Year-One Progress Report

Implementation and Effectiveness Monitoring of Hydraulic Projects


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Major Findings for 2013

Major Findings from Implementation Monitoring

The findings for implementation monitoring are organized under four key questions.

1. Did the permittor issue a complete permit, that is, one that contains provisions and/or project plans for all critical structural dimensions?

Culverts

- One-fifth of permits lacked a specification in permit provisions or project plans *for at least one critical structural dimension* (culvert width, culvert slope, countersink depth, or length).
- Permits for 9 culverts lacked information needed to determine compliance (for at least one critical structural dimension).
- The design type could not be determined for 9 of 54 culverts (17%).

Marine Shoreline Armoring

- 38% of 106 permits for marine shoreline armoring had no clear statement of the project's length in the permit's text.
- Of 26 hard armoring permits, only 12% described the structure's location as a distance to a benchmark or permanent structure.
- For the other 88% of hard armoring permits, determining compliance with the permitted location was difficult if not impossible.

2. Did the permit or application materials contain other information needed to determine consistency with rules and/or guidelines?

Culverts

- Channel width information was *unavailable for roughly 50%* of 54 culverts (in application or permit materials).
- Permittees reported estimates for various types of channel/stream width: "stream width", "stream size", "streambed width", "channel bed width", "width at ordinary high water mark", and something called "top channel width."
- Only 20% of 54 applications reported an estimate of bankfull width.
- When permittees reported a BFW estimate in their application materials (N=10), *80% of the time their estimate was narrower* than our monitoring team's estimate.
- And, when the applicant's BFW estimate was narrower, it was about 22% narrower, on average.

Marine Shoreline Armoring

- Compliance was challenging to assess due to difficulties with interpreting plans and use of reference points that could change over time or be altered by construction activities.
- Though information was provided in the permit materials, compliance with some provisions could not be assessed with only a post-construction survey.

3. Did the permittee comply with the permit?

Culverts

- Permittee compliance with permit for the four critical structural dimensions was 76% (N=45).
- 11 culverts (24%) were noncompliant: 5 were too narrow and 6 were countersunk too shallow.
- Compliance with permit by culvert type:

no-slope	85%	(N= 13)
stream simulation	60%	(N=10)
bottomless	85%	(N=13)
unknown type	67%	(N=9)

Marine Shoreline Armoring

- 9 of 10 structures had at least one structural dimension that was inconsistent with the permitted dimension.
- 50% of the structures were longer than indicated in the permit
- 30% were taller than indicated in the permit.
- 60% were farther water ward relative to at least one reference elevation.

4. Does the completed hydraulic project agree with the hydraulic code rules or follow the design guidelines?

Culverts

- 50% of 40 culverts had a critical structural dimension that was not consistent with the hydraulic code rules or culvert design guidelines.
- Consistency with rules for no-slope culverts:
  47% (N=19) were consistent based on our monitoring team's BFW estimates;
  80% (N=10) were consistent based on the permittees' channel width estimates.
- *Our findings for consistency with rules/guidelines may be unreliable because we lack a widely accepted, standard procedure for measuring BFW*

Major Findings from Effectiveness Monitoring

Culverts

- 83% of 52 new culverts passed the Level A fish passage barrier assessment.
- For the nine culverts that did not pass level A, 6 were too narrow and 3 were not countersunk deep enough.

Marine Shoreline Armoring

- Nothing to report. Effectiveness monitoring sites require at least two years of data collection.

Recommendations for Improving the HPA Permitting Process

Culverts

- Key information – such as bankfull width, channel slope, culvert design type, and culvert dimensions – should be reported and easy to find.

- Language referring to stream channel width should be identical in hydraulic code rules, permit provisions, and culvert design guidelines.

- Standard procedures for estimating mean bankfull width and channel slope should be developed by WDFW and widely distributed for use by HPA applicants.

- Bankfull width measurements submitted by HPA applicants should be checked by WDFW or some other credible organization.

- For no-slope culverts, channel slope submitted by HPA applicants should be checked by WDFW or some other credible organization.

Marine Shoreline Armoring

- Key information – such as bulkhead length, bulkhead height, bulkhead design type – should be reported and easy to find.

- The location of marine shoreline armoring should be described in HPA applications with respect to engineering benchmarks or permanent structures in the upland that will not change over time.

Executive Summary

To help ensure that hydraulic structures are compliant with current rules and that current rules effectively protect fish habitats, WDFW is monitoring its hydraulic project approval (HPA) program. The main purpose of monitoring is to provide information which overtime helps us to improve both implementation of the current hydraulic code rules and the effectiveness of those rules at protecting fish habitats.

In 2013 we limited the scope of implementation and effectiveness monitoring to new and replacement culverts on fish-bearing streams in western Washington and new and replacement marine shoreline armoring in Puget Sound. Only these two types of hydraulic structures were monitored in 2013 because: 1) these two types are the most common types and both have a potential to damage fish habitats, and 2) limitations imposed by funding forced us to concentrate our efforts on only two types of hydraulic structures.

The purpose of implementation monitoring is process improvement. Two entities are involved in implementation of a hydraulic project: WDFW (the permittor) and the permittee. The success or failure of project implementation depends on the performance of both entities. Hence, implementation monitoring collects information that could be used to improve the performance of both WDFW and the permittee. Successful implementation of hydraulic projects occurs when the issued permit is in agreement (i.e., accordance) with the hydraulic code rules (WAC 220-110-070)[1] and/or follows WDFW's design guidelines, and the hydraulic structure fully complies with the permit.

Effectiveness monitoring is done to determine whether or not hydraulic projects are yielding the desired habitat conditions. For culverts, the desired condition is "no-net-loss of productive capacity of fish and shellfish habitat" (WAC 220-110-070). For marine shoreline armoring, the intended habitat protection is no "permanent loss of critical food fish or shellfish habitat" (WAC 220-110-285).

Monitoring of Culverts

In 2013 we conducted implementation monitoring on 54 culverts in western Washington. Implementation monitoring focused on four critical structural dimensions: culvert width at streambed, culvert slope, countersunk depth at outlet, and culvert length. We also estimated bankfull width (BFW) at each site. In 2013 we attempted to answer two questions about the HPA permitting process: 1) Did permittees comply with their HPA permits?, and 2) Did hydraulic structures agree with the hydraulic code rules or follow WDFW's design guidelines?

For the purposes of process improvement, the most important findings in 2013 are related to the measurement of channel width. *The most important parameter for culvert design is channel width,* and yet information on channel width was unreported for roughly half of 54 HPA permits that we reviewed, including engineering drawings and other supporting documentation. WDFW's operational definition of channel width is bankfull width, and yet only 20% of permittees reported a bankfull width estimate for their project site. From culvert plans and other supporting documents, we found that instead of reporting BFW, many permittees reported estimates for "stream width", "stream size", "streambed width", "channel bed width", "width at ordinary high water mark", or something called "top channel width."

We also found that when permittees explicitly reported a BFW estimate, 80% of the time their estimate was narrower than our monitoring team's estimate and it was about 22% narrower, on average. The difference between our monitoring team's BFW estimate and the permittee's estimate may be due to the

[1] In November 2014 WDFW promulgated revised hydraulic code rules. All references to hydraulic code rules in this report refer to the rules in effect immediately prior to November 2014.

lack of a widely accepted, standard procedure for estimating mean BFW. In other words, some permittees and our monitoring team likely use different methods for estimating mean BFW, and different methods lead to different estimates. Apparently many *permittees do not know what they should be measuring or how they should be measuring it*.

Our second most important finding was that a significant proportion of HPA permits lacked information necessary to determine whether the culvert's dimensions will be consistent with rules and/or design guidelines. We assessed 53 culverts for permit compliance. *About one-fifth of these permits lacked a specification for at least one critical structural dimension*. In all cases, information missing from the permit included culvert width at the streambed.

For the purposes of process improvement, our third most important finding was the considerable difficulty in locating information essential to the hydraulic project approval process. We searched the permit, plans, JARPA, and other materials submitted by the applicant. Basic information such as channel width, channel slope, culvert design type, and critical structural dimensions were missing or difficult to find. These difficulties greatly reduced the efficiency of our monitoring efforts, and we suspect these same difficulties must plague habitat biologists as well. *Substantial increases in efficiency for permitting, rule enforcement, and monitoring might be realized if key information – such as bankfull width, channel slope, culvert design type, and culvert dimensions – were reported and easy to find.*

The fourth most important finding is the permittee compliance rate. The permittee compliance rate for the four critical structural dimensions was 76% (N=45). Five noncompliant culverts were too narrow and six were countersunk too shallow. Only two culverts were noncompliant for more than one of the four critical structural dimensions. The compliance rate varied by design type. The compliance rate for no-slope culverts was 85% and for stream simulation culverts was 60%.

The fifth most important finding is the permit accordance rate. For the purposes of determining hydraulic structure agreement with rules or design guidelines, no-slope culverts were compared to specifications in the hydraulic code rules and stream simulation culverts were compared to design guidelines. We found that 50% of the 40 culverts for which design type was known did not agree with the hydraulic code rules or culvert design guidelines. The low rate of accordance was mainly due to one structural dimension − streambed width at culvert outlet, which was too narrow. However, the lack of a widely accepted, standard procedure for measuring BFW means that permittees, permittors, and monitoring staff are likely to be estimating streambed width in different ways, and this is likely to result in different estimates. Therefore, *we question the reliability of the permit accordance rate in 2013*. We do not have the same concern about the calculation of compliance rates.

The rates of agreement with hydraulic code rules or design guidelines (i.e., accordance) varied greatly by design type. Stream simulation culverts had the lowest rate of accordance: 27%, that is, 73% were not built according to the guidelines. The accordance rate for no-slope culverts was 47%, and the most common reason for nonaccordance was insufficient culvert width at the streambed. In contrast, the permittee compliance rates for stream simulation and no-slope culverts were 60% and 85%, respectively.

We found that permittee compliance with an HPA permit (provisions and project plans) does not necessarily result in hydraulic structure accordance with the hydraulic code rules or design guidelines. Our monitoring results revealed a discrepancy between the permittee compliance rate (76%) and the permit accordance rate (50%). This occurs when a permittee complies with his/her permit but that permit is not in accordance with the hydraulic code rules or culvert design guidelines. Accordance with the rules and guidelines is the responsibility of the permittor issuing the permit. We found that the culvert width at streambed for many no-slope and stream simulation culverts complied with the permit but was not in accordance with rules or guidelines, respectively. The size of this discrepancy may be largely due to different methods for estimating channel or streambed width as mentioned above.

We monitor culvert effectiveness through two processes: 1) fish passage over time, and 2) changes in channel morphology over time. Fish passability is monitored over time using Level A and Level B fish passage barrier assessments. In year one we were able to determine that *83% of the new culverts we monitored passed the Level A fish passage barrier assessment*. We were unable to make a determination regarding fish passage for the other 17% of culverts because we did not do measurements required for the Level B fish passage barrier assessment. We will in 2014.

Monitoring of Marine Shoreline Armoring

In 2013 all the monitoring of HPAs for marine shoreline armoring occurred in Kitsap and San Juan Counties as the work was primarily funded through a grant provided to these counties to cooperatively assess the shoreline armoring permitting process. We reviewed 106 marine shoreline armoring permits: 31% were new/extension projects, 49% were replacement projects, and 20% were repair projects. Eighty-eight percent of projects used primarily hard armoring, and 8% and 4% used soft armoring or a combination of hard and soft armoring, respectively.

The most critical information for marine shoreline armoring projects is the length of armoring and the location of armoring with respect to the ordinary high water line. We found 40 of 106 (38%) of HPA permits had no clear statement of the project's length. We also found that while almost all permits, 99%, provided some measure of the maximum water ward extent of armoring, many used a benchmark or reference point that could be altered or made difficult to access after the project was completed. Of 26 hard armoring permits (new or extension), only 12% of the permits described the project's location as a distance to a benchmark or permanent structure that would not change as a result of project activities. For the other 88% of permits, determining compliance with the permitted location of shoreline armoring was difficult if not impossible.

In 2013 we surveyed 13 marine shoreline armoring projects for implementation monitoring – 10 were post-construction surveys and three were pre-construction surveys. According to our measurements, nine of 10 projects surveyed post-construction had at least one measurement that was greater than indicated in the permit. Half of the projects were longer than indicated in the permit, 30% were taller, and 60% were further water ward relative to at least one reference elevation. However, it should be noted that the terminus of projects were often difficult to identify in the field and the reference elevations identified in permits were subject to change by construction activities and natural processes, resulting in a high degree of uncertainty when comparing field measurements with permit specifications.

Recommendations

The first year of implementation and effectiveness monitoring of culverts leads us to make the following recommendations for improving the HPA permitting process:

- Language referring to stream channel width should be identical in hydraulic code rules, permit provisions, and culvert design guidelines.
- Standard procedures for estimating mean bankfull width and channel slope should be developed by WDFW and widely distributed for use by HPA applicants.
- Key information – such as bankfull width, channel slope, culvert design type, and culvert dimensions – should be reported and easy to find. We recommend a mandatory form for all HPA applications to be completed by the applicant.
- Bankfull width measurements submitted by HPA applicants should be checked by WDFW or some other credible organization.

- For no-slope culverts, channel slope submitted by HPA applicants should be checked by WDFW or some other credible organization.
- Standard permit provisions for culverts used by WDFW habitat biologists should be reviewed for consistency with hydraulic code rules and design guidelines.

The first year of implementation and effectiveness monitoring of marine shoreline armoring leads us to make the following recommendations for improving the HPA permitting process:

- Key information – such as bulkhead length, bulkhead height, bulkhead design type – should be reported and easy to find. We recommend a mandatory form for all HPA applications to be completed by the applicant.
- The location of the ends and water ward extent of marine shoreline armoring should be described in HPA applications with respect to engineering benchmarks or permanent structures in the upland that will not change over time.

Part 1. Monitoring for the Hydraulic Project Approval Program

Introduction

One of the main responsibilities of WDFW's Habitat Program is protecting fish and fish habitats through the administration and enforcement of the hydraulic code rules (Chapter 220-110 Washington Administrative Code). Through these rules WDFW regulates the construction of hydraulic structures or the performance of other work that will use, divert, obstruct, or change the natural flow or bed of any of the salt or fresh waters of the state. The rules set forth procedures for obtaining a hydraulic project approval (HPA, i.e., a permit), and the rules incorporate criteria used by WDFW for project review and conditioning HPAs. Furthermore, the hydraulic code rules reflect the best available science and practices related to the protection of fish life, and WDFW will incorporate new information into the rules as it becomes available (WAC 220-110-010).

To help ensure that hydraulic structures (e.g., bridges, culverts, freshwater and marine shoreline armoring) are compliant with current rules and that current rules effectively protect fish habitats, WDFW is monitoring its hydraulic project approval (HPA) program. The main purpose of monitoring is to provide information which overtime helps us to improve both implementation of the current hydraulic code rules and the effectiveness of those rules at protecting fish habitats. Specifically, the purpose of monitoring the HPA program is to provide reliable, useful information that describes:

1. opportunities to improve WDFW's process for issuing HPA permits;
2. opportunities to improve compliance by permittees;
3. failures of properly implemented hydraulic structures to protect fish; and
4. characteristics of properly implemented hydraulic structures that are commonly associated with failures to protect fish habitats.

The ultimate purpose of monitoring is improving the implementation and effectiveness of hydraulic projects. Implementation monitoring simply determines whether or not hydraulic projects are implemented properly (Wilhere et al. 2014). Two entities are involved in implementation of a hydraulic project: WDFW (the permittor) and the permittee. The success or failure of project implementation depends on the performance of both entities. Hence, implementation monitoring collects information that could be used to improve the performance of both WDFW and the permittee. Successful implementation of hydraulic projects occurs when the hydraulic structure fully complies with the permit, and the issued permit fully agrees with the hydraulic code rules[2] (WAC 220-110-070) and/or follows WDFW's culvert design guidelines (Bates et al. 2003)[3].

A successfully implemented hydraulic project must have permittee compliance and permittor accordance. *Compliance* refers only to the permittee's performance relative to the permit. Compliance means the hydraulic structure constructed by the permittee conforms to the HPA permit. Permittee compliance is based strictly on the contents of the permit, even when the permit is incomplete, vague, ambiguous, or contains errors. *Accordance* refers to either the permittor's or permittee's performance relative to the hydraulic code rules or design guidelines. For the permittor, accordance means 1) the HPA permit he or she issued includes all provisions that are necessary and sufficient for construction of a hydraulic structure, and 2) the permit's provisions, including reference to the permittee's plans, fully conform to hydraulic code rules or WDFW's design guidelines. For the permittee, accordance means the hydraulic

[2] In November 2014 WDFW promulgated revised hydraulic code rules. All references to hydraulic code rules in this report refer to the rules in effect immediately prior to November 2014.

[3] The current culvert design guidelines are Barnard et al. (2013), however, all the culverts monitored in year one were planned and designed prior to 2013, and hence, they should have followed the guidelines of Bates et al. (2003).

structure he or she constructed fully conforms to hydraulic code rules or design guidelines. It is possible for a permittee to construct a hydraulic structure that complies with their HPA permit but does not accord with rules or guidelines.

Implementation of a hydraulic project is a complete failure when a permit is in not accordance with the hydraulic code rules or design guidelines and the permittee is not in compliance with the permit (Table 1-1). Partial failures occur when: 1) a permit is in accordance with the rules or design guidelines but the permittee is not in compliance with the permit, or 2) when a permittee is compliant with the permit but the permit lacks accordance. Partial success occurs when the permit is not in accordance with the rules or design guidelines, but the permittee, nevertheless, constructs a hydraulic structure that is accordant with the rules or design guidelines. Partial success is rare but is known to occur (Quinn et al. 2006).

Table 1-1. Outcomes for hydraulic project implementation as determined by permittee and permittor actions.

<table>
<tr><td colspan="2" rowspan="3"></td><td colspan="4">Permittee</td></tr>
<tr><td colspan="2">culvert NOT compliant with permit</td><td colspan="2">culvert compliant with permit</td></tr>
<tr><td>culvert NOT accordant with rules</td><td>culvert accordant with rules</td><td>culvert NOT accordant with rules</td><td>culvert accordant with rules</td></tr>
<tr><td rowspan="2">Permittor</td><td>permit NOT in accordance with rules</td><td>complete failure</td><td>partial success</td><td>partial failure</td><td></td></tr>
<tr><td>permit in accordance with rules</td><td>partial failure</td><td></td><td></td><td>complete success</td></tr>
</table>

There are four questions that should be answered through implementation monitoring: 1) Did the permittor issue a complete permit, that is, one that contains provisions and/or project plans for all critical structural dimensions?; 2) Is the permittor's permit accordant with hydraulic code rules and design guidelines?; 3) Did the permittee comply with the permit?; and 4) Is the completed hydraulic project in accordance with hydraulic code rules or design guidelines? In 2013 we did not conduct a systematic evaluation of the permittor's side of the process. That is, we did not attempt to answer questions 1 and 2. Nonetheless, we believe that information obtained in 2013 through monitoring permittee compliance and hydraulic structure accordance will lead to more effective and efficient HPA process. In the future we will address all four questions regarding implementation.

Effectiveness monitoring is done to determine whether or not hydraulic projects are yielding the desired habitat conditions. For culverts, the desired condition is "no-net-loss of productive capacity of fish and shellfish habitat" (WAC 220-110-070). "Net loss" refers to the "net loss of habitat functions necessary to sustain fish life" and the "loss of area by habitat type" (220-110-020(68)). For marine shoreline armoring, the intended habitat protection is no "permanent loss of critical food fish or shellfish habitat" (WAC 220-110-285).

Year One Goals and Objectives

In 2013 the Habitat Program's Science Division assumed responsibility for implementation and effectiveness monitoring of recently permitted hydraulic structures. The scope of implementation and effectiveness monitoring was limited to new and replacement culverts and new and replacement marine shoreline armoring. Only these two types of hydraulic structures were monitored in 2013 because: 1) these two types are the most ubiquitous, and hence, have the greatest potential to damage fish habitats, and 2) funding limitations forced us to focus on only the hydraulic structure types with the greatest potential to damage fish habitats.

The objectives for the first year of monitoring by the Science Division were:

1. develop and refine the strategy, tactics, and procedures of implementation monitoring;
2. develop and refine the strategy, tactics, and procedures of effectiveness monitoring;
3. collect implementation monitoring data on as many culverts and marine shoreline armoring sites as time and resources allow;
4. collect effectiveness monitoring data on as many culverts and marine shoreline armoring sites as time and resources allow;
5. report on problems in issued permits;
6. report on rates of non-compliance by permittees;
7. report on rates of non-accordance for hydraulic structures;
8. describe the physical characteristics of effectiveness monitoring sites.

Part 2. Implementation and Effectiveness Monitoring of Culverts

Introduction

Because of limited resources and staff time, implementation monitoring of culverts did not cover all provisions specified on HPA permits. Implementation monitoring focused on those provisions that can: 1) be evaluated post-construction; 2) be objectively measured, and hence, do not require the specialized expertise of a habitat biologist; and 3) require only one site visit. For instance, provisions related to construction timing or equipment were not evaluated because they cannot be reliably evaluated post-construction, and provisions related to re-vegetation or mitigation were not valuated because they require either a subjective expert judgment or more than one site visit. Furthermore, implementation monitoring focused on the hydraulic structure because relative to other activities regulated under the HPA permit (e.g., re-vegetation), the culvert has the greatest potential to adversely impact fish habitats and is the principal impact being regulated.

Methods

We expected our field season to run from July to mid-October. The beginning of the field season is determined by the HPA in-water work window. According to most HPA permits, in-water work is allowed from roughly mid-July to mid-September, depending on the water body. The end of the field season is determined by weather. When fall and winter rains arrive, stream flows rise and culverts cannot be reliably measured or measured safely. We did not monitor culverts after high stream flows because such flows could change the stream channel, and hence, alter important dimensions such as culvert width at streambed and countersink depth.

In 2013, culvert implementation and effectiveness monitoring was limited to western Washington. The number of sites that could be visited for monitoring was limited by available staff. The field staff consisted of one half-time biologist who was intermittently assisted by one or two technicians.

The monitoring process consisted of 5 major steps: (1) finding culvert projects to monitor, (2) recording information from the project permit and plans, (3) measurements at the project site, (4) data entry, and (5) data analysis.

Finding Projects. Finding culvert projects to monitor entailed contacting the permittee to determine when the project would be completed. Using the Hydraulic Permit Management System (HPMS), we constructed a list of culvert projects, both new and replacement, on fish-bearing streams that had been issued permits over the past 2 years (July 2011 to August 2013). We then contacted the permittee identified on each permit. In several cases the culvert had already been built prior to the 2013 in-water work window or the culvert project was not scheduled for 2013. If the culvert project was scheduled for 2013, often the permittee or their contractor would be uncertain about the completion date. In such cases, the permittee would sometimes agree to contact us when the project was complete or we would periodically contact the permittee to check on the project's status. If the culvert was on private land, then we also requested permission to conduct monitoring activities on the permittee's property. In some cases, permission was denied. One landowner denied access to numerous recently installed culverts. Implicit denials occurred when landowners ceased replying to our telephone messages or e-mails.

Due to difficulties in finding completed culverts and obtaining permission to access private property, we were unable to randomly select culverts for implementation monitoring. Our sampling scheme for culvert selection was opportunistic – we visited culverts as their availability became known to us and, when the culvert was on private land, we were granted permission to visit the site. Consequently, our sampling scheme does not allow valid inferences to the larger population of all culverts installed in 2013. While we can calculate compliance or accordance rates for the culverts we visited, we cannot calculate valid confidence intervals for those rates.

Implementation Monitoring of Culverts

The next three steps – measurement at the project site, data entry, and data analysis – were different for implementation and effectiveness monitoring.

Information from Permits. The test of compliance by the permittee is a comparison of the completed culvert project with the HPA permit's provisions. The first step in that comparison is finding and recording the culvert dimensions specified in the permit's provisions. For the purposes of compliance monitoring we assessed the following critical structural dimensions: culvert width at stream bed, culvert slope, countersink depth at outlet, and culvert length (Box 2-1). For each permit we recorded presence/absence of a provision for each critical structural dimension. We also evaluated the clarity of those provisions and their consistency with hydraulic code rules or culvert design guidelines.

A common permit provision is "work shall be accomplished per plans and specifications approved by the Washington Department of Fish and Wildlife." This provision refers to engineering drawings or plans submitted by the permittee. Hence, many of the critical dimensions are not explicitly stated in the permit per se but are contained in the associated engineering drawings or plans. In some cases, critical dimensions were not stated in the provisions or plans, and consequently, we were forced to estimate those dimensions manually from the engineering drawings. In other cases, we could not ascertain critical dimensions from permit provisions, engineering drawings, or any other documentation associated with the permit.

Box 2-1. Critical Measurements for Implementation Monitoring

- bankfull width
- culvert width at streambed
- culvert slope
- countersunk depth at outlet
- culvert length

The test of overall implementation success, which encompasses both accordance by the permittor and compliance by the permittee, is a comparison of the completed culvert with the hydraulic code rules (WAC 220-110-070) or design guidelines (Bates et al. 2003). Accordance requires that the permittor issued a HPA permit that follows hydraulic code rules or design guidelines. Compliance requires that the permittee follows the permit. We used the same critical structural dimensions for evaluating accordance and compliance (Box 2-1).

Measurements at Project Site. At the project site, we measured all critical culvert dimensions and bankfull width (Box 2-1). In addition, we made all the measurements necessary for Level A fish passage barrier assessment (WDFW 2009). Many of the measurements made for implementation monitoring are the same or very similar to those done for Level A barrier assessment, and hence, the methods used for monitoring were the same methods used by WDFW's culvert inventory crews. A full list of the recorded information and measurements for each culvert is given in Appendix A. All measurements for implementation monitoring required about 45 minutes to complete per culvert.

Data Entry. In year one of implementation and effectiveness monitoring we did not construct a database. We believe the design of a programmatic database (contents, structure, and functionality) will be much better informed after one to two years of monitoring. In year one all data were transferred from paper data forms to a Microsoft Excel spreadsheet.

Data Analyses. Data analyses for implementation monitoring were done in Excel. For permittee compliance the structural dimensions of the completed culvert must follow the provisions of the permit, which often refer to the engineering drawings or plans submitted by the permittee. Hence, regardless of design type, permittee compliance was based on a comparison to the permit provisions. HPA permits for no-slope culverts often explicitly state the culvert dimensions in the provisions. In contrast, permits associated with stream simulation culverts often rely on the “work shall be accomplished per plans” provision. Engineering drawings sometimes lack critical dimensions, in particular, culvert width at stream bed. This structural dimension is often difficult to determine from the drawings attached to HPA permits, especially when drawing are not to scale. If the specification for a culvert dimension could not be found, then that culvert was dropped from the permittee compliance rate calculation.

We encountered four culvert design types: no-slope, stream simulation, bottomless, and unknown. Bottomless culverts could be no-slope, stream simulation, or unknown design. Each culvert design type has its own set of rules or design guidelines. Hence, the assessment of accordance rates was done separately for each design type. When evaluating accordance rates for no-slope culverts, we compared the dimensions of each culvert against the specifications in WAC 220-110-070 (3)(b)(i). Specifications for stream simulation culverts are not in WAC, and consequently, when evaluating accordance for stream simulation culverts, we compared the dimensions of each culvert against the specifications in Bates et al. (2003). For some culverts the design type could not be determined. Accordance cannot be determined when culvert design type is unknown.

Comparisons of culverts against rules, guidelines, or permit provisions were mostly one-sided. That is, for structural dimensions such as culvert width and countersinking, the actual dimension could be greater than permitted but not less than. Permit provisions for culvert length often state that the length “shall not exceed” a specified length. Consequently, for culvert length the actual dimension could be less than permitted but not greater than.

Many physical measurements associated with hydraulic projects – bankfull width (BFW), channel gradient, countersink depth – are made in challenging settings or require subjective judgments that result in high inter-observer variability. In other words, such measurements may be inherently imprecise and inaccurate. Implementation monitoring must take into account the inexact nature of the measurements associated with the permitting and construction processes. This is done through measurement and engineering tolerances. A tolerance is the maximum acceptable difference between the actual value of a quantity and the value specified for it. Measurement tolerances are applied to the site measurements necessary for project design such as bankfull width and channel gradient. An engineering tolerance is the acceptable difference between the actual physical dimension of a constructed structure and the dimension specified on the construction project’s plan. In implementation monitoring, engineering tolerances were applied to dimensions such as culvert slope and culvert countersinking.

Implementation compliance and accordance rates will be sensitive to our error tolerances, and therefore, tolerances should be realistic and fair. Tolerance values are difficult to specify *a priori*, and hence, our preliminary measurement tolerances may change as we learn more about the capabilities of habitat biologists and HPA permittees or their contractors. Preliminary engineering tolerances for most structural dimensions were set to ± 5% error (D. Ponder, WDFW, pers. comm.). There were two exceptions to this rule-of-thumb. First, culvert length had a relative tolerance of +5% and an absolute tolerance of +1 foot, and for each culvert compliance was based on the more lenient error tolerance. Second, for culvert slope we used the compliance threshold in Barnard et al. (2013) which says the slope of a compliant no-slope culvert must be less than 2%. We applied the same error tolerance, ± 2% slope, to other culvert design types as well. Hence, to be in compliance with the permit the actual culvert slope had to be within ± 2% of the slope specified in the permit provisions or plans, and to be in the accordance with the rules/design guidance, the actual culvert slope had to be within ± 2% of the slope specified in the rules/design guidance. An error tolerance of ± 5% was also applied to bankfull width measurements.

Compliance with permit provisions and accordance with hydraulic code rules is based on language in those permit provisions or rules. For instance, the rule for no-slope culverts (WAC 220-110-070(3)(b)(i)) says culverts should be "placed on a flat gradient." This part of the rule is clear, and therefore, evaluating accordance for this part of the rule is straightforward. The later part of the rule for no-slope culverts, however, is problematic when evaluating accordance. The hydraulic code rule for no-slope culverts says, "The culvert width at the bed, or footing width, shall be equal to or greater than the average width of the bed of the stream." A common HPA permit provision for specifying culvert width also refers to "width of the streambed" (See Appendix B). WDFW's operational definition for "width of the bed of the stream" is bankfull width (BFW), and hence, for the purposes of implementation monitoring we measured BFW. Consequently, with the data we collected, we cannot conclusively determine whether the no-slope culverts we monitored were compliant with the permit provision or accordant with the rule that specify culvert width at the streambed. That is, the provision and rule say one thing, "width of the streambed", but WDFW's operational definition and our implementation monitoring measurement say another, "bankfull width."

Effectiveness Monitoring of Culverts

We monitor culvert effectiveness through two processes: 1) fish passage over time, and 2) changes in channel morphology over time. Effectiveness monitoring compares stream channel conditions near and in a culvert with desired channel conditions. Assuming that HPA provisions were implemented correctly, repeated failures to achieve desired conditions at multiple sites would suggest that hydraulic code rules are not protecting fish habitats.

Detecting changes in stream channels that are caused by culverts and conclusively detrimental to fish is a conceptually and technically daunting problem (Wilhere at al. 2014). We intend to identify adverse impacts to fish and fish habitats through metrics that are indicative of a fish passage barrier or the imminent physical failure of the structure due to deposition or transport of sediment. Fish passability is monitored over time using Level A and Level B fish passage barrier assessments (WDFW 2009). If a culvert passes Level A, then we believe it is not a barrier to fish passage. If the passibility of a culvert cannot be determined with Level A, then it is assessed with Level B. If a culvert fails Level B, then, is it believed to be a barrier to fish passage. In year one we did not do measurements required for the Level B fish passage barrier assessment.

Changes in channel morphology over time are monitored using standard stream channel survey methods (Wilhere et al. 2014, Appendix B). All properly implemented culverts, regardless of upstream conditions or disturbances, are presumably designed to avoid retention of sediment that becomes a barrier to fish movement at the structure's inlet and to avoid scour of sediment that would create a vertical barrier to fish movement at the culvert's outlet. Effectiveness monitoring measures steam channel characteristics that enable us to compare the intended culvert performance versus the actual culvert performance. We measured streambed elevations, water depths, bed and bank elevations, and sediment sizes at three transverse cross-sections above and three transverse cross-sections below the culvert. The first cross-sections were placed immediately adjacent to the culvert structure, and subsequent cross-sections were spaced approximately one bankfull width apart. If measurements could be taken safely, then a longitudinal transect was measured along the channel thalweg over the entire length of the culvert.

Substrate size distribution, thalweg depth, stream gradient, and cross-section area can be calculated for the site and for the channel upstream of, downstream of, and within the stream crossing structure. For example, thalweg depth was calculated as the mean of the depths of the deepest wetted measurement on each cross section. Substantial changes in channel characteristics indicate that the culvert may be constraining the flows of water and sediment. If measurements indicate sediment aggradation, shallower thalweg, or reduced gradient upstream of the culvert and not downstream of the culvert, then the structure may be impeding the flow of water and sediment and will likely result in a fish passage barrier, and, in extreme cases, destruction of the culvert. Alternatively, if substrate scour, deeper thalweg, or increased gradient downstream of the structure are found, then too the structure may impede the flow of water and sediment and will likely result in a fish passage barrier and possibly destruction of culvert.

In future reports, bed elevation measurements, such as the ones used to calculate thalweg depth, can be compared within sites and among years. Increases in elevation indicate deposition of bed material and decreases indicate erosion. These estimates should be made independently for the upstream and downstream cross sections, because we expect deposition upstream and erosion downstream of structures that are not functioning properly. Similarly, stream gradient should be calculated for the entire site and for transects that are upstream and downstream of the structure.

Results

Implementation Monitoring

We visited 54 culverts for implementation monitoring. Our 54 culverts corresponded to 45 HPA permits because eight HPAs covered more than one culvert. Monitoring occurred during the months of July 2013 through January 2014. Because of dryer than normal weather conditions, more than two-thirds of the site visits occurred in October, November, and January. No sites were visited in December. Sites were visited in Clallam, Cowlitz, King, Kitsap, Lewis, Mason, Pierce, Skagit, Snohomish, Thurston, and Whatcom Counties. Snohomish and Lewis counties had the largest number of sites with 12 and 10 sites, respectively, and Cowlitz, Skagit, Thurston, and Whatcom had the smallest number of sites with 2 each. Twenty five of the culverts visited for implementation monitoring were installed by city or county governments, 17 were installed by various state government agencies, and the remainder were installed on private roads.

The plurality of culverts monitored for implementation were no-slope design and eight culverts were of unknown design (Table 2-1). Culverts of unknown design may have been the hydraulic design type, but there was no indication of that in any permits, plans, or other documentation. Specification of culvert design was haphazard. When we could find an explicit specification of culvert design type, usually only a single statement of design type was found in one of the various documents associated with the HPA: permit provisions, engineering drawings or other plans, the Joint Aquatic Resource Permits Application (JARPA), the summary form for fish passage design (taken from Bates et al. 2003), a cover letter, a "design report", a "permit project description" or a "specific project information form."

All 54 HPA permits included a provision resembling, "work shall be accomplished per plans and specifications approved by the Washington Department of Fish and Wildlife." (Table 2-2). All but three permits also included in that provision language similar to, "except as modified by this hydraulic project approval." If an HPA permit relies on a permittee's plans, then finding critical culvert dimensions on those plans is essential. We could not find on or measure from plans a value for culvert width at streambed for 11 culverts. Nine of these culverts were no-slope design, but for three of these culverts we could calculate the permitted culvert width at streambed from other information in the project plans. The most common provision for culvert dimensions was for width: 70% of 54 permits had a width provision. Only 15% of permits had a provision for maximum countersinking. Provisions for minimum countersinking were four times more common than provisions for maximum countersinking. We found no clear relationship between the number of provisions for structural dimensions in a permit and the rate of compliance (Table 2-3).

Many permit provisions for culvert width, 89% of 38 such provisions, had language issues (Table 2-4). The most common problem was specifying culvert width in terms of "width of the streambed." This language conflicts with WDFW's operational definition of streambed width which is BFW. A common provision for stream simulation culverts said the culvert will be installed "in a manner consistent with the stream simulation method." This provision assumes that the permittee understands all aspects of the stream simulation design method and it may lack a level of specificity required for permit enforcement.

Table 2-1. Number of culvert design types measured in year one of implementation and effectiveness monitoring.

	Monitoring type	
Design Type	**Implementation**	**Effectiveness**
no slope	19	6
stream simulation	11	1
bottomless*	15	6
unknown	9	1
total	54	14

*15 bottomless culverts were described as follows: 9 stream simulation, 2 no slope, and 4 no design type specified.

Table 2-2. Number of permits with specific provision for each critical dimension of culvert. "Work per plans" refers to provision that typically says, "work shall be accomplished per plans and specifications approved by the Washington Department of Fish and Wildlife." Culvert slope was not applicable for bottomless culverts.

Provision	**work per plans**	**culvert width**	**culvert slope**	**countersink**		**culvert length**
				minimum	**maximum**	
present	54	38	22	32	8	20
absent	0	16	20	22	46	34
not applicable	0	0	12	0	0	0
total	54	54	54	54	54	54

Table 2-3. Number of compliant HPA permits versus the number of permit provisions for culvert structural dimensions. Fifteen bottomless culverts were excluded from tally.

Number of Provisions in Permit	**Number Compliant Culverts**	**Number Non-compliant Culverts**	**Number with Insufficient Information to Determine Compliance**	**Total Culverts**
zero	6	2	0	8
one	0	1	0	1
two	4	4	0	8
three	4	1	4	9
four	9	1	3	13
five	0	0	0	0
total	23	9	7	39

Table 2-4. For 54 HPA permits, number of provisions for each critical dimension of culverts with language issues.

Structural Dimension	Number of Provisions	Number with language issues	Examples
culvert width	38	34	1) "The culvert width at the streambed shall be equal to or greater than the average width of the streambed." 2) "footings equal to or greater than average width of streambed" but culvert is arched, and therefore, culvert width at streambed is too narrow. 3) width covered by a blanket provision: "in a manner consistent with the stream simulation design method", however, it also says culvert width "greater than average width of streambed." It should say 1.2*BFW + 2. 4) Provision specifies culvert span but not culvert width at streambed. 5) Provision says culvert will not "exceed" a certain width. It should say width will not be less than.
culvert slope	22	8	1) Provision says, "culvert shall be placed on a maximum 3% gradient," but culvert is no-slope design. 2) slope covered by a blanket provision: "in a manner consistent with the WDFW stream simulation method." This may be too vague.
countersink inlet	32	11	1) For bottomless culvert says footings shall be buried "sufficiently deep" so they will not become exposed by scour. This may be too vague. 2) countersink covered by a blanket provision: "in a manner consistent with the WDFW stream simulation method." This may be too vague. 3) Provisions say bottomless but the culvert is not bottomless.
countersink outlet	8	2	1) countersink covered by a blanket provision: "in a manner consistent with the WDFW stream simulation method."
culvert length	20	0	none

We lacked sufficient information to determine permittee compliance for 9 culverts. For eight culverts the missing information was culvert width at streambed, which could not be found in the permit provisions or associated plans. The overall rate for permittee compliance with HPA permits was 76% (Table 2-5). Five of the noncompliant culverts were too narrow and six were countersunk too shallow. Only two culverts were noncompliant for more than one critical structural dimension, and both were noncompliant for two dimensions. The compliance rate varied by design type. The lowest rate of permit compliance, 60%, was for stream simulation culverts. Three of the four noncompliant stream simulation culverts were countersunk too shallow and the culvert width of another was too narrow. The high compliance rate for bottomless culverts, 85%, may have been because only two structural dimensions could be assessed for that design type: width and length.

The overall rate of accordance with hydraulic code rules and/or culvert design guidelines was 50%. This rate is subject to three qualifiers. First, for no-slope culverts, we assumed that streambed width means bankfull width. As described above this is a tenuous assumption. Second, for stream simulation culverts, we assumed that the permittee used WDFW's design guidance (Bates et al. 2003). This is a strong assumption, however, other stream simulation designs exist (e.g., USFS 2008) and permittees rarely refer to the technical guidance documents used in designing their culvert. Third, we assumed that the error tolerances we applied for bankfull width measurements and culvert dimensions are reasonable expectations. If any of these assumptions are false for one of more culverts, then the success rate could increase.

The rate of accordance varied greatly by design type (Table 2-6). When comparing stream simulation culverts against the design guidelines, this design type had the lowest accordance rate: 27%. Six of the eight nonaccordant culverts were due to insufficient culvert width at the streambed and two were due to insufficient countersinking depth. Accordance with culvert slope guidelines was not evaluated in 2013. The accordance rate for no-slope culverts was 47%, and the main reason for all nonaccordant culverts was insufficient culvert width at the streambed. Bottomless culverts had the highest accordance rate: 70%, but the rate may have been highest because only two structural dimensions could be assessed: width and length.

We cannot assess accordance with rules or guidelines for culverts with unspecified or unknown design. Culverts of unknown design may have actually been no-slope, stream simulation, or hydraulic design types. However, eight of these culverts were unlikely to have been no-slope culverts because the permitted culvert slopes ranged from 1.5% to 12%, with six of the nine culverts permitted to have slopes of 2% or greater. Two percent culvert slope is our threshold for nonaccordance (Barnard et al. 2013). If they were intended to be stream simulation culverts, then only one of the nine culverts was wide enough to accord with design guidelines (Bates et al. 2003). In short, these culverts were neither no-slope nor stream simulation, and may have been *ad hoc* designs.

The rate of accordance also varies by structural dimensions (Table 2-7). The highest accordance rate (97% overall) was for culvert length. Barnard et al. (2013) suggest that no-slope culverts are generally appropriate for culvert lengths less than 75 ft (22.9 m). All 19 of the no-slope culverts were less than 66 ft. Barnard et al. (2013) also suggest a length/width ratio less than 10 for stream simulation culverts. All but one stream simulation culverts were in accordance with this guideline. The lowest accordance rate was for culvert width at the streambed (52% overall), with the stream simulation culvert design type having the lowest accordance rate for culvert width at the streambed (45%).

Insufficient culvert widths may have been due to mismeasurement of BFW. Permits for six of the stream simulation culverts reported the permittee's stream channel measurement. The accordance rate for these six culverts based on the permittees' stream channel measurement was 50% (Figure 2-1). Permits for ten of the no-slope culverts reported the permittee's stream channel measurement. The accordance rate for these ten culverts based on the permittees' stream channel measurement is 80%. One of the two culverts that were nonaccordant, did so because it was too long, therefore, the accordance rate for width alone for these 10 culverts was 90%.

Table 2-5. Permittee compliance with HPA permits for culverts in 2013.

Design Type	Number of Culverts	Number with Sufficient Information to Determine Compliance	Number Compliant	Percent Complaint
no slope	19	13	11	85
stream simulation	11	10	6	60
bottomless*	15	13	11	85
unknown	9	9	6	67
total	54	45	34	76

*Only two structural dimensions assessed for bottomless culverts: width and length.

Table 2-6. Accordance rates for culverts during year one of implementation monitoring. Accordance cannot be determined for the 13 culverts of unspecified or unknown design type.

Design Type		N	Number with Sufficient Information	Number Accordant	Percent Accordant
no slope*		19	19	9	47
stream simulation‡		11	11	3	27
bottomless†	no slope	2	2	2	100
	stream simulation	9	8	5	62
total		41	40	20	50

* Accordance for width, slope, and countersink based onWAC-220-110-070, and length based on guideline in Barnard et al. (2013).

‡ Accordance for width, countersink, and length based on design guidelines (Barnard et al. 2013). Accordance with guideline for culvert slope was not evaluated in 2013.

† Bottomless culverts follow accordance standards of no-slope or stream simulation depending on the design type specified in permit. Design type of 4 bottomless culverts was not specified and culvert width could not be measured for another culvert.

Table 2-7. Accordance rates (i.e., percent) for specified structural dimensions assessed in year one of implementation monitoring. Accordance cannot be determined for the 13 culverts of unspecified or unknown design type.

	Design Type			
Culvert Dimension	**No-slope***	**Stream Simulation‡**	**Bottomless†**	**Overall**
width of stream bed at outlet	47	45	70	52
slope	100	not evaluated	na	100
countersink depth at outlet	89	54	na	76
length	100	91	100	97
overall	47	27	70	47
number of culverts	19	11	10	40

* Accordance for width, slope, and countersink based onWAC-220-110-070, and length based on guideline in Barnard et al. (2013).

‡ Accordance for width, countersink, and length based on design guidelines (Barnard et al. 2013). Accordance with guideline for culvert slope was not evaluated in 2013.

† Bottomless culverts follow accordance standards of no-slope or stream simulation depending on the design type specified in permit. Design type of 4 bottomless culverts was not specified and culvert width could not be measured for another culvert.

Measuring BFW correctly requires knowing what to measure and how to measure it. We reviewed 54 HPA permits and steam channel width measurements were reported in 27 of them. Ten different terms were used to describe channel width (Box 2-2). In addition, the channel width measurements were difficult to find in a permit or its supporting documentation. There was no consistency in the where channel width was reported (Box 2-3).

Box 2-2. Terms in HPA applications used to describe channel width:

- Bankfull Width (BFW)
- Average Bankfull width
- 2 Year Bankfull Width
- Streambed Width
- Average Streambed Width
- Stream Width
- Channel Bed Width
- Ordinary High Water (OHW, OHWM)
- Top Channel Width
- Approximate Stream Size

Channel width not found in 28 of 54 applications

We compared our bankfull width measurements to the channel width measurements of 25 permits. On average, our BFW measurement was 2.4 ft wider than permittees' channel width measurements[4]. Ten of the 25 permits described their channel width as BFW. When our BFW measurement was wider than the permittees (8 out of 10 permits), it was, on average, 2.2 ft wider. This amounted to a 22% error in BFW measurement by permittees. For permits that did not describe their channel width as bankfull width, our BFW measurement was 3.0 ft wider than the permittees'. Our BFW measurement was wider than the permittees' channel width for 80 percent of the 25 permits.

Implementation success rates will be sensitive to our error tolerances. For purposes of estimating compliance and accordance rates, we applied a one-sided ± 5% error tolerance to both site measurements and structural dimensions. However, this error rate may be an unreasonable expectation. Hence, we explored how different tolerances for error would affect accordance rates. We applied a range of error tolerances ranging from 5% to 65% to BFW and recalculated accordance rates for culvert width at streambed. Our 5% error tolerance yields 47% and 27% accordance rates for no-slope and stream simulation culverts, respectively. A substantial change in accordance rates occurs at 25% error tolerance for no-slope culverts and at 15% for stream simulation (Figure 2-1). Accordance rates for culvert width at streambed do not exceed 75% until error tolerances for BFW estimates reach 45% and 35% for no-slope and stream simulation culverts, respectively.

Box 2-3. Documents in HPA applications where channel width was reported:

- HPA Permit
- Forest Practices Approval Permit
- Engineering Drawings
- JARPA
- Summary Form for Fish Passage Design
- Wetland and Stream Technical Memo
- Critical Areas Study
- Culvert Replacement Plan
- Design Report

Channel width no found in 28 of 54 applications

Effectiveness Monitoring of Culverts

Eighty-three percent of 52 culverts passed the Level A fish passage barrier assessment. For the nine culverts that did not pass level A, six were too narrow and three were not countersunk deep enough. The barrier status of nine culverts could not be determined with the Level A assessment and we did not collect data for a Level B assessment. Therefore, for these nine culverts, we cannot make determinations regarding fish passage.

Fourteen culverts surveyed in 2013 were selected for long-term effectiveness monitoring. Six culverts were no-slope, six were bottomless, one was a stream-simulation, and another was of unknown design. Of the fourteen culverts analyzed, most were in relatively narrow streams (mean bankfull width = 3.14 m; std. dev.= 1.24 and mean toe width = 2.90 m; std. dev.= 1.19 m; Table 2-8)[5]. Most of the sites were relatively shallow at the time of measurement (mean depth = 0.25 m, std.dev. = 0.19 m) and thalweg depth had little variability with most sites.

At the time of our measurements, channel gradients were relatively steep at most sites, and upstream and downstream gradients were different for every culvert, sometimes substantially (Figure 2-3). According

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[4] Hydraulic code rules, HPA permit provisions, and design guidelines use English measurement units, and therefore, we follow that convention.

[5] By convention, the units of scientific studies guidelines are metric. Effectiveness monitoring is, in part, a scientific study regarding the effects of culverts on stream channels.

to our measurements, upstream or downstream channel gradients at five of these six no-slope culverts were greater than 3% and site gradient (including the structure) was greater than 3% for three of the no-slope culverts. Bates et al. (2003) recommends no-slope culverts for sites with channel gradients less than 3%.

We should reconsider the design of our stream channel survey. The lengths of the upstream and downstream channel sections over which we took measurements were set at two to three bankfull widths. At most study sites this resulted in channel sections that were shorter than the culvert length (mean length = 28.9 m, std. dev. = 8.7 m). Additionally, the lengths of channel sections above and below the culvert were occasionally unequal because of obstacles encountered along the stream channel. These factors could significantly affect the accuracy of channel gradient estimates, especially in non-plane bed streams or channels with high bed roughness.

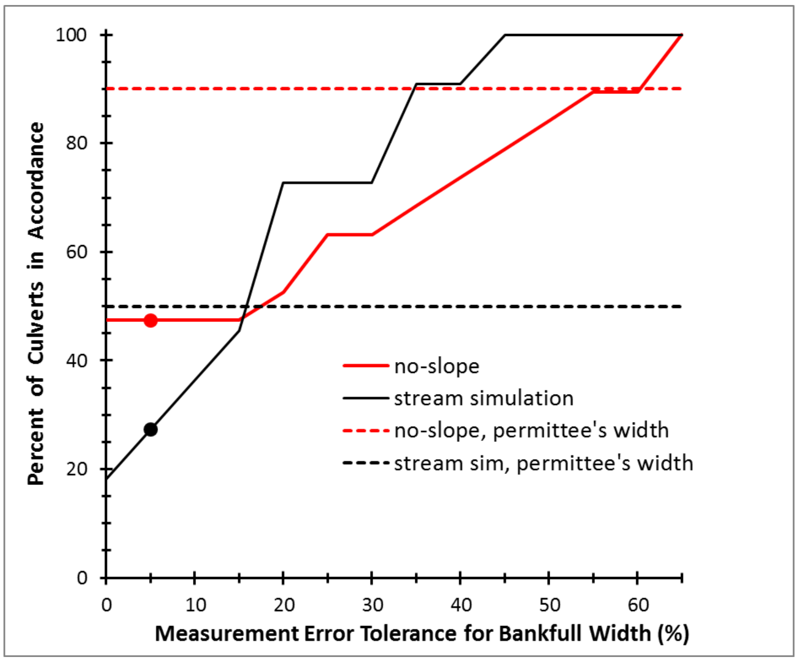


Figure 2-1. Sensitivity of accordance rates for no-slope and stream simulation culverts to measurement error tolerance for bankfull width. Dots are accordance rates for culvert width at stream bed for 2013 calculated with 5% error tolerance for BFW measurement. Horizontal dashed lines are mean accordance rates for culvert width at stream bed calculated with the permittees' stream width measurements and a 5% error tolerance (10 no-slope and 6 stream simulation culverts).

Table 2-8. Stream channel characteristics for 14 effectiveness monitoring sites. All units in meters except for channel gradient, which is percent slope. SD indicates standard deviation. The abbreviations ns, ss, uk, and bot in the design column signify no-slope, stream simulation, unknown and bottomless, respectively. NA in culvert length column indicates that a longitudinal transect along thalweg in culvert was not measured. Elevation difference and total gradient are from the upper most channel cross-section to the lower most channel cross-section.

Site	Design	BFW	Upper Section Length	Lower Section Length	Combined Section Length	Toewidth Mean	Toewidth SD	Mean Depth	SD Depth	Culvert Length	Elevation Difference	Total Gradient	Upper Gradient	Lower Gradient
1	ns	3.53	7.00	7.00	34.10	3.67	1.87	0.22	0.16	20.00	1.34	3.93	3.14	5.71
2	ns	3.50	7.85	6.60	28.30	3.58	1.46	0.25	0.10	11.50	0.79	2.79	4.71	2.27
3	ns	1.74	4.50	4.15	16.90	2.49	1.10	0.22	0.10	NA	0.00	0.00	2.67	5.30
4	ns	2.60	5.20	5.20	24.20	2.18	0.79	0.20	0.18	14.00	0.58	2.40	0.00	4.81
5	ns	2.30	8.00	8.00	24.70	2.84	0.76	0.38	0.07	8.70	0.23	0.93	1.62	1.50
14	ns	3.40	6.80	6.60	17.60	2.11	0.36	0.06	0.01	NA	0.82	3.53	8.60	1.63
8	ss	2.15	4.30	4.30	23.20	1.49	0.29	0.10	0.05	14.50	0.25	1.01	2.92	1.67
9	uk	1.30	4.00	4.00	26.90	1.43	0.79	0.12	0.04	18.00	0.17	0.54	3.63	1.62
6	bot/ ss	2.80	8.00	8.00	38.90	2.81	1.17	0.10	0.03	23.00	1.27	4.72	5.00	5.25
7	bot/ ss	5.40	10.80	10.80	26.20	4.61	2.07	0.21	0.03	4.80	0.18	0.45	1.63	1.47
11	bot/ ns	5.10	12.30	10.90	40.20	4.81	2.25	0.39	0.23	NA	0.44	1.13	1.00	0.13
12	bot/ uk	1.93	6.50	6.00	24.70	1.18	0.37	0.15	0.06	NA	0.77	4.37	5.59	3.79
13	bot/ ns	4.00	8.00	8.00	31.30	4.42	1.29	0.30	0.12	NA	1.19	4.54	2.69	5.65
15	bot/ uk	4.20	9.60	20.00	47.70	3.06	0.85	0.82	2.11	15.00	1.37	2.87	2.60	4.50

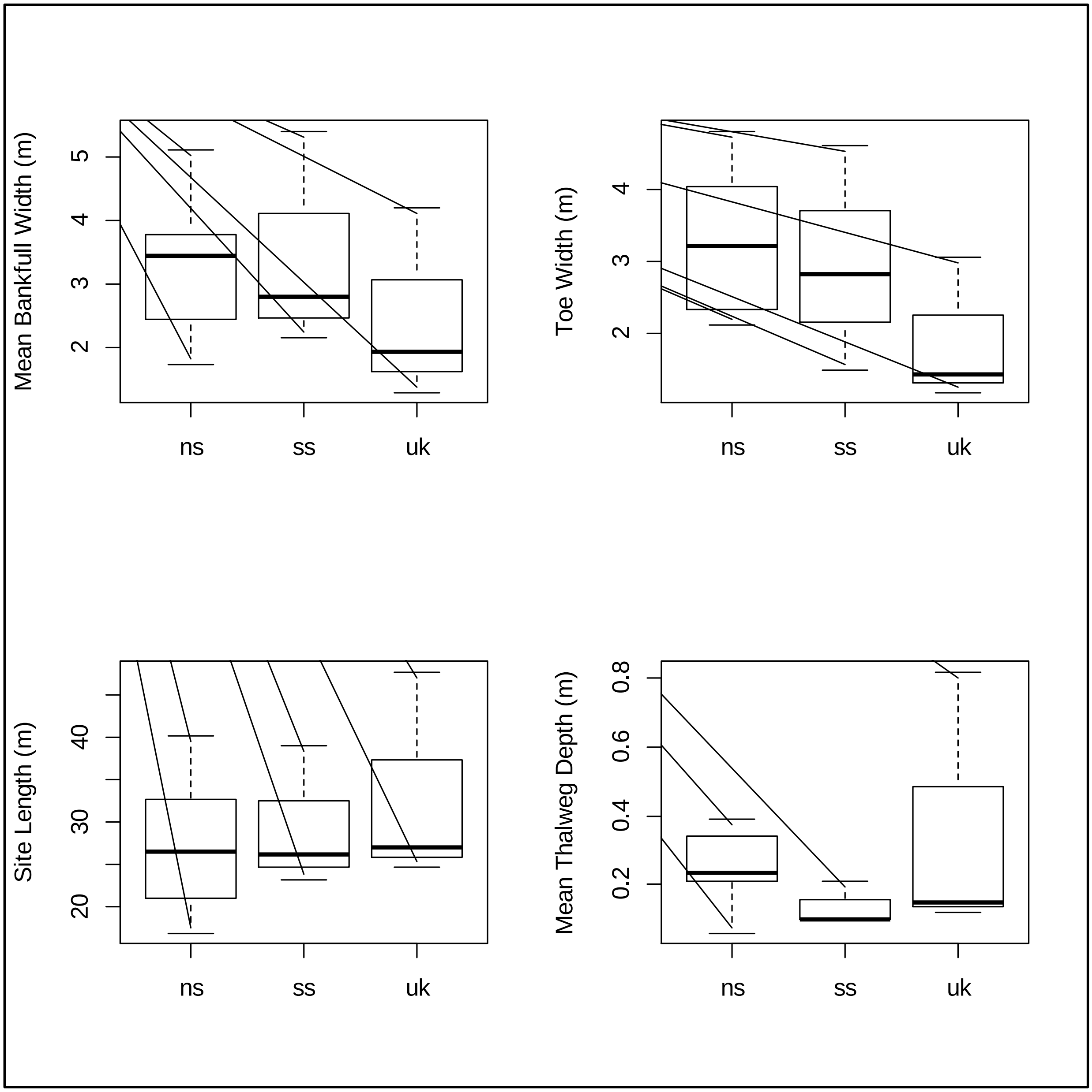


Figure 2-2. Boxplots of mean bankfull width, toe width, mean thalweg depth, and site length at 14 culverts measured in 2013. NS, SS, and UK are abbreviations for no-slope, stream simulation, and unknown culvert design, respectively. Center line is the median, bottom and top edges of box denote the 1st and 3rd quartiles, respectively, and whiskers represent the minimum and maximum values.

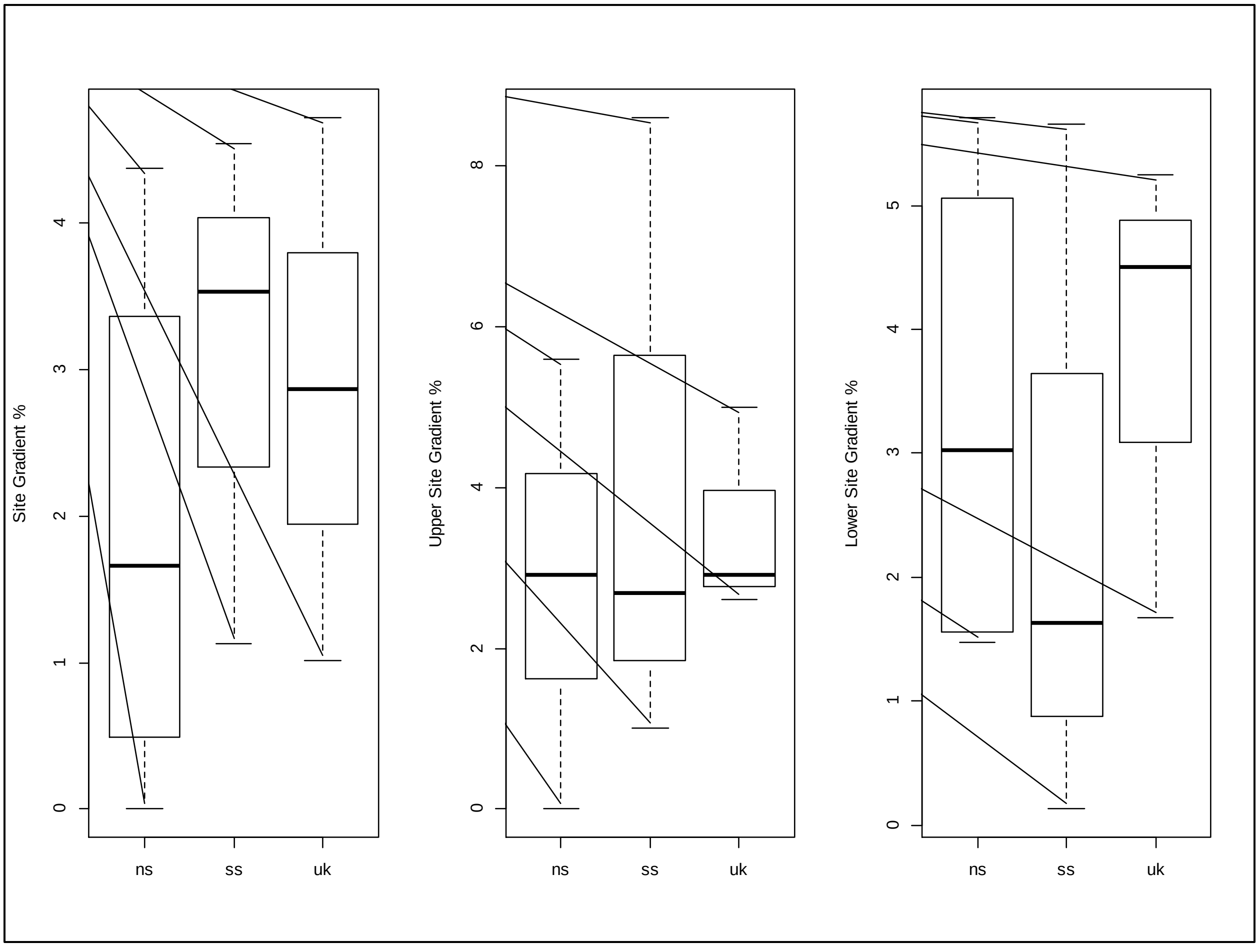


Figure 2-3. Boxplots of overall channel gradient, gradient upstream of the structure (upper channel gradient) and downstream of the structure (lower channel gradient) at 14 culverts measured in 2013. NS, SS, and UK are abbreviations for no-slope, stream simulation, and unknown culvert design, respectively. Center line is the median, bottom and top edges of box denote the 1st and 3rd quartiles, respectively, and whiskers represent the minimum and maximum values.

Discussion

Implementation Monitoring

For the purpose of process improvement, the most important findings from implementation monitoring in 2013 are related to the measurement of channel width. The most important parameter for culvert design is channel width (Barnard et al. 2013), and yet information on channel width was absent from roughly half of 54 HPA permits that we reviewed, including the associated plans or engineering drawings. WDFW's operational definition of channel width is bankfull width, and yet only 20% of permittees reported a bankfull width estimate for their project site. From plans and other supporting documents, we found that many permittees were measuring "stream width", "stream size", "streambed width", "channel bed width", "width at ordinary high water mark", and something called "top channel width." This confusion may be due in part to the mismatch between language in the hydraulic code rule (WAC 220-110-070(3)(b)(i)) and common permit provisions which use the term "streambed width" and WDFW's operational definition for streambed width which is "bankfull width."

We also found that even when permittees explicitly reported a BFW estimate, 80% of the time their estimate was narrower than our estimate and it was about 22% narrower, on average. The difference between our BFW estimate and the permittee's estimate may be due to the lack of a widely accepted, standard procedure for estimating mean BFW. In other words, WDFW and some permittees use different methods for estimating mean BFW, and different methods lead to different estimates. Apparently many permittees do not know what they should be measuring or how they should be measuring it. WDFW might eliminate much of this confusion through exclusive use of the term "bankfull width" when referring to channel or streambed width and by developing a standard procedure for estimating mean BFW.

The lack of a widely accepted, standard procedure for estimating mean BFW may also affect the reliability of implementation monitoring. That is, estimates of mean BFW by WDFW technicians engaged in implementation monitoring of culverts may be too wide, and therefore, accordance rates found through implementation monitoring may underestimate actual accordance rates.

The accordance rate for no-slope culverts was 47% (N=19) when we used our channel width measurement but 80% (N=10) when we used the permittees' channel width measurement. Our sensitivity analysis (Figure 2-1) showed that if our estimates of BFW were mistakenly 20% too wide, then the accordance rate for stream simulation culverts changes dramatically from 27% to 73%. Also, we observed that even among staff in WDFW there could be significant disagreement about estimates of mean BFW. Therefore, based on these observations and because a standard procedure for estimating mean BFW does not exist at this time, we question the reliability of accordance rates for culverts in 2013. We do not have the same concern about the calculation of compliance rates.

Our second most important finding was that a significant proportion of HPA permits lacked information that is necessary for construction of an accordant hydraulic structure and enforcement of the hydraulic code rules. We assessed 53 culverts for permit compliance. Specifications for all four critical structural dimensions could be obtained from 45 HPA permits or from the plans referred to by permit provisions. This includes permits where specifications were obtained by manually measuring culvert dimensions on plans, which was necessary for about three permits. For eight permits (15%), specifications for at least one critical structural dimension could not be obtained. If we include the three permits that required manual measurements from plans, then 21% of permits lacked a specification for at least one critical structural dimension. For all eight permits the missing information was culvert width at the streambed. Six of these eight permits were for no-slope culverts and specified that the culvert's width at the streambed must be equal to "streambed width", but neither culvert width at the streambed nor the streambed's width was described in the culvert's plans.

For the purposes of process improvement, our third most important finding was the considerable difficulty in locating information essential to the HPA permitting process. Basic information such as culvert design type was missing or difficult to find. Design type could not be found for at least 17% of approved culverts. Difficulties with channel width information are explained above. Channel slope is also essential for determining the appropriate culvert design, but we found that information on channel slope was either absent or difficult to ascertain on permits, plans, or other supporting documentation. Values for critical structural dimensions of a culvert, such as countersink depth at outlet, might be obtained from plans or engineering drawings but were difficult to locate amongst the many pages of plans and supporting documentation. Original engineering drawings are either 11 inches x 17 inches or 22 inches x 34 inches, but the drawings attached to HPA permits are usually 8.5 inches x 11 inches – a 50% or 87% reduction in size, respectively. This size reduction plus the loss of fidelity after scanning and printing make the drawings difficult to interpret. In addition, every engineering firm (maybe every engineer) seems to do drawings differently, and some are not drawn to scale. Consequently, we had to re-decipher nearly every set of drawings. In some cases the only way to obtain channel or culvert dimensions was to manually measure them on the plans or engineering drawings. These difficulties greatly reduced the efficiency of our monitoring efforts, and we suspect these same difficulties must plague habitat biologists as well. Therefore, for the purposes of permitting, rule enforcement, and monitoring, key information – such as bankfull width, channel slope, culvert design type, and culvert dimensions – should be reported and easy to find.

The permittee compliance rate was 76% (N=45) and 50% of 40 culverts were not constructed in accordance with the hydraulic code rules or design guidelines. Therefore, in effect, we found that permittee compliance with an HPA permit does not necessarily result in hydraulic structure accordance with the hydraulic code rules or design guidelines. Our monitoring results revealed a large discrepancy between the permittee compliance rate and the accordance rate (76% vs. 50%). This occurs when a permittee complies with his/her permit but that permit is not in accordance with the hydraulic code rules or culvert design guidelines. Accordance with the rules and guidelines is the responsibility of the habitat biologists issuing the permit. We found that the culvert width at streambed for many no-slope and stream simulation culverts complied with the permit but was not in accordance with rules or guidelines, respectively. The size of this discrepancy may be largely due to different methods for estimating channel or streambed width as described above

We must reiterate that due to difficulties in finding completed culverts and obtaining permission to access private property, our sampling scheme does not allow valid inferences to the larger population of all culverts completed in 2013. Therefore, the results for 2013 describe only the 54 culverts we visited. Compliance and accordance rates for all culverts completed in 2013 could be very different. Furthermore, our "sample" suffers from pseudo-replication. Our 54 culverts corresponded to 45 HPA permits because eight HPAs covered more than one culvert. Therefore, seven pairs and one trio of culverts were designed and constructed by the same people and permitted by the same habitat biologist. This may bias the results, and it did slightly. If we eliminate pseudo-replication by using just one culvert per permit than the permittee compliance rate is 71%.

We did not conduct an in-depth evaluation of HPA permits, but we did tabulate the number specific provisions for each critical structural dimension. We found that permit provisions exhibited both consistent and inconsistent qualities. All permits that we examined included a provision similar to "work shall be accomplished per plans and specifications approved by the Washington Department of Fish and Wildlife" and nearly all permits included the clause "except as modified by this hydraulic project approval." Provisions for culvert width at streambed, culvert slope, minimum countersink, maximum countersink, and culvert length were included in 72, 54, 60, 15, and 38 percent of permits, respectively. This apparent inconsistency across structural dimensions raises a number of questions. First, what circumstances lead habitat biologists to include or exclude provisions for structural dimensions? Second, will including specific provisions for structural dimensions lead to better results, i.e., does including more provisions result in better compliance or accordance rates? The first year of implementation monitoring indicated the answer is no (Table 2-3). Third, if including specific provisions for structural dimensions does not result in better compliance rates, then is consistency, both across permits and across structural dimensions, in including certain provisions desirable for some other reason?

We encountered three common problems with the language of permit provisions (Table 2-9). First, culvert width was specified in terms of "width of the streambed." This language conflicts with WDFW's operational definition of streambed width which is BFW. Second, we found several permits for no-slope culverts with a provision stating that the maximum allowed culvert slope (or gradient) was 3%. Barnard et al. (2013) says, "Culverts installed at greater than 2% slope should be considered noncompliant and reset at zero grade." Third, we found several permits for bottomless culverts with a provision stating that the footings should be equal to or greater than the average width of the streambed. Footings are countersunk into the streambed, and therefore, when the culvert is arched, as some were, the culvert width at the streambed is narrower than the streambed.

An important question, but one incompletely addressed in year one, is whether the culvert design was appropriate for the site. According to the most recent design guidelines (Barnard et al. 2013), the main factors determining the appropriate design type are channel slope, channel width, and road bed width (which influences culvert length). However, Bates et al. (2003), which are the guidelines ostensibly used for designing the culverts we monitored, do not provide guidance for these site factors. We can, nevertheless, compare our culverts to values given by Barnard et al. (2013). In year one, we did not measure channel slope for implementation monitoring, and hence cannot report on this factor (we will in future years). We did measure bankfull width, and according to Barnard et al. no-slope culverts are generally appropriate for streams with bankfull width less than 10 ft (3.05 m). Four of 19 no-slope culverts were on stream channels greater than 10 ft wide. Two were on channels only slightly wider than the recommendation, 11.1 and 11.6 ft, but two were on channels slightly more than 20 ft wide.

Effectiveness Monitoring

Because we have not yet collected data over multiple years there is little that can be said about the effectiveness of culverts. The prevailing assumption is that new culverts complying with the HPA permit effectively achieve the desired condition: "no-net-loss of productive capacity of fish and shellfish habitat." The main purpose of effectiveness monitoring is to test that assumption. However, as discussed in Wilhere et al. (2014), measuring no net loss of fish habitat is technically challenging, and consequently, we may not reach any conclusions about culvert effectiveness for some time. In year one we were able to determine that 83% of the new culverts we monitored passed the Level A fish passage barrier assessment. In the future we will also conduct the Level B barrier assessment.

Prerequisites for scientifically-sound effectiveness monitoring are scientifically-defensible criteria for determining effectiveness. The Level A and Level B fish passage barrier assessments (WDFW 2009) address the effectiveness of fish passage over time. When applying these barrier assessments for effectiveness monitoring, a question arose regarding the origins of their passability criteria. One of the passability criteria of the Level A assessment is culvert span equal to or greater than 75% of channel width, where channel width is defined as bankfull width. The 75% was based on professional opinions of engineers and biologists. Their rationale was never documented, however, one participant recalls that 75% of channel width was chosen because it is mid-way between 50% and 100% of channel width (P. Powers, former WDFW engineer, personal communication). The scientific defensibility of the 75% value is questionable, and therefore, it should be reconsidered. We also learned that the use of "culvert span" rather than "culvert width at streambed" (the width dimension specified in no-slope and stream simulation culvert designs) is apparently a mistake that has never been corrected (M. Barber, WSDOT, personal communication). Level B passability criteria are based on flow velocities and depths that would obstruct the movement of a 6 inch long trout. These flow velocities, which are also in the current hydraulic code rules, were the professional opinion of a fish biologist in 1985 (K. Bates, former WDFW engineer, personal communication). The rationale for this opinion was never documented, and hence, its scientific credibility is questionable. However, the Level B flow velocities have been partly substantiated by recently collected empirical data. Peterson et al. (2013) estimated, using a culvert test bed, that about 80% of cutthroat trout (*Oncorhynchus clarkii clarkii*), most of which were less than 6 inches long, can successfully pass through a 40 ft culvert at flow velocities of 4 feet/sec or less. In the Level B passability criteria, 4 feet/sec is the maximum velocity allowed for a 40 ft culvert. By using the Level B passability criteria we are in effect saying that an 80% passage rate is satisfactory. Peterson et al. (2013) had only one culvert length in their study. The scientific basis for the Level B passability criteria should be reviewed for longer culvert lengths as well.

Our year-one results from effectiveness monitoring suggest either channel slopes measured by HPA applicants were inaccurate or culvert design guidelines were ignored. According to our measurements, five of the six no-slope culverts monitored for effectiveness had upstream or downstream channel gradients greater than 3%. Bates et al. (2003) recommends no-slope culverts for sites with channel gradients less than 3%. The channel gradients greater than 3%, however, were possibly due to measurement error caused by the short length of stream measured (two to three BFWs).

The relatively short channel sections measured for effectiveness monitoring may be inadequate for detecting changes in channel morphology, including channel gradient. That is, our measurements probably will not indicate changes in channel morphology just upstream and downstream of the culvert, such as depositional bars and scour pools, respectively. Therefore, our channel survey methods should be reconsidered before more data are collected.

Small sample sizes for each culvert design type preclude reliable comparisons among designs, but results were presented separately to allow easy assessment and to demonstrate what is possible with the data that are being collected. The relatively narrow stream widths suggests that improved measurement accuracy and precision could be achieved through improved methods (e.g., number and spatial allocation of measurements) and training to consistently use those methods, rather than through the application of new tools. High similarity between mean bankfull width and mean toe width suggests that either measure might prove useful, but we suggest consistent use of bankfull width measurements because they are needed by many engineering and stream dynamics models. Thalweg measurements were variable within and among sites, suggesting that additional measurements are likely to improve the reliability of our monitoring, especially because the thalweg is used to estimate stream gradient.

Perhaps most importantly, our preliminary analyses emphasized the need for a project database and data quality assurance methods. The relatively simple effectiveness monitoring measurements collected at only fifteen locations during a single year resulted in a dataset with more than 30 columns and 1,900 rows of data, each of which must be indexed appropriately and consistently to allow for reliable analysis. A decision to change the analysis from simply describing all samples to describing samples by design type required four days to implement, including one day to attempt to find and correct data entry errors that would not be possible if a database were used.

Management Recommendations

The first year of implementation and effectiveness monitoring of culverts leads us to make the following recommendations for improving the HPA permitting process:

- Language referring to stream channel width should be identical in hydraulic code rules, permit provisions, and culvert design guidelines

- Standard procedures for estimating mean bankfull width and channel slope should be developed by WDFW and widely distributed for use by HPA applicants.
- Key information – such as bankfull width, channel slope, culvert design type, and culvert dimensions – should be reported and easy to find. We recommend a mandatory form for all HPA applications to be completed by the applicant.
- Bankfull width measurements on fish-bearing streams submitted by HPA applicants should be checked by WDFW or some other credible organization.
- For no-slope culverts, channel slope submitted by HPA applicants should be checked by WDFW or some other credible organization.
- Standard permit provisions for culverts used by WDFW habitat biologists should be reviewed for consistency with hydraulic code rules and design guidelines.

And, we make the following recommendations for improving culvert implementation and effectiveness monitoring:

- All permittees should be required to notify WDFW when culvert construction is complete.
- The scientific rationale for Level A and Level B passability criteria used in fish passage barrier assessments should be reviewed and documented. This could begin with a review of the relevant scientific literature that has accumulated since 1985.
- Channel survey methods should be redesigned to attain greater accuracy and sensitivity.

Table 2-9. Problematic HPA permit provisions found on more than 1 permit.

Design Type	Permit Language	Comment
no slope	provision says, "The culvert width at the streambed shall be equal to or greater than the average width of the streambed."	The language of this provision does not specify the correct channel width parameter. WDFW wants culvert width at bed to be equal to bank full width not "width of the streambed." This provision was used often in permits for no-slope culverts because it follows the language in WAC 220-110-070(3)(b)(i)).
	provision says, "culvert shall be placed on a maximum 3% gradient"	No slope culverts should be placed on a flat gradient (0%) gradient. This provision allows too much tolerance for construction error. The design guidelines (Barnard et al. 2013) say culverts installed at greater than 2% slope should be considered out of compliance and reset at 0% slope.
bottomless	provision says, "The width between the culvert footings for a bottomless culvert shall be equal to or greater than the average width of the streambed."	The language of this provision does not specify the correct channel width parameter. WDFW wants culvert width at bed to be equal to bankfull width not "width of the streambed." This provision was used often in permits for bottomless culverts.
		Distance between footings equals width of streambed, however, culvert is arched with about 30% countersink. Therefore, culvert width at streambed is less than width of streambed. The same language regarding culvert footings appears in WAC 220-110-070(3)(b)(i).
stream simulation	provision says, "Culvert will be installed as per plan in a manner consistent with the stream simulation method . . ."	This language assumes the permittee understands all aspects of the stream simulation design method and may lack level of specificity required for rule enforcement.
		The words "in a manner consistent with" are vague.
All	Project description or provisions on HPA permit do not state culvert design type.	No culvert design type on permit was typical rather than the exception. If design type were stipulated in permit provisions, then compliance inspections and implementation monitoring would be more efficient and accurate.

Part 3. Implementation and Effectiveness Monitoring of Marine Shoreline Armoring

Introduction

This report serves as a preliminary summary of results and description of challenges identified during work completed in 2013 to assess the implementation and effectiveness of HPA permits issued for marine shoreline armoring. All the HPA projects that we assessed were in Kitsap and San Juan Counties as the work was primarily funded through a grant provided to these counties to assess the shoreline armoring permitting process. Cooperation from county staff, WDFW habitat biologists, and HPMS database managers has been essential to helping science staff to access and interpret HPA documents.

Throughout the process of assessing the permitting process, we have encountered elements that have presented unforeseen challenges to our ability to effectively or efficiently complete this task. Recognizing that our ability to document improvement in the permitting process relies on our ability to effectively assess the quality and outcomes of the service we provide, we have made an effort to document these challenges.

Methods

Permit and Survey Site Selection. For our initial site selection, Kitsap and San Juan counties provided us with a list of 67 and 82 marine shoreline armoring projects, respectively. This list represented all permitted marine shoreline armoring projects identified by each county from 2007 (Kitsap County) and 2006 (San Juan County) to April of 2013. We used name and address information provided from the county databases to search HPMS for the HPA permit records that corresponded to these permits. If no corresponding results were identified in HPMS, we then attempted to find the permit in archived HPA records. Once HPA records, such as the HPA, JARPA, and project plans were obtained, we reviewed project descriptions to ensure that they corresponded with the expected armoring project. Any permits that did not match were removed from the project list.

Of the 149 records provided to us by the counties, we were able to match 114 to an HPA. Eight HPAs were discarded because the permit was not yet finalized, or it was not a relevant project type, leaving 106 HPA permits to assess. From these 106 permits, selection for onsite surveys in 2013 was ultimately determined by our ability to make contact with and acquire permission from property owner to access project sites.

Data Compilation/Permit Review. Many of the HPA records were in the form of PDF files. Once we obtained the permit materials and matched it to the project, we had to transfer information from the permit and project plans to Microsoft Excel spreadsheets so that we could more easily access, review, and summarize the information. Each project was categorized as follows: 1) new armoring or an extension of existing armoring, 2) repair of existing armoring, or 3) replacement of existing armoring. Both repair and replacement activities were limited to the preexisting footprint. We also noted whether “hard” or “soft” armor would be used, or some combination of both (hybrid), and what material was to be used to build the structure. For field surveys of shoreline armoring projects, the measurements we focused on recording from the HPA documents were the length of the armoring and the water ward extent of the armoring. We selected length and water ward extent of armoring as key measurements based on our assumption that the longer and farther water ward the armoring, the greater the potential impact to fish and habitat. We also recorded other measurements, such as armor height.

While compiling measurements from HPA documents, we assumed information in the HPA itself provided the most accurate and up to date information (rather than the JARPA or other documents). This approach was taken to help reconcile differences we observed between the HPA permit, JARPA, the applicant's proposal or the permittee's final plans. For example, if the JARPA and plans indicate that a structure will be 200 feet long, but the HPA states that the structure will be 150 feet long, then we assumed 150 feet as the approved length, however, if the HPA makes no mention of length, then we assumed 200 feet is the approved length.

HPA conditions or provisions often specify how, when, or where a project may be completed, and what actions the project proponent may or may not need to take before, during, and after the project. We found that permits often contain dozens of provisions, most of which cannot be measured quantitatively or even observed post construction. Rather than recording all of the conditions in a permit, we focused on protective or mitigation provisions and noting when these provisions were present or absent from a permit so that we can better understand under what circumstances these provisions are applied. Such provisions include work time windows for salmon and/or forage fish, beach nourishment requirements, and re-vegetation requirements.

Implementation Surveys. Using the information compiled while reviewing permits, we created a data sheet noting information such as GPS coordinates and parcel address to help us to identify the site while in the field, and a list of measurable and observable permit conditions for each site. Once field measurements were recorded, the list was used to identify and note whether observable provisions recorded from the permit, such as armoring material, match what is observed at the site. For measurable provisions, such as structure length, water ward extent, height, or elevation, measurements were taken using a tape measure, stadia rod and laser level, or high resolution GPS unit (Trimble Geo XH 6000 Centimeter Edition).

Effectiveness Surveys. We conducted pre-construction surveys at project sites whenever possible. Surveys included beach profiles, log line and wrack line surveys, forage fish surveys, and sediment sampling. Whenever practicable, we located a reference site to be paired with each project site. Where possible the reference site was located in the up-drift zone of the same drift cell, was unarmored, and possessed beach profile and sediments similar to the project site. We surveyed both the project site and reference site. Survey methods for beach profiles, log line surveys, and wrack surveys are described in greater detail in the Quality Assurance Project Plan we prepared for Puget Sound Marine and Nearshore Protection and Restoration Grant (Dionne et al. 2013). These methods were adapted from methods described by McBride et al. (2012) for quantifying the effects of shoreline armoring on nearshore ecology.

Beach profiles were taken using a tape measure, stadia rod, and laser level, or a GPS unit. The locations of where habitat elements such as the wrack line and log line crossed the profile were noted.

Log line surveys included drift wood recruited from the sea and fallen trees recruited from the bluff. For trees recruited from the bluff, trees that clearly recruited from the adjacent uplands (with roots) were counted; trees that were clearly cut and placed or dropped from the edge of the bank are not counted. The general orientation of the fallen logs was recorded (parallel, perpendicular to the shoreline). For drift wood, at five points along a 50m transect perpendicular to the shoreline we measured the width of the log line (perpendicular to the shoreline), counted the number of logs intersecting the transect, and recorded their size: large (> 2 m length) or small (< 2 m length).

Using the same transect and random points used for the log line survey, we measured the width and percent cover of wrack material under a quadrat using a 1 m^2 quadrat. Wrack included all organic matter.

The forage fish survey evaluated presence, relative abundance, and condition of eggs. Surveys consisted of sampling the surface layer of beach substrate for surf smelt and sand lance eggs based on Moulton and Penttila (2001) to document presence/absence and quantify proportions of embryo condition (live/dead). The samples were labeled with collection site and date, and stored in a cool place for no more than 48 hours before they were processed or preserved in either Stockard's Solution in 16 oz. sample jars. Portions of each sample were dispensed into counting dishes winnowed and examined under a dissecting microscope following the methods pf Moulton and Penttila (2001).

A sediment sample was collected at mean high water using a frequency-by-weight bulk sampling method. In this method, a volume of material is excavated from the beach and sieved into half-phi size classes. Each size class is then weighed and frequency distributions developed. The frequency-by-weight sampling method requires a volume of material based on the largest mobile particle on the surface. The sampling volume must be large enough that the largest particle is less than 1% of the sample by weight to obtain significant results (Church et al. 1987). The surface area covered by the sample is approximate and depends on the type of sediment. The coarser the sediment, the larger the sample size: approximately 5 x 10 cm for sand, 10 x 15 cm for pebble, 20 x 20 cm for cobble. This method best represents the low % of coarse sediments in the overall sample. Quantitative grain size analysis in the laboratory involves sieving dry sediments through progressively finer sieves and weighing the amount retained in each sieve. Preliminary results are presented as the percent by weight of sediment in each size class.

Preliminary Results

Data analysis and collection is ongoing. Analysis of data collected during 2013, and during follow up surveys in 2014 is expected to be completed by March of 2015.

Data Compilation/Permit Review. In 2013 we reviewed 106 marine shoreline armoring permits. Of the 106 permits reviewed, 31% (26 permits) were new/extension projects, 49% (46) were replacement projects, and 20% (21) were repair projects (Table 3-1). All permits noted the construction material to be used for the project; the majority 93 (88%) of projects used primarily hard armoring, and 8% (9) and 4% (4) used soft armoring or a combination of hard and soft armoring respectively.

Table 3-1. Summary of marine shoreline armor permit types reviewed in 2013.

Armor	New/Extension	Replacement	Repair	*Total*
Hard	26	46	21	93
Soft	6	3	0	9
Hybrid	1	3	0	4
Total	33	52	21	106

Specific measurements such as the project length were often not stated in the permit, rather, the plans were reviewed and sometimes measured to extract such details. We found that 38% of permits or JARPAs did not record project length in text[6]. While nearly all permits, 99% (105), provided some measure of the maximum water ward extent of armoring; of 26 hard armor new/extension permits, only

[6] In many cases, the forward extent of a bulkhead can be measured by using the plans, when provided, and manually measuring distances on the plans. When possible we try to avoid relying on such measurements because they are often time consuming, and subject to additional measurement errors. Additionally, the plans may be difficult to read and interpret, and elements in some plans have been found to be miss-labeled or do not match the project description. Due to the additional time and effort required to obtain these measurements from the plans, we have until recently only taken measurements from plans for those projects that we were able to arrange site visits.

12% (3) referenced the distance to a structure that could be considered permanent (e.g., house corner). The distance to a point that could be altered or made difficult to access by the project activities, such as the distance to the OHWL, MHHWL, or the toe of the bank was referenced for the remaining 23 hard armor new/extension permits.

Habitat protection and mitigation conditions that were of interest or appeared frequently in permits included whether beach nourishment or re-vegetation were required, whether the conditions stated construction waste must be removed and depression on the beach caused by construction had to be filled, and weather there were timing restrictions on when work could occur to protect salmon, herring, or beach spawning forage fish. Beach nourishment was required in 53% (56) of permits, re-vegetation was required in 42% (45) of permits, waste removal was required in 100% (106) of permits, and filling depressions caused by construction activity was required in 96% (102) of permits. All permits stated a time frame for when work could occur, and 98% (104) specified that the time frame was related to protection of salmon, herring, or beach spawning forage fish. Timing restricts for salmon were included in 98% (104) of permits, for herring in 12% (13) of permits, and for beach spawning forage fish in 25% (27) of permits. Of the 27 permits that set timing restrictions for beach spawning forage fish, 78% (21) also required beach nourishment, and 56% (15) required re-vegetation.

Implementation Surveys. In 2013 we surveyed 13 project sites (Figure 3-1). Of these sites, 10 were post construction surveys and three were pre construction surveys. Implementation surveys focused on comparing field measurements to permit provisions. The results of this comparison are presented in Table 3-2. Discrepancies between permit specifications and field measures are noted by gray highlighted cells. Since our assumption is that structures that are longer, taller, and or extend further water ward pose a potentially greater risk to fish and habitats, we only highlighted instances where the survey measurement was greater than the permit specified, and if a value was provided in the permit, then the survey value had to also be at least 5% greater than the permit value to allow for potential measurement error. If an elevation was qualitative, e.g., “landward of MHHW”, then the 5% error tolerance was not applied. When a permit referenced more than one qualitative elevation (e.g., OHWL, MHHW, toe of bank, etc.), we checked the water ward location of the structure relative to all elevations referenced.

Based on these measurements, nine of ten projects surveyed post construction had at least one measurement that was greater than indicated in the permit. Half of the projects were longer than indicated in the permit, 30% were taller, and 60% were further water ward relative to at least one reference elevation.

Effectiveness Surveys. Of the 13 sites surveyed, three were surveyed prior to the construction of new armoring. Additional data not included in this report were collected at these sites. The data includes beach profiles, log and wrack line surveys, and forage fish surveys. These surveys will be repeated post construction at these sites in addition to implementation surveys and reported in future annual reports.

In addition to the 13 project sites we surveyed in 2013, we also identified and surveyed two potential reference sites, and completed an effectiveness survey at the closest project site to each reference site. Analysis of effectiveness surveys is ongoing. Preliminary results of beach profile and sediment size comparison between neighboring armored and unarmored sites is represented in Figures 3-2 and 3-3.

Discussion

While the majority (9 of 10) of projects surveyed post construction had at least one structural dimension that was larger than the permitted dimension, because of the uncertainty associated with some of these measurements, it is unlikely that all nine failed to implement the project as permitted. Therefore, we cannot confidently state a compliance rate for the marine shoreline armoring projects that we monitored in 2013. This high degree of uncertainty mainly stemmed from difficulties identifying and translating the measurements provided by plans and permits that were made in reference to conditions described pre-construction to the conditions encountered post-construction. For example if a permit specifies that "*the bulkhead will extend no further water ward than 6 feet from the toe of the bank, and will tie into adjacent bulkheads on either side*", it becomes very difficult to accurately determine the distance to the toe of the bluff or the start and end point after the bulkhead has been installed.

Preliminary impressions from permit reviews indicate that some permit conditions are almost ubiquitous in marine shoreline armoring permits. Such conditions may be good candidates for including in all marine shoreline permits as standard text.

Areas that have proven to be most challenging from the perspective of implementation monitoring have mostly related to the lack of, or difficulty in identifying and interpreting information in the documents provided in the permit application or the permit. The quality and detail of plans is highly variable, and a great deal of time and effort would be saved, and uncertainty would be reduced if the maximum length and water ward extent of a structure was stated clearly on the permit application or the approved permit, and also if a stable reference point from which to measure these was identified in the application or the permit. Additionally, since OHWL can be variable on a beach and the MHHW changes regionally, stating the elevation of both measures and what tidal station or bench mark was used as a reference would also help to ensure that implementation measures are taken using similar datum.

Continuing implementation and effectiveness monitoring work will include assessment of beach spawning forage fish timing conditions, beach nourishment conditions, and the project distance to documented spawning beaches. We have also begun to utilize the risk assessment criteria provided in the newly released Marine Shoreline Design Guidelines (MSDG) to assess whether permitted projects utilize armoring techniques recommended by the MSDG risk assessment criteria.

To improve our ability to assess projects in the future, we will refine our methods for implementation and effectiveness monitoring. Monitoring staff will work with habitat biologists to identify new marine armoring projects before they are constructed so that they can conduct more pre construction surveys. By conducting pre construction surveys, we will have more complete data on conditions prior to construction, making assessments of the results of the project simpler. Conducting more pre construction surveys will also give us the ability to identify and survey more potential effectiveness monitoring sites.

The first year of implementation and effectiveness monitoring of marine shoreline armoring leads us to make the following recommendations for improving the HPA permitting process:

- Key information – such as bulkhead length, bulkhead height, bulkhead design type – should be reported and easy to find. We recommend a mandatory form for all HPA applications to be completed by the applicant. This would presumably save time for both Habitat Biologists tasked with reviewing new permit applications and staff tasked with assessing implementation of the project.
- The location of the ends and water ward extent of marine shoreline armoring should be described in HPA applications with respect to engineering benchmarks or permanent structures in the upland that will not change over time.

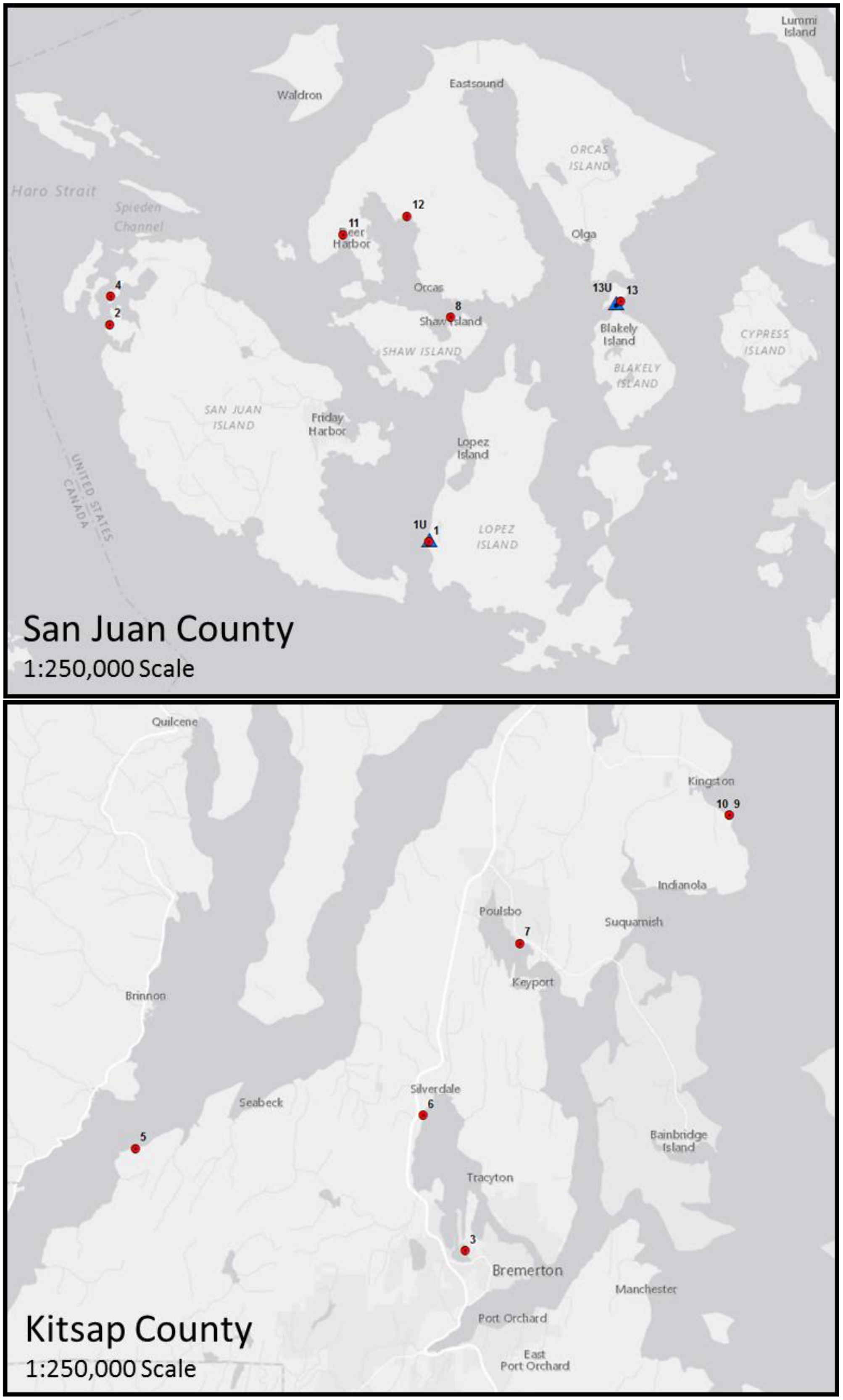


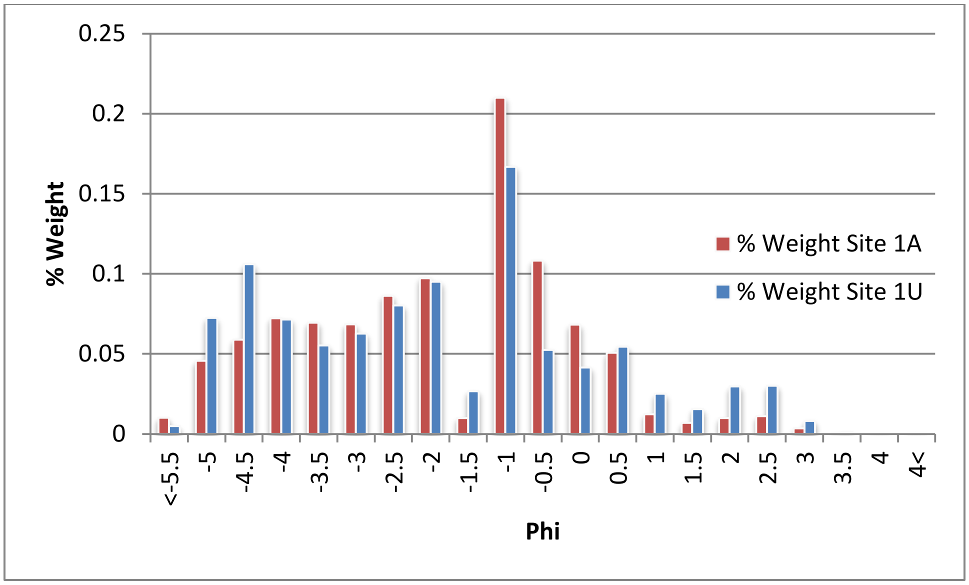
Figure 3-1: Maps of 2013 survey sites. Red circles indicate HPA project sites and blue triangles indicate unarmored reference sites.

Table 3-2. Comparison of measurements recorded in permit document or plans and measurements recorded in field. Cells are highlighted in gray where there is a discrepancy between the permit and field measurement; i.e. the structure is measured to be either longer, taller, and/or further water ward than stated in the permit documents (*only discrepancies greater than 5% of permit measurement are highlighted*). Some discrepancies may be due to changes to the shoreline occurring between the original measurement and our subsequent measurements. Some discrepancies in length measurements are likely the result of difficulty in identifying the project end points. Note that sites 2, 3, and 4 were pre-construction surveys only.

Site Information					Armor Dimensions				Water Ward Extent of Armor					
					Length (ft.)		Max Height (ft.)		Relative to OHWL		Relative to MHHWL		Other	
Site #	County	Type	Time Frame	Material	Permit	Field	Permit	Field	Permit	Field***	Permit	Field***	Permit	Field***
1	San Juan	New	Post Construction	LWD & boulders	400	429.79*	NA	6.89	-	-	-	+	6ft from toe of bank	11.55ft from toe of bank
2	San Juan	New	Pre Construction	Rock	30	NA	5	NA	=/+	NA	+	NA	6ft from toe of bank	NA
3	Kitsap	New	Pre Construction	Rock	330	NA	5	NA	=/+/-3ft	NA	NA	NA	NA	NA
4	San Juan	New	Pre Construction	Geo-textile	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	Kitsap	Replacement	Post Construction	Rock	108	167*	8	5.58	NA	=/+	NA	=/+	inline w/ adjacent armor	inline w/ adjacent armor
6	Kitsap	Replacement	Post Construction	Rock	45	24.85*	8	8.75	+	=	+	=/+	9ft land ward of existing armor	9.35ft land ward of existing armor
7	Kitsap	Replacement	Post Construction	Rock	115	122.38	6	4.9	-	-	-	-	18 ft. from road	17.06ft from road
8	San Juan	Replacement	Post Construction	Concrete	71	73.2	5	7.41	=	=/-	+	+	10ft elevation	9.2ft +/-4" elevation
9	Kitsap	Replacement	Post Construction	Rock	60	58.72*	7	5.58	=	=/-	=	=/-	70ft forward of deck	**80.97ft forward of deck
10	Kitsap	Replacement	Post Construction	Rock	60	95.8*	10	8.56	-	=/-	-	=/-	54ft forward of house	**54.46ft forward of house
11	San Juan	Repair	Post Construction	Rock	NA	45.28*	NA	NA	-6ft	=	NA	=	NA	NA
12	San Juan	Repair	Post Construction	Rock	165	160.8**	11.5	6.89	-	-	+	=/+	NA	NA
13	San Juan	Repair	Post Construction	Rock	150	173.56	4	4.79	NA	=	NA	+	6ft from toe of bank	6.4ft from toe of bluff

Gray cells indicates unfavorable discrepancy between measures
****Post construction distance relative to OHWL, MHHWL, and toe of bank may differ from pre construction measures do to construction activities or natural processes.*
***Linear geodesic measure*
**Unable to confirm project start and end point to confirm length.*

"-" is water ward of reference.
"+" is land ward of reference.
"=" is at the reference.
"NA" indicates that the measurement was not provided or recodred.



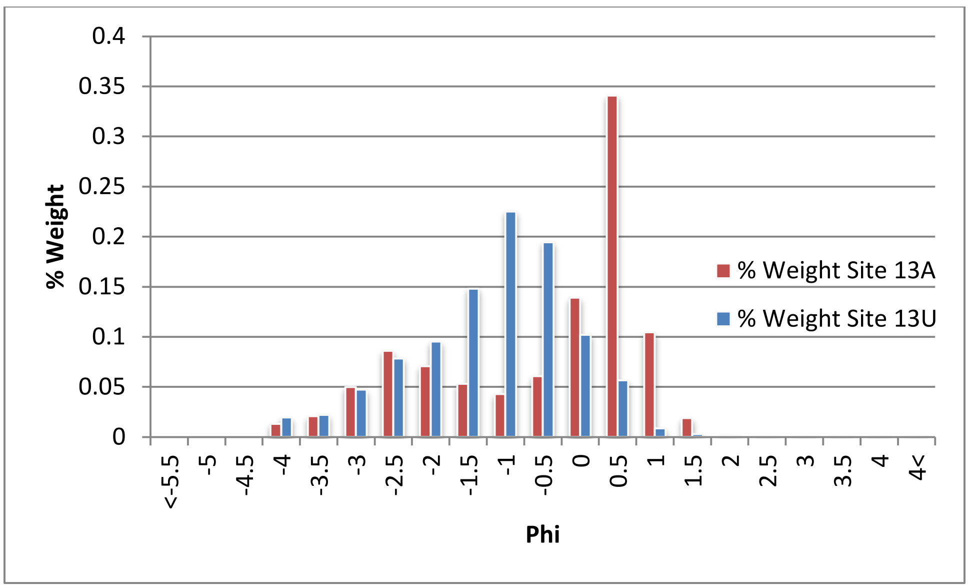
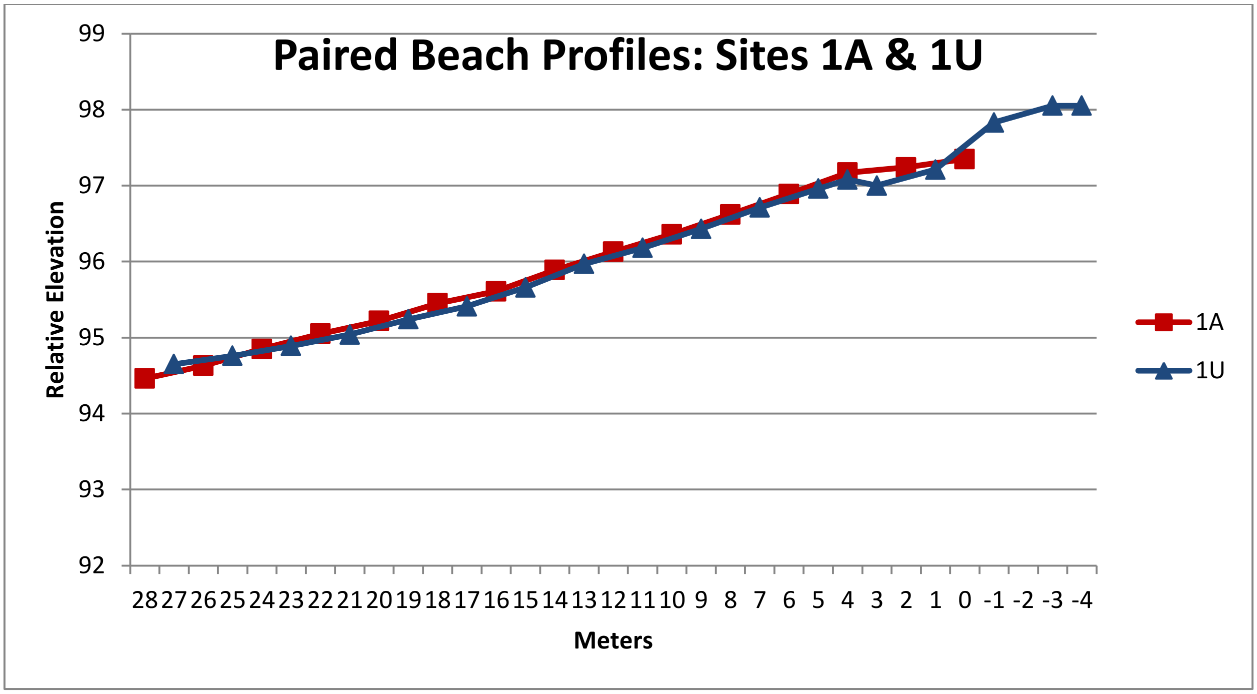


Figure 3-2. Comparison of sediment size distribution between armored sites (1A and 13A) and unarmored reference sites (1U and 13U). The phi scale is a measure of sediment grain diameter with larger values corresponding to smaller grain size. In the phi scale, -5.0 phi corresponds with a 32mm diameter grain size or the threshold between coarse and very coarse pebble on the Wentworth scale, 0.0 phi corresponds to 1mm or the threshold between coarse and very coarse sand on the Wentworth scale, and 4.0 phi corresponds with 0.62mm or the threshold between coarse silt and very fine sand on the Wentworth scale. This figure represents the percentage of sediment by weight that is larger than the given phi diameter, but smaller than the next phi diameter class.



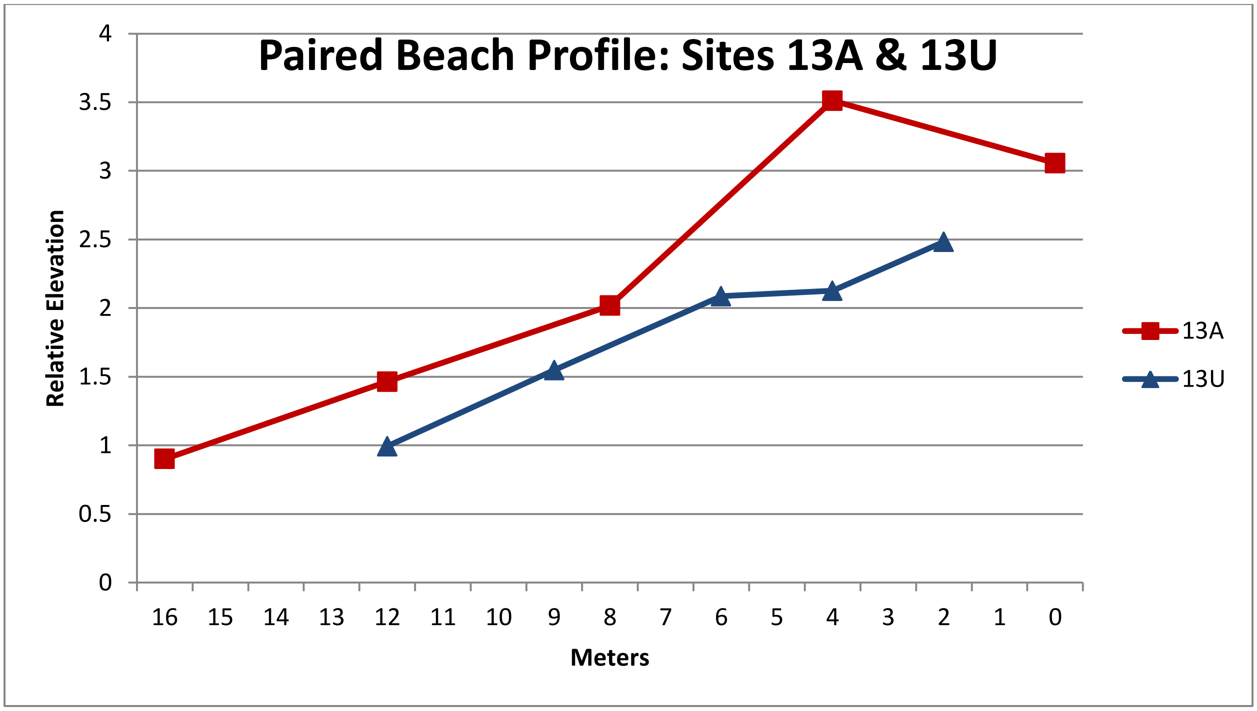


Figure 3-3. Comparison of beach profiles for armored (1A and 13A) and unarmored reference sites (1U and 13U). A beach profile represents a cross section of the surface of the beach. The horizontal axis is measured in meters from the approximate toe of the bank or armoring. The vertical axis is the difference in elevation (in meters) relative to a fixed elevation reference.

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Appendix A. Information collected for Implementation Monitoring of Culverts

Information recorded in office (obtained from permit, plans, JARPA, and other documentation)
HPA permit number
culvert ID code (if more than 1 culvert on permit)
County
Owner
Habitat Biologist
FPDSI
Date of data collection
Effectiveness Monitoring Site
Culvert Design Type
Where culvert design type was found in permit and supporting documentation
Where BFW was found in permit and supporting documentation
Applicant's BFW estimate (or channel width estimate of some sort)
Culvert Shape
Permitted Culvert Span
Permitted Culvert Width at Streambed at Outlet
Permitted Culvert Width at Streambed at Inlet
Permitted Culvert Length
Permitted Culvert Slope
Permitted Countersink at Outlet
Permitted Countersink at Inlet
Permitted Culvert Rise
Comments

Information recorded at culvert site
BFW
Actual Culvert Shape
Actual Culvert Span
Actual Culvert Width at Streambed at Outlet
Actual Culvert Width at Streambed at Inlet
Actual Culvert Length
Actual Culvert Slope
Actual Streambed Slope in Culvert
Actual Countersink at Outlet
Actual Countersink at Inlet
Actual Culvert Rise
Comments

Appendix B. Language Problem in Culvert Rules, Provisions and Guidelines

Prior to November 2014, the hydraulic code rule for no-slope culverts (WAC 220-110-070(3)(b)(i)) referred to "width of the bed of the stream" (Box B1). A common HPA permit provision also refers to "width of the streambed." WDFW's operational definition for "width of the bed of the stream" is bankfull width. However, that definition is not found in statute (i.e., WAC 220-110), and we found no permits which explain that width of streambed means bankfull width.

In *Design of Road Culverts for Fish Passage* (Bates et al. 2003, p. 17), the first paragraph of the guidance for no-slope culverts refers to channel bed width. Later, the same guidance says, "The most reliable parameter for bed width in alluvial channels is the distance between channel bankfull elevations." However, the reference to bankfull is a recommendation, not a requirement. The same guidance also implies that ordinary high water mark is a flawed but legitimate way to measure channel width.

The new culvert design guidance in *Water Crossing Design Guidelines* (Barnard et al. 2013, p. 23) replaces the words "channel bed width" with words "bankfull width."

Box B1. Language in WAC, permit provision, and design guidelines that conflicts with bank full width.

<u>WAC-220-110-070 Water Crossing Structures</u>

(b) To facilitate fish passage, culverts shall be designed to the following standards:

(i) Culverts may be approved for placement in small streams if placed on a flat gradient . . . . The culvert width at the bed, or footing width, shall be equal to or greater than the *average width of the bed of the stream*.*

<u>Common Provision in HPA Permits</u>

The culvert width at the streambed shall be equal to or greater than the average *width of the streambed*.

<u>Design of Road Culverts for Fish Passage (Bates et al. 2003, p. 17)</u>

A no-slope culvert is defined by the following characteristics:

- width equal to or greater than the average *channel bed width* at the elevation the culvert meets the streambed,
- a flat gradient,
- . . . .

Information needed for the No-Slope Design Option includes:

- the average *natural channel-bed width*,
- the natural channel slope,
- . . .

* Original text is italicized for emphasis.