

Best Practices for Inter-agency Coordination on The Regulatory Review of Simple Water Crossings

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PART A – RECOMMENDED STANDARD PRACTICES FOR CULVERT REVIEW

Culverts are a fundamentally important infrastructure, at the intersection of aquatic ecosystems and transportation networks. To date, we have prioritized moving people and supplies in private vehicles, and have severely degraded aquatic ecosystems at a broad scale. Both public sentiments and legal precedents demand that we increase the rate of culvert improvements while meeting high design and performance standards.

Culvert installation is a simple project in a complicated context. A road culvert is a fixed structure with a service life of 50-100 years. Streams are actively evolving, both following glaciation, and under modern physical and ecological changes in a changing climate. The decision to install a new culvert system at the intersection of a road and a stream requires production, submission, revision, and resubmission of documents, correspondence, meetings, site visits, negotiation, and debate over local, state, and federal standards. This work results in increased project cost. In this complex context we aim to accelerate the rate of culvert replacement. This best practices project attempts to reduce the time and labor spent in regulatory review of a culvert design, while insuring high quality projects that control project impacts, and minimize unintended consequences. This guidance reflects a collaborative effort between regulators and project developers.

Regulatory processes can create value. Review insures that each culvert design meets legal standards, and reduces ecological risk. An individual engineer may have limited experience predicting the evolution of a stream corridor. A county road management institution may place a low value on perpetuating a fish population that has no benefit for the institution's political economy. The review process provides the opportunity to improve a design, and may result in learning by the parties involved. Reflection on the review experience can increase the efficiency of both design and review processes.

Standardization and Process Improvement

Our restoration industry lacks a shared standard practice for producing and reviewing culvert designs. It is difficult to improve a process, if different actors are continuously reinventing the process. We propose that the initial step toward reducing waste of public resources in culvert design¹, is to establish a process standard. Our use of the term standard here follows Kaizen practices in manufacturing², and is different from “streamlining” which suggests increasing speed of flow, with an ambiguous commitment to quality. Following Imai (2012) a standard is “the process that’s the safest and easiest for workers and the most cost-effective and productive for the company to ensure quality for its customers ... In the beginning, any new work process is unstable. Before one starts working on [improvement], any current process must be stabilized ... Only after a standard has been established and followed, stabilizing the current process, should one move on to the [improvement] cycle.”

Using an individual regulatory review event for the purpose of negotiating and improving a processes is inefficient. During review, participants may have conflicting interests, and evaluation is focused on the single case at hand, rather than examining programmatic patterns that cause waste. This improvement effort aims to stabilize the current processes, outside the context of individual review by defining a set of practices that are good enough for now, and adopted by enough members of our community, so that our design and review processes can then be improved over time.

¹ “Waste” in this context is used broadly and in the context of Kaizen theory, meaning any work that does not directly generate the desired values of a product, and may include necessary processes.

² Kaizen is a Japanese term meaning “continuous improvement” developed as part of the Toyota Production System, and thereafter adopted by Lean Management practitioners.

Principles for Culvert Regulation Waste Reduction

The following principles underlie the proposal herein:

1. **Establish standard practices among teams** – Both the design and regulatory teams need a common understanding of procedures, sequence, requirements and language to insure that culvert review processes can be completed without unnecessary communications, reiteration, or information requests.
2. **Integrate the review package into engineering design** – Less effort is wasted if the engineering design process naturally generates the products necessary for both internal review and bids, and for external regulatory review.
3. **Verify the conceptual design solution, before design development** – an ideal sequence insures that key design decisions (such as crossing type and bank-full width determination approach) are not rejected later in review, requiring the redevelopment of engineering designs. This requires that we identify problematic irregularities prior to design development, and make irregularity clear during early review.
4. **Complete review in parallel rather than serial** – where possible, we obtain a regulatory opinion or determination simultaneously from multiple parties. This may involve designing a sequence of review so that initial determinations support subsequent determinations.
5. **Organize relevant information to support regulatory decision, and exclude the irrelevant** – A standardized review package structure would provide all the information required for determinations, in a predictable format, at a minimum cost.
6. **Negotiate landscape sequencing outside of project review** – a culvert replacement is most reliable when designed in the context of the watershed. Defining an appropriate planning basis for culvert replacement at a landscape scale will reduce negotiation of these issues through individual application review.

These principles are used to design the two elements of this standard: 1) the review sequence, and 2) the review package. Under well-managed conditions, we aim to develop mechanisms by which most culvert replacements can be reviewed through a single review sequence without iteration, using a single review package without additional information, or where design improvement is required, a single negotiation and revision of design.

This guidance is not a regulatory requirement. It is a best practice, developed by the project community, support development and presentation of an engineering product, in a way most likely to meet the many needs present when we install a new culvert into an aquatic ecosystem.

Review Sequence and Package

The **review sequence** aims to 1) integrate review package development into engineering design, 2) maximize parallel review, while 3) identifying design irregularities prior to design development. To minimize waste the design team must have clear mechanisms for efficiently generating the review package.

The **review package** contains three components: 1) a Joint Aquatic Regulatory Project Application, 2) A standard culvert project description, and 3) standard attachments.

Table 1 - Summary of Review Sequence – the following set of benchmarks describe the idealized sequence in preparation and review of a culvert application.

Benchmark	Objective (Ideal Outcome)
1. Define Design Solution	Complete fieldwork and determine the design approach.

2. Verify Design Solution	Share Design Solution with County, Tribal and DFW regulators to verify direction prior to package development. Biologists ratify design approach. In Snohomish County this may coincide with WDFW/Tribal consultation on road maintenance. If a batch review process will be pursued, the justification for that process should be verified.
3. JARPA Submission	Prepare and submit full permit package
4. County SEPA determination	County verifies that project is suited to the fish habitat SEPA exception and notifies both Proponent and WDFW
5. WDFW HPA review	WDFW defines fish window and sets aquatic habitat BMPs and approves an HPA.
6. Tribal preview opportunity	Tribe notifies USACE and applicant about concerns.
7. USACE jurisdiction review	USACE determines if federal review is required and then distributes the application to tribes, and makes CWA determinations.
8. USACE ESA review	NOAA and USFWS programmatic used to review project based on SPIF content.
9. USACE s106 review	USACE makes determination, notifies SHPO/THPOs, and receives concurrence
10. Treaty Rights Review	Tribes review projects, note consistency with preview, and provides concurrence.
11. USACE determination	USACE makes s404 and s10 determination and submits to Ecology for review.
12. Ecology CZMA/CWA review	Ecology concurs with USACE s404 determination, and confirm consistency with CZMA.
13. USACE NWP issued	USACE issues appropriate NWP.

PART B - CULVERT PROJECT DESCRIPTION

The following form organizes a systematic summary of the culvert design process in a way that is complementary to the JARPA application. Some cells of this form are intended to be cut and paste into the JARPA, but are repeated here for ease of review and continuity. Designers are encouraged to use this form to organize their work, and record decisions through the design process, so that additional effort is not required to reconstruct design analysis into a regulatory project description. In this way, for this guidance to minimize cost, this culvert project description should serve both internal design and design review processes, as well as external regulatory review processes.

CULVERT PROJECT DESCRIPTION		
See JARPA Parts 1-5 for Project Name, Applicant, Authorized Agent, Property Owner, and Project Locations.		
PROJECT DESCRIPTION - See JARPA Part 6 for project category, major elements, start and stop dates, fair market value, and presence of federal funding.		
1. Project name (JARPA Question 1)		
2. Briefly summarize the overall project. (Paste to JARPA Question 6a)		
This description provides the high-level summary of the action. It should describe: Who – the institution completing the work and their motive. Where – the stream system being improved, and the position of the culvert in that system. What – the current and designed future character of the stream crossing. When – the planned construction window.		
3. Describe the purpose of the project and why you want or need to perform it. (Paste to JARPA Question 6b)		
Describe the objectives of the design Summarize the biotic context of the design Summarize the physical context of the design		
4. Describe how you plan to construct each project element checked in 6d [in this case “culvert”]. Include specific construction methods and equipment to be used. (Paste to JARPA Question 6e)		
Define the workplace isolation method to be used. It seems that there are limited options for working in moving water, and that BMPs could be standardized, based on DOE and WDFW best practices, with a focus on where practices deviate from BMPs due to extenuating circumstances. Consider using the standard BMP checklist.		
5. Provide measurements that describe existing and proposed culvert conditions.		
	Existing	Proposed
Culvert Shape		
Culvert Material		

Rise (<i>feet</i>)		
Span (<i>feet</i>):		
Upstream Invert Elevation:		
Downstream Invert Elevation:		
Length (<i>feet</i>):		
Slope (<i>feet/feet</i>):		
Upstream Culvert Countersink:		
Upstream Culvert Bed Width (<i>feet</i>):		
Downstream Culvert Countersink:		
Downstream Culvert Bed Width (<i>feet</i>):		
Culvert Skew Angle to Stream (<i>degrees</i>):		
Slope Ratio (Channel Slope/Culvert Slope):		
Height of Road Fill from Top of Culvert (<i>feet</i>):		
WETLANDS - See JARPA Part 7 for declared impact to wetlands and buffers, delineation status, rating, mitigation planning, and quantification and explanation of excavation and fill.		
6. WETLAND SUMMARY - Describe how the project has been designed to avoid and minimize adverse impacts to wetlands. (Paste to JARPA Question 7a):		
This section is used to define how the culvert project will address wetlands. Efficient design and construction would allow for minor impacts to wetlands, with compensation provided by vegetation management in the vicinity of the project, ideally without the need to perform a formal delineation or rating. The supplemental application would clarify information necessary to determine the scale of impact, and if a low-cost approach to wetland evaluation is warranted. Projects with extensive impacts to wetlands should be flagged. This section may reference a wetland memo, which may be short of a , which has not been defined.		
7. WETLAND CHARACTER - Describe the size and character of contiguous wetlands adjacent to the worksite, and if wetland delineation and rating has been completed.		
Wetland delineation and rating may not be necessary if impacts are small, and proposed mitigating actions can be demonstrated as clearly in excess of impacts. However, the application must show a clear understanding of the extent and nature of the wetland environment in order to make this judgement.		
8. HYDROLOGIC IMPACTS - Describe the degree to which backwatering at the culvert constriction affect wetland hydrology unstream of the culvert.		
Culvert projects typically result in an increase in culvert diameter and thus potentially increased drainage of upstream habitats (a lowering of the invert elevation). A wetland ecologist reviewing this		

application must understand if the project design will increase drainage, and thereby either lower average water level or increase water level fluctuation.

WATERBODIES - See **JARPA Part 8** for declaration of impact, mitigation planning, quantification of impacts including clearing, dredging, filling, pile driving, as well as placement of fill or excavation or dredging.

9. AQUATIC ECOSYSTEM IMPACT SUMMARY - Describe how the project is designed to avoid and minimize adverse impacts to the aquatic environment. (Paste to JARPA Question 8a)

The potential for impacts to streams is driven by both the power (slope and discharge) of the system, and the geomorphic context of the system. A large portion of this entry should summarize the assessment process, the basis of design, and the proposed design solution described below, to provide the reviewer with an overview of what they are about to review.

Provide a summary of attached documents, and how assessment work was organized.

10. HYDROLOGY & HYDRAULICS - Describe the method for estimating stream hydrology, and the estimated 2-year and 100-year discharge. Indicate if climate change predictions were included in these methods.

The design of the water crossing depends on an accurate estimation of the discharge that the crossing will be designed to manage. That discharge estimate is based on one or more estimation approaches. Ideally, several methods are considered to insure there is no strong discrepancy among estimates driven by an error in underlying assumptions. Ideally, hydrology is based on a systematic local watershed or drainage planning effort. The following methods are commonly used:

- Hydrologic Simulation Program – Fortran (HSPF) for hydrology of 2-year and 100-year flows.
- USGS Regression Equations (Mastin et al 2016; USGS 2017)
- Monitoring station data

11. FISH USE - Describe the methods used to evaluate fish use at the road crossing, and your findings.

County stream data, WFDW fish use records, and tribal biologists all provide independent records of the presumed or confirmed presence or absence of fish species, their anticipated habitat use both above and below the crossing, as well as the position of the crossing in a network of streams which may have multiple fish passage barriers. It is most effective to present this information in an attached map, showing catchment context.

12. WATER CROSSING TYPE - Describe the method used to select the water crossing type (abandonment, bridge, culvert, etc.)

The federal injunction indicates hierarchy of preference for: 1) avoiding water crossings, 2) use of a full span bridge, and finally 3) stream simulation. An alternative to these options requires the existence of extraordinary circumstances.

Based on WDFW stream crossing guidelines, a bridge should be considered for a site if the Floodplain Utilization Ratio (FUR) is greater than 3.0, the stream has a bank-full width greater than 15 feet, the channel is believed to be unstable, the slope ratio between the upstream existing channel and the proposed channel exceeds 1.25, or the culvert length to width ratio is greater than 10.

Therefor a culvert justification should begin with clear and logical statements for 1) why the crossing is not being abandoned, and 2) why a bridge is not being installed.

13. BANKFULL WIDTH - Describe the methods used to calculate bank-full width and the results. Attach a bank-full width memorandum.

This cell summarizes the findings of the **Bank-full Width Memo** prepared following site investigation (see standard attachments below). Be sure to describe: the method for bank-full width determination, the estimated bank-full width, and a summary of evidence that the bank-full width estimate has identified natural channel conditions.

14. GEOMORPHIC RISK - Describe your assessment of aggradation, incision or head-cutting risk at the site and within the catchment. Attach a catchment or watershed assessment that supports your claims.

Describe the increment of the whole system that was assessed and mark on the **Catchment Map**. Describe when the assessment was completed, the methods used to assess the system, the degree to which the system is in a natural state, and any findings that either indicate the presence of geomorphic risk, or the absence of geomorphic risk. Cite the relevant document, either within the **Bank-full Width Memo**, or in a separate **Catchment or Watershed Assessment Memo**.

15. BEAVER – Describe methods used to determine if there is any beaver activity in the vicinity of the project, and how this was considered in design and maintenance.

In this cell describe any observations of beaver activity, including the area examined, the presence of beaver habitat components, and evidence that beaver are active in the site, or evidence that beaver are not active on the site. Cite the appropriate document that describes methods, results, and discussion, typically the **Catchment or Watershed Assessment Memo**.

16. CHANNEL STABILIZATION - Describe the design proposal concerning channel evolution. To what extent will the channel be allowed to evolve vertically and horizontally, or will it be constrained?

In this cell, present any elements of the proposed design solution that will constrain or attempt to control future channel evolution. Differentiate between existing elements that will be relied upon, or new elements that will be constructed. Cite the relevant plan that best summarizes the channel stabilization features.

17. BED MATERIAL - Describe the methods for calculating stream bed material specifications, and your proposed specification. Attach any hydraulic assessment.

In this cell, describe any addition of stream bed material, the specifications and quantities of that material, and the method for determining those specifications. Cite the appropriate document, where assessment or calculation of stream bed material specifications are provided (typically a **Hydraulic Calculations Memo**).

18. CLEARANCE - Describe the method used to determine water height, and culvert clearance or bridge freeboard.

WAC220-110-070 (Hydraulic Code Rules) (1) (e) requires stream crossings to “pass the 100-yr flow with consideration of debris likely to be encountered.” This cell should be used to describe the

method used to calculate water height, freeboard, and likely debris. Cite the appropriate document that describes the methods, results, and discussion (typically a **Hydraulic Calculations Memo**).

ADDITIONAL INFORMATION - See **JARPA Part 9** for agency contacts, work within 303(d) listed waterbodies, HUC and WRIA, SMA context, Water Type, declaration of stormwater manual compliance, presence of contaminated sediment, historical land use, cultural resource status, ESA listed species present, and PHS species presence.

We would likely benefit from a standard classification of culvert projects based on the presence of these issues, and which issues are most likely to create the need for additional assessment or review, and then a clear description of the information necessary to determine the triggers.

19. NATIVE MATERIAL - Describe the methods used to determine the extent of native material, and the degree to which the project will excavate into native material.

Describe your basis for estimating the location of native material as opposed to fill.

20. UNINTENDED DISCOVERY - Describe the method used to determine archaeological risk at the site. Attached any description of unintentional discovery procedures.

Briefly describe your inadvertent archaeological discovery plan, who has agreed to the plan, and when it was drafted.

COMPLIANCE - See **JARPA Part 10** for SEPA status, and permits requested.

It is unclear if any further consideration is useful here.

PART C – BATCH REVIEW PROCEDURES

There may be time efficiency in reviewing culvert designs where all the culverts are located within the same catchment, or where the culverts are similar in their character, impact and risk. In particular, there is a Clean Water Act exception where USACE may determine that federal review is not warranted where “maintenance does not include modifications to the character, scope, or size of the original fill design” (33CFR 323.4)

The following diagram describes groups of culvert projects that are anticipated to be similar in their level of regulatory review. This taxonomy supports batch review in two ways. First, projects subject to a similar level of review may be bundled as a batch, so that information can be provided in a consistent way. Second, projects that exceed known thresholds can be excluded from a batch to reduce the risk that the batch of actions is delayed due to the atypical attributes of a single project.

The following project attributes are likely to affect the level of scrutiny provided a project.

- Qualifies for Fish Enhancement Exemption
- Likely to qualify for CWA maintenance exemption
- Anticipated to have no impacts to wetlands
- Meets all standard stream simulation design criteria
- The project investigation demonstrates a low geomorphic risk

[Insert Flow Chart describing thresholds causing increased submittals and intensity of review]

The following standard table can be used to describe an application which includes multiple culverts. Each culvert should include a standard culvert project description. A single JARPA may include multiple culverts. The batch strategy should be verified at the same time that the fundamental design solution is verified.

CULVERT BATCH COVERSHEET

This JARPA APPLICATION includes a set of culverts that are intended to be reviewed as a single action.

1. What justifies aggregation of these projects into a batch review?

- ☐ Project have minimal impacts, and use standard practices, and may qualify for exception under Clean Water Act Review (33 CFR 323.4).
- ☐ Projects are diverse in character and impact, but are all located within the same catchment or system.
- ☐ Projects are very similar in character and impacts, and use standard practices, but are located over a diverse geography.

2. Describe how the projects are geographically or technical similar and different?

This helps the reviewer anticipate what they will be viewing in the batch. First indicate the way that the projects included in the batch are similar, and how that is anticipated to support review. Then describe the most salient differences among the projects, and how those differences are anticipated to affect review.

3. List the projects being considered within this batch?

With culvert modification, this question is useful for summarizing the context for culvert replacement within the biotic environment, and the physical context of the catchment.

4. Summary map of culvert locations

5.

6.

7.

PART D - STANDARD ATTACHMENTS

In addition to a JARPA application, and standard JARPA attachments, and this new “culvert projects description”, a robust regulatory application will include certain supporting documents. To the extent possible, these documents are generated as part of design engineering. Up to three technical memoranda describe culvert context at three scales: 1) a catchment scale, 2) the reach scale, and 3) a local stream energy scale. In addition there may be an additional document describe wetland conditions. These analyses are supported by a set of standard plans and figures.

These assessments may be integrated into a single basis of design report, however, the methods used to collect information, and the findings of each should be easy to locate, and clearly cited in the project summary.

1. Catchment Assessment Memo (Catchment Scale Assessment)

A catchment or watershed assessment memo puts the culvert worksite into the context of a whole stream channel system, including a hydrologic assessment of discharge at the water crossing. The assessment evaluates if there are risks at the scale of the stream that should inform stream crossing design. These risks typically revolve around evidence that a stream bed is changing, or is prone to change, such that the proposed stream crossing type or design may fail to future to pass water, fish or sediment over the lifetime of the infrastructure. This memo and associated figures provides the opportunity to clarify both the biological, physical, and legal context of a culvert. This assessment can revolve around a standard catchment figure, using shared GIS data.

- The extent of the mapped channel (typically represented by county stream line typing or best available
- The estimated distribution of fish use within the channel (considering county water typing, WDFW fish distribution data, or tribal records).
- The local regulatory jurisdictions affecting the catchment.
- Estimated channel slope (SSHAP or similar data).
- Extent of FEMA or otherwise determined floodplains.
- Land Cover
- Surface Geology and Soils
- Impoundments affecting sediment supply in the system, or other structures controlling bed elevation.
- A channel profile
- Hydrologic assessment of the system at the water crossing to estimate the range of discharge used to develop a design.
- Consideration of climate change in the estimation of future hydrology.
- The potential for catastrophic events not described by stream flow under flood conditions (debris flow, land slide, etc.)

2. Bank-full Width Calculation Memo (Reach Scale Assessment)

The bank-full width calculation memo documents the methods used to determine bank-full width, which drives crossing type decision making, and culvert size under stream simulation.

- The timing of fieldwork.
- The method and result for selecting creek cross sections examined for the purpose of determining bank-full width.
- Justification for which sections were used to establish bank-full width, and which were not used.

- Observation of stream and bank attributes that indicate whether the stream is in a natural state, including evidence of re-alignment, incision, armoring, or other human effects.
- Observation of stream and bank attributes that indicate whether the stream is in a transition to a new form, including bank erosion, channel migration, flood flow pathways, or deposition.
- Photographs of cross-sections used to establish bank-full width.
- Comparison of observed bank-full width to WDFW Water Crossing Design Guidance, Appendix C regression methods based on catchment size.
- Presence of contiguous wetlands adjacent to the worksite.
- The methods consistent with Wihere et al (2016) for incorporating climate change into design of water crossing structures.

3. Hydraulic Calculations Memo (Worksite Scale Assessment)

The Hydraulic calculations memo converts the hydrologic assessment into estimates of the force at work on the stream bed in the vicinity of the water crossing. Hydraulic calculations are used to justify and design bed control structures and to design stream sediment reconstruction, as part of stream simulation design.

- The methods used to convert hydrology to depth, velocity, and shear stress, and findings.
- How stream sediment specifications are related to the mobility of sediment given the shear stress estimates.
- Stream bed material specifications.

4. Wetland Assessment Memo

A wetland memo may be necessary to describe projects that result in substantive impacts to wetlands.

5. Inadvertent Archaeological Discovery Plan

An inadvertent discovery plan describes the method used to monitor construction, evaluate discoveries, and mitigate or prevent impacts to cultural resources.

6. Plans and Figures

Required plans should provide information that helps answer specific questions, and adequately represent assessments.

1. All Plans and Diagrams
 - a. Use letter or tabloid size paper
 - b. Use same scale for vertical on horizontal scales
 - c. Minimize the number of pages
2. Catchment Map (Catchment Scale Map)
 - a. Fish use
 - b. Stream slope
 - c. Retention
 - d. Parent material
 - e. Water crossings and fish passage barriers
 - f. Basin area
 - g. Basin topography and elevation
 - h. Jurisdictional boundaries (cities, counties, state)
 - i. Extent of geomorphic risk assessment fieldwork
 - j. Project site
3. Reach Map (Reach Scale Map)

- a. All waterways with labels
 - b. Estimated extent and character of wetlands
 - c. All roads and streets and proposed and existing structures.
 - d. Milage to nearest town or city limits
 - e. Boundary and label for each project area
 - f. Boundary and label for each mitigation area
 - g. Extent and character.
 - h. Existing grade control
 - i. Proposed grade control
 - j. Distance to known location
 - k. Floodplain extent
 - l. Topographic contours
4. Plan View Existing and Proposed (2 sheets)
- a. All waterways with labels
 - b. Marine/Tidal Areas: Harbor lines MHW/MHHW
 - c. Freshwater: OHWL
 - d. Estimated extent and character of wetlands
 - e. All roads and streets and proposed and existing structures.
 - f. Milage to nearest town or city limits
 - g. Boundary and label for each project area
 - h. Boundary and label for each mitigation area
 - i. Extent and character.
 - j. Existing grade control
 - k. Proposed grade control
 - l. Distance to known location
 - m. Floodplain extent
 - n. Topographic contours
 - o. Extent and type of fill or excavation (area and volume)
 - p. Direction of currents or flows (tidal ebb, beach drift, creek flow, etc..)
 - q. Describe surfaces and substrates.
5. Cross Section and Profile Existing and Proposed (2-4 sheets)
- a. Tidal Data or OHWL
 - b. 2-year water level
 - c. 100-year water level
 - d. Elevation Scale (use consistent scale for all drawings)
 - e. Existing grade, and elevation from benchmark to top and bottom of any structures.
 - f. Width and height of key structures and slopes.
 - g. Extent of native material
 - h. Describe surfaces and substrates.

PART E - Standard Best Management Practices Checklist

Standard BMPs are worksite management practices, typically included as part of a design set, that anticipate and represent the integrated requirements under the panoply of permits.

Sets of Standard BMPs are managed in individual shops and as part of regional programmatic processes (for example the Regional Road Maintenance Program, shared by WDOT and local counties which supports and Endangered Species Act 4d exception by NOAA.)

Add list of current curators of Standard BMPs

PART F - Source Materials

The following documents were consulted while generating this guidance:

Barnard, R. J., J. Johnson, P. Brooks, K. M. Bates, B. Heiner, J. P. Klavas, D.C. Ponder, P.D. Smith, and P. D. Powers (2013), [Water Crossings Design Guidelines](#), Washington Department of Fish and Wildlife, Olympia, Washington.

Washington Department of Fish and Wildlife. 2018. [Water crossing structure drawing checklist](#). 2 pp.

WDFW. 2018. [Example drawings - typical stream channel details](#). Washington Department of Fish and Wildlife. 11 pp.

Bates, K., B. Barnard, B. Heiner, J.P. Klavas, P.D. Powers. 2003. [Design of Road Culverts for Fish Passage](#). By Washington Department of Fish and Wildlife, Habitat Program, Olympia, WA. 110 pp.

US Army Corps of Engineers. 2018. Drawing Checklist. Seattle District, Seattle, WA. Compiled guidance and drawings. 7 pp.

Washington Department of Fish and Wildlife. 2015. [Design guidelines approved for use in designing water crossings over fish-bearing waters in Washington state](#). Anadromous salmonid passage facility design. Olympia, Washington. 2 pp.

National Marine Fisheries Service (NMFS). 2011. [Anadromous Salmonid Passage Facility Design](#). NMFS, Northwest Region, Portland, Oregon. 140 pp.

Whihere, G., J. Atha, T. Quinn, L. Helbrecht, I. Tohver. 2016. [Incorporating climate change into the design of water crossing structures](#). Washington Department of Fish and Wildlife, Habitat Program, Science Division, Olympia, WA. 48 pp.