14b. Streams and Fish Habitat: Fish Passage

Goal: Maintain or restore the natural range and frequency of aquatic habitat conditions on the Tongass National Forest to sustain the diversity and production of fish and other freshwater organisms.
Objectives: Use baseline fish habitat objectives, identified in the Forest Plan Standards and Guidelines, to evaluate the relative condition of riparian and aquatic habitat.

Background: Fish and aquatic resources on the Tongass National Forest provide major subsistence, commercial, and sport fisheries. Abundant rainfall and watersheds with high densities of streams provide a high quantity and diversity of freshwater fish habitats. The Tongass National Forest provides spawning and rearing habitat for the majority of fish produced in Southeast Alaska. Past riparian harvest altered aquatic habitat by reducing the supply of large wood available to streams. Maintenance of this habitat and associated waters is a focal point for the public, State and Federal agencies, and Native organizations.

Streams and Fish Habitat Question*: Is the natural range and frequency of aquatic habitat conditions maintained?*

Fish Passage at Road Crossings

Upstream migration is essential for many fish species in the Tongass National Forest. Anadromous fish (fish that migrate from the ocean to freshwater to spawn) require access to spawning habitat. Juvenile anadromous fish migrate during their freshwater life stage, seeking seasonal habitats. Resident fish (fish that spend their entire life in freshwater) also may migrate seasonally in response to food, shelter and spawning needs.

Providing for fish passage at stream and road intersections to ensure fish migration is an important consideration when constructing or reconstructing forest roads. Improperly located, installed or maintained stream crossing structures can restrict these migrations, thereby adversely affecting fish populations. These structures can present a variety of potential obstacles to fish migration. The most common obstacles are excessive vertical barriers, debris blockages, and extreme water velocities that can inhibit fish passage, especially smaller or juvenile fish.

The Tongass National Forest strives to incorporate an adaptive management process to achieve the desired management goals and objectives for the fish passage at road crossings program. The adaptive management approach includes a continuous process of using, or developing, state-of-the-art assessment and restoration techniques followed by monitoring and adjustment of the techniques, accordingly.

Designing the crossing structure to fit the stream is the key for attaining fish passage objectives and avoiding many unintended and undesirable impacts. Culverts that constrict the stream channel may cause excessive water velocity, excessive bedload deposition or rapid change in water surface profile at the inlet. Culverts installed at a gradient significantly different than the natural stream grade can induce stream head cutting upstream or excessive deposition of bedload at the culvert inlet. Culverts that do not retain adequately sized bedload may lead to excessive water velocities within the culvert. Culverts with excessive water velocities within them may release energy by eroding the outlet control, leaving the outlet perched.

Design techniques to provide fish passage across roads include:

Natural Stream Bottom Design: Maintaining the natural streambed using bridges and bottomless arch culverts;

Stream Simulation Design: Installing culverts that mimic and retain the natural stream characteristics of stream width, gradient, substrate and pool depth and spacing. Stream simulation assumes that if a culvert is installed in a manner that mimics that of the stream channel the ability for fish movement will be no less or greater at the road crossing than in the natural channel (Photo 1).

Minimally Engineered Aquatic Organism Passage (MEAOP) Design: An experimental, potentially cost effective method of installing culverts in a manner that over time are expected to provide conditions in the culvert that closely mimic and retain natural stream characteristics of stream width, gradient and substrate. This is achieved by sufficiently sizing and countersinking the culvert and then staging bedload material directly upstream. Over time, as the result of high flows, the staged and native bedload material becomes deposited within the culvert and fish passage conditions are achieved.

No Slope Design: Installing culverts that are countersunk and at a flat gradient. This technique has limited application and is only effective where the natural stream grade is also flat and the water is pooled and backwatered, as is found in palustrine, estuarine and occasionally floodplain channels.

Hydraulic Design: Culverts designed to result in predetermined water velocities or depths at predetermined flows. This design often includes installing culverts equipped with a system of weirs or baffles. The complex hydraulics and poor bedload transport associated with baffled culverts require very careful design considerations if fish passage is to be retained over time. This hydraulic design technique must match estimated fish swimming performance to calculated hydraulic conditions at a range of flows.

Removal: Removing culverts and restoring the natural stream channel.

Evaluation Criteria

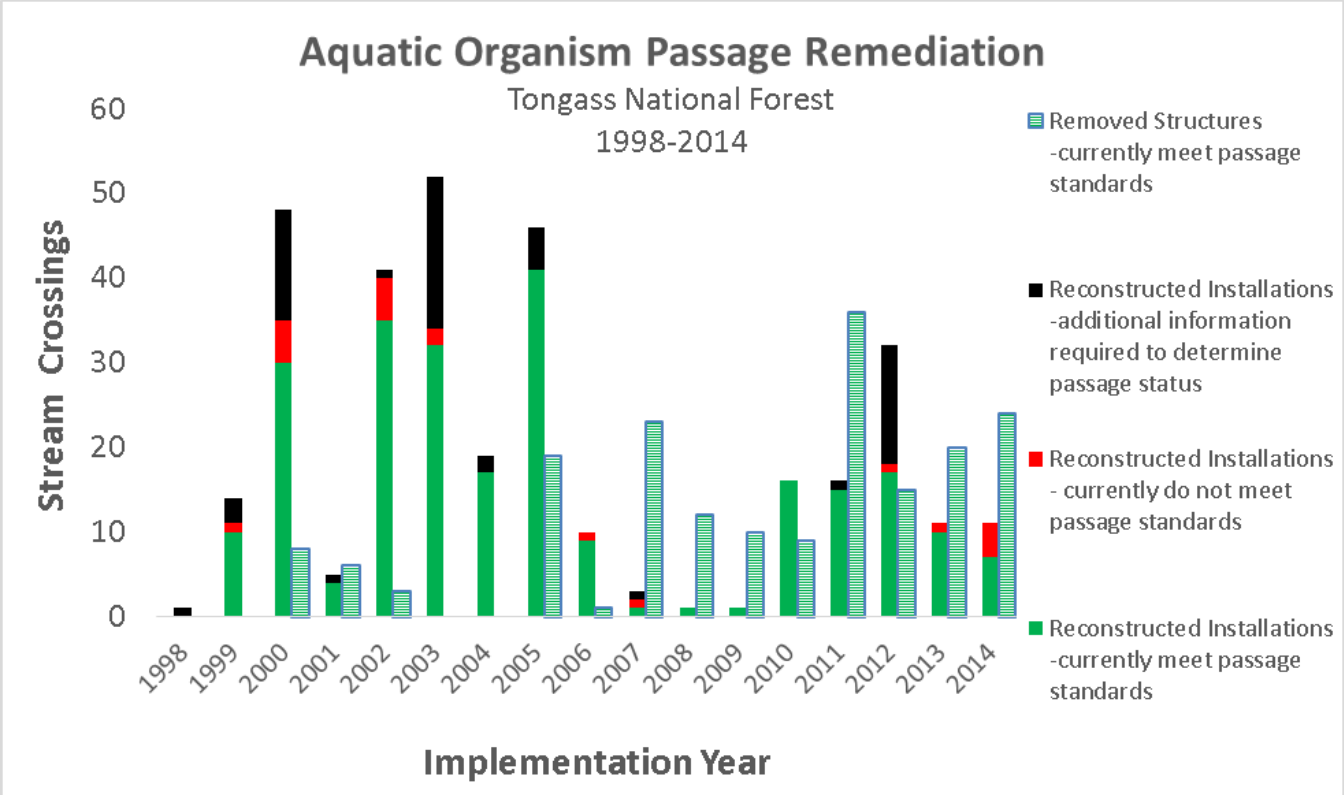
The Tongass National Forest has identified and surveyed 3,650 fish stream road crossings along approximately 5,000 miles of forest roads. Thirty-six percent of these are anadromous crossings, while the remaining 64 percent are resident fish streams. Approximately 55 percent of the crossings are culverts and 45 percent are bridges or removed structures. Approximately 90 percent of the crossings have had fish passage determinations completed and 34 percent of those have been determined not to meet State of Alaska fish passage standards. There is an average of 0.33 mile and a median of 0.18 mile of fish habitat stream length upstream of the anadromous crossings and an average of 0.20 mile and a median of 0.11 miles upstream of the resident crossings not meeting passage standards.

Fish Passage Standards and Guidelines including drainage-structure-design-criteria have evolved over time and are still evolving as information on fish swimming performance, fish movement patterns and culvert hydraulics is improved. Therefore, the assessment of the effectiveness of the Standards and Guidelines contained in the Forest Plan can only be meaningfully conducted on drainage structures more recently designed and installed.

Between 1998 and 2014, the Tongass has re-installed, retrofitted or removed approximately 513 crossings that were not previously meeting passage standards in fish streams and potentially impeding fish passage. One-hundred and eighty-six of those were remediated by being removed and 327 of them were reinstallations (Figure 1). The estimated cost of this remediation is 18.5 million dollars, indexed to 2015 dollars. Approximately 76 percent of the reinstallations were replaced with culverts and 24 percent were replaced with bridges. The monitoring provided in this report excludes bridges, removed structures and bottomless culverts since they routinely do not impede fish passage. Only non-bottomless culvert installations were evaluated since they are more problematic for fish passage.

Stream and Fish Photo 1. Time series of culvert replacement for fish passage remediation using a stream simulation design

Streams and Fish Figure 1. Aquatic organism passage remediation on the Tongass National Forest 1998 - 2014



- **GREEN category**: conditions are assumed to be adequate for fish passage and to meet State of Alaska juvenile fish passage flow standards.
- **RED category**: conditions are assumed not to be adequate for fish passage and not to meet State of Alaska juvenile fish passage flow standards.
- **GRAY category**: conditions are such that additional and more detailed analysis is required to determine their juvenile fish passage ability. This additional analysis includes use of the FishXing analytical software.
- **YELLOW category**: Conditions are assumed to be adequate for fish passage and to meet State of Alaska juvenile fish passage flow standards. However, the potentially insufficient depth of bedload material in the bottom of the culvert elevates concerns about the ability of the bedload to be retained. These culverts are on a more frequent inspection schedule to assure that bedload is retained
- **BLACK category**: The fish passage condition is unknown because critical survey measurements are not currently available.

Stream and Fish Table 1. **USFS Alaska Region juvenile salmonid fish passage criteria matrix**

Structure Group #	Structure Group	Green Conditions assumed adequate to pass juvenile fish	Gray Conditions require additional analysis	Red Conditions assumed inadequate to pass juvenile fish
1	Bottomless pipe arch or embedded[11] pipe arch or embedded CMP[2].	Culvert span to bed width ratio >= 0.75 and no blockage or backwatered[3] and no blockage.	Culvert span to bed width ratio of 0.5 to 0.75 OR blockage >0 percent but <=10 percent.	Culvert span to bed width ratio <0.5 or blockage >10 percent
2	Non-embedded pipe arches and culvert span <= 144 inches or non-embedded CMP and culvert span > 48 inches and <=144 inches.	Culvert gradient <0.5 percent and no perch[4] and no blockage and culvert span to bed width ratio > 0.75 or backwatered and no blockage.	Culvert gradient between 0.5 percent - 2.0 percent or perch >0.0 feet but <=4 inches or blockage >0 percent but <=10 percent or culvert span to bed width ratio between 0.5 to 0.75.	Culvert gradient >2.0 percent or >4 inches perch or blockage >10 percent or culvert span to bed width ratio <0.5.
3	Non-embedded CMP and <= 48 inch span.	Culvert gradient <0.5 percent and no perch and no blockage and culvert span to bed width ratio > 0.75 or backwatered and no blockage	Culvert gradient between 0.5 percent - 1.0 percent or perch >0.0 feet but <=4 inches or blockage >0 percent but <=10 percent or culvert span to bed width ratio between 0.5 to 0.75.	Culvert gradient >1.0 percent or >4 inch perch or blockage >10 percent or culvert span to bed width ratio <0.5.
4	Non-embedded culvert and culvert span >144 inches	Culvert gradient <1.0 percent and no perch and no blockage and culvert span to bank full ratio > 0.75 or backwatered and no blockage.	Culvert gradient between 1.0 percent - 2.0 percent or perch >0.0 feet but <=4 inches or blockage >0 percent but <=10 percent or culvert span to bed width ratio between 0.5 to 0.75.	Culvert gradient >2.0 percent or >4 inch perch or blockage >10 percent or culvert span to bed width ratio <0.5.
5	Box culverts, tidally influenced culverts, culverts with non-standard configurations or materials or baffled culverts.	Fully backwatered	All	Perch >4 inches
6	Bridges or fords or removed structures	No road fill caused blockage	Not Applicable	Road fill causing blockage. Water piping through road fill
7	Multiple structure installations	Multiple structures are assessed as other similar structures with the exception that constriction is calculated by dividing the stream bedwidth by the sum of all the structure widths. The structure with the best passage performance is used to determine the passage capability of the entire array.		

Note: These criteria are not design criteria, but rather indicate whether the structure is likely to provide fish passage for juvenile salmonids at a particular point in time.

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[1] Culverts are considered embedded if they have 100 percent bedload cover and average substrate depth >=20 percent of culvert rise. If culverts have 100 percent bedload cover and the average substrate depth is < 20 percent but > 5 percent of the culvert rise at both the inlet and outlet of the culvert and meet other criteria for a Green culvert than it will be identified as a Yellow crossing and requires more frequent re-inspections to assure bedload depth is retained.

[2] CMP – corrugated metal pipe

[3] The culvert is considered backwatered if the elevation of the top-of-water at the downstream control is greater than the elevation of the upstream invert of the culvert. Culvert gradient, constriction, and perch criteria are not considered in the assessment of fish passage in backwatered culvert.

[4] Perch is calculated as a flow dependent value. Perch is the defined as the difference in height between the downstream invert of the culvert (or top of bedload at downstream end of culvert if bedload is present) and top-of-water at the downstream control.

Annually a subsample of the culverts that are evaluated using the USFS Alaska Region juvenile fish passage criteria matrix are also assessed more comprehensively by comparing physical conditions within the culvert against those in reference reaches in the vicinity of the culvert.

Mimicking site specific natural channel conditions within a culvert is the strategy of a stream simulated culvert design. Stream simulation assumes that if a culvert is installed in a manner that mimics that of the stream channel the ability for fish movement will be no less or greater at the road crossing than in the natural channel. Channel characteristics such as stream width, gradient, substrate and pool depth and spacing is measured and compared. In addition, a comparison of stream velocities within the culvert to the reference reach was completed using a sodium chloride salt tracer and measuring changes of conductivity over time. This method provides a simple means of obtaining a velocity profile in a stream reach with high variability of channel geometry and roughness characteristics.

Sampling/Reporting Period

The sampling period is annual. A subsample of culverts installed from 1998 - 2014 in fish streams are monitored annually. The reporting and evaluation period is a 5-year interval.

Monitoring Results

As part of a multi-year monitoring project, 40 culverts spanning fish streams were monitored in fiscal year 2014 to assess their ability to provide fish passage (Photo 2). These culverts were chosen from 246 culverts which have been installed, reinstalled or retrofitted in fish streams from 1998 through 2014. The culverts monitored in 2014 are located on Chichagof, Wrangell, Zarembo and Prince of Wales Islands. From 2009 through 2013, 138 similar culverts were monitored on Kupreanof, Kuiu, Wrangell, Mitkof, Zarembo, Revillagigedo and Prince of Wales Islands. Nine culverts that were installed in 2012 and 2013, using a minimally engineered aquatic organism passage (MEAOP) design, are monitored annually and were resurveyed in 2014. The 164 unique stream crossings monitored to date as part of this assessment constitute approximately 67 percent of the culverts (excluding bottom-less culverts) recently installed, reinstalled or retrofitted in fish streams on the Tongass National Forest.

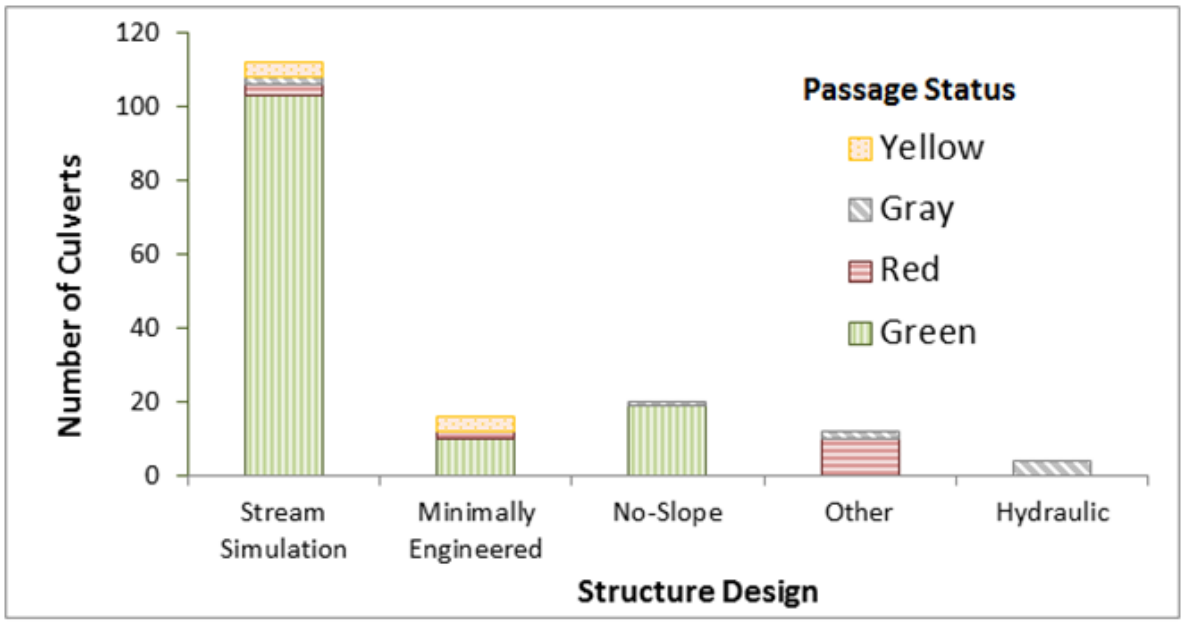
Eighty-six percent of the culverts monitored are green or yellow and have met the acceptable passage criteria established in the juvenile fish passage criteria matrix (Figure 2). They are consistent with State of Alaska juvenile fish passage standards and are assumed to provide unimpeded juvenile and adult fish passage. Five percent of the culverts are Gray and require more comprehensive analysis to determine passage status. The remaining 9 percent are red and are assumed not to provide adequate passage at all desired stream flows. The majority (68 percent) of the 164 stream crossings monitored were installed between 2000 and 2005 (Table 3).

Sixty-nine percent of the monitored culverts used stream simulation designs, 10 percent were installed using a MEAOP design, 2 percent are hydraulic designed baffled culverts, 12 percent utilized a no-slope design and 7 percent were incorrectly designed without adequate fish passage considerations. Two percent of the stream simulated designed culverts are red. Of the three red stream simulated designed culverts, two have had a segment of their length completely scoured free of bedload and one was blocked by woody debris. Thirteen percent of the MEAOP designed culverts are red due to insufficient bedload accumulation within the culverts. None of the 20 installed no-slope

Stream and Fish Photo 2. Survey of culvert conditions

designed culverts were red. All of the hydraulic designed culverts require additional more comprehensive analysis to determine passage status. Twelve culverts were installed without discernable fish passage design considerations and as a result 83 percent of them are red. Six of those most likely were not identified as crossings requiring passage at time of installation and therefore were not designed appropriately (Figure 2). It is undetermined why the other four culverts were installed without adequate design considerations.

Streams and Fish Figure 2. Design type and juvenile fish passage status of monitored culverts.



Of the culverts that were determined to be consistent with passage standards, most were ideal installations. They contained appropriate bedload depth and material, were not blocked with debris, were not perched at the outlet and did not constrict the channel or cause any undesirable channel modifications.

However, some of the crossings determined to be consistent with passage with standards had some issues associated with them that required or may require some action. Four of the culverts had woody debris blockages in them but were subsequently cleared. Several of the culverts which have bedload retaining weirs installed in them are not retaining bedload to the desirable amount. This causes slight vertical drops at the weirs and may provide a less than an ideal amount of channel roughness within the culvert. One culvert had a section of subsurface flow within the culvert which was most likely due to an insufficient amount of finer bedload material. However, this stream channel also had a section of naturally occurring interrupted flow directly downstream of the culvert.

Stream and Fish Table 2. **Culvert Measurements**

District	Road	MP.	Culvert Type	Design	Year Installed	Year Monitored	Culvert Outlet Perch	Percent Culvert Bedload Cover	Ratio Bedload Depth to Culvert Rise	Ratio Stream Bedwidth to Culvert Width	Percent Culvert Gradient to Percent Channel Gradient	Percent Debris Block-age	Juvenile Passage Status
Petersburg	40000	2.492	round	simulation	2002	2009	No perch	100	0.32	1.41	2.8 : 8	0	Green
Petersburg	40000	3.129	round	simulation	2002	2010	No perch	100	0.40	1.00	4.6 : 7	0	Green
Petersburg	40000	3.194	arch	simulation	2002	2010	No perch	100	0.23	1.31	6.3 : 7	0	Green
Petersburg	40000	3.292	round	simulation	2002	2009	No perch	100	0.38	1.28	4.1 : 6	0	Green
Petersburg	40000	3.337	arch	simulation	2002	2009	No perch	100	0.26	0.97	6.7 : 9	0	Green
Petersburg	40000	3.356	round	simulation	2002	2009	No perch	100	0.35	0.93	5.2 : 7	0	Green
Petersburg	40000	3.552	arch	simulation	2002	2010	No perch	100	0.23	1.62	7.1 : 8	0	Green
Petersburg	40000	3.739	round	simulation	2003	2011	No perch	100	0.47	0.94	6.7 : 12	0	Green
Petersburg	40000	5.001	round	hydraulic	2002	2009	No perch	n/a	n/a	n/a [4]	6.9 : 0	0 [1]	Gray
Petersburg	6235	12.361	round	simulation	2002	2009	No perch	100	0.35	1.22	5.1 : 7	0	Green
Petersburg	6235	12.932	round	simulation	2002	2009	No perch	100	0.41	1.50	4.7 : 5	0	Green
Petersburg	6235	15.450	round	simulation	2003	2009	No perch	100	0.35	1.27	0.1 : 3	0	Green
Petersburg	6235	15.846	round	simulation	2002	2009	No perch	100	0.42	1.01	1.0 : 2	0	Green
Petersburg	6235	17.071	round	simulation	2002	2009	No perch	100	0.36	1.25	1.4 : 1	0	Green
Petersburg	6235	17.579	arch	simulation	2002	2009	No perch	100	0.41	2.00	2.7 : 1	0	Green
Petersburg	6245	0.940	arch	simulation	1998	2009	No perch	100	0.28	0.95	1.6 : 4	0	Green
Petersburg	6245	1.256	arch	simulation	2003	2009	No perch	100	0.50	1.15	8.8 :16	0	Green
Petersburg	6245	1.503	round	simulation	2003	2009	No perch	100	0.23	1.00	5.0 : 7	0	Green
Petersburg	6245	4.690	round	simulation	2003	2009	No perch	100	0.43	1.21	1.7 : 5	0	Green
Petersburg	6245	4.962	round	simulation	2003	2009	No perch	100	0.51	1.21	4.8 : 8	0	Green
Petersburg	6245	8.562	round	simulation	2003	2009	No perch	100	0.31	1.14	6.4 :7	0	Green
Petersburg	40010	0.146	arch	simulation	2001	2009	No perch	100	0.20	0.76	1.6 : 6	0	Green
Petersburg	6204	0.318	round	no slope [2]	2009	2009	No perch	38	0.04	1.18	1.4 : 4	0	Green
Petersburg	6204	1.997	round	simulation	2003	2009	No perch	100	0.49	1.00	2.0 : 9	0	Green
Petersburg	6204	8.002	round	simulation	2003	2009	No perch	100	0.34	1.33	2.0 :3	0 [1]	Green

District	Road	MP.	Culvert Type	Design	Year Installed	Year Monitored	Culvert Outlet Perch	Percent Culvert Bedload Cover	Ratio Bedload Depth to Culvert Rise	Ratio Stream Bedwidth to Culvert Width	Percent Culvert Gradient to Percent Channel Gradient	Percent Debris Block-age	Juvenile Passage Status
Petersburg	6350	4.612	round	no slope [2]	2002	2010	No perch	100	0.04	1.45	-0.7 : 5	0	Green
Petersburg	6350	4.693	round	no slope [2]	2002	2010	No perch	0	0.00	1.30	0 : 2	0	Green
Petersburg	6350	17.465	plastic	other[7]	2013	2014	0.7 feet	0	0.00	0.69	1 : 3	0	Red
Petersburg	6402	7.872	arch	simulation	2005	2010	No perch	100	0.27	1.00	0.9 : 3	0	Green
Petersburg	6402	11.170	arch	simulation	2005	2010	No perch	100	0.17	2.22	5.3 : 5	0	Yellow
Petersburg	6407	1.743	round	simulation	2005	2010	No perch	100	0.41	1.17	11.4 : 8	0	Green
Petersburg	6407	4.526	round	simulation	2005	2010	No perch	100	0.38	1.28	5.4 : 7	0	Green
Petersburg	6407	6.208	round	simulation	2005	2010	No perch	100	0.39	1.43	1.4 : 8	0	Green
Petersburg	6415	2.339	dual arch[3]	simulation	2000	2010	No perch	100	0.15	1.00	3.5 : 4	0	Green
Petersburg	6415	2.341	dual arch[3]	simulation	2000	2010	No perch	100	0.22	1.00	3.6 : 4	0 [1]	Green
Petersburg	6415	2.836	arch	simulation	2000	2010	No perch	100	0.21	0.78	3.1 : 4	0	Green
Petersburg	6415	3.366	arch	simulation	2000	2010	0.3 feet[6]	100	0.14	1.14	1.1 : 4	0	Yellow
Petersburg	6415	4.223	arch	simulation	2000	2010	No perch	100	0.43	1.19	4.6 : 3	0	Green
Petersburg	6415	7.198	arch	simulation	2000	2010	No perch	100	0.17	0.90	4.8 : 9	0	Yellow
Petersburg	6415	8.772	arch	simulation	1998	2010	No perch	100	0.12	0.96	0 : 3	0	Green
Petersburg	6415	12.729	arch	simulation	2005	2010	No perch	100	0.26	1.95	4.9 : 6	0	Green
Petersburg	6314S	8.739	round	other[7]	2002	2010	0.1 feet	0	0.00	0.61	4.5 : 12	0	Red
Petersburg	6314S	8.817	round	no-slope	2002	2010	No perch	100	0.10	1.09	0.0 : 1	0	Green
Petersburg	6314S	8.915	round	no slope [2]	2002	2010	No perch	0	0.00	1.04	0.3 : 0	0	Green
Petersburg	6314S	8.959	round	no slope [2]	2002	2010	No perch	100	0.29	0.98	0.3 : 1	0	Green
Petersburg	6314S	9.575	round	simulation	2002	2010	No perch	100	0.20	2.06	5.3 : 10	0	Green
Petersburg	6314S	9.669	round	other[7]	2002	2010	0.4 feet	0	0.00	1.05	3.8 : 8	0	Red
Petersburg	6314S	12.535	round	simulation	2002	2010	No perch	100	0.27	0.96	2.1 : 12	0	Green
Petersburg	6314S	13.223	arch	simulation	2002	2010	No perch	100	0.20	0.81	3.5 : 6	0	Green
Petersburg	6314S	13.284	round	other[7]	2002	2010	No perch	0	0.00	1.11	2.9 : 4	0	Red

District	Road	MP.	Culvert Type	Design	Year Installed	Year Monitored	Culvert Outlet Perch	Percent Culvert Bedload Cover	Ratio Bedload Depth to Culvert Rise	Ratio Stream Bedwidth to Culvert Width	Percent Culvert Gradient to Percent Channel Gradient	Percent Debris Block-age	Juvenile Passage Status
Petersburg	45001	0.185	round	simulation	2001	2010	No perch	100	0.14[8]	1.16	5.5 : 8	0	Green
Petersburg	45001	0.485	round	simulation	2001	2010	No perch	100	0.14	1.52	1.9 : 6	0	Yellow
Petersburg	6030	0.512	round	simulation	2001	2010	No perch	100	0.47	0.92	1.1 : 4	0	Green
Petersburg	6031	0.583	round	simulation	2003	2011	No perch	100	0.22	1.56	0.5 : 2	0	Green
Petersburg	6031	0.597	round	simulation	2003	2011	No perch[9]	100	0.13	1.04	2.6 : 6	0	Red
Petersburg	6031	3.161	arch	simulation	2003	2011	No perch	93	0.14[10]	1.46	5.1 : 5	0	Red
Petersburg	6031	3.833	round	simulation	2003	2011	No perch	100	0.32	1.16	3.6 : 5	0	Green
Petersburg	6031	4.340	round	no slope [2]	2003	2011	No perch	100	0.11	0.85	1.8 : 2	0	Green
Petersburg	6031	5.840	round	simulation	2003	2011	No perch	100	0.39	1.43	1.5 : 3	0	Green
Petersburg	6031	6.631	round	simulation	2003	2011	No perch	100	0.39	1.28	3.1 : 10	0	Green
Petersburg	6319	8.413	round	simulation	2003	2011	No perch	100	0.40	0.96	4.2 : 4	0	Green
Petersburg	6319	10.975	round	simulation	2003	2011	No perch	100	0.30	1.79	2.9 : 5	0	Green
Petersburg	6323	0.162	round	simulation	2003	2011	No perch	100	0.27	2.17	4.2 : 2	0	Green
Petersburg	6256	3.146	arch	simulation	2006	2011	No perch	100	0.30	n/a[4]	0.2 : 1	0	Green
Petersburg	6256	4.499	round	simulation	2006	2011	No perch	100	0.38	n/a[4]	1.8 : 0	0	Green
Petersburg	6256	5.528	round	simulation	2006	2011	No perch	100	0.42	n/a[4]	0 : 0.6	20 [11]	Red
Wrangell	6259	2.334	arch	MEAOP	2014	2014	No perch	100	0.18	1.21	4.0 : 4	0	Yellow
Wrangell	6259	2.782	arch	MEAOP	2014	2014	No perch	100	0.25	0.63	4.0 : 3	0	Green
Wrangell	6259	2.787	arch	MEAOP	2014	2014	No perch	70	0.11[2]	0.84	3.7 : 3	0	Green
Wrangell	6299	2.263	arch	simulation	2003	2010	No perch	100	0.29	0.90	4.8 : 9	0	Green
Wrangell	6299	2.508	round	simulation	2003	2010	No perch	100	0.33	1.11	3.3 : 5	0	Green
Wrangell	6299	2.577	round	simulation	2003	2010	No perch	100	0.23	0.95	3.8 : 5	0	Green
Wrangell	6585	5.127	round	simulation	2005	2012	No perch	100	0.28	1.14	10.4:11	0	Green
Wrangell	6585	5.285	round	simulation	2005	2012	No perch	100	0.42	1.04	0.8 : 6	0	Green
Wrangell	6585	5.597	round	simulation	2005	2012	No perch	100	0.41	1.02	7.3 : 10	0	Green

District	Road	MP.	Culvert Type	Design	Year Installed	Year Monitored	Culvert Outlet Perch	Percent Culvert Bedload Cover	Ratio Bedload Depth to Culvert Rise	Ratio Stream Bedwidth to Culvert Width	Percent Culvert Gradient to Percent Channel Gradient	Percent Debris Block-age	Juvenile Passage Status
Wrangell	6585	11.447	arch	simulation	2005	2012	No perch	100	0.21	1.17	3.1 : 6	0	Green
Wrangell	6590	0.677	arch	no-slope[2]	2014	2014	Red-perch	100	0.38	0.83	0.3 : 3	0	Green
Wrangell	6590	1.674	round	other	2014	2014	Red-perch	50	0.12	1.38	1.1 : 2	0	Red
Wrangell	6590	4.396	round	other[13]	2007	2014	Red-perch	0	0.00	1.20	1.7 : 5	0	Red
Wrangell	6590	6.433	arch	simulation	2005	2012	No perch	30	0.00[2]	0.56[2]	1.8 : 6	0	Green
Wrangell	6590	11.197	round	simulation	2005	2012	No perch	100	0.36	1.10	3.7 : 5	0	Green
Wrangell	6590	11.597	dual arch[3]	simulation	2005	2012	No perch	100	0.03	0.57	0.8 : 6	0	Gray
Wrangell	6590	14.046	round	no-slope	2014	2014	No perch	83	0.06	1.11	-0.4 : 6	0	Green
Wrangell	6590	18.550	round	simulation	2005	2012	No perch	100	0.34	1.00	7.0 : 9	0	Green
Wrangell	6590	18.734	round	hydraulic	2005	2012	No perch	10	0.12	1.03	10.4 : 9	0	Gray
Wrangell	6590	22.056	arch	no-slope	2014	2014	No perch	96	0.11	0.88	0.2 : 5	0	Green
Wrangell	6590	28.661	round	simulation	2005	2012	No perch	100	0.35	1.17	11.5:12	0	Green
Wrangell	6590	36.018	round	simulation	2005	2012	No perch	100	0.34	0.98	8.5 : 11	0	Green
Wrangell	6590	36.079	round	simulation	2005	2012	No perch	100	0.38	1.10	9.5 : 12	0	Green
Wrangell	50054	0.033	arch	MEAOP	2014	2014	No perch	0	0.00	0.88	2.2 : 5	0	Red
Wrangell	50054	0.063	round	MEAOP	2014	2014	No perch	100	0.08	0.80	1.3 : 1	0	Yellow
Wrangell	50054	0.086	round	MEAOP	2014	2014	No perch	100	0.14	0.95	1.5 : 3	0	Yellow
Wrangell	50055	0.031	arch	MEAOP	2014	2014	No perch	100	0.5	1.69	2.5 : 2	0	Yellow
Craig	2024200	0.810	round	simulation	1999	2010	No perch	100	0.18[2]	0.84	1.4: 4	0	Green
Craig	2024300	0.236	round	simulation	1999	2011	No perch	100	0.23	0.82	3.1 : 4	0	Green
Craig	2024300	0.260	round	simulation	1999	2011	No perch	100	0.50	0.88	0.4 : 4	0	Green
Craig	2100000	0.230	round	simulation	2005	2010	No perch	100	0.42	1.36	3.3 : 4	0	Green
Craig	2100000	2.070	round	simulation	2000	2010	No perch	100	0.18	1.11	0.4 : 7	0	Green
Wrangell	6259	2.334	arch	MEAOP	2014	2014	No perch	100	0.18	1.21	4.0 : 4	0	Yellow
Wrangell	6259	2.782	arch	MEAOP	2014	2014	No perch	100	0.25	0.63	4.0 : 3	0	Green

District	Road	MP.	Culvert Type	Design	Year Installed	Year Monitored	Culvert Outlet Perch	Percent Culvert Bedload Cover	Ratio Bedload Depth to Culvert Rise	Ratio Stream Bedwidth to Culvert Width	Percent Culvert Gradient to Percent Channel Gradient	Percent Debris Block-age	Juvenile Passage Status
Wrangell	6259	2.787	arch	MEAOP	2014	2014	No perch	70	0.112	0.84	3.7 : 3	0	Green
Wrangell	6299	2.263	arch	simulation	2003	2010	No perch	100	0.29	0.90	4.8 : 9	0	Green
Wrangell	6299	2.508	round	simulation	2003	2010	No perch	100	0.33	1.11	3.3 : 5	0	Green
Wrangell	6299	2.577	round	simulation	2003	2010	No perch	100	0.23	0.95	3.8 : 5	0	Green
Wrangell	6585	5.127	round	simulation	2005	2012	No perch	100	0.28	1.14	10.4:11	0	Green
Wrangell	6585	5.285	round	simulation	2005	2012	No perch	100	0.42	1.04	0.8 : 6	0	Green
Wrangell	6585	5.597	round	simulation	2005	2012	No perch	100	0.41	1.02	7.3 : 10	0	Green
Wrangell	6585	11.447	arch	simulation	2005	2012	No perch	100	0.21	1.17	3.1 : 6	0	Green
Wrangell	6590	0.677	arch	no-slope2	2014	2014	Red-perch	100	0.38	0.83	0.3 : 3	0	Green
Wrangell	6590	1.674	round	other	2014	2014	Red-perch	50	0.12	1.38	1.1 : 2	0	Red
Wrangell	6590	4.396	round	other13	2007	2014	Red-perch	0	0.00	1.20	1.7 : 5	0	Red
Wrangell	6590	6.433	arch	simulation	2005	2012	No perch	30	0.002	0.562	1.8 : 6	0	Green
Wrangell	6590	11.197	round	simulation	2005	2012	No perch	100	0.36	1.10	3.7 : 5	0	Green
Wrangell	6590	11.597	dual arch3	simulation	2005	2012	No perch	100	0.03	0.57	0.8 : 6	0	Gray
Wrangell	6590	14.046	round	no-slope	2014	2014	No perch	83	0.06	1.11	-0.4 : 6	0	Green
Wrangell	6590	18.550	round	simulation	2005	2012	No perch	100	0.34	1.00	7.0 : 9	0	Green
Wrangell	6590	18.734	round	hydraulic	2005	2012	No perch	10	0.12	1.03	10.4 : 9	0	Gray
Wrangell	6590	22.056	arch	no-slope	2014	2014	No perch	96	0.11	0.88	0.2 : 5	0	Green
Wrangell	6590	28.661	round	simulation	2005	2012	No perch	100	0.35	1.17	11.5:12	0	Green
Wrangell	6590	36.018	round	simulation	2005	2012	No perch	100	0.34	0.98	8.5 : 11	0	Green
Wrangell	6590	36.079	round	simulation	2005	2012	No perch	100	0.38	1.10	9.5 : 12	0	Green
Wrangell	50054	0.033	arch	MEAOP	2014	2014	No perch	0	0.00	0.88	2.2 : 5	0	Red
Wrangell	50054	0.063	round	MEAOP	2014	2014	No perch	100	0.08	0.80	1.3 : 1	0	Yellow
Wrangell	50054	0.086	round	MEAOP	2014	2014	No perch	100	0.14	0.95	1.5 : 3	0	Yellow
Wrangell	50055	0.031	arch	MEAOP	2014	2014	No perch	100	0.5	1.69	2.5 : 2	0	Yellow

District	Road	MP.	Culvert Type	Design	Year Installed	Year Monitored	Culvert Outlet Perch	Percent Culvert Bedload Cover	Ratio Bedload Depth to Culvert Rise	Ratio Stream Bedwidth to Culvert Width	Percent Culvert Gradient to Percent Channel Gradient	Percent Debris Block-age	Juvenile Passage Status
Craig	2000000	102.907	arch	MEAOP	2012	2014	No perch	90	0.37	0.94	1 : 2	0	Green
Craig	2000000	122.678	round	MEAOP	2013	2014	No perch	40	0.22	1.39	3.8 : 4.5	0	Green
Craig	2000000	125.242	arch	MEAOP	2013	2014	No perch	100	0.16	1.09	1.8 : 3.5	0	Green
Craig	2000860	0.659	arch	MEAOP	2013	2014	No perch	100	0.26	1.01	2.7 : 3.5	0	Green
Craig	2085000	0.944	round	MEAOP	2013	2014	No perch	100	0.28	1.16	3.8 : 4.5	0	Green
Craig	2024200	0.810	round	simulation	1999	2010	No perch	100	0.182	0.84	1.4: 4	0	Green
Craig	2024300	0.236	round	simulation	1999	2011	No perch	100	0.23	0.82	3.1 : 4	0	Green
Craig	2024300	0.260	round	simulation	1999	2011	No perch	100	0.50	0.88	0.4 : 4	0	Green
Craig	2100000	0.230	round	simulation	2005	2010	No perch	100	0.42	1.36	3.3 : 4	0	Green
Craig	2100000	2.070	round	simulation	2000	2010	No perch	100	0.18	1.11	0.4 : 7	0	Green
Craig	2700000	0.710	arch	MEAOP	2012	2014	No perch	100	0,17	1.36	3.0 : 2.5	0	Green
Thorne Bay	3000000	89.221	arch	MEAOP	2013	2014	No perch	100	0.24	1.19	3.8 : 6.5	0	Green
Thorne Bay	3015000	1.773	arch	MEAOP	2012	2012	No perch	100	0.11	0.76	3.4 : 10	0	Red
Thorne Bay	3015000	1.773	arch	MEAOP	2012	2013	No perch	100	0.15	0.76	3.4 : 10	0	Red
Thorne Bay	3015000	1.773	arch	MEAOP	2012	2014	No perch	98	0.11	0.76	3.4 : 10	0	Red
Thorne Bay	3015000	2.641	arch	simulation	2010	2011	No perch	100	0.21	0.98	6.6 : 6	0	Green
Thorne Bay	3015000	0.344	round	simulation	2010	2011	No perch	100	0.25	1.67	5.5 : 2	0	Green
Thorne Bay	3015000	8.743	arch	MEAOP	2012	2012	No perch	50 [12]	0.1512	1.34	4.2 : 7	0	Green
Thorne Bay	3015000	8.743	arch	MEAOP	2012	2013	No perch	58 [12]	0.1512	1.34	4.2 : 7	0	Green
Thorne Bay	3015000	8.743	arch	MEAOP	2012	2014	No perch	100	0.41	1.34	4.2 : 7	0	Green
Thorne Bay	3015000	6.830	round	simulation	2010	2011	No perch	100	0.29	1.22	5.5 : 4	0	Green
Thorne Bay	3015250	0.030	round	simulation	2010	2011	No perch	100	0.39	1.26	4.6 : 5	0	Green
Thorne Bay	3030850	0.270	concrete box	hydraulic	2002	2010	No perch	100	n/a	n/a [4]	5.0 : 4	0 [1]	Gray
Thorne Bay	3030850	0.300	round	simulation	2002	2010	No perch	100	0.34	1.72	6.0 : 7	0	Green
Thorne Bay	3030850	0.480	concrete box	hydraulic	2002	2010	No perch	100	n/a	n/a [4]	0.7 : 3	0	Gray

District	Road	MP.	Culvert Type	Design	Year Installed	Year Monitored	Culvert Outlet Perch	Percent Culvert Bedload Cover	Ratio Bedload Depth to Culvert Rise	Ratio Stream Bedwidth to Culvert Width	Percent Culvert Gradient to Percent Channel Gradient	Percent Debris Block-age	Juvenile Passage Status
Sitka	7540CB	6.827	arch	simulation	2000	2013	No perch	100	0.25	1.02	6.1 : 5	0	Green
Sitka	7540CB	6.845	round	simulation	2000	2013	No perch	100	0.182	0.652	0.3 : 5	0	Green
Sitka	7540CB	7.267	round	simulation	2004	2013	No perch	100	0.41	1.61	Unk : 1	0	Green
Sitka	7540CB	7.755	round	simulation	2004	2013	No perch	100	0.25	1.14	4.1 : 4	0	Green
Sitka	7540CB	8.143	Round	simulation	2004	2013	No perch	100	0.39	1.56	4.6 : 3	0	Green
Sitka	7540CB	8.184	round	simulation	2004	2013	No perch	100	0.38	1.72	4.3 : 3	0	Green
Sitka	7540CB	8.980	round	simulation	2004	2013	No perch	100	0.31	0.81	7 : 6.1	0	Green
Sitka	7540CB	14.008	round	simulation	2004	2013	No perch	100	0.37	1.00	5.7 : 6	0	Green
Sitka	7542	0.027	arch	simulation	2005	2013	No perch	100	0.22	0.78	4.5 : 3	0	Green
Sitka	7542	0.109	round	simulation	2004	2013	No perch	100	0.37	1.35	1.7 : 1	0	Green
Sitka	7542	0.314	round	simulation	2004	2013	No perch	100	0.40	0.59	2.3 : 2	0	Gray
Sitka	7551	0.168	round	simulation	2004	2013	No perch	100	0.36	1.52	1.9 : 2	0	Green
Ketchikan	8000000	22.413	round	simulation	2010	2013	No perch	100	0.27	1.13	5.8 : 8	0	Green
Ketchikan	8000000	22.493	round	simulation	2010	2013	No perch	100	0.24	1.08	3.3 : 12	0	Green
Ketchikan	8040000	1.771	arch	simulation	2010	2013	No perch	100	0.29	0.91	4.7 : 9	0	Green
Ketchikan	8040000	4.187	round	simulation	2010	2013	No perch	100	0.26	1.32	3.2 : 5	0	Green
Ketchikan	8040000	5.134	arch	simulation	2010	2013	No perch	100	0.25	0.96	4.3 : 5	0	Green
Hoonah	8504	0.089	round	no-slope	1999	2014	No perch	100	0.26	0.83	0.5: 5	0	Green
Hoonah	8504	1.169	round	no-slope	1999	2014	No perch	100	0.21	0.88	-0.3 : 4	0	Green
Hoonah	8504	1.181	round	no-slope	1999	2014	No perch	100	0.13	0.88	0.5 : 4	0	Green
Hoonah	8513	0.273	round	other	1999	2014	No perch	15	0.00	1.36	7 : 21	0	Red
Hoonah	8513	0.954	round	no-slope	2000	2014	No perch	100	0.14	0.84	-0.1 : 14	0	Green
Hoonah	8513	1.463	round	no-slope	2000	2014	No perch	100	0.27	0.92	-0.1 : 9	0	Green
Hoonah	8513	1.922	round	other	2000	2014	No perch	100	0.08	0.61	0.8 : 2	0	Gray
Hoonah	8530	3.077	round	simulation	2005	2014	No perch	100	0.35	0.63	1.8 : 2	0	Green

District	Road	MP.	Culvert Type	Design	Year Installed	Year Monitored	Culvert Outlet Perch	Percent Culvert Bedload Cover	Ratio Bedload Depth to Culvert Rise	Ratio Stream Bedwidth to Culvert Width	Percent Culvert Gradient to Percent Channel Gradient	Percent Debris Block-age	Juvenile Passage Status
Hoonah	8530	4.130	round	simulation	2005	2014	No perch	100	0.36	1.33	6.4 : 5	0	Green
Hoonah	8530	10.912	round	no-slope	2000	2014	No perch	100	0.48	0.77	-0.1 : 2	0	Green
Hoonah	8530	13.886	round	other	1999	2014	No perch	100	0.10	1.4	1.8 : 4	0	Gray
Hoonah	8534	0.397	arch	simulation	2005	2014	No perch	100	0.20	1.05	4.4 : 6	0	Green
Hoonah	8534	1.445	round	simulation	2005	2014	No perch	100	0.36	0.98	7.1 : 9	0	Green
Hoonah	8534	1.554	round	other	2000	2014	No perch	100	0.04	0.78	2.9 : 10	0	Red
Hoonah	8534	1.895	round	no-slope	2000	2014	No perch	100	0.25	0.64	-0.8 : 7	0	Grey

[1] Culvert was partially blocked by woody debris at initial site visit but was subsequently cleared and fish passage was restored.

[2] Flow is backwatered in the culvert.

[3] There are two culverts installed at this crossing. One is occasionally dewatered at lower flows and acts as an overflow culvert.

[4] Channel is palustrine therefore comparing channel width to culvert width is not as relevant.

[5] At base flows, stream flow through the culvert is subsurface for approximately 60 percent of its length and is most likely due to lack of finer bedload material. Stream flow 50 feet downstream of the culvert has interrupted flow for 5 feet which may naturally also impede fish passage at some flows.

[6] The bedload retaining weirs placed in this culvert have not adequately retained bedload and the retaining weir at the culvert outlet has a 3 inch perch due to an inadequate downstream control. Fifteen feet upstream of the culvert is a 2.7 foot vertical natural fish barrier with a 5 inch jump pool.

[7] Stream crossing structure was not designed to provide fish passage due to it not being identified as a fish stream in the Tongass AOP database prior to installation.

[8] The installed bedload retaining weirs have not retained bedload to the desirable depths and small 0.2 foot vertical drops are present at most weirs.

[9] Furthest downstream rock band in culvert has scoured bedload downstream of it leaving a 0.8 foot drop. Need to potentially raise downstream control and reinsert rock in last several feet of culvert.

[10] No bedload present in upstream 4 feet of culvert however approximately 29 percent bedload depth in remaining section of culvert

[11] Culvert is partially blocked by woody debris and as of report date has not been cleared.

[12] This simplified stream simulation culvert does not have 100 percent bedload cover or does not meet the minimum threshold of 20 percent of bedload depth to culvert rise criteria, however the section without bedload or insufficient bedload depth is backwatered and effective passage is achieved. Bedload material is expected to continue to accumulate in the culvert.

[13] Stream crossing structure was not designed to provide fish passage due to project personnel apparently not aware of fish stream status reported in Tongass AOP database.

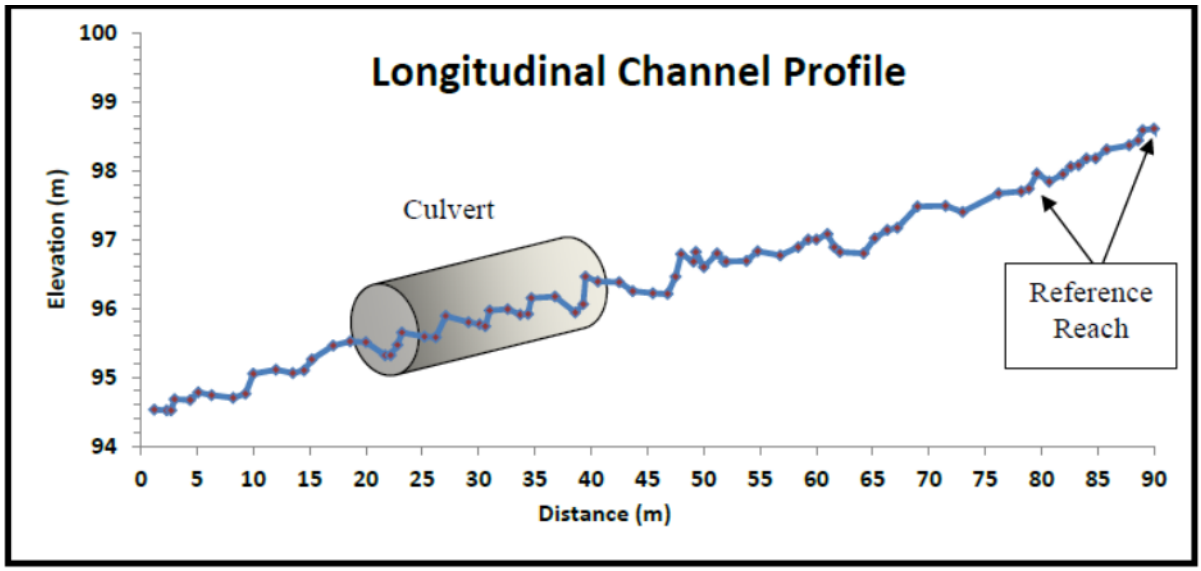
In addition to evaluating the stream crossings against the criteria of the Alaska Region's juvenile fish passage criteria matrix, a subsample of stream crossings are assessed by comparing them to adjacent reference reaches. These reference reach surveys include comparisons of longitudinal profile, cross-sectional profile, particle size composition and salt tracer rates. Additional reference reach survey results have been reported in previous Tongass Monitoring and Evaluation Reports.

Road 3015250 milepost 0.030 (Photos 3 and 4)

The 144 inches round corrugated metal culvert installation on road 3015250 milepost 0.030 uses a stream simulated design and was installed in 2010 (Photos 3 and 4). It was evaluated by comparing it to an upstream reference reach representative of this section of the stream. The channel in the vicinity of the culvert is a moderate gradient channel with mixed bedrock and alluvium control with a pool-riffle bed form. The channel gradient within the reference reach is 5.8 percent and within the culvert it is 4.8 percent (Figure 3).

Design type and juvenile fish passage status of monitored culverts.

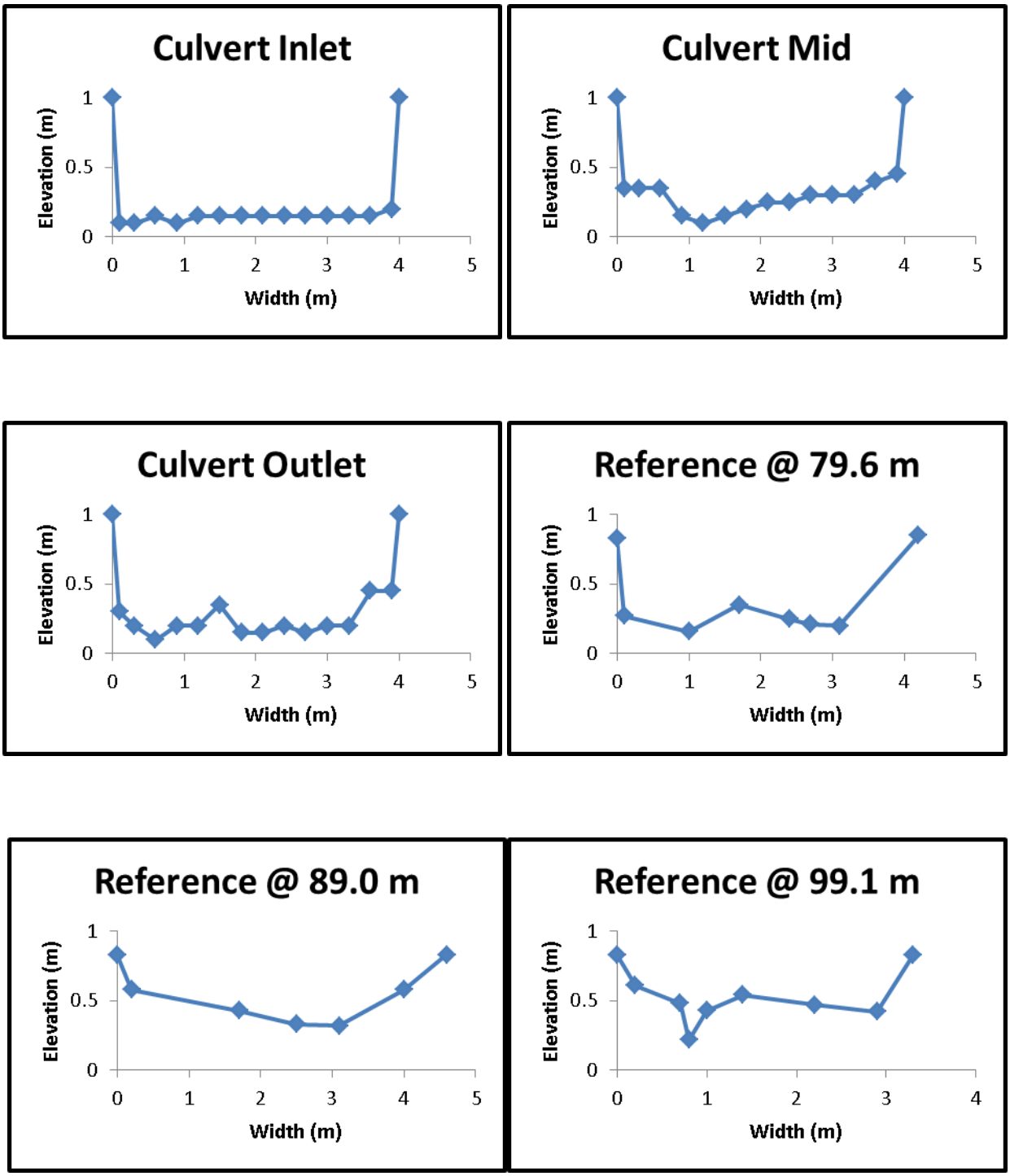
Streams and Fish Figure 3. Cross-sectional culvert and channel reference profiles – road 3015250 milepost 0.030



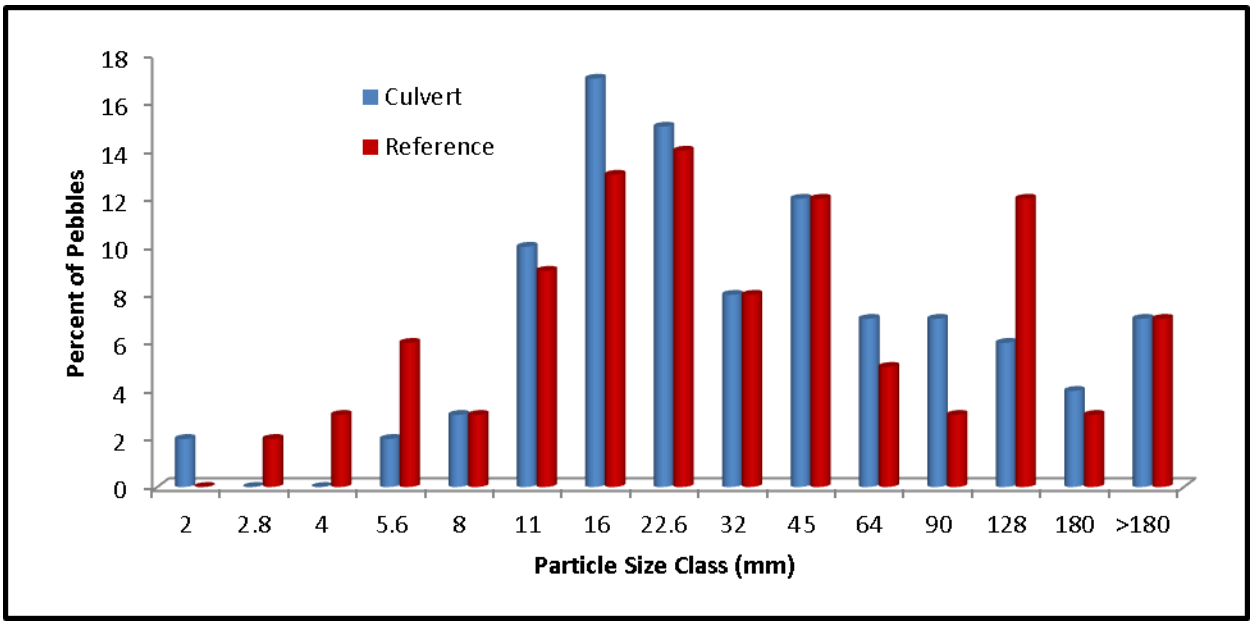
Cross sectional channel profiles were surveyed at three locations within the culvert and in the reference reach (Figure 3). Stream bed and bankfull width in the culvert is obviously more controlled by the culvert walls and is more contained than the reference reach. Channel bedwidths and profiles within the culvert and reference reach were fairly similar. The bedwidth in the culvert is 3.9 meters and the average bedwidth in the reference reach is 3.1 meters.

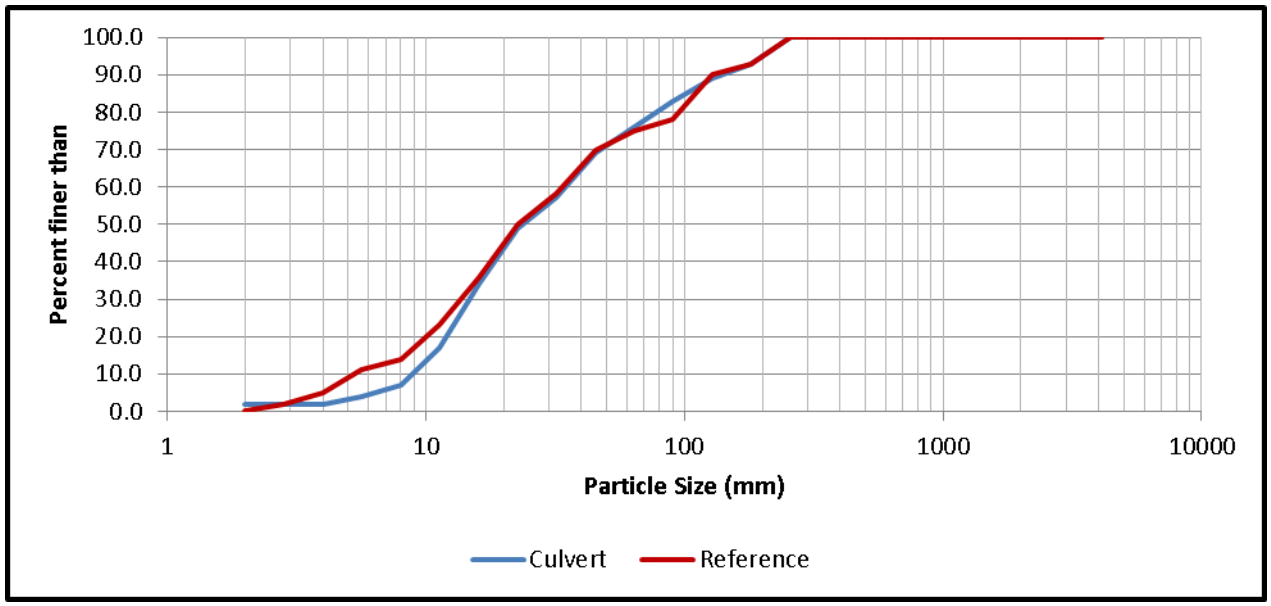
Particle size distribution was measured within the culvert and within the upstream reference reach. Both the reference reach and the culvert particle distribution were well-graded and similar (Figure 4). The median particle size (D50) in the culvert, as well as in the reference reach, is 22.6 mm (Figure 5).

Streams and Fish Figure 4. Cross Sectional Culvert and Channel Reference Profiles - Road 3015250 milepost 0.030



Streams and Fish Figure 5. Particle Size Histogram - Road 3015250 milepost 0.030





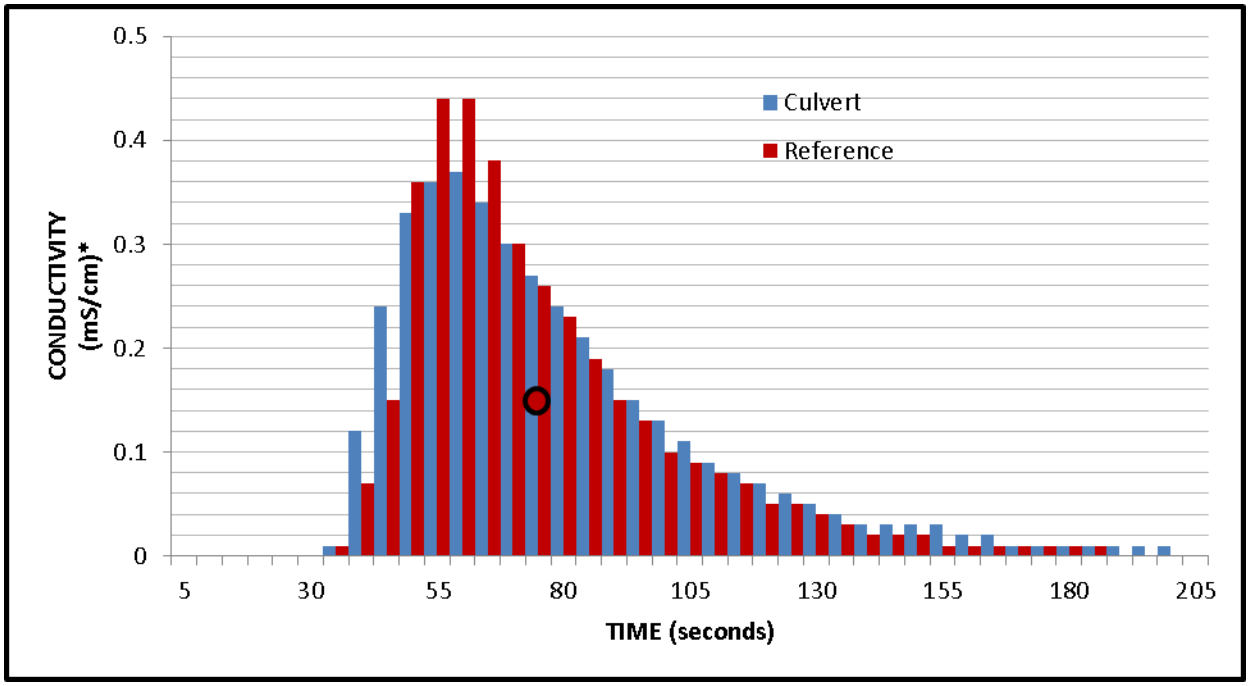
Streams and Fish Figure 6. Particle Size Cumulative Frequency - Road 3015250 milepost 0.030

The results of the salt tracer comparison indicated a very similar pattern in the flow characteristics within the culvert and reference reach (Figure 7). Results from the calculation of minimum, centroid and maximum flow velocities also indicates similar conditions in the culvert and the reference reach (Table 8).

Stream and Fish Photo 3. Culvert inlet, road 3015250 milepost 0.030

Stream and Fish Photo 4. Culvert bedload, road 3015250 milepost 0.030

Streams and Fish Figure 7. Salt tracer – road 3015250 milepost 0.030



Stream and Fish Table 3. **Velocity road 3015250 milepost 0.030**

Reach	Maximum Velocity	Centroid Velocity	Minimum Velocity
Culvert	0.52 meters /sec	0.25 meters/sec	0.09 meters/sec
Reference	0.52 meters /sec	0.26 meters/sec	0.10 meters/sec

Road 40000 milepost 3.706 (Photo 5)

This culvert is an un-remediated stream crossing that does not meet fish passage standards (i.e., red crossing). The evaluation of the un-remediated red culvert was done to provide a relative comparison to that of the remediated culverts.

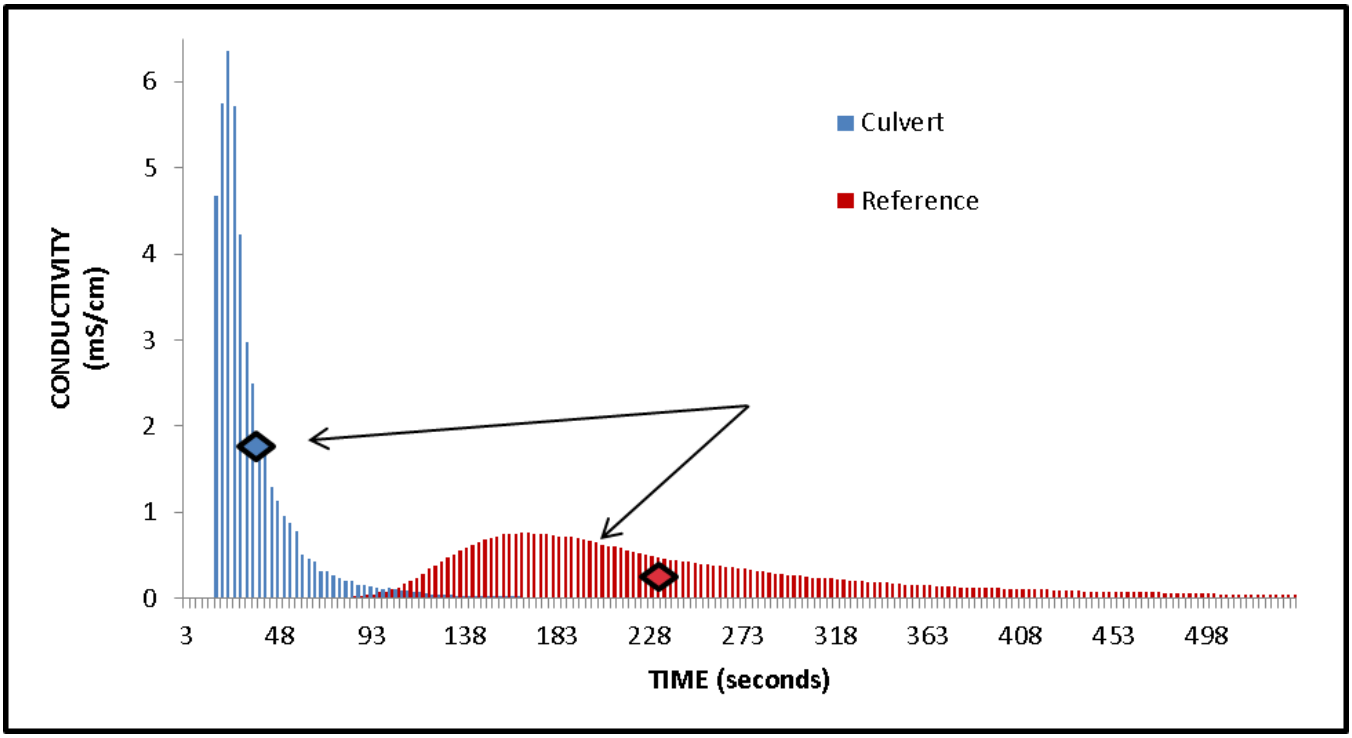
Stream and Fish Photo 5. Red culvert, road 40000 milepost 3.706

The culvert is within a high gradient contained channel with a channel gradient of 8 percent and a bedwidth of 11.7 feet. The structure is a 48 inch round corrugated metal culvert installed at 7 percent with no bedload retention and has a 0.7 feet outlet perch (Photo 5). The culvert is undersized for the channel and the culvert width to channel bedload width ratio is 0.34

The salt trace results clearly indicate the substantial differences in flow velocities between the culvert and an upstream reference reach (Photo 6, Figure 8). Obviously this culvert does not match the flow conditions found within the reference reach and is assumed to impair the efficient passage of fish. The maximum, centroid and minimum velocities of the sodium chloride solution are not similar (Table 4).

Stream and Fish Photo 6. Reference reach, road 40000 milepost 3.706

Streams and Fish Figure 8. Salt tracer – road 40000 milepost 3.706



Stream and Fish Table 4. **Road 40000 milepost 3.706 salt tracer velocities**

Reach	Maximum Velocity	Centroid Velocity	Minimum Velocity
Culvert	0.97 meters /sec	0.41 meters/sec	0.09 meters/sec
Reference	0.68 meters /sec	0.06 meters/sec	0.02 meters/sec

Minimally Engineered Aquatic Organism Passage (MEAOP) Designed Culverts

In an effort to reduce the significant costs associated with the survey, design and installation of culverts intended to provide fish passage, the Tongass National Forest has installed four culverts in 2012 five in 2013 and seven in 2014 using a design coined minimally engineered aquatic organism passage (MEAOP).

This approach strives to produce stream conditions, overtime, in the culvert that are reasonably similar to that found in the natural stream. Similar to stream simulated designed culverts, the goal is to create fish passage conditions in the culvert which reasonably mirror that of the natural channel by attempting to match stream gradient, width and bedload roughness. The general process involves embedding a properly sized culvert then depositing (surcharging) bedload material, sized to be capable of mobilizing at high flows, in the channel immediately upstream of the culvert (Photo 7). The expectation is that the material will mobilize, be deposited and retained in the embedded culvert.

The MEAOP design contrasts with stream simulation design in a few important ways. Stream simulation design typically entails a more comprehensive stream survey and engineering analysis which potentially reduces the risk of adverse effects. The most noticeable visual difference is an improved matching of the natural channels, roughness, bedform, diversity of stream velocities, depths and widths due to the greater attention to bedload size selection and placement within the culvert of a steam simulated designed structure.

The MEAOP design is an experimental design concept and monitoring is conducted annually by Tongass personnel on all of the installations. All 16 MEAOP designed culverts were monitored in 2014 after flow

events significant enough to mobilize the surcharged bedload material deposited upstream of the culvert.

Stream and Fish Photo 7. **MEAOP culvert with surcharge material upstream of culvert, MEAOP designed culvert, road 6259 milepost 2.334**

During 2014 the 9 MEAOP culverts installed in 2012 and 2013 were also evaluated by the Forest Service's Washington Office Virtual AOP Design Assistance Team (Gubernick and Weinhold 2015). The intent of this review was to look at how well the structures were performing and gain insight on how subsequent MEAOP installations might be modified in the following years. Some of the recommendations from the review have already been incorporated into several 2015 MEAOP installations.

MEAOP – 2014 Installations

Road 6259 milepost 2.334 (Photo 8)

Approximately 6 inches minus surcharged material was placed in the channel upstream of the culvert. Finer surcharge material is evident downstream of culvert. The installation was found to be adequate for fish passage (Table 5). Less than 1 cubic yard of the surcharged material remains upstream of the culvert following a high flow.

Stream and Fish Table 5. **Road 6259 milepost 2.334; culvert specifications**

Size	60" x 90" x 42'
Culvert gradient/natural channel gradient	4.0 percent / 4.0 percent
Percent of culvert length with bedload material	100 percent
Bedload depth to culvert rise proportion at inlet/outlet	0.06 / 0.32
Bedload particle size in culvert/natural channel	Gravel Cobble / Sand Gravel Organic
Culvert width to channel bedwidth proportion	1.21
Outlet perch present	No
Backwatered flow conditions	0 percent of length
Headcutting evident	No
Debris blockage present	No

Stream and Fish Table 6. **Road 6259 milepost 2.782; culvert specifications**

Size	43” x 52” x 38’
Culvert gradient/natural channel gradient	4.0 percent / 3.0 percent
Percent of culvert length with bedload material	100 percent
Bedload depth to culvert rise proportion at inlet/outlet	0.11 / 0.39
Bedload particle size in culvert/natural channel	Gravel Sand / Gravel Cobble Sand
Culvert width to channel bedwidth proportion	0.63
Outlet perch present	No
Backwatered flow conditions	98 percent of length
Headcutting evident	No
Debris blockage present	No

Culvert outlet, looking upstream

Culvert inlet, looking downstream

Culvert barrel, looking upstream

Culvert barrel, looking downstream

Stream and Fish Photo 8. MEAOP designed culvert, road 6259 milepost 2.782

Road 6259 milepost 2.787 (Photo 9)

Design specifications required that 1.5 inches minus surcharged material be placed in the channel upstream of the culvert. The installation was found to be adequate for fish passage (Table 7). Approximately 2 cubic yards of the surcharged material remains upstream of the culvert following a high flow.

Stream and Fish Table 7. **Road 6259 milepost 2.787; culvert specifications**

Size	44” x 51” x 40’
Culvert gradient/natural channel gradient	3.7 percent / 3.0 percent
Percent of culvert length with bedload material	70 percent
Bedload depth to culvert rise proportion at inlet/outlet	0.0 / 0.26
Bedload particle size in culvert/natural channel	Gravel Sand / Gravel Cobble Organic
Culvert width to channel bedwidth proportion	0.84
Outlet perch present	No
Backwatered flow conditions	100 percent of length
Headcutting evident	No
Debris blockage present	No

Culvert outlet, looking upstream

Culvert inlet, looking downstream

Culvert barrel, looking upstream

Culvert barrel, looking downstream

Stream and Fish Photo 9. MEAOP designed culvert, road 6259 milepost 2.787

Road 50054 milepost 0.033 (Photo 10)

Design specifications required that 1.5 inches minus surcharged material be placed in the channel upstream of the culvert. The installation was found not to be adequate for fish passage (Table 8). A headcut is present upstream. Approximately 2 cubic yards of the surcharged material remains upstream of the culvert following a high flow.

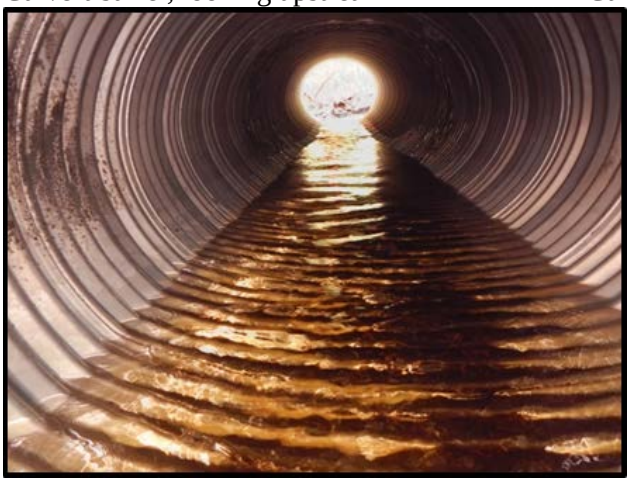
Stream and Fish Table 8. **Road 50054 milepost 0.033; culvert specifications**

Size	44” x 53” x 33’
Culvert gradient/natural channel gradient	2.2 percent / 5.0 percent
Percent of culvert length with bedload material	0 percent
Bedload depth to culvert rise proportion at inlet/outlet	0.07 / 0.12
Bedload particle size in culvert/natural channel	None / Gravel, Cobble, Organic
Culvert width to channel bedwidth proportion	0.88
Outlet perch present	No
Backwatered flow conditions	Only 25 percent of length
Headcutting evident	Yes
Debris blockage present	No

Culvert outlet, looking upstream

Culvert inlet, looking downstream

Culvert barrel, looking upstream



Culvert barrel, looking downstream

Stream and Fish Photo 10. *MEAPOP designed culvert, road 50054 milepost 0.033*

Road 50054 milepost 0.063 MEAOP (Photo 11)

Design specifications required that 1.5 inches minus surcharged material be placed in the channel upstream of the culvert. The installation was found to be adequate for fish passage (Table 9). None of the surcharged material remains upstream of the culvert following a high flow.

Stream and Fish Table 9. **Road 50054 milepost 0.063; culvert specifications**

Size	36” x 36” x 32’
Culvert gradient/natural channel gradient	1.3 percent / 1.0 percent
Percent of culvert length with bedload material	100 percent
Bedload depth to culvert rise proportion at inlet/outlet	0.07 / 0.12
Bedload particle size in culvert/natural channel	Gravel & Sand / Sand, Silt, Organic
Culvert width to channel bedwidth proportion	0.80
Outlet perch present	No
Backwatered flow conditions	90 percent of culvert length
Headcutting evident	No
Debris blockage present	No

Culvert outlet, looking upstream

Culvert inlet, looking downstream

Culvert barrel, looking upstream

Culvert barrel, looking downstream

Stream and Fish Photo 11. MEAOP designed culvert, road 50054, milepost 0.063

Road 50024 milepost 0.086 (Photo 12)

Design specifications required that 1.5 inches minus surcharged material be placed in the channel upstream of the culvert. The installation was found to be adequate for fish passage (Table 10). Approximately 1 cubic yard of surcharged material remains upstream of the culvert following a high flow.

Stream and Fish Table 10. **Road 50024 milepost 0.086; culvert specifications**

Size	36 ”x 36” x 28’
Culvert gradient/natural channel gradient	1.5 percent / 3.0 percent
Percent of culvert length with bedload material	100 percent
Bedload depth to culvert rise proportion at inlet/outlet	0.19 / 0.09
Bedload particle size in culvert/natural channel	Gravel & Sand / Sand & Silt
Culvert width to channel bedwidth proportion	0.95
Outlet perch present	No
Backwatered flow conditions	Only 85 percent of length
Headcutting evident	No
Debris blockage present	No

Culvert outlet, looking upstream

Culvert inlet, looking downstream

Culvert barrel, looking upstream

Culvert barrel, looking downstream

Stream and Fish Photo 12. MEAOP designed culvert, road 50024 milepost 0.086

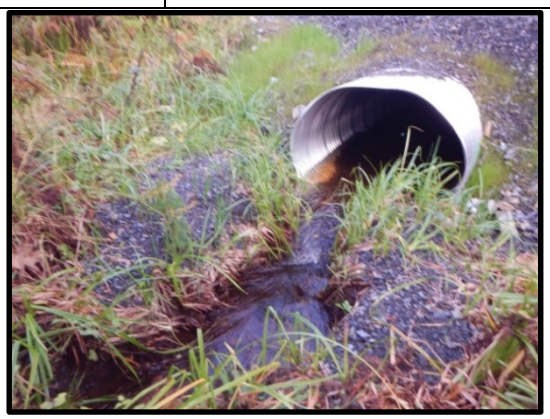
Road 50055 milepost 0.031 (Photo 13)

Design specifications required that 6 inches minus surcharged material be placed in the channel upstream of the culvert and in-filled approximately 6 feet from each end of the culvert to a depth of 1.0 feet. The installation was found to be adequate for fish passage (Table 11). A small amount of surcharged material remains upstream of the culvert following a high flow.

Stream and Fish Table 11. **Road 50055 milepost 0.031; culvert specifications**

Size	55” x 73” x 40’
Culvert gradient/natural channel gradient	2.5 percent / 2.0 percent
Percent of culvert length with bedload material	100 percent
Bedload depth to culvert rise proportion at inlet/outlet	0.05 / 0.08
Bedload particle size in culvert/natural channel	Sand & Gravel / Gravel & Sand
Culvert width to channel bedwidth proportion	1.69
Outlet perch present	No
Backwatered flow conditions	Only 66 percent of length
Headcutting evident	No
Debris blockage present	No

Culvert outlet, looking upstream



Culvert inlet, looking downstream

Culvert barrel, looking upstream

Culvert barrel, looking downstream

Stream and Fish Photo 13. *MEAOP designed culvert, road 50055 milepost 0.031*

MEAOP – 2013 Installations

The 2013 MEAOP installed culverts were monitored in both 2013 and 2014.

Road 2085000 milepost 0.944 (Photo 14)

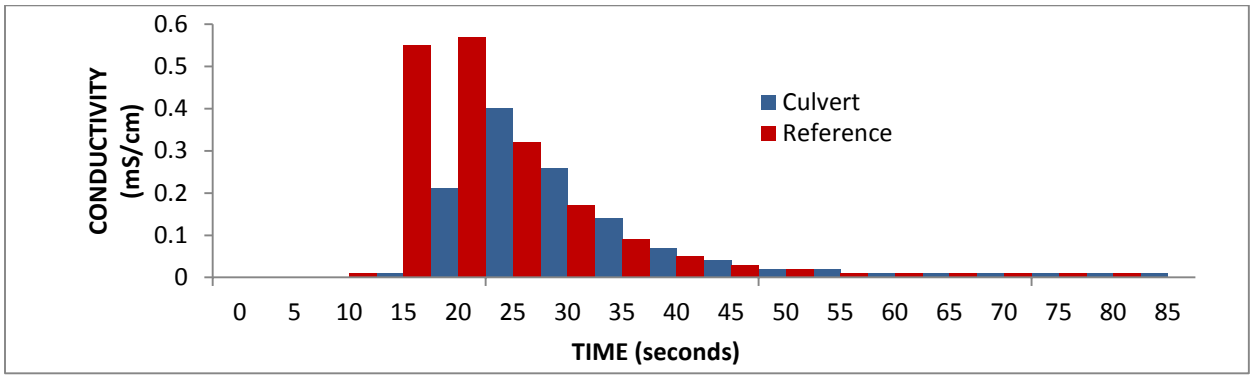
Design specifications required that surcharged material deposited upstream of the culvert and in-filled approximately 6 feet from each end of the culvert to a depth of 1.5 feet. The installation was found to be adequate for fish passage (Table 12). Following a high flow a substantial amount of the surcharged material deposited upstream of the culvert still remained. Much of this material is above bankfull and will most likely not be mobilized into the culvert during usual high flow events.

Stream and Fish Table 12. **Road 2085000 milepost 0.944; culvert specifications**

Size	55" x 73 "x 38'	
Culvert gradient/natural channel gradient	2013: 3.8 percent / 4.5 percent	
Percent of culvert length with bedload material	2013: 100 percent	2014: 100 percent
Bedload depth to culvert rise proportion at inlet/outlet	2013: 0.30 / 0.26	2014: 0.30 / 0.28
Bedload particle size in culvert/natural channel	Gravel & Cobble / Gravel & Cobble	
Culvert width to channel bedwidth proportion	1.16	
Outlet perch present	No	
Backwatered flow conditions	No	
Headcutting evident	Yes	
Debris blockage present	No	

In addition to assessing the culvert with the criteria of the fish passage matrix a comparison of culvert conditions to a reference reach was completed with a salt trace. The results of the salt trace comparison indicated a fairly similar pattern in the flow characteristics within the culvert and reference reach (Figure 9). The minimum, centroid and maximum flow velocities were computed from the salt trace and are presented in Table 13.

Streams and Fish Figure 9. Salt tracer, road 2085000 milepost 0.944 - 2013



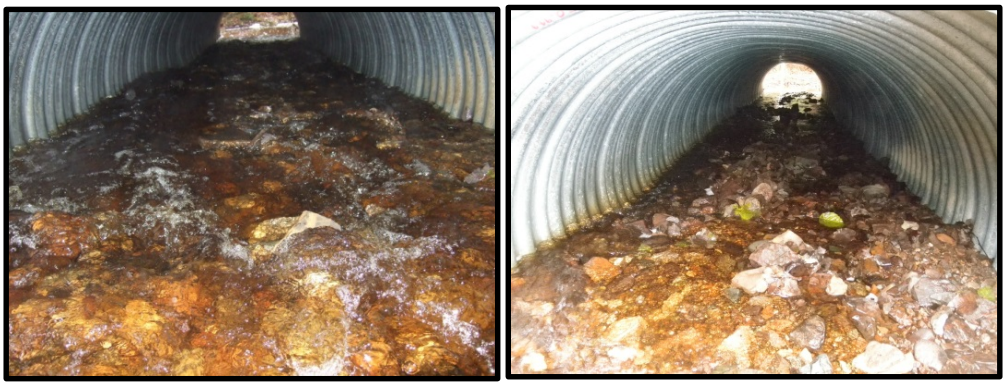
Stream and Fish Table 13. **Road 2085000 milepost 0.944 salt tracer velocities (2013)**

Reach	Maximum Velocity	Centroid Velocity	Minimum Velocity
Culvert	0.77 meters /sec	0.25 meters/sec	0.14 meters/sec
Reference	1.16 meters /sec	0.27 meters/sec	0.15 meters/sec

Culvert outlet, looking upstream in 2013 and 2014

Culvert inlet, looking downstream in 2013 and 2014

Culvert barrel, looking upstream in 2013 and 2014



Culvert barrel, looking downstream in 2013 and 2014

Stream and Fish Photo 14. *MEAOP designed culvert, road 2085000 milepost 0.944*

Road 2000000 milepost 122.678 (Photo 15)

Design specifications required that surcharged material be in-filled approximately 6 feet from each end of the culvert to a depth of 1.0 feet and placed upstream of the culvert. The installation was found to be adequate for fish passage (Table 14). The culvert has 40 percent of its length covered with bedload material but the section of the culvert without bedload was backwatered.

Following a high flow approximately 3 cubic yards of the surcharged material deposited upstream of the culvert still remained. Much of this material is above bankfull and will most likely not be mobilized into the culvert during usual high flow events. No native bedload material has mobilized into the culvert and is not likely to due to palustine character of the stream.

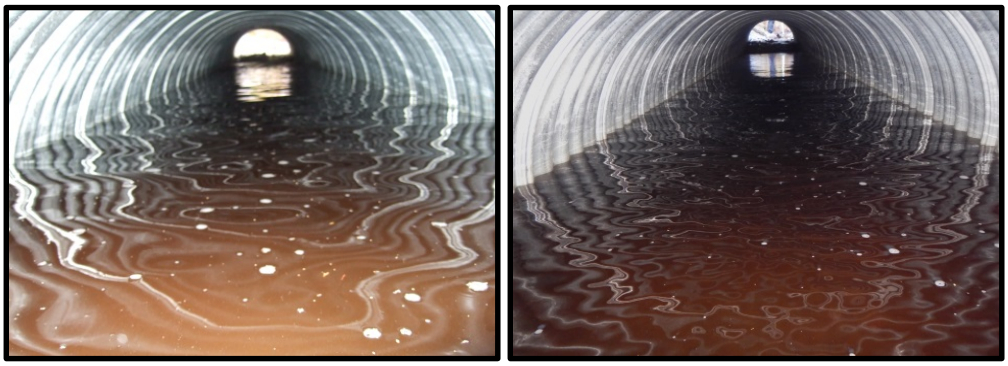
Stream and Fish Table 14. **Road 2000000 milepost 122.678; culvert specifications**

Size	46” x 60” x 46’	
Culvert gradient/natural channel gradient	3.8 percent / 4.5 percent	
Percent of culvert length with bedload material	2013: 38 percent	2014: 40 percent
Bedload depth to culvert rise proportion at inlet/outlet	2013: 0.37 / 0.22	2014: 0.43 / 0.22
Bedload particle size in culvert/natural channel	Gravel & Cobble / Silt & Organics	
Culvert width to channel bedwidth proportion	1.39	
Outlet perch present	No	
Backwatered flow conditions	72 percent of culvert length	
Headcutting evident	No	
Debris blockage present	No	

Stream and Fish Photo 15. Road 2000000 milepost 122.678

Culvert outlet, looking upstream in 2013 and 2014

Culvert inlet, looking downstream in 2013 and 2014



Culvert barrel, looking upstream in 2013 and 2014

Culvert barrel, looking downstream in 2013 and 2014

Road 2000000 milepost 125.242 (Photo 16)

Design specifications required that surcharged material be in-filled approximately 10 feet from each end of the culvert to a depth of 2.0 feet as well as upstream of the culvert for stream flow mobilization. The installation was found to be adequate for fish passage (Table 15). The culvert has 100 percent of its length covered with bedload material which is an increase from the previous year.

Following a high flow, approximately 5 cubic yards of the surcharged material deposited upstream of the culvert still remained. Much of this material is above bankfull and will most likely not be mobilized into the culvert during usual high flow events. Approximately 20 percent of the bedload within the culvert is composed of native material.

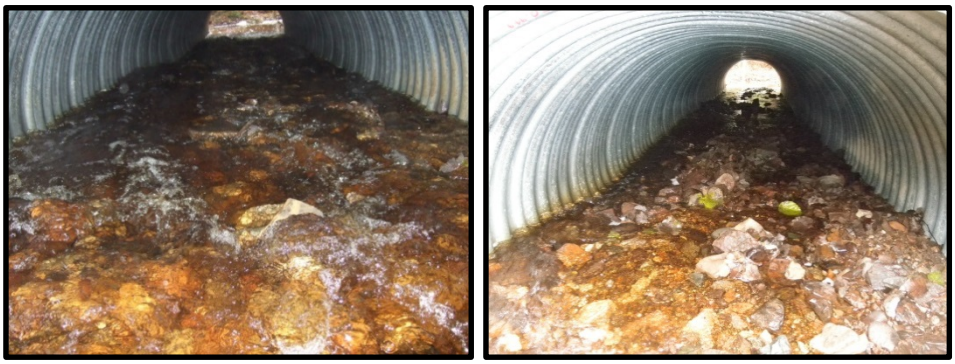
Stream and Fish Table 15. **Road 2000000 milepost 125.242; culvert specifications**

Size	101” x 157” x 65’ mitered inlet and outlet	
Culvert gradient/natural channel gradient	1.8 percent / 3.5 percent	
Percent of culvert length with bedload material	2013: 86 percent	2014: 100 percent
Bedload depth to culvert rise proportion at inlet/outlet	2013: 0.23 / 0.17	2014: 0.20 / 0.16
Bedload particle size in culvert/natural channel	Gravel, Cobble, Sand/Gravel, Cobble, Sand	
Culvert width to channel bedwidth proportion	1.09	
Outlet perch present	No	
Backwatered flow conditions	Yes, 35 percent of culvert length	
Headcutting evident	Yes	
Debris blockage present	No	

Culvert outlet, looking upstream in 2013 and 2014

Culvert inlet, looking downstream in 2013 and 2014

Culvert barrel, looking upstream in 2013 and 2014



Culvert barrel, looking downstream in 2013 and 2014

Stream and Fish Photo 16. MEAOP designed culvert, road 2085000 milepost 0.944

Road 2000000 milepost 122.678 (Photo 17)

Design specifications required that surcharged material be in-filled approximately 6 feet from each end of the culvert to a depth of 1.0 feet and placed upstream of the culvert. The installation was found to be adequate for fish passage (Table 16). The culvert has 40 percent of its length covered with bedload material but the section of the culvert without bedload was backwatered.

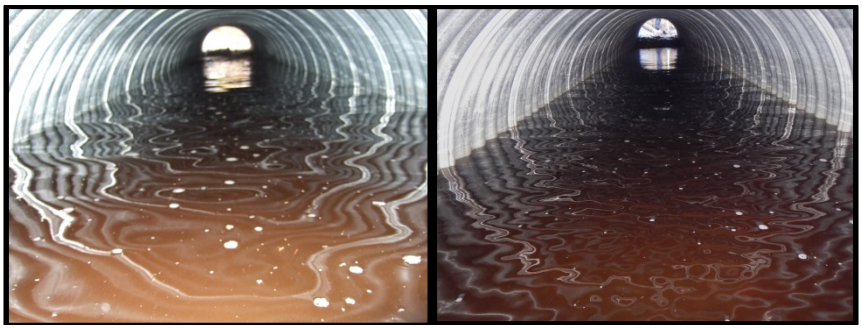
Following a high flow approximately 3 cubic yards of the surcharged material deposited upstream of the culvert still remained. Much of this material is above bankfull and will most likely not be mobilized into the culvert during usual high flow events. No native bedload material has mobilized into the culvert and is not likely to due to palustine character of the stream.

Stream and Fish Table 16. **Road 2000000 milepost 122.678; culvert specifications**

Size	46” x 60” x 46’	
Culvert gradient/natural channel gradient	3.8 percent / 4.5 percent	
Percent of culvert length with bedload material	2013: 38 percent	2014: 40 percent
Bedload depth to culvert rise proportion at inlet/outlet	2013: 0.37 / 0.22	2014: 0.43 / 0.22
Bedload particle size in culvert/natural channel	Gravel & Cobble / Silt & Organics	
Culvert width to channel bedwidth proportion	1.39	
Outlet perch present	No	
Backwatered flow conditions	72 percent of culvert length	
Headcutting evident	No	
Debris blockage present	No	

Culvert outlet, looking upstream in 2013 and 2014

Culvert inlet, looking downstream in 2013 and 2014



Culvert barrel, looking upstream in 2013 and 2014

Culvert barrel, looking downstream in 2013 and 2014

Stream and Fish Photo 17. MEAOP designed culvert - Road 2000000 milepost 122.678

Road 2000000 milepost 125.242 (Photo 18)

Design specifications required that surcharged material be in-filled approximately 10 feet from each end of the culvert to a depth of 2.0 feet as well as upstream of the culvert for stream flow mobilization. The installation was found to be adequate for fish passage (Table 17). The culvert has 100 percent of its length covered with bedload material which is an increase from the previous year.

Following a high flow, approximately 5 cubic yards of the surcharged material deposited upstream of the culvert still remained. Much of this material is above bankfull and will most likely not be mobilized into the culvert during usual high flow events. Approximately 20 percent of the bedload within the culvert is composed of native material.

Stream and Fish Table 17. **Road 2000000 milepost 125.242; culvert specifications**

Size	101” x 157” x 65’ mitered inlet and outlet	
Culvert gradient/natural channel gradient	1.8 percent / 3.5 percent	
Percent of culvert length with bedload material	2013: 86 percent	2014: 100 percent
Bedload depth to culvert rise proportion at inlet/outlet	2013: 0.23 / 0.17	2014: 0.20 / 0.16
Bedload particle size in culvert/natural channel	Gravel, Cobble, Sand/Gravel, Cobble, Sand	
Culvert width to channel bedwidth proportion	1.09	
Outlet perch present	No	
Backwatered flow conditions	Yes, 35 percent of culvert length	
Headcutting evident	Yes	
Debris blockage present	No	

Culvert outlet, looking upstream in 2013 and 2014

Culvert inlet, looking downstream in 2013 and 2014

Culvert barrel, looking upstream in 2013 and 2014

Culvert barrel, looking downstream in 2013 and 2014

Stream and Fish Photo 18. MEAOP designed culvert, Road 2000000 milepost 125.242

Road 2000860 milepost 0.659 (Photo 19)

Design specifications required that surcharged material be in-filled approximately 8 feet from each end of the culvert to a depth of 2.0 feet as well as upstream of the culvert for stream flow mobilization. The installation was found to be adequate for fish passage (Table 18). The culvert has 100 percent of its length covered with bedload material which is a significant increase from the previous year.

Following a high flow approximately 2 cubic yards of the surcharged material deposited upstream of the culvert still remained. Much of this material is above bankfull and will most likely not be mobilized into the culvert during usual high flow events. The bedload within the culvert is a mix of native and surcharge material.

Stream and Fish Table 18. **Road 2000860 milepost 0.659; culvert specifications**

Size	67” x 95” x 35’	
Culvert gradient/natural channel gradient	2.7 percent / 3.5 percent	
Percent of culvert length with bedload material	2013: 54 percent	2014: 100 percent
Bedload depth to culvert rise proportion at inlet/outlet	2013: 0.30 / 0.25	2014: 0.34 / 0.26
Bedload particle size in culvert/natural channel	Gravel, Sand, Cobble / Gravel, Sand, Cobble	
Culvert width to channel bedwidth proportion	1.01	
Outlet perch present	No	
Backwatered flow conditions	No	
Headcutting evident	Yes	
Debris blockage present	No	

Stream and Fish Photo 19. MEAOP designed culvert, road 2000860 milepost 0.659

Culvert outlet, looking upstream in 2013 and 2014

Culvert inlet, looking downstream in 2013 and 2014

Culvert barrel, looking upstream in 2013 and 2014

Culvert barrel, looking downstream in 2013 and 2014

Road 3000000 milepost 89.221 (Photo 20)

Design specifications required that surcharged material be in-filled approximately 6 feet from each end of the culvert to a depth of 1.5 feet as well as upstream of the culvert for stream flow mobilization. The installation was found to be adequate for fish passage (Table 19). The culvert has 100 percent of its length covered with bedload material, which is a significant increase from the previous year. Approximately 10 percent of the culvert bedload is native material.

Following a high flow surcharged material deposited upstream of the culvert still remained. Much of this material is above bankfull and will most likely not be mobilized into the culvert during usual high flow events.

Stream and Fish Table 19. **Road 3000000 milepost 89.221; culvert specifications**

Size	55” x 73” x 65’	
Culvert gradient/natural channel gradient	3.8 percent / 6.5 percent	
Percent of culvert length with bedload material	2013: 54 percent	2014: 100 percent
Bedload depth to culvert rise proportion at inlet/outlet	2013: 0.15 / 0.21	2014: 0.17 / 0.24
Bedload particle size in culvert/natural channel	Gravel, Cobble, Sand / Gravel, Cobble, Sand	
Culvert width to channel bedwidth proportion	1.19	
Outlet perch present	No	
Backwatered flow conditions	11 percent of culvert length	
Headcutting evident	No	
Debris blockage present	No	

Culvert outlet, looking upstream in 2013 and 2014

Culvert inlet, looking downstream in 2013 and 2014

Culvert barrel, looking upstream in 2013 and 2014

Culvert barrel, looking downstream in 2013 and 2014

Stream and Fish Photo 20. Stream and Fish Photo 19. MEAOP designed culvert, road 3000000 milepost 89.221

MEAOP – 2012 Installations

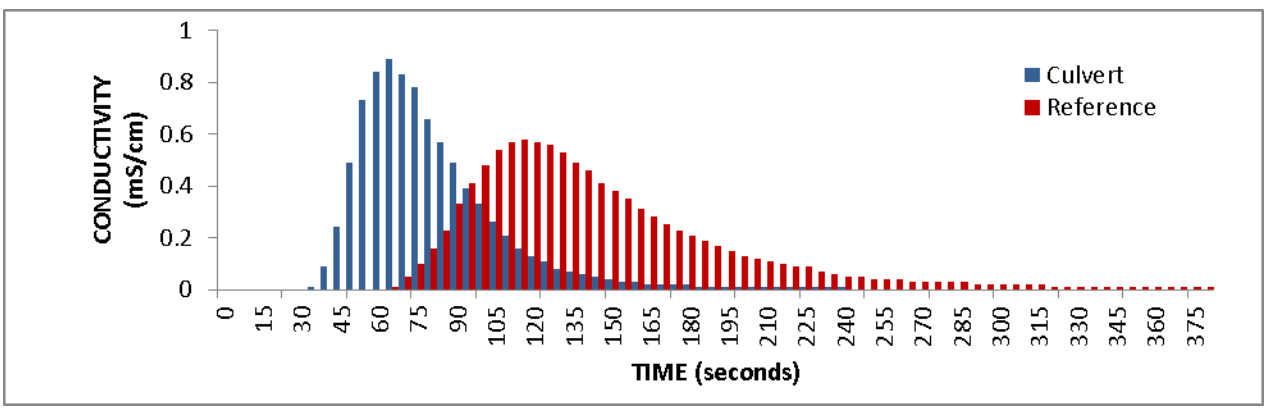
The 2012 MEAOP installed culverts were monitored in 2012, 2013 and 2014.

Road 3015000 milepost 1.773 (Picture 21)

The MEAOP designed culvert was found not to be adequate for fish passage using the Alaska Region's Juvenile Fish Passage Criteria Matrix (Table 20). There is loss of bedload material at the inlet due to a potentially poorly located rock grade control causing scour. In addition to assessing the culvert with the criteria of the fish passage matrix a comparison of culvert conditions to a reference reach was completed with a salt trace. The results of the salt trace comparison indicated a dissimilar pattern in the flow characteristics within the culvert and reference reach (Figure 10). The minimum, centroid and maximum flow velocities were computed from the salt trace and are presented in Table 21.

Stream and Fish Table 20. **Road 3015000 milepost 1.773; culvert specifications**

Size	46" x 60" x 40'
Culvert gradient/natural channel gradient	3.5 percent / 10 percent
Percent of culvert length with bedload material	2012: 100 percent 2013: 100 percent 2014: 98 percent
Bedload depth to culvert rise proportion at inlet/outlet	2012: 0.09 / 0.11 2013: 0.14 / 0.17 2014: 0.00 / 0.20
Bedload particle size in culvert/natural channel	Gravel, Cobble, Sand / Gravel, Sand, Cobble
Culvert width to channel bedwidth proportion	0.76
Outlet perch present	No
Backwatered flow conditions	No
Headcutting evident	No
Debris blockage present	No



Streams and Fish Figure 10. Salt tracer - road 3015000 milepost 1.773 (2013)

Stream and Fish Table 21. **Road 3015000 milepost 1.773 salt tracer velocities (2013)**

Reach	Maximum Velocity	Centroid Velocity	Minimum Velocity
Culvert	0.77 meters /sec	0.25 meters/sec	0.14 meters/sec
Reference	1.16 meters /sec	0.27 meters/sec	0.15 meters/sec

Stream and Fish Photo 21. Road 3015000 milepost 1.773 Culvert outlet, looking upstream

2012 2013 2014

Culvert outlet, looking upstream

2012 2013 2014

Culvert barrel inlet

2012 2013 2014

Culvert barrel, looking upstream

2012 2013 2014

Culvert barrel, looking downstream

Road 3015000 Milepost 8.743 (Photo 22)

The MEAOP designed culvert was found to be adequate for fish passage using the Alaska Region's juvenile fish passage criteria matrix. The extent and depth of the bedload in the culvert increased dramatically from previous years (Table 22). Approximately 2 cubic yards of the surcharged material deposited upstream of the culvert still remains following several high flow events. Much of this material is above bankfull and will most likely not be mobilized into the culvert during usual high flow events.

Stream and Fish Table 22. **Road 3015000 milepost 8.743; culvert specifications**

Size	63" x 87" x 32'		
Culvert gradient/natural channel gradient	4.2 percent / 7.5 percent		
Percent of culvert length with bedload material	2012: 50 percent percent	2013: 58 percent	2014: 100
Bedload depth to culvert rise proportion at inlet/outlet	2012: 0.30 / 0.00 049	2013: 0.31 / 0.00	2014: 034 /
Bedload particle size in culvert/natural channel	Gravel, Cobble, Sand / Gravel, Sand, Cobble		
Culvert width to channel bedwidth proportion	1.34		
Outlet perch present	No		
Backwatered flow conditions	No		
Headcutting evident	Yes		

Stream and Fish Photo 22. Road 3015000 Milepost 8.743

Culvert outlet, looking upstream

2012 2013 2014

Culvert inlet, looking downstream

2012 2013 2014

Culvert barrel, looking upstream

2012 2013 2014

Culvert barrel, looking downstream

2012 2013 2014

Road 2000000 milepost 102.907 (Photo 23)

The culvert was found to be adequate for fish passage using the Alaska Region's Juvenile Fish Passage Criteria Matrix (Table 23). The depth of bedload in the culvert inlet has decreased from the previous year due to poor culvert alignment with the stream channel. Bedload material and flow velocities are variable transversely within the culvert. Approximately 90 percent of the surface bedload in the culvert is native material. Surcharge material is distributed downstream of the culvert to approximately 200 feet. Approximately 3 cubic yards of the surcharged material deposited upstream of the culvert still remains following several high flow events. Much of this material is above bankfull and will most likely not be mobilized into the culvert during usual high flow events.

Stream and Fish Table 23. **Road 2000000 milepost 102.907; culvert specifications**

Size	110" x 171" x 40' mitered inlet and outlet
Culvert gradient/natural channel gradient	1 percent / 2 percent
Percent of culvert length with bedload material	2012: 100 percent 2013: 100 percent 2014: 100 percent
Bedload depth to culvert rise proportion at inlet/outlet	2012: 0.12 / 0.18 2013: 0.18 / 0.24 2014: 0.05 / 0.37
Culvert width to channel bedwidth proportion	0.94
Outlet perch present	No
Backwatered flow conditions	0 percent of culvert length
Headcutting evident	Yes
Debris blockage present	No

Stream and Fish Photo 23. MEAOP designed culvert, road 2000000 milepost 102.907

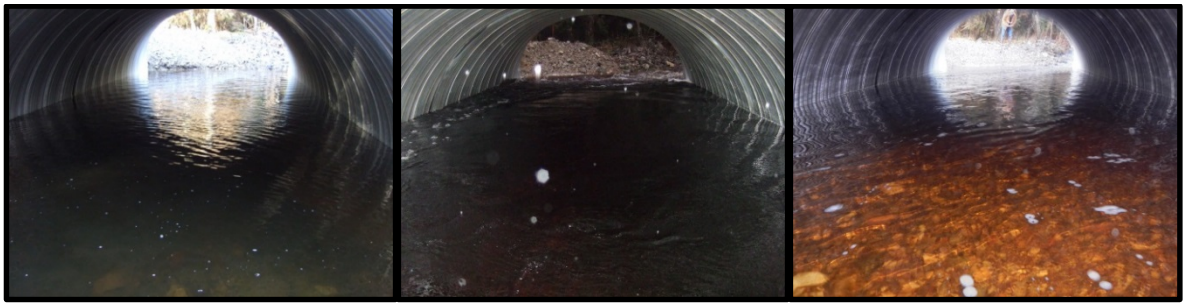
Culvert outlet, looking upstream

2012 2013 2014

Culvert inlet, looking downstream

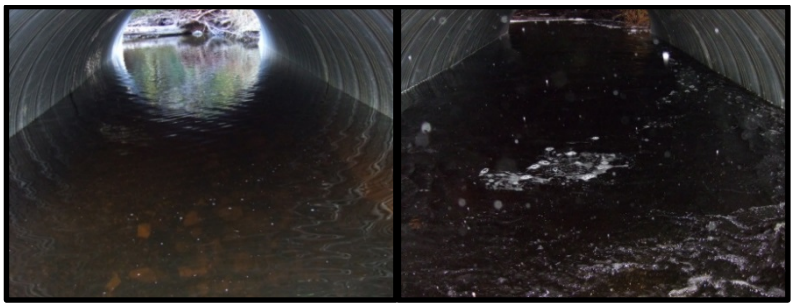
2012 2013 2014

Culvert barrel, looking upstream



2012 2013 2014

Culvert barrel, looking downstream



Not available

2012 2013 2014

Road 2700000 milepost 0.710 (Photos 24 and 25)

The culvert was found to be adequate for fish passage using the Alaska Region's juvenile fish passage criteria matrix. The extent and depth of bedload in the culvert has increased significantly from the previous year (Table 24). The bedload material at the inlet is mostly native material (80 percent) while at the outlet it is present to a much lesser extent (10 percent). The culvert installation has undermined existing upstream grade controls. This has caused a headcut which has hit a bedrock ledge causing a potential fish migration barrier. It is anticipated that that the headcut will continue to advance upstream once a woody debris grade control on the bedrock lip fails (Photo 23). A few cubic yards of the surcharged material deposited upstream of the culvert still remains following several high flow events. Much of this material is above bankfull and will most likely not be mobilized into the culvert during usual high flow events.

Stream and Fish Table 24. **Road 2700000 milepost 0.710; culvert specifications**

Size	71" x 103" x 42'
Culvert gradient/natural channel gradient	3.0 percent / 2.5 percent
Percent of culvert length with bedload material	2012: 45 percent 2013: 45 percent 2014: 100 percent
Bedload depth to culvert rise proportion at inlet/outlet	2012: 0.31 / 0.00 2013: 0.31 / 0.00 2014: 0.34 / 0.17
Culvert width to channel bedwidth proportion	1.36
Outlet perch present	No
Backwatered flow conditions	Yes, 88 percent of culvert length
Headcutting evident	Yes
Debris blockage present	No

An additional assessment was completed at this stream crossing to evaluate how similar physical and hydraulic conditions are within the structure and at the inlet and outlet transition zones compared to that of a nearby representative stream reach. The assessment compared bankfull width, wetted width, maximum depth, key particle sizes and bank irregularity (i.e., frequency of protrusions). The analysis calculates the median, 25 percent and 75 percent quartile and minimum and maximum measured values for the reference reach which is compared to measurements within the structure and at the inlet and outlet transition zones. These values are used to determine a relative rating. Poor ratings were given to the bankfull width within the culvert, over-widened channel widths at the outlet and uniform bank configuration in the culvert (Table 23).

Culvert gradient is comparable with that of the natural channel but the culvert bed profile is homogenous and does not mimic the step-pool bedform of the channel (Figure 11).

Stream and Fish Photo 24. Headcut upstream of road 2700000 milepost 0.710

Stream and Fish Table 25. **Bankfull Width Comparison**

Bankfull Width (ft.)	Minimum	25 percent Quartile	Median	75 percent Quartile	Maximum	Rating
Reference Reach	9.4	11.4	13.4	13.65	15.5	N/A
Structure	8.4	8.4	8.4	8.4	8.4	Poor
Inlet Transition	8.5	9.7	10.8	11.6	17	At-Risk
Outlet Transition	10.6	12.2	13.2	13.65	14.3	Good

Stream and Fish Table 26. **Wetted Width Comparison**

Wetted Width (ft.)	Minimum	25 percent Quartile	Median	75 percent Quartile	Maximum	Rating
Reference Reach	3.9	4.9	6.6	7.4	9.4	N/A
Structure	8.4	8.4	8.4	8.4	8.4	At-Risk
Inlet Transition	6.4	7.1	7.2	8.0	8.5	Good
Outlet Transition	10	10.45	11.2	11.75	12.3	Poor

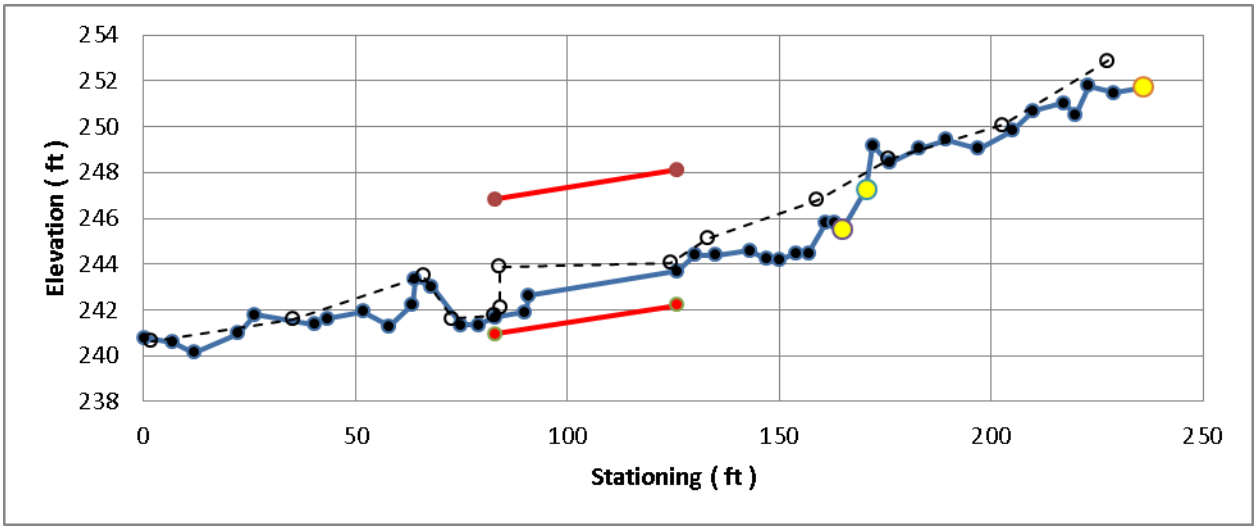
Stream and Fish Table 27. **Key Particle Comparison**

Key Particle Size	Minimum	25 percent Quartile	Median	75 percent Quartile	Maximum	Rating
Reference Reach	170	200	210	250	290	N/A
Structure	165	190	230	260	390	Good
Inlet Transition	170	210	220	260	320	Good
Outlet Transition	N/A Pool					

Stream and Fish Table 28. **Bank Irregularity Comparison**

Bank Protrusions	Number	Channel Length (ft.)	Channel Width (ft.)	Frequency	Rating
Reference Reach	10	40	13.4	3.4	N/A
Structure	1	42	8.4	2.4	Uniform
Inlet Transition	4	18	10.8	0.2	Irregular
Outlet Transition	5	16	13.2	4.1	Irregular

Streams and Fish Figure 11. Road 2700000 milepost 0.710, longitudinal profile



Stream and Fish Photo 25. MEAOP designed culvert ; road 2700000 milepost 0.710

Culvert outlet, looking upstream

2012 2013 2014

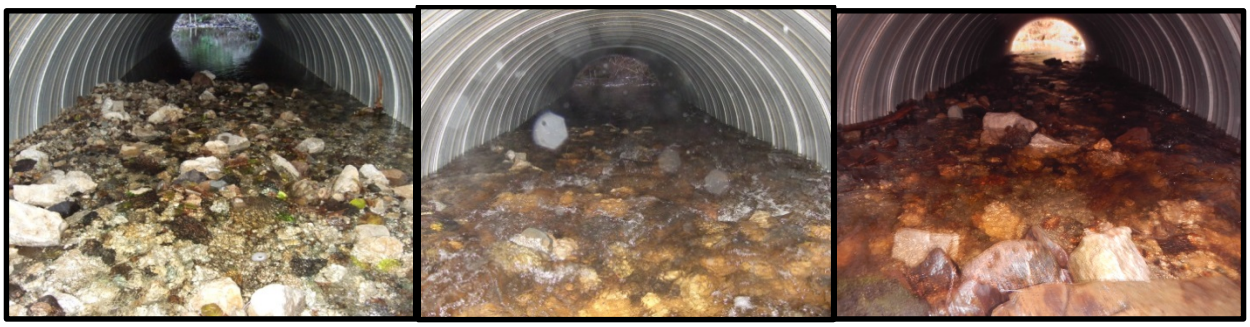
Culvert inlet, looking downstream

2012 2013 2014

Culvert barrel, looking upstream

2012 2013 2014

Culvert barrel, looking downstream



2012 2013 2014

Evaluation of Results

Fifteen (9 percent) of the 164 culverts monitored to date and assessed via the Alaska Region juvenile fish passage criteria matrix do not meet State of Alaska passage standards (red) and may to some extent impede the passage of juvenile fish. The 15 crossings determined not to be consistent with juvenile passage standards can be generally attributed to several different reasons. 1) Three of the 15 red culverts were known fish stream crossings requiring passage considerations but were installed without fish passage design considerations due to project personnel apparently being unaware of aquatic passage objective. 2) Four of the red crossings were installed without passage considerations because they were not identified as crossings requiring fish passage until after construction was completed. 3) Two of the culverts not meeting juvenile passage standards are MEAOP designed culverts and have not accumulated enough bedload within them to provide adequate roughness and moderate water velocity. These culverts will potentially continue to accumulate bedload overtime. 4) Two of the red culverts are stream simulated designed culverts that have had sections completely scoured free of bedload. 5) One culvert is not providing adequate passage because it is blocked by woody debris. 6) Three are red due to inadequate fish passage design considerations.

In an effort to reduce the significant costs associated with designing and installing culverts which provide fish passage, the Tongass National Forest is evaluating an approach coined minimally engineered aquatic organism passage (MEAOP) design. Similar to stream simulation design, the goal is to create fish passage conditions in the culvert which attempt to mirror that of the natural channel as much as possible by matching stream gradient, width and bedload roughness. Compared to stream simulation design MEAOP design typically involves less comprehensive stream survey and engineering analysis and relies to some degree on natural stream bedload mobilization to infill the culvert. Due to these differences there may be an inherent greater risk of not achieving or maintaining fish passage and greater associated maintenance costs.

Results from this monitoring indicate that 2 (13 percent) of the 16 installed MEAOP culverts are red and not meeting juvenile fish passage standards. By comparison, 2 percent of the 112 monitored stream simulated designed culverts are red.

The Forest Service's Washington Office (WO) Virtual AOP Design Team reviewed the nine MEAOP designed culverts installed during 2012 and 2013. The review was a critique of the existing installations and it provided recommendations for modifications to the design approach (Gubernick and Weinhold 2015).

The review found that the MEAOP designed culverts had a number of design considerations and site risks not recognized or analyzed during the design process. These omissions will likely require additional maintenance.

In general, the WO review recommended more consideration of the following in future MEAOP design.

1. Reduce the potential for headcut by considering: 1) the effect of the free erodible face in the streambed caused by embedding a culvert without infilling the culvert bed; 2) the effect of reducing the channel width cross-section and the associated increase in shear stress by the placement of the surcharge material upstream of the culvert; 3) tie the design profile to existing stable grade controls or constructing new grade control; 4) the size and mobility of the channel substrate.
2. Improve the longitudinal survey and use grade control and pool scour data to assist with determining structure design profile instead of a reach-averaged gradient method.
3. Improve the design of constructed grade controls and the stability evaluation of existing natural grade controls.
4. Improve inlet and outlet transitions from culvert to natural stream channel.
5. Use a representative reach to determine structure width and cross-section shape instead of the 66th percentile of a measured and pooled stream widths obtained over a variety of channel gradients.
6. Assure adequate sediment supply is available for infilling the culvert.
7. Conduct a simple geomorphic assessment to identify subsurface conditions.

MEAOP design was founded on the desire to reduce the cost of AOP remediation. The economic analysis of MEAOP design provided in the WO report suggests that the cost savings afforded with the use of a MEAOP design over stream simulation is a small percentage of project costs. In general, MEAOP design may reduce the cost of survey and design at small stream crossings by $2,000 - $3,000 and construction costs by another $3,000 - $4,000.

The WO review recommended the development of a Forest interdisciplinary AOP design team(s) consisting of Tongass National Forest biologists, hydrologists and engineers. They also recommended continuing to monitor the MEAOP installations.

Actions in Response to Monitoring Results

We do not recommend any changes to Forest Plan standards and guidelines in response to preliminary monitoring results.

Recommended actions:

1. Continue to monitor all new and recent culvert installations in fish streams including annual monitoring of all MEAOP culvert designs.
2. Review the economics and value of MEAOP design.
3. Improve the accessibility of Tongass AOP data.
4. Develop a Tongass AOP IDT design team.