-Up

Additional Comments: [No response.]

National Oceanic and Atmospheric Administration

Contact: Aaron Beavers, Hydraulic Engineer, dual position with NOAA Fisheries/U.S. Fish and Wildlife Service, 503-231-2177, aaron.beavers@noaa.gov.

Fish Passage Solutions: Introduction

Fish passage role: Review engineering actions and designs affecting ESA-listed salmonids and ensure those actions/designs are consistent with NMFS fish passage criteria and ESA recovery.

Fish Passage Solutions: Engineering

1. **Program/agency goal to fully remediate barriers for adult and juvenile salmon?** Yes.
 - 1A. **Factors other than costs that determine grade or velocity solution:** Water rights, design flow requirements, project operation and management, structure maintenance, bank stability, upstream and downstream channel condition and evolution, reach-scale sediment transport characteristics, and hydrology methods used to develop structural design discharges and fish passage design flows.
2. **Threshold of fish passage efficiency to determine if hydraulic/partial solution is appropriate:** For larger-scale projects (such as high head dams), there is typically a performance standard, irrespective of solution type. Post-construction monitoring is conducted to ensure the project meets the standard. The question of the “appropriateness” of the solution is determined by the relative confidence of the agency, supported by past monitoring of similar projects along the West Coast and Pacific Northwest, that the design will achieve the required performance standard. Passage performance standards in the Pacific Northwest are often in the range of 95 percent to 99 percent efficiency.

For small-scale projects, such as irrigation diversions, road crossings or fishways, where monitoring for performance standards is often cost-prohibitive, and efficiency is not well documented, designs that are the most compatible with existing or modified infrastructure and channel morphology determine what is “appropriate.” Since monitoring is seldom conducted at this scale, the closer the solution can mimic the natural channel the greater confidence the agency has that passage exists and has been maximized. Hydraulic designs for small-scale projects also suffer from large error bounds in hydrology, which are typically unaccounted for in fish passage designs. Some places in [California] have +/-100 percent error in calculated hydrology. This error is rarely addressed adequately in fish passage designs for small-scale projects.

Many hydraulic projects fail, not due to engineering methods, but due to the fact that calculated hydrology did not actually provide the frequency and duration of passage as was intended. Another typical mode of failure for hydraulic/grade control designs is that geomorphic site conditions were not properly assessed; this is true for any type of design, hydraulic or otherwise.

Small-scale projects that have funding to conduct monitoring and make post-construction modifications to project designs to stay within compliance of performance standards may benefit from developing and implementing project designs based on post-construction measurement of passage efficiency.

3. **Determine costs and anticipated benefits for grade and velocity solutions?** No.
4. **Frequency of addressing sedimentation and improving water quality:** Often.

When water quality is addressed: Whenever project operations or structures directly influence water quality.

5. **Standard plans and costs?** No.
6. **Links to standard plans and costs:** [No response.]

Fish Passage Solutions: Project Permitting

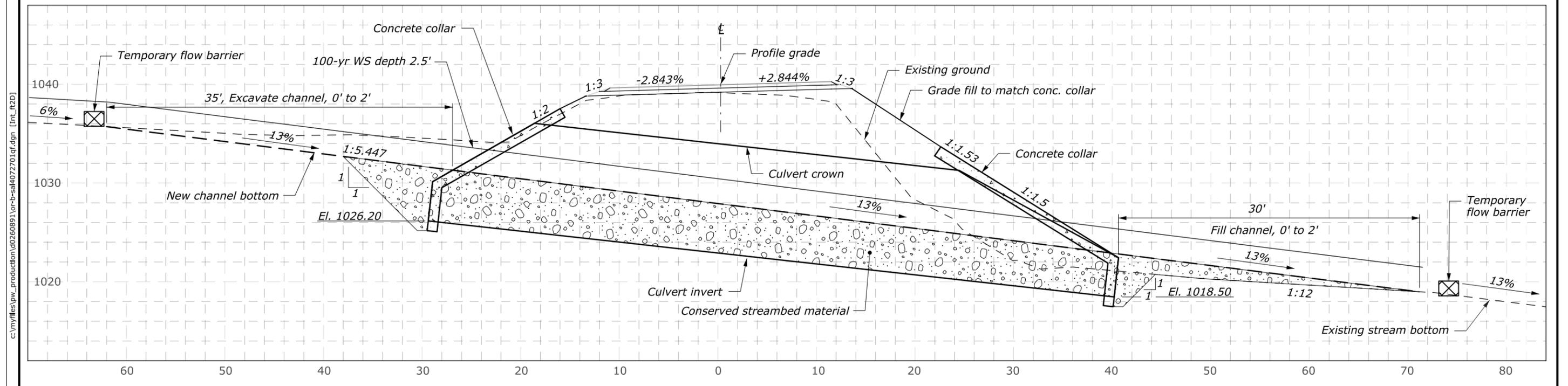
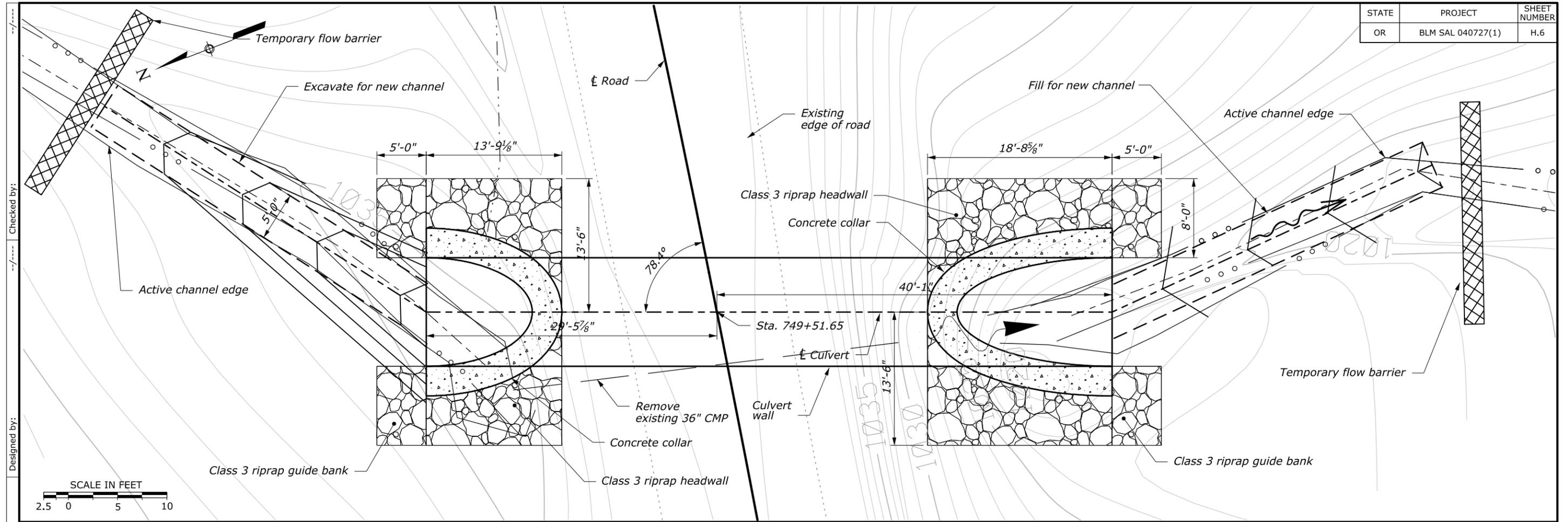
1. **Streamlined permitting process for remediation?** Yes.
- 1A. **Agencies and permits included in permitting process:** Some agencies have developed programmatic ESA consultation pathways [that] do not require a B.A. [biological assessment]. I am not familiar with this type of permitting in California.
- 1B. **Engineering and environmental review and approval process:** I do not work in California. I can't comment on [the] California approval process.
2. **Participation in partnering to implement solutions?** Yes.
3. **Coordination process:** [No response.]
4. **Common, involved stakeholders:** [No response.]

Fish Passage Solutions: Species Benefits

1. **Program intent:**
 - To provide access to salmon and steelhead species.
 - To provide access to other aquatic species.
2. **Expanded focus:** Regulated species (e.g., state and federal listed species) and habitat.
3. **Species and habitats benefiting from full-span remediation:** Lamprey, bull trout, green sturgeon.
4. **Add in costs to address terrestrial species?** No.

Fish Passage Solutions: Construction and Implementation

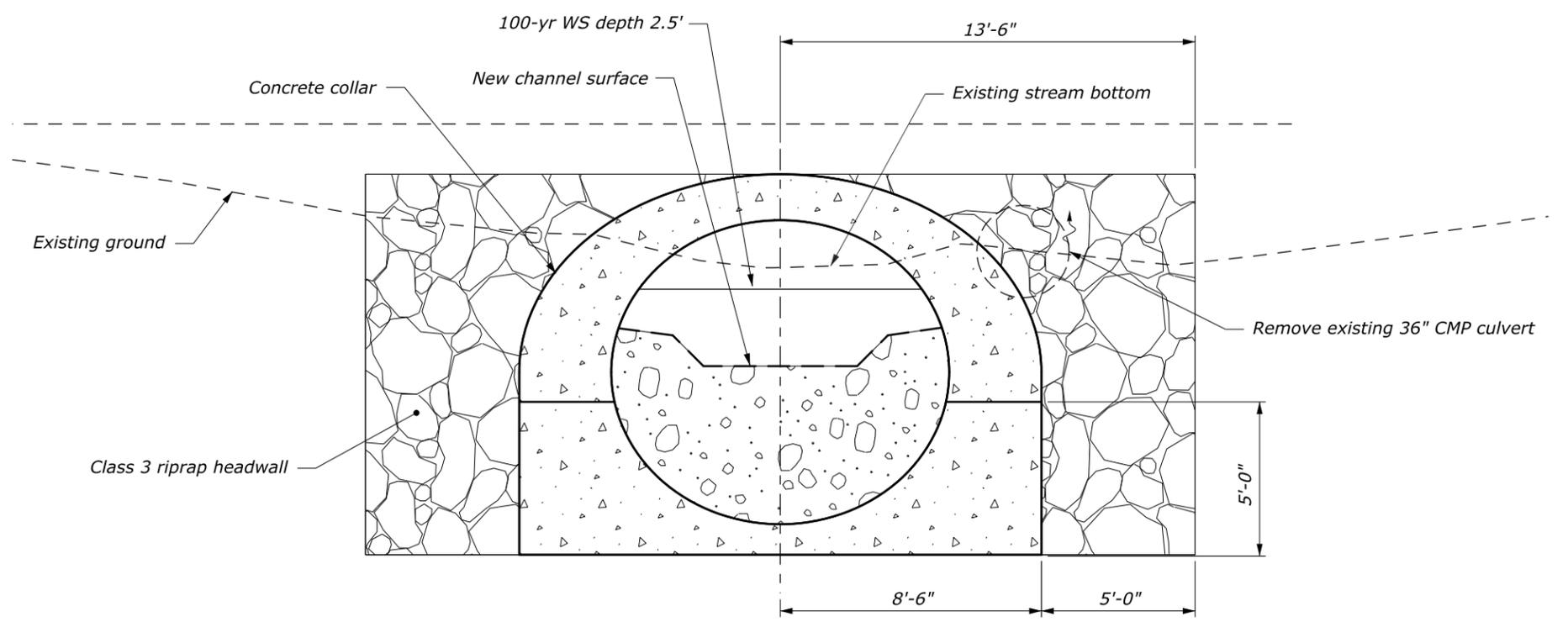
1. **How to ensure proper implementation during construction?** Monitoring during construction occurs as internally identified.
2. **Additional coordination or oversight for complex solutions?** Yes. NMFS engineers in Oregon, Washington and Idaho make sure to be on-site during complex implementations.
3. **Monitoring or oversight by fish passage engineer or biologist?** No.
4. **Implement remediation projects in response to emergency declarations?** Yes.
5. **If remediation projects are not implemented in response to emergency declarations, are permanent restoration projects initiated after the emergency?** [No response.]



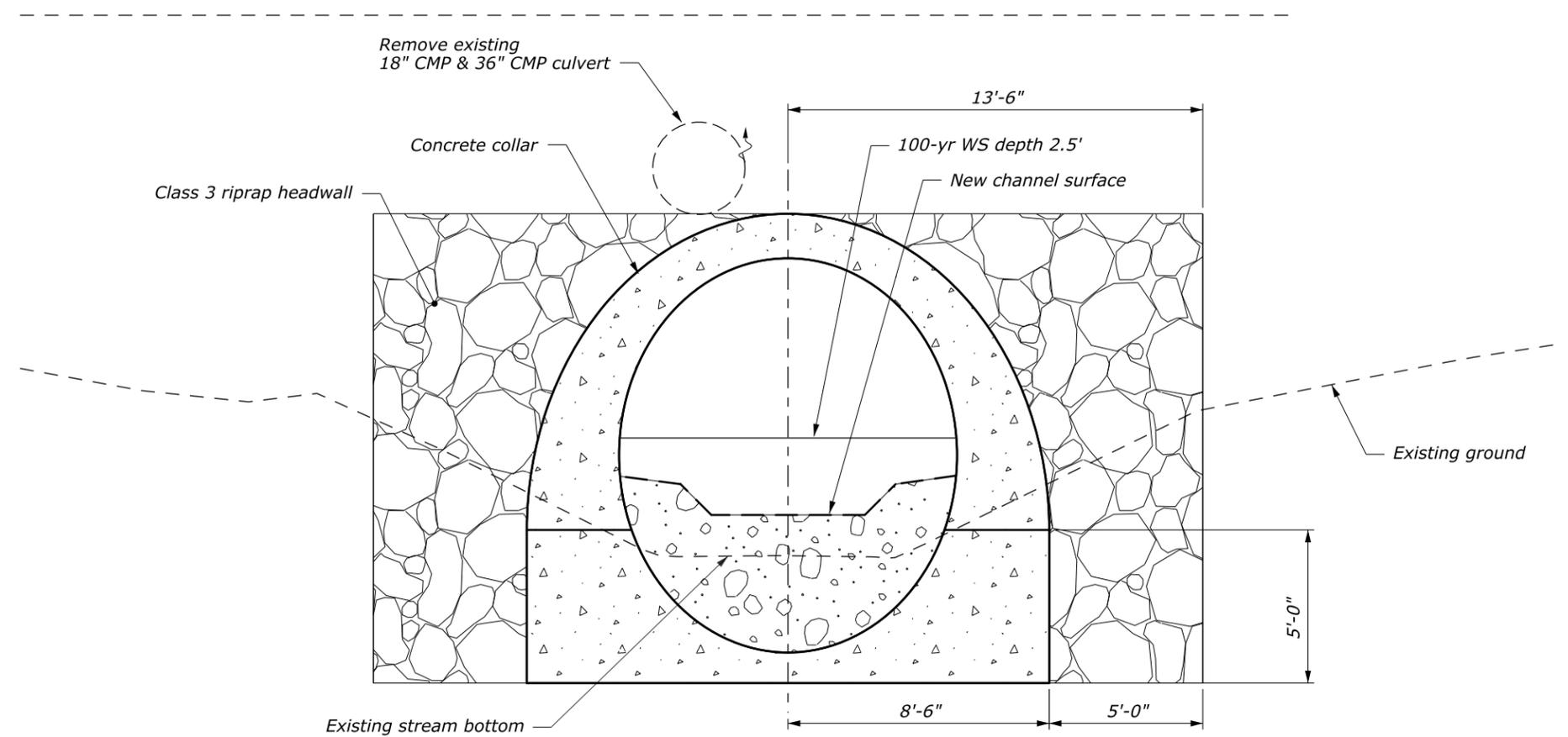
15 November 2016 7:58 AM c:\myfiles\pw_production\00260891\or-b-sal\040727(1).dgn [In: h2d]	HYDRAULIC INFORMATION		PIPE		INLET		OUTLET		NO NAME CREEK AOP CULVERT PLAN & PROFILE
	Q ₂ : 25 cfs	OHW : 0.5 feet	TYPE: CMP - AL	SPAN: 11'-0"	RISE: 11'-0"	INV N/E/EL: 1026.2	INV N/E/EL: 1018.5		
	Q ₁₀₀ : 79 cfs	HW ₁₀₀ : 1.3 feet	LENGTH: 70 feet	WALL THICKNESS: 0.138 in	BURIAL DEPTH: 5.4 feet	BURIAL DEPTH: 4.4 feet			
	FISH SPECIES:		PIPE SLOPE: 0.11 ft/ft	FLOWLINE SLOPE: 0.13 ft/ft	LOWER BEVEL HEIGHT: 4.0 feet	LOWER BEVEL HEIGHT: 4.0 feet			
	INSTREAM WORK WINDOW: 7/1- 9/15		INFILL TYPE: SBM	TYPE: Conserved	BEVEL: 1.37(h):1(v)	BEVEL: 2.44(h):1(v)			
ACTIVE CHANNEL WIDTH: 5 feet				HEADWALL: Conc. Collar/Riprap	HEADWALL: Conc. Collar/Riprap				

STATE	PROJECT	SHEET NUMBER
OR	BLM SAL 040727(1)	H.7

05/2016
 K. Harrison
 Checked by:
 05/2016
 S. Leon
 Designed by:
 05/2016
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 8 November 2016 6:59 AM



CULVERT INLET



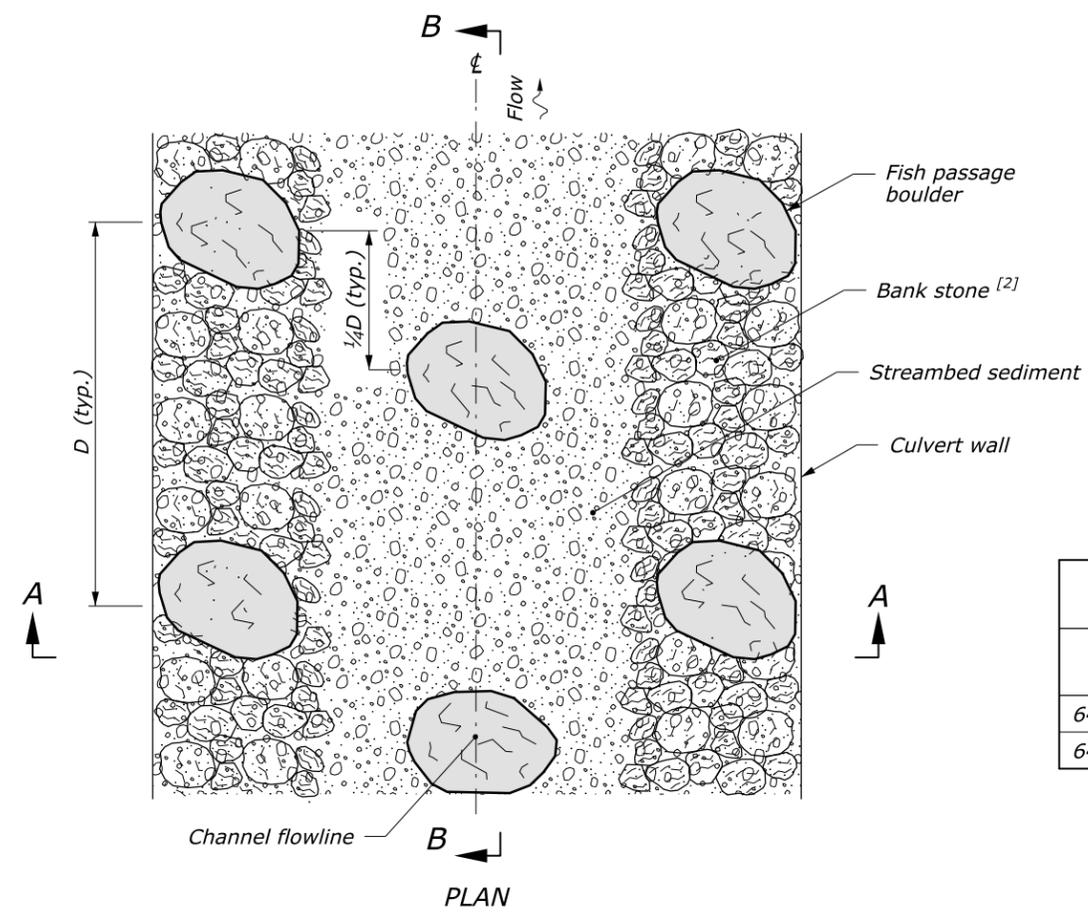
CULVERT OUTLET

Not to scale.

**NO NAME CREEK
AOP CULVERT
ELEVATIONS**

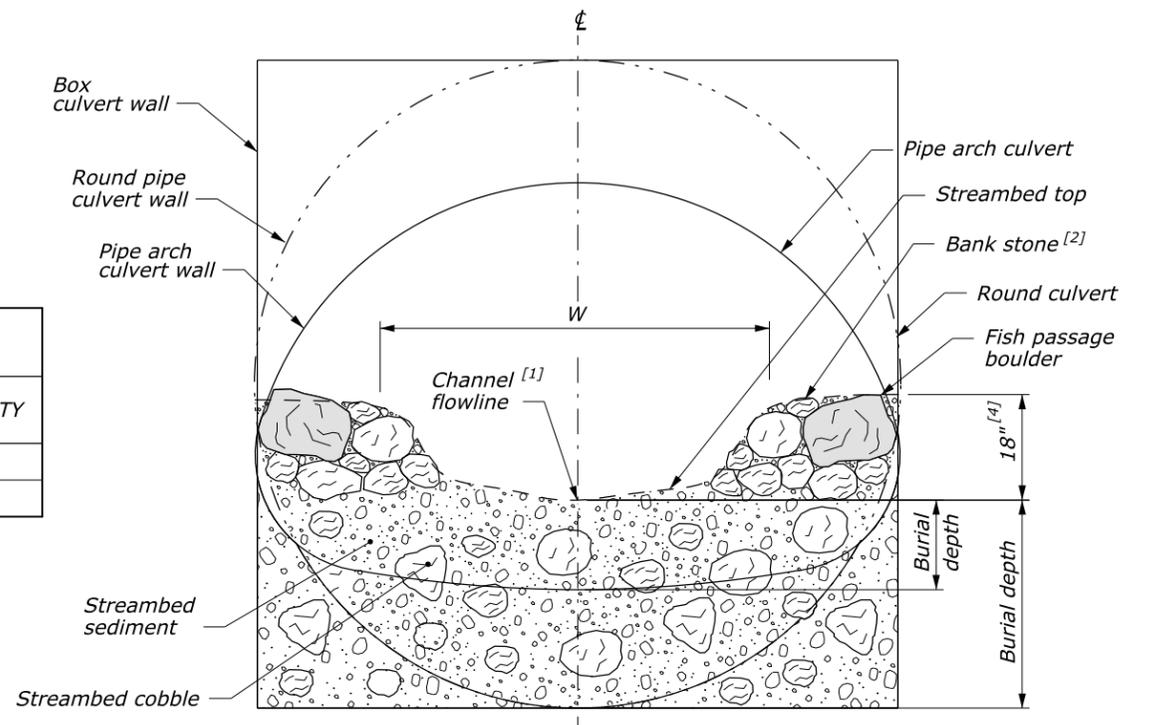
INFILL INFORMATIONAL QUANTITIES ^[5]

LOCATION	D (FT)	W (FT)	STREAMBED COBBLE GRADATION (IN)	STREAMBED COBBLE (CUYD)	STREAMBED SEDIMENT (CUYD)	FISH PASSAGE BOULDER DIAMETER (IN)	FISH PASSAGE BOULDER (EACH)	BANK STONE (CUYD)
No Name Creek 1	11	5	Class E	30	120	30 - 36	21	34
Davidson Pit Creek			None	0	0	30 - 36	21	0

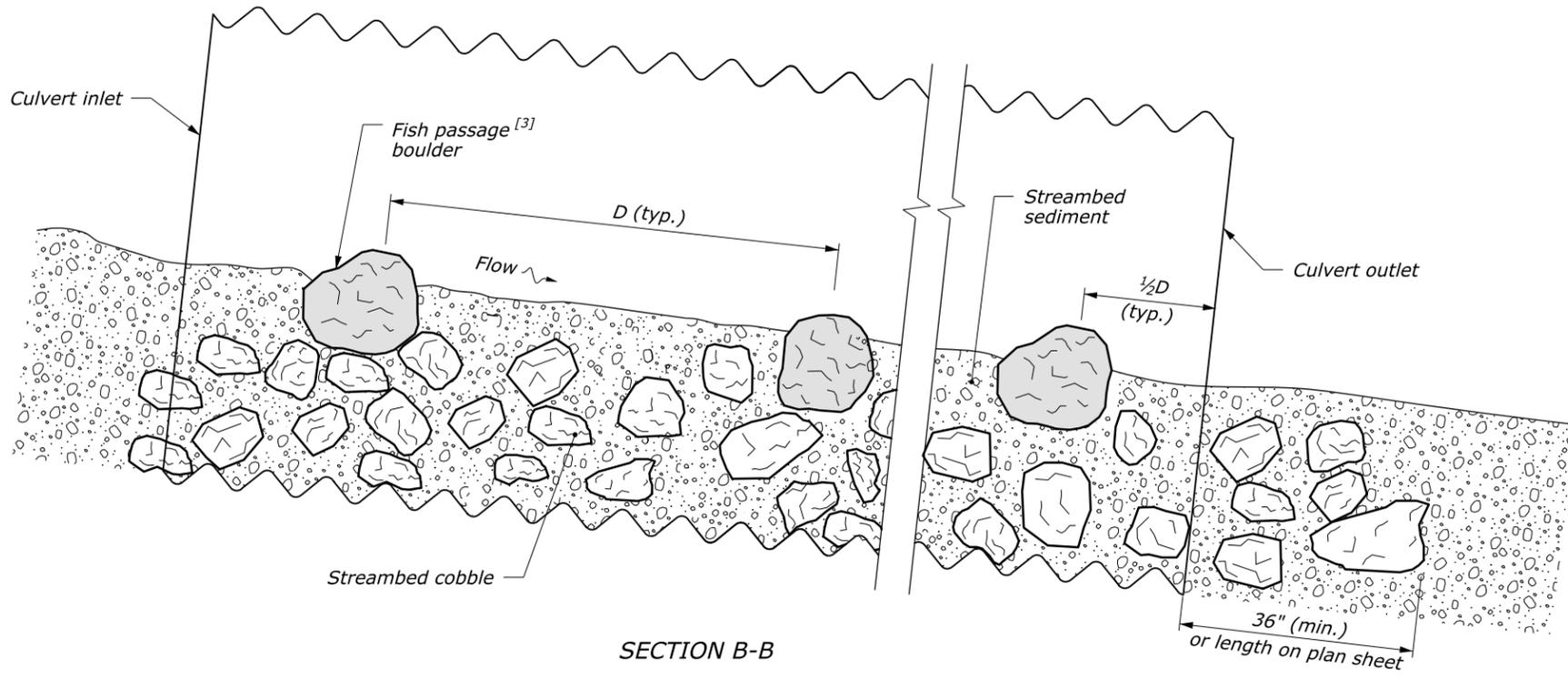


MITIGATION QUANTITIES

ITEM	DESCRIPTION	UNIT	QUANTITY
64704-1000	STREAMBED MATERIAL	CUYD	184
64703-6000	FISH PASSAGE BOULDER	EACH	42



SECTION A-A



SECTION B-B

NOTE:

1. Mix streambed cobbles evenly throughout streambed sediment.
2. See special contract requirements for streambed sediment, streambed cobble, and bank stone gradations.
3. Stagger in-channel fish passage boulder within the culvert span.

FOOTNOTE:

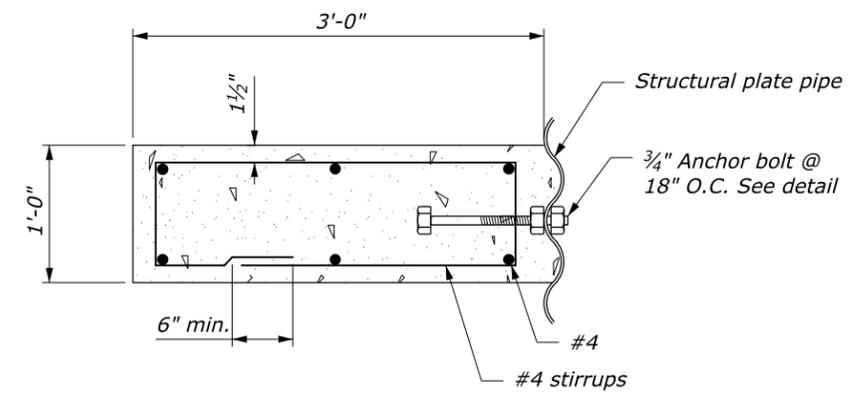
- [1] Slope streambed aggregate towards flowline to ensure parabolic shape.
- [2] Construct well defined banks with bank stone and streambed sediment.
- [3] Embed fish passage boulders within active channel 3/4 smallest dimension.
- [4] 18-inches or as specified on plan sheet.
- [5] Quantities included in Item 64704-1000 Mitigation, Streambed Material.

SIMULATED STREAM CULVERT INTERIOR TREATMENT

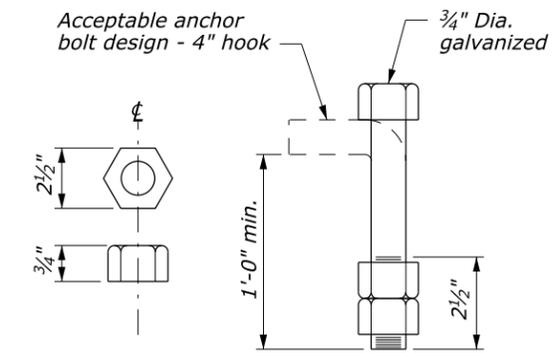
NO SCALE

16 November 2016 9:06 AM
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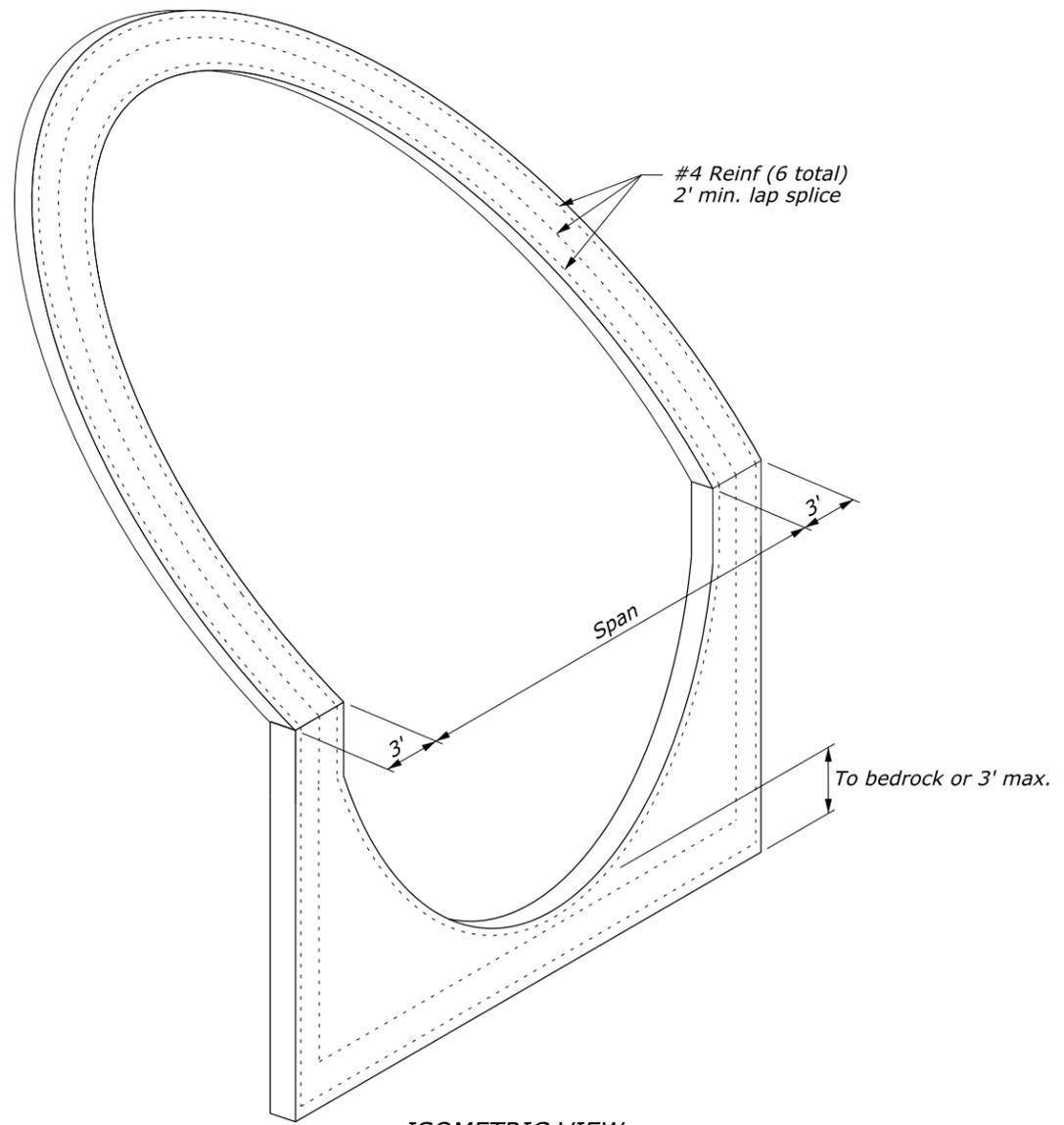
STATE	PROJECT	SHEET NUMBER
OR	BLM SAL 040727(1)	H.10



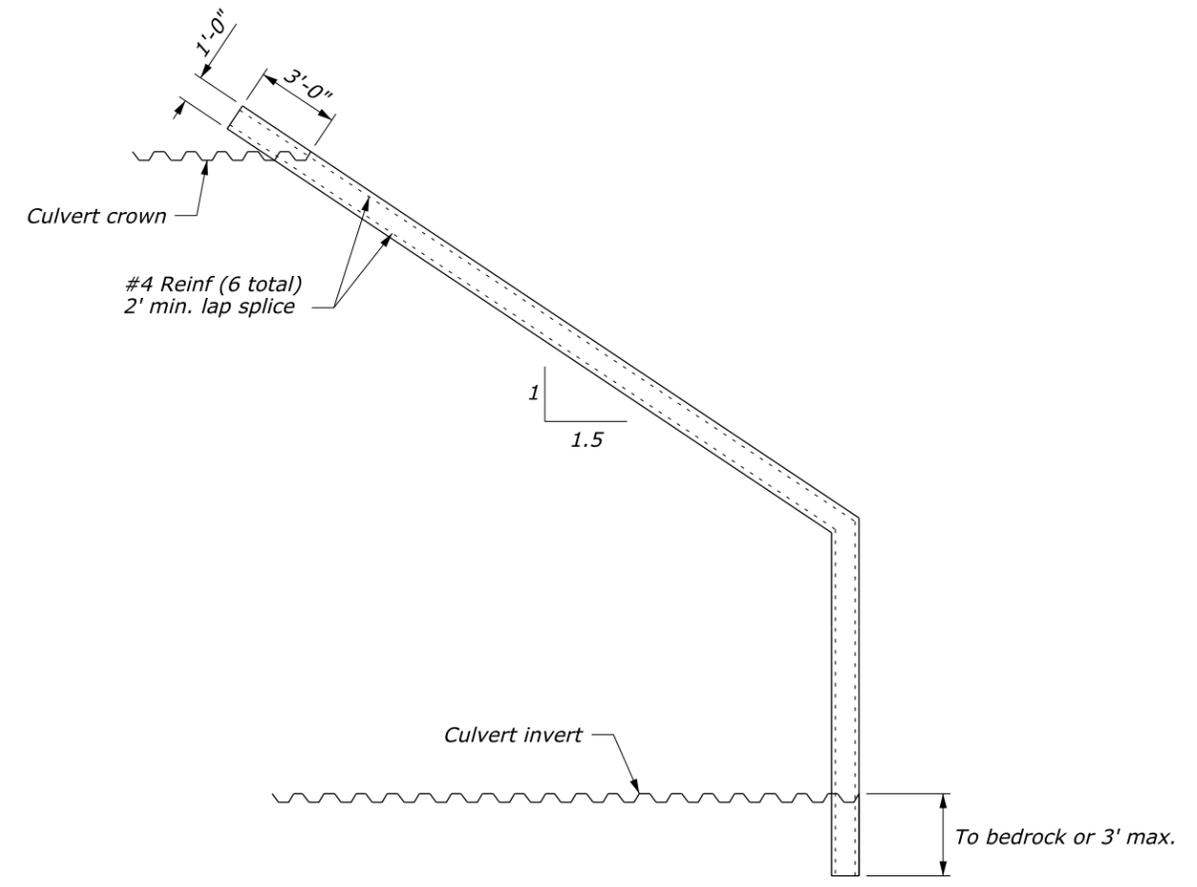
TYPICAL SECTION THRU COLLAR



ANCHOR BOLT DETAIL



ISOMETRIC VIEW INLET COLLAR

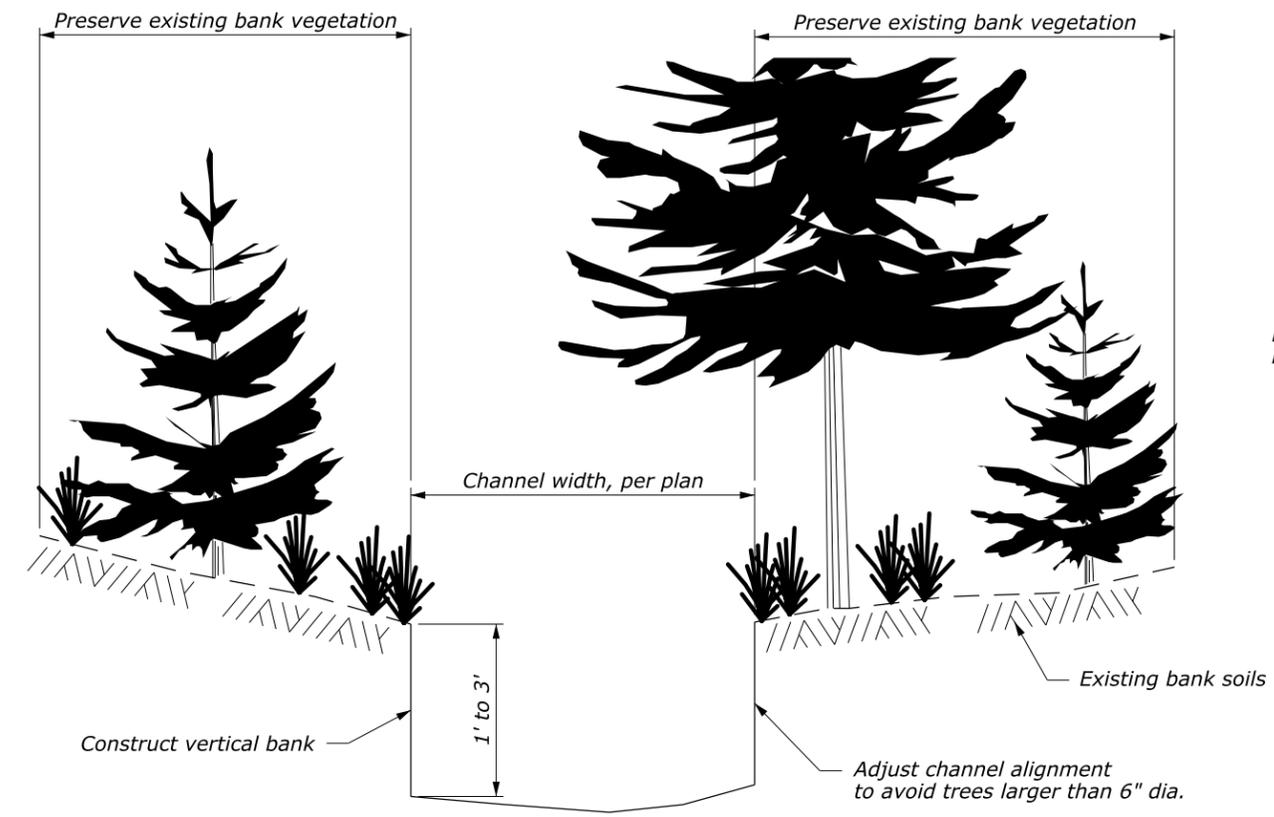


SECTION VIEW

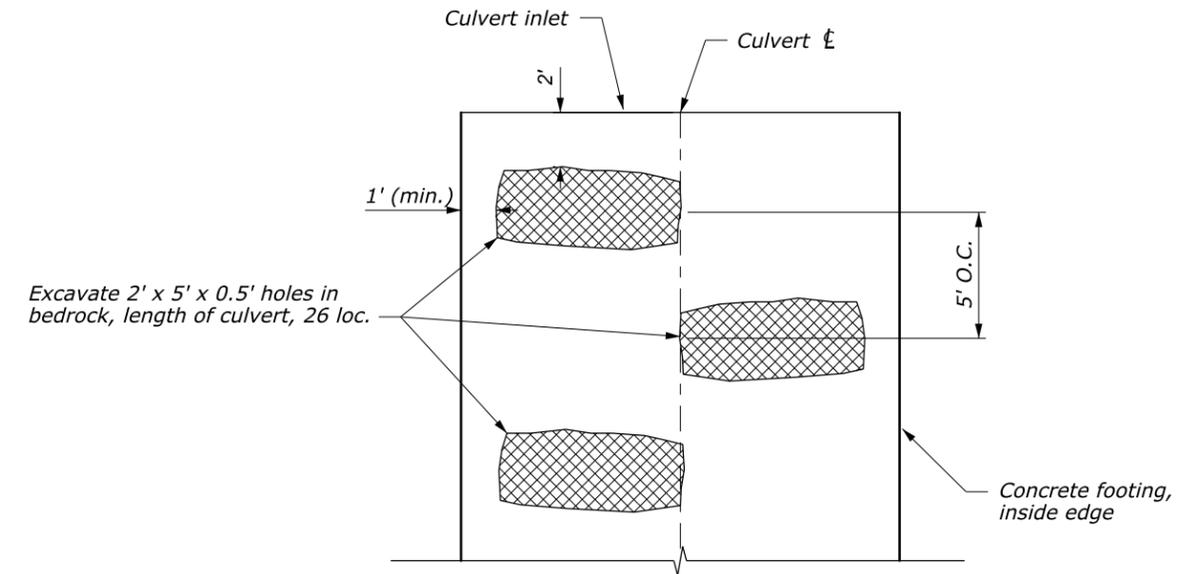
LARGE CULVERT REINFORCED CONCRETE COLLAR DETAILS

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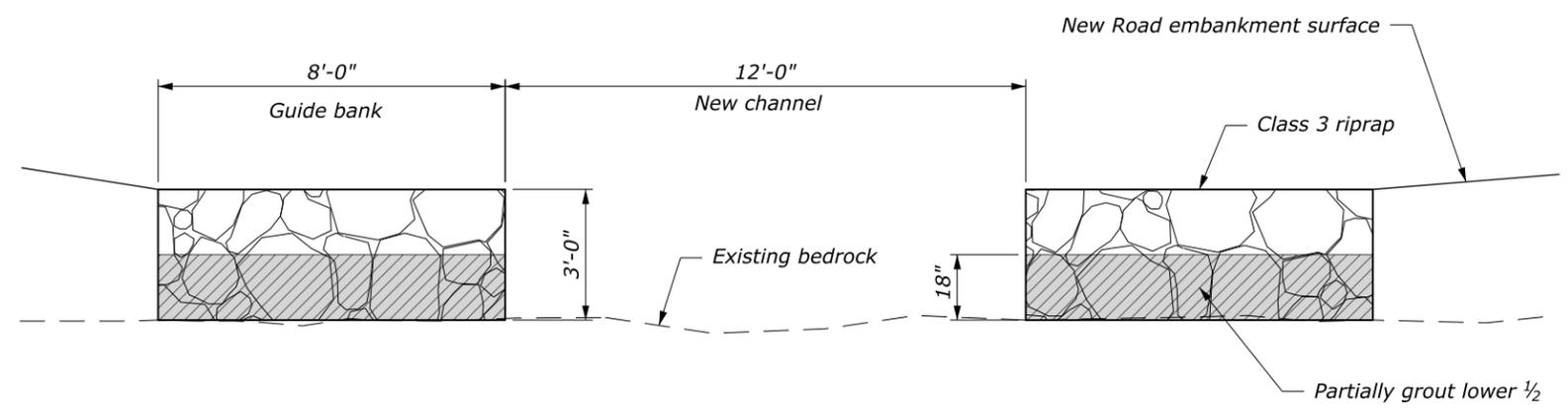
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OR	BLM SAL 040727(1)	H.14



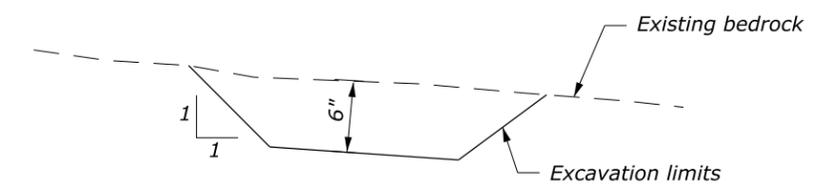
NEW STREAM CHANNEL
TYPICAL DETAIL



EXCAVATED BEDROCK HOLES PLAN



PARTIALLY GROUTED RIPRAP GUIDE BANK
TYPICAL DETAIL



EXCAVATED BEDROCK HOLE
TYPICAL DETAIL

CHANNEL IMPROVEMENTS
TYPICAL DETAILS

NO SCALE

16 November 2016 8:48 AM
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