Fishery Data Series No. 18-28

Fish Passage Assessment and Culvert Inventory on the King Cove and Cold Bay Road Systems

by

Mark Eisenman

Gillian O'Doherty

December 2018

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 18-28

FISH PASSAGE ASSESSMENT AND CULVERT INVENTORY ON THE KING COVE AND COLD BAY ROAD SYSTEMS

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December 2018

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/. This publication has undergone editorial and peer review.

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This document should be cited as follows:
Eisenman, M., and G. O'Doherty. 2018. Fish passage assessment and culvert inventory on the King Cove and Cold Bay road systems. Alaska Department of Fish and Game, Fishery Data Series No. 18-28, Anchorage.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF APPENDICES

ABSTRACT

The Alaska Department of Fish and Game's Fish Passage Assessment project assessed culvert sites on the road systems of Cold Bay in October 2014 and King Cove in August 2015. In Cold Bay the project assessed 10 sites and rated 6 Red, or assumed to be inadequate for fish passage; 3 Gray, or unlikely to allow adequate fish passage; and 1 Green, or likely to provide fish passage. In King Cove the project assessed 20 culvert sites, and rated 6 Red, 7 Gray, and 7 Green.

Key words: culvert, fish passage, assessment, Cold Bay, King Cove

INFORMATION AND PURPOSE

Culverted road crossings often delay, impede, or block fish movement into and out of stream systems, resulting in habitat fragmentation with the potential to affect fish populations. Culvert assessments throughout the Pacific Northwest (Botkin et al. 1994; Kahler and Quinn 1998; Mirati 1999; Taylor et al. 2003) and Southeast and Southcentral Alaska (Flanders and Cariello 2000; O'Doherty 2014; O'Doherty and Eisenman *in prep*) suggest that a majority of existing culverts obstruct fish movements to some degree.

Culverts may be barriers to fish immediately upon installation or develop into barriers over time due to alterations in streamflow and channel morphology up- and downstream or poor maintenance and debris jams. Types of barriers include over-steepened reaches, excessive water velocities, impassable jumps at the entry into the culvert, physical blockage due to damaged pipes or debris, and inadequate water depth or subsurface flow at damaged structures. Free and efficient movement through culverts is necessary for anadromous and resident fishes of all age classes and life stages to allow unobstructed access to important habitats (Kahler and Quinn 1998). Adult fish, including salmon, lamprey, flounder, eulachon and other anadromous and resident species, must have access spawning areas, and juvenile salmon such as Chinook (*Oncorhynchus tshawytscha*), coho (*Oncorhynchus kisutch*), and sockeye salmon (*Oncorhynchus nerka*) spend up to two years in fresh water as juveniles, moving to exploit diverse habitats for feeding and overwintering. Fish passage barriers affect resident species such as grayling, which use specific streams for spawning, juvenile rearing, summer feeding, and over-wintering. Culverts are most likely to have a negative effect on the movements of fish with limited swimming and leaping abilities, such as juvenile salmonids, and on species that rely on small streams for spawning and rearing habitat, such as coho salmon.

GOALS

The goal of this project was to assess and inventory the culverts on fish bearing streams that cross the road systems in and around the cities of King Cove and Cold Bay. Data on all sites including physical measurements of the stream and culvert, photographs, longitudinal profile, and site map are available online on the Fish Resource Monitor located at https://adfg.maps.arcgis.com/apps/webappviewer/index.html?id=f5aac9a8e4bb4bf49dc39db33f950bbd.

OBJECTIVES

The objectives of this project were to:

1. Locate, inventory, and assess stream crossings (culverts) for fish passage on any accessible road, driveway, or trail within the communities and road systems of the cities of King Cove and Cold Bay.
2. Determine if the crossing structures impede the movements of resident and/or anadromous fish.

3. Add all inventoried culvert crossing sites to the Alaska Department of Fish and Game's (ADF&G) Fish Passage Improvement Database and make available on the internet along with mapped information on fish presence through the Department's online interactive Fish Resource Monitor.
4. Develop and prioritize a list of sites recommended for replacement.
5. Submit any fisheries information to the Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes and its associated Atlas (AWC).

METHODS

STUDY AREA

The study area consisted of about 66 miles of road in the King Cove and Cold Bay area. It was estimated from satellite imagery and using ArcGIS that there were 136 potential sites that needed to be investigated. Thirty total sites were assessed, 10 in Cold Bay and 20 in King Cove (Appendix B1; Table 1; Figures 1 and 2).

Table 1.–Estimated miles of road assessed, potential sites to investigate, and actual sites assessed by community.

Road System	Approximate Total Miles of Road Assessed	Potential Sites	Actual Sites Assessed
Cold Bay	~38	20	10
King Cove	~28	116	20
Totals	66	136	30

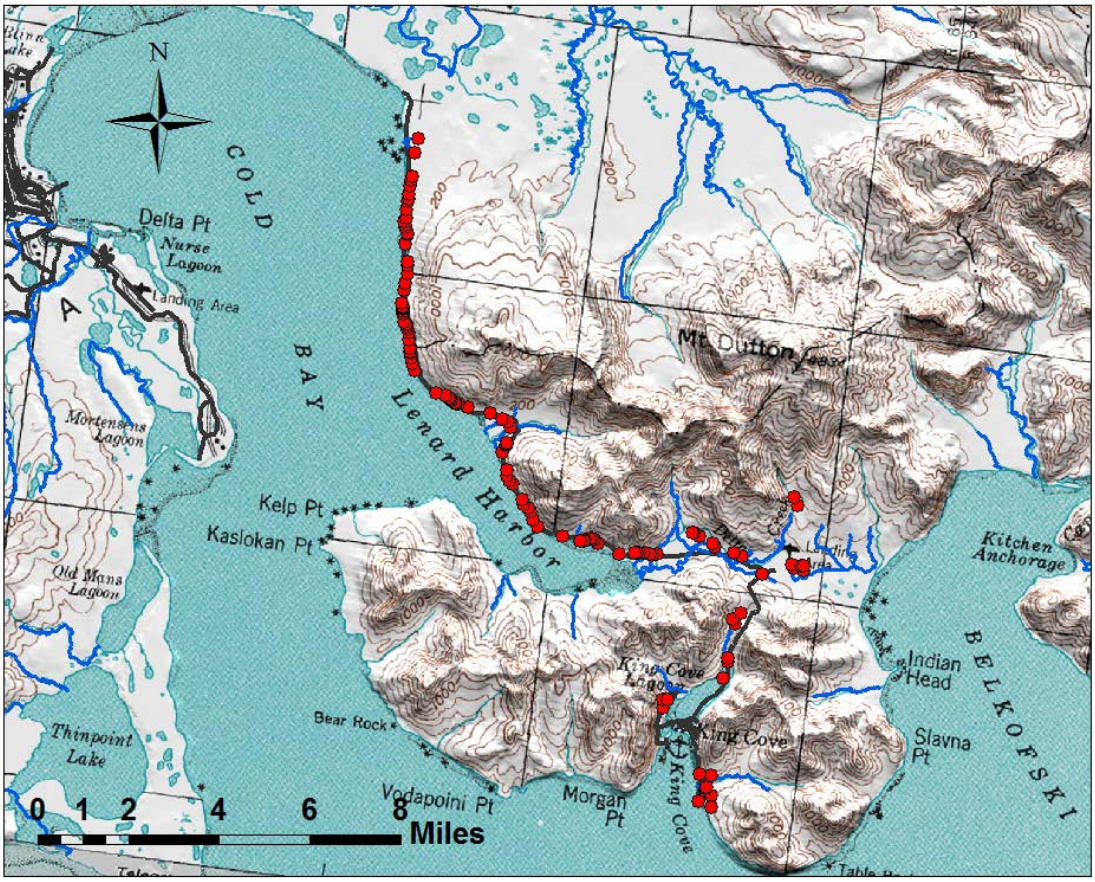

Figure 1.–Map of the potential culvert sites in King Cove and the surrounding road system.

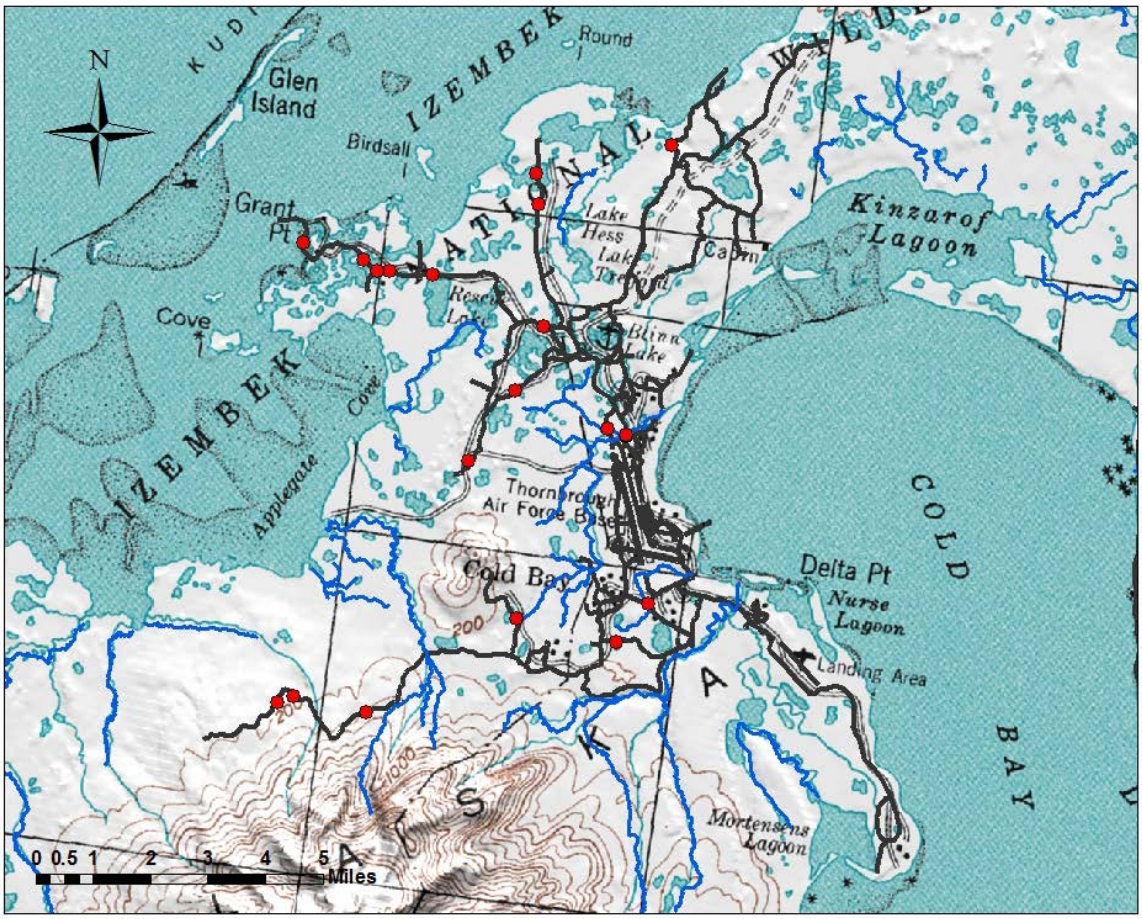

Figure 2.–Map of the potential culvert site locations on the road system around Cold Bay and the Izembek National Wildlife Refuge.

Site selection and Naming

Prior to beginning fieldwork all known and potential stream crossing locations were identified and mapped using ArcGIS. These locations were downloaded to a handheld Garmin GPS unit used to locate sites in the field. The survey crew also visually located and recorded additional stream crossings on the road when encountered.

Once in the field only sites known or reasonably expected to be fish bearing were included in the assessment project. Sites that were typically assumed to be non-fish bearing include ephemeral drainages that do not contain a defined channel, disconnected ponds, extremely steep channels, or crossings located above known natural barriers such as waterfalls or bluffs that exclude fish from the upstream area. Crossings that are located above man-made barriers were assessed because the potential exists for barriers to be removed and fish relocated.

All surveys received a Survey ID, which identifies the project, the year, and the survey location and followed the previously used alphanumeric conventions for project name and location. For example, in the Survey ID SWA15APT01, SWA15 refers to the project and year (Southwest Alaska 2015), and APT01 refers to the location the survey was conducted (Airport Road) and survey number on that road (01; O'Doherty 2010). After fieldwork was completed, each new survey was given a unique permanent site ID. The permanent site ID is a unique 8-digit number

in which the first 3 digits indicate the 3rd level Hydrologic Unit Code and the last 5 digits are unique to that site (e.g., 30103441).

All culvert sites selected for the inventory were surveyed using the protocol described below and in the Culvert Inventory and Assessment Manual for Fish Passage in the State of Alaska: A Guide to the Procedures and Techniques used to Inventory and Assess Stream Crossings 2009-2014 (Eisenman and O'Doherty 2014). All data was recorded on project data forms (Appendix A) and in survey notebooks and later entered into the project database.

FISH PASSAGE RATING OVERVIEW

To rate sites for effects on juvenile and weak swimming fish passage ADF&G follows a standardized method that was developed through coordination with other state and federal agencies specifically for use in Alaska. Culverts are categorized by type and size, three Critical Values are calculated (gradient, outfall height, and constriction ratio; see calculating the critical values below), and the results are compared to a decision matrix (Table 2) to rate the crossings as Red, Green, or Gray (Clarkin et al. 2005, Gordon et al. 2004, Karle 2005). In addition, potential barriers to adult salmon and strong swimming fish can be identified using the survey data.

Green: Conditions at crossing likely to be adequate for fish passage;

Red: Conditions at crossing likely to be inadequate for fish passage:

Gray: Conditions at crossing may be inadequate for fish passage.

The decision matrix uses the best available information to predict the ability of a young of the year juvenile coho salmon (55 mm) to pass through a variety of culvert types. A 55 mm coho salmon was chosen as the model fish because they are believed to be the weakest swimming juvenile salmonid fish and therefore culverts that are passable by 55 mm coho salmon should be passable by other juvenile salmonids.

Where structures were damaged or there were other factors affecting fish passage, those factors were also considered and were noted in the site comments. For example, if professional judgement was used to determine a culvert was damaged to the point where fish could not swim through it, then it would have been rated Red and a note made in the comments section.

Figure 3.–ADF&G Level 1 Fish Passage Matrix (Eisenman and O'Doherty 2014).

	Structure Type	Green	Grey	Red
1	Bottomless pipe arch, embedded pipe arch, corrugated metal pipe (CMP), box culvert or other embedded structure that functions in a similar fashion.	Installed at channel **gradient** (+/- 1% slope), AND **constriction ratio** greater than or equal to 0.75 OR fully backwatered	Structure not installed at channel gradient (+/- 1%), OR **constriction ratio** of 0.5 to 0.75	**Constriction ratio** less than 0.5
2	Culverts (all span widths) with 2x6 inch corrugations or greater, not embedded.	Culvert **gradient** less than 1.0%, AND outfall hgt.= 0, AND **constriction ratio** greater than 0.75 OR fully backwatered	Culvert **gradient** 1.0 to 2.0%, OR less than or equal to 4-inch **outfall hgt**., OR **constriction ratio** of 0.5 to 0.75	Culvert **gradient** greater than 2.0%, OR **outfall hgt**. greater than 4 inches, OR **constriction ratio** less than 0.5
3	Pipe arch or circular CMP (span width greater than 4 feet), less than 2x6 inch corrugations, not embedded	Culvert **gradient** less than 0.5%, AND outfall hgt. = 0, AND **constriction ratio** greater than 0.75 OR fully backwatered	Culvert **gradient** 0.5 to 2.0%, OR less than or equal to 4-inch **outfall hgt**., OR **constriction ratio** of 0.5 to 0.75	Culvert **gradient** greater than 2.0%, OR **outfall hgt**. greater than 4 inches, OR **constriction ratio** less than 0.5
4	Pipe arch or circular CMP (span width less than or equal to 4 feet), less than 2x6 inch corrugations, not embedded	Culvert **gradient** less than 0.5%, AND **outfall hgt**.= 0, AND **constriction ratio** greater than 0.75 OR fully backwatered	Culvert **gradient** 0.5 to 1.0%, OR less than or equal to 4-inch **outfall hgt**., OR **constriction ratio** of 0.5 to 0.75	Culvert **gradient** greater than 1.0%, OR **outfall hgt**. greater than 4 inches, OR **constriction ratio** less than 0.5.
5	Non-embedded box culverts, culverts with non-standard configurations or materials, culverts with baffles or downstream weirs or step pools, fish ladders, bridges with aprons.	Fully backwatered as described below.	All others	**Outfall height** at downstream end of structure greater than 4 inches.
6	Multiple Structure Installations	Individual culverts all classified as Green as above	Individual culverts all classified as Gray or as some mix of Green, Gray or Red as above.	Individual culverts all classified as Red as above.

Notes:

1. These criteria are not design standards, but rather indicate whether the structure is likely to provide fish passage for juvenile salmonids based on a one-time evaluation.
2. Ordinary high water (OHW) is the mean stream width measured either upstream or downstream of the culvert beyond the hydraulic influence of the culvert.
3. An embedded culvert must have 100% bed load coverage. Circular and box culverts must be embedded at least 20% of their height. A pipe-arch must be embedded so that the mean bed load depth is greater than or equal to the vertical distance from the bottom of the pipe to the point of maximum horizontal dimension of the culvert (haunch height) or is 1 foot deep, whichever is greater.
4. A culvert is considered backwatered if one of the following conditions is met: 1) elevation of the tailwater control exceeds the elevation of the invert at both the outlet and inlet of the culvert and the invert of any aprons or other inlet or outlet structures, or 2) the culvert is located in a pond, slough or other area with slow moving or still water and the tailwater and headwaters surface are equivalent and water surface is continuous throughout the entire structure and at least 0.1 feet in depth at the shallowest point. Culvert gradient, span to OHW ratio, and outfall height criteria are not considered in the assessment of fish passage in backwatered culverts. A culvert is not backwatered if a hydraulic jump occurs within the barrel.
5. Outfall height is the difference between the water surface elevation at the outlet and in the outlet pool (or the equivalent tailwater surface)

ASSESSMENT PROTOCOL

A standard assessment protocol (Eisenman and O'Doherty 2014) was used to collect data on crossings throughout the project and a summary of those protocols is presented here. Definitions for specific assessment terminology can be found in the glossary (Appendix C1).

Crossing and Assessment Information

The location of each crossing (coordinates) was recorded using a Garmin GPS, as well as the date and time of assessment and the names of the assessment crew.

Description of the Crossing Structure

Information was collected on culvert length, dimensions, shape, and the type of material used for construction. The type of inlet and outlet—projecting, mitered, or flared—was noted, as was the presence of a headwall, wingwalls, or an apron. Where a crossing structure consisted of multiple culverts, each individual culvert was numbered according to its position sequentially from left to right as the observer faces downstream.

Each culvert outfall was categorized as either set at stream grade (AG), a free-fall into an outlet pool (F), a free-fall onto riprap (FR), a cascade over rip-rap (C), a fish passage structure (PS), smooth flow over an apron (SF), an overflow pipe (OP), or a hydraulic jump (HJ) at the time of survey (Eisenman and O'Doherty 2014). If an inlet or outlet apron existed, the construction material was noted and the length measured as described above.

Culverts that contained substrate were inspected to determine whether they were considered embedded by measuring the depth of the substrate at the inlet and outlet to the nearest 0.10-foot. For a culvert to be considered embedded, both inverts must be lower than the streambed elevation, the barrel must contain streambed material throughout its length, circular culverts must be buried at least 20 percent of their diameter, and pipe-arch culverts must be embedded so that the mean depth of the substrate within the pipe is equal to or greater than the vertical distance from the bottom of the culvert to the point of maximum horizontal dimension or 20 percent of the height, whichever is greater. Where substrate is greater than approximately 0.5 feet deep, substrate depth was estimated by driving a steel rod of known length into the material and subtracting the height of the rod projecting above the substrate from the total length.

The condition of each culvert was ranked 1 through 5 according to the following definitions-:

(1) Defective: culvert is in dire need of prompt repair or replacement, flaws threaten to disrupt or are hindering fish passage;

(2) Poor: culvert is in need of repair and shows potential for further deterioration;

(3) Fair: culvert is operational but may need maintenance to restore function to full potential, distinct rust line and/or abraded bottom present, adverse conditions could lead to major problems;

(4) Good: culvert shows minor deficiencies, beginning of rust line formation may be visible; with continued maintenance should be trouble free;

(5) Excellent: culvert shows no signs of problems or rust, could allow flow at full capacity without disrupting fish passage.

Longitudinal Profile

A longitudinal profile is a survey of the stream down the length of the thalweg. For assessment purposes, the longitudinal profile encompassed the reach of the stream containing the culvert(s). The purpose is to collect relative elevations of the stream, water surface, and culvert structure in order to calculate water depth at outlet, outfall height, and pipe gradient. Occasionally, when a longitudinal profile could not be carried out, the water depth at outlet and outfall heights were measured using hand-held tape measures and documented in the survey notes.

Stream Measurements

The average width of the stream at ordinary high water (OHW) above the culvert was measured along three straight runs or heads of riffles at locations upstream of any obvious influence of the crossing structure. All channel widths were measured perpendicular to stream flow and to the nearest 0.10-foot using a fiberglass measuring tape. If the upstream channel was a lake, wide slough or braided channel, channel widths of the downstream channel was recorded instead. Average stream width was not recorded if both up- and downstream water bodies were ponds, lakes, or sloughs.

The alignment of the inlet with the upstream channel was determined to the nearest one degree using a sighting compass. The approach angle was calculated by subtracting the back azimuth of the line looking downstream through the culvert, from the azimuth of the channel looking upstream from the culvert inlet.

The dominant and subdominant substrate type at the inlet and outlet and in the up and downstream channels outside of the culvert influence were determined visually and recorded.

In 2011, it became standard project protocol to collect the gradient of the stream. This is measured as the change in elevation of the water surface over a curvilinear distance of at least 10 times the OHW width. The stream gradient is calculated outside the influence of the culvert.

Site Observation Codes

Site Observation Codes refer to circumstances that affect fish passage at a site and are used to clarify the reasons why a site was placed into the Gray or Red categories as well as to note problems that are not part of the Red Gray Green classification system, but potentially affect fish passage or the prioritization of the culvert for replacement or repair. These include poor alignment, significant sedimentation, beaver activity, deliberate blockage by means of a screen or grill, debris blockage, or various types of structural damage.

Site Sketch

The site sketch includes the culvert and road, direction of flow, location of fish traps, and any significant features observed at the site.

Photographs

A series of photographs were taken at each site with a digital camera. The order of photographs and a description of each are recorded in the survey notebook. At minimum photographs included the following views:

- Site marker. The Site ID, road and date are written on a dry erase board and photographed at the site;

- View of the road surface at the crossing site;
- View from the culvert looking downstream at the tailcrest and beyond;
- View from below the tailcrest looking upstream showing the culvert outlet type, condition, and road embankment. This photograph should show channel roughness (substrate, debris, vegetation, etc.) and culvert outlet height above the tailwater;
- View from an upstream location (looking downstream) showing the culvert inlet type, condition, and road embankment. This photograph should show channel roughness (substrate, debris, vegetation etc.) and culvert inlet conditions;
- View from the culvert looking upstream;
- When possible, a photograph of typical stream substrate and other channel roughness elements upstream of the culvert's influence;
- Additional photographs of conditions, if any, that may be negatively affecting fish passage (e.g., damage, debris, undesirable bed load deposition).

Fish Trapping

Minnow traps were set at each site in Cold Bay. In King Cove there was not enough time to conduct fish trapping at all sites, but visual observations of adult fish were made at numerous sites. Where fish trapping occurred, traps were baited with cured salmon roe and set near the bank far enough up and downstream of the culvert to minimize disturbance from surveying activities. Traps soaked approximately one to two hours at most sites. Any captured fish were identified to species and measured then released in pools at or adjacent to capture site. Fish observed at the site but not trapped or handled were also noted as visual observations. All captured or observed fish information was submitted as additional or backup information to the AWC.

Calculating the Critical Values

Gradient

Culvert gradient was calculated as the difference in elevations between inlet invert and outlet invert, divided by the length of the culvert and multiplied by 100. In the case of an embedded culvert, or a culvert with sediment at inlet and/or outlet, top of culvert elevations were used instead of invert elevations:

$$\frac{(Inlet\ elevation - Outlet\ elevation)}{Culvert\ lenth} * 100 = Pipe\ Gradient$$

During the project any structures found to contain sections that were considerably steeper than the average slope were calculated separately and are referred to as "maximum gradients" and are used to rate the culvert. Maximum gradients may also be calculated for aprons where they are significantly steeper than the culvert itself and may impede fish passage. If a maximum gradient was used it was noted in the comments for that site.

Outfall height

Outfall height (OH) was calculated from longitudinal survey elevation data and is the distance from the water surface at outlet (OWS) to the outlet pool surface or tailwater surface (TWS).

$$OH = OWS - TWS$$

The outfall height for a freefall into pool outfall type is the outlet water surface elevation subtracted from the outlet pool surface elevation (Figure 4).

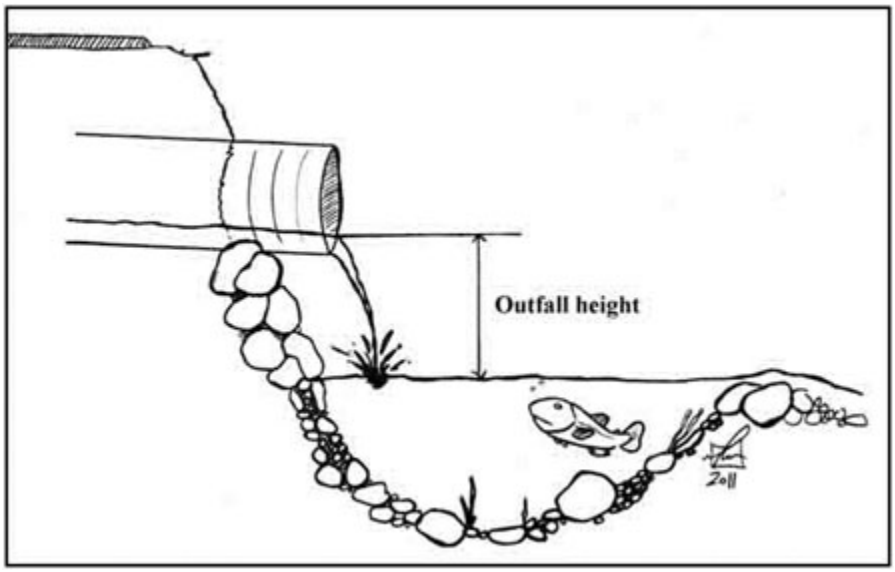

Figure 4.–Illustration showing where outfall height is measured on a freefall into pool outfall type.

Where the outfall was a fall onto rip-rap, cascade over rip-rap, hydraulic jump, or fish passage structure, the outfall height was measured from the water surface at the outlet invert to the water surface at the end of cascade or fish passage structure (Figure 5; Eisenman and O'Doherty 2014).

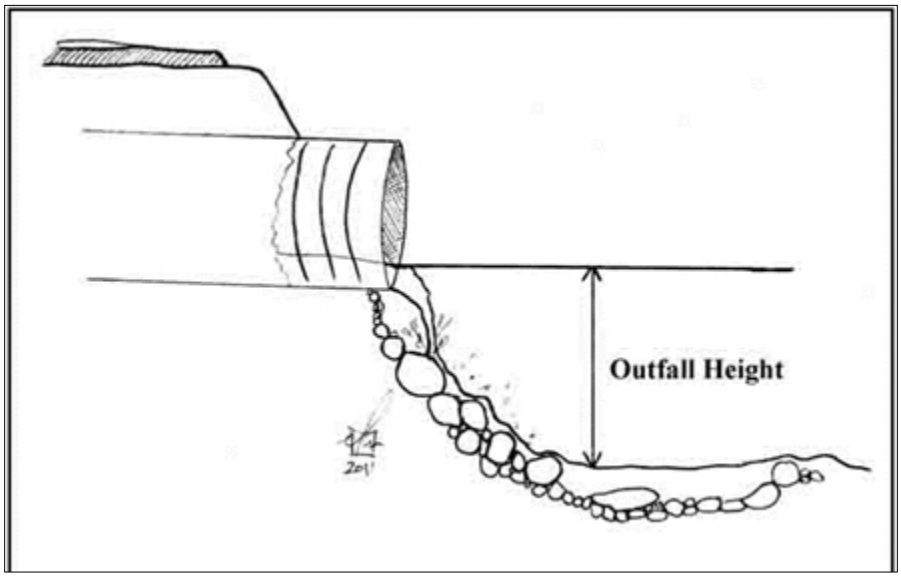

Figure 5.–Illustration showing the outfall height measurement for a free fall onto riprap and cascade over riprap outfall types.

Constriction Ratio

The constriction ratio (CR) for one culvert was calculated as the culvert width (CW) divided by the average channel width at OHW.

(CW/OHW):1

The constriction ratio for sites that had more than one circular culvert was calculated by the following formula:

$$CR = \sqrt{(r_1{}^2 + r_2{}^2 + r_{x,\ldots}{}^2)} * 2/\ OHW$$

where r is the radius of each culvert.

DATA MANAGEMENT AND QUALITY CONTROL

Data was collected on paper data sheets and entered into the fish passage database throughout the field season. At the end of the field season, all data was printed out and compared to the original field sheets manually by two project staff in order to catch data entry errors. A series of automated data checks was then used to identify any outlying values or inconsistent entries, such as sites with a high outfall that were not rated as Red. Locations of sites were checked individually using GIS, and photographs and comments were reviewed for accuracy at each site by two project personnel. Where site locations were inconsistent with the mapped locations of creeks and roads, it was found that the mapped locations of creeks and roads were typically in error and therefore sites were not "snapped" to existing GIS features. Instead, locations were accurately represented on the Fish Passage mapper and the coordinates in the database are those collected at the site at the time of survey.

A final review of all ratings was carried out independently by both authors before each season's data was released as draft and an additional review took place at the end of the project.

RESULTS

COLD BAY

In October 2014, the Fish Passage Assessment Project investigated the 20 predicted sites on the road system of Cold Bay and the Izembek National Wildlife Refuge (NWR). Ten sites were assessed to be fish bearing or potentially fish bearing. Three of the sites were on roads maintained by the State of Alaska and 7 sites on roads maintained by the Izembek NWR. The City of Cold Bay and Izembek NWR are located where the decommissioned Thornbough Air Force Base once operated. The road system of Cold Bay consists of the main city center, located alongside the city airport; three main roads, Grant Point Road, Outer Marker Road, and Frosty Peak Road, leading out onto the Izembek NWR; and many legacy roads and trails dating back to the construction of the airstrip and base during World War II.

Fish Passage Rating

Of the 10 assessed sites in Cold Bay, the project rated 6 sites Red (60%), or crossings likely to be inadequate for fish passage; 3 sites Gray (30%), or crossings may be inadequate for fish passage; and 1 site Green (10%), or crossings are likely adequate for fish passage (Table 2, Figure 6).

Table 2.–Site ratings for culverts on the Cold Bay and Izembek NWR road systems.

Site Rating	No. of Sites	% of Sites
Red	6	60.0%
Gray	3	30.0%
Green	1	10.0%
Total	10	100%

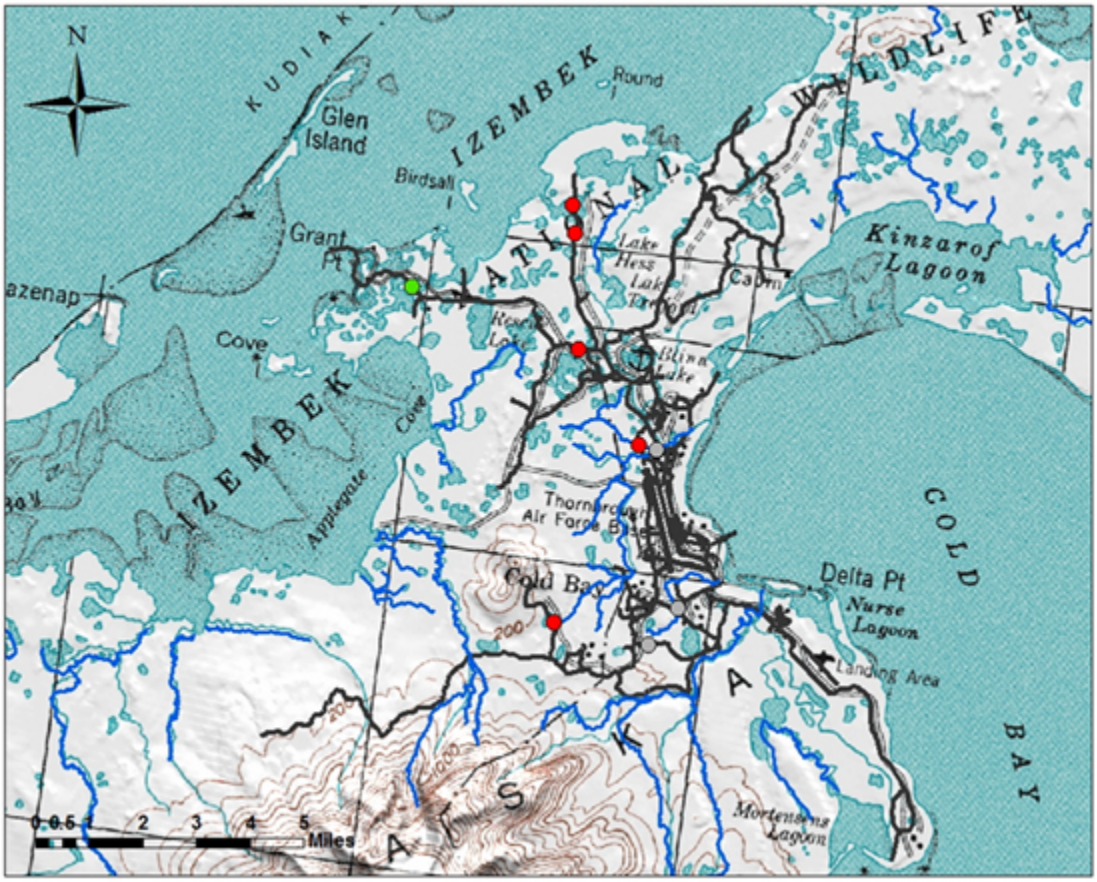

Figure 6.–Site map showing assessed site locations and their ratings on the road system in Cold Bay and the Izembek NWR.

Culvert Type and Dimensions

The majority of culverts assessed in Cold Bay were under 50 feet in length and under 3 feet in diameter (Tables 3 and 4). The majority of assessed culverts were also circular and made of corrugated steel. Only one site had more than one culvert at the crossing (Tables 5-7).

Table 3.–Culvert lengths for culverts assessed on the Cold Bay and Izembek NWR road systerms.

Culvert Length (ft)	No. of Culverts	% of Culverts
20-30	1	9.1%
30-40	2	18.2%
40-50	4	36.4%
50-60	0	0.0%
60-70	0	0.0%
70-80	2	18.2%
80-90	1	9.1%
90-100	0	0.0%
100-110	0	0.0%
110-120	0	0.0%
120-130	0	0.0%
130-140	0	0.0%
140-150	0	0.0%
150-160	1	9.1%
Total	11	100.0%

Table 4.–Culvert widths for culverts assessed on the Cold Bay and Izembek NWR road systems.

Culvert Width (ft)	No. of Culverts	% of Culverts
1.5-2	2	18.2%
2-2.5	2	18.2%
2.5-3	4	36.4%
3-3.5	0	0.0%
3.5-4	0	0.0%
4-4.5	0	0.0%
4.5-5	0	0.0%
5.5-6	0	0.0%
6-6.5	0	0.0%
6.5-7	0	0.0%
7-7.5	0	0.0%
7.5-8	2	18.2%
8.5-9	1	9.1%
Total	11	100.0%

Table 5.–Culvert type for culverts assessed on the Cold Bay and Izembek NWR road systems.

Culvert Type	No. of Culverts	% of Culverts
Box culvert	1	9.1%
Circular pipe	10	90.9%
Total	11	100%

Table 6.–Culverts construction material for assessed culverts on the Cold Bay and Izembek NWR road systems.

Culvert Material	No. of Culverts	% of Culverts
Corrugated aluminum	1	9.1%
Corrugated steel	7	63.6%
Non-corrugated metal	2	18.2%
Wood	1	9.1%
Total	11	100%

Table 7.–Number of culverts at site for sites assessed on the Cold Bay and Izembek NWR road systems.

No. of Culverts at Site	No. of Sites	% of Sites
1	9	90.0%
2	1	10.0%
Total	10	100%

Factors Affecting Fish Passage

The most common factor affecting fish passage was gradient, with 7 of the 11 culverts (at 10 sites) surveyed having a Red gradient (see Fish Passage Matrix, Figure 3). Mechanical damage was also a significant factor, with 7 culverts noted with defects and an additional 2 culverts noted with structural problems (Table 8).

Critical Values

The ADF&G Level 1 assessment uses three critical values to assign ratings to culverts in the Fish Passage Matrix (Figure 3). These include outfall height, culvert gradient, and constriction. Some culverts accessed during this project may have more than one Red critical value and additional noted factors affecting passage. Level 1 assessments rate culverts based on the swimming ability of a 55mm juvenile coho salmon, but data collected can also indicate potential adult barriers. Any culvert with an outfall over 4 inches is rated red and the project considers culverts with an outfall height greater than one foot and/or having a gradient (slope) greater than 4% to be a potential barrier to adult salmon and trout.

Outfall Height and Outfall Type

The project found that most culverts in Cold Bay were At Grade, or having no discernable outfall and not perched above the stream. The project also found 2 culverts with Red outfalls, one of which was more than 1 foot. The most common type of outfall was free fall onto rip rap (Tables 9 and 10).

Table 8.–Factors affecting fish passage for culverts assessed on the Cold Bay and Izembek NWR road systems.

Factors Affecting Fish Passage	No. of Culverts with Factor	No. of Culverts Assessed for Factor	% of Culverts with Factor
Culvert gradient Red	7	11	63.6%
Mechanical damage or joints parting	7	11	63.6%
Material inadequate for designed use	4	11	36.4%
Compound gradient in pipe	2	11	18.2%
Shallow fill; inadequate roadfill volume above culvert	2	11	18.2%
Structural Problem	2	11	18.2%
Outfall height Red	2	11	18.2%
Hydraulic flows exceeded capacity	2	11	18.2%
Constriction ratio Red	1	7	14.3%
Cut-slope slumping or sliding into culvert (single event)	1	11	9.1%
Constriction ratio Gray	1	7	14.3%
Outfall height Gray	1	11	9.1%
Road Fill (pushed off road by grader)	1	11	9.1%
Inlet perch	1	11	9.1%

Table 9.–Outfall heights for culverts assessed on the Cold Bay and Izembek NWR road systems.

Outfall Height (inches)	No. of Culverts	% of Culverts	Rating
At Grade (AG)	8	72.7%	Green
>0-4	1	9.1%	Gray
4-12	1	9.1%	Red
12-24	0	0.0%	
24-36	0	0.0%	
36-48	1	9.1%	
Total	11	100%	

Table 10.–Outfall types for culverts assessed on the Cold Bay and Izmebek NWR road systems.

Outfall Type	No. of Culverts	% of Culverts
At Grade	8	72.7%
Free Fall on To Rip Rap	2	18.2%
Hydraulic Jump	1	9.1%
Total	11	100%

Culvert Gradient

Culvert gradient is calculated as the difference in elevation of the inlet and outlet divided by the culvert length. It reflects the overall slope of the culvert as installed. Most culverts assessed had a gradient under 2%. Any culvert that has a gradient over 2% is considered Red, unless it is

embedded or backwatered. The project also found one culvert with a gradient over 4%, a potential barrier to adult salmon (Table 11).

Table 11.–Assessed culvert gradients on the Cold Bay and Izembek NWR road systems.

Culvert Gradient	No. of Culverts	% of Culverts
0-1	2	18.2%
1-2	6	54.5%
2-3	2	18.2%
4-5	0	0.0%
5-6	0	0.0%
6-7	0	0.0%
7-8	1	9.1%
Total	11	100.0%

Constriction Ratio

Constriction Ratio refers to the degree to which a culvert constricts or narrows a stream as it passes under the railroad. The constriction ratio is calculated by dividing the culvert inlet width by the average stream width at OHW where there is a natural channel with a consistent width to measure. The smaller the number the more constricted a site is. Stream width is not collected at sites where there is not a defined natural channel, such as wetlands or ditched systems.

Of the 7 sites were stream widths were collected and constriction ratio could be calculated, 5 sites were rated Green with a ratio of 0.75 or higher, 1 site was rated Gray with a constriction ratio between 0.5 and 0.75, and 1 site was rated Red with a constriction ratio of 0.5 or smaller (Table 12).

Table 12.–Constriction ratio of sites assessed on the Cold Bay and Izembek NWR road systems.

Constriction Ratio	No. of Culverts	% of Culverts	Site Code Rating
0.25-0.5	1	14.3%	Red
0.5-0.75	1	14.3%	Gray
0.75-1	1	14.3%	Green
1-1.25	1	14.3%	
1.25-1.5	0	0.0%	
1.5-1.75	2	28.6%	
1.75-2	1	14.3%	
Total	7	100.0%	

Other culvert and site data

Assessments showed that 1 culvert met the project's standards for being embedded (ADF&G Fish Passage Matrix, Figure 3). Additionally, 1 site was found to be backwatered, 3 were found to potentially have tidal influence, and 2 culverts (sites 30103336 and 30103337) were found to have structures that could be considered baffling. Sites 30103336 and 30103337 are constructed out of old 8 foot diameter fuel tanks laid end to end with the inlet and outlet opens cut to create a large lip at the openings (Tables 13-16, Figure 7).

The project also noted the overall condition of culverts in Cold Bay and the Izembek NWR to be very poor, rating 45% as 1 or defective, and 27% as 2 or poor (Table 17; see Methods for condition code definitions).

Figure 7.–Site 30103336, internal view of culvert looking upstream from outlet and showing the internal connection between tank sections and the created baffling.

Table 13.–Number of embedded culverts for sites assessed on the Cold Bay and Izembek NWR road systems.

Embedded?	No. of Culverts	% of Culverts
No	10	90.9%
Yes	1	9.1%
Total	11	100%

Table 14.–Backwatered sites for sites assessed on the Cold Bay and Izembek NWR road systems.

Backwatered?	No. of Sites	% of Sites
No	9	90.0%
Yes	1	10.0%
Total	10	100%

Table 15.–Tidally influenced sites for sites assessed on the Cold Bay and Izembek NWR road system.

Tidal Influence?	No. of Sites	% of Sites
Maybe	3	30.0%
No	7	70.0%
Total	10	100%

Table 16.–Culverts with baffles for sites assessed on the Cold Bay and Izembek NWR road system.

Baffles?	No. of Culverts	% of Culverts
No	9	81.8%
Maybe	2	18.2%
Total	11	100%

Table 17.–Condition ratings for assessed culverts on the Cold Bay and Izembek NWR road systems (see Methods for condition definitions).

Condition Rating	No. of Culverts	% of Culverts
1	5	45.4%
2	3	27.3%
3	2	18.2%
4	1	9.1%
Total	11	100%

Stream Characteristics

The local topography consisted of treeless tundra foothills and flats with tidal marshes and kettle ponds. All culverted streams except for Trout Creek were small and all major streams were bridged (Table 18). Of the 4 streams where stream gradient was measured, the majority were less than 0.50% gradient (Table 19). Water levels were low during assessments, which was noticeable with many of the shallower kettle ponds being completely dry. The project found 3 sites to be dry at the time of survey. Two of these crossings connected kettle pond complexes that provide connectivity at high water levels, and the third (30103340) was located at the uppermost point of anadromy for an unnamed stream (AWC Stream #283-34-10300-2031), where the road crossing was holding back a small pond (Tables 20 and 21).

Fish Collection Data

The project placed minnow traps at all surveyed locations and confirmed the presence of fish at all sites except 30103340. The project also confirmed the presence of juvenile coho salmon at all the known anadromous streams (3) and one previously uncatalogued stream, which was nominated to the AWC. Dolly Varden char, three spine stickleback, and slimy sculpin were the other species captured during this assessment. The project submitted 5 nominations to the AWC, 4 back-up information nominations and 1 addition.

Table 18.–Average stream width at ordinary high water (OHW) for sites assessed on the Cold Bay and Izembek NWR road systems.

Average Stream Width at OHW (ft)	No. of Sites	% of Sites
1-2	3	42.9%
2-3	0	0.0%
3-4	1	14.3%
4-5	1	14.3%
5-6	0	0.0%
6-7	0	0.0%
7-8	0	0.0%
8-9	1	14.3%
10-11	0	0.0%
11-12	0	0.0%
12-13	0	0.0%
13-14	0	0.0%
14-15	0	0.0%
15-16	0	0.0%
16-17	0	0.0%
17-18	0	0.0%
18-19	0	0.0%
19-20	0	0.0%
20-21	0	0.0%
21-22	0	0.0%
22-23	0	0.0%
23-24	1	14.3%
Total	7	100.0%

Table 19.–Stream gradient for sites assessed on the Cold Bay and Izembek NWR road systems.

Stream Slope (%)	No. of Sites	% of Sites
0-0.5	2	50.0%
.5-1	0	0.0%
1-1.5	0	0.0%
1.5-2	2	50.0%
Total	4	100.0%

Table 20.–Water depth at outlet for culverts assessed on the Cold Bay and Izembek NWR road systems.

Water Depth at Outlet (in.)	No. of Culverts	% of Culverts
Dry	4	36.3%
>0-0.25	3	27.3%
0.25-0.5	1	9.1%
0.5-0.75	1	9.1%
0.75-1	1	9.1%
>1	1	9.1%
Total	11	100%

Table 21.–Stream stage at time of survey for assessed sites on the Cold Bay and Izembek NWR road systems.

Stream Stage	No. of sites	% of Sites
Dry, Defined Channel	1	10.0%
Dry, No Defined Channel	2	20.0%
Low	2	20.0%
Medium	5	50.0%
Total	10	100%

KING COVE

In August 2015, the Fish Passage Assessment project investigated the 116 potential crossings on the King Cove road system. The project found 20 sites on city- and state-owned roads that were on known fish-bearing streams or suspected of being fish-bearing streams. The City of King Cove's road system consists of the town center and King Cove Lagoon area, the 5-mile road north to the airport, and 18 miles of road that dead end at the now defunct King Cove-Cold Bay hovercraft landing area (Figure 7).

Fish Passage Rating

Of the 20 sites assessed, 6 (30%) were rated Red, or crossings likely to be inadequate for fish passage; 7 were rated Gray (35%), or crossings that may be inadequate for fish passage; and 7 (35%) were rated Green, or crossings that are likely adequate for fish passage (Table 22, Figure 8).

Table 22.–Site ratings for sites assessed on the King Cove road system.

Site Rating	No. of Sites	% of Sites
Red	6	30.0%
Gray	7	35.0%
Green	7	35.0%
Total	20	100.0%

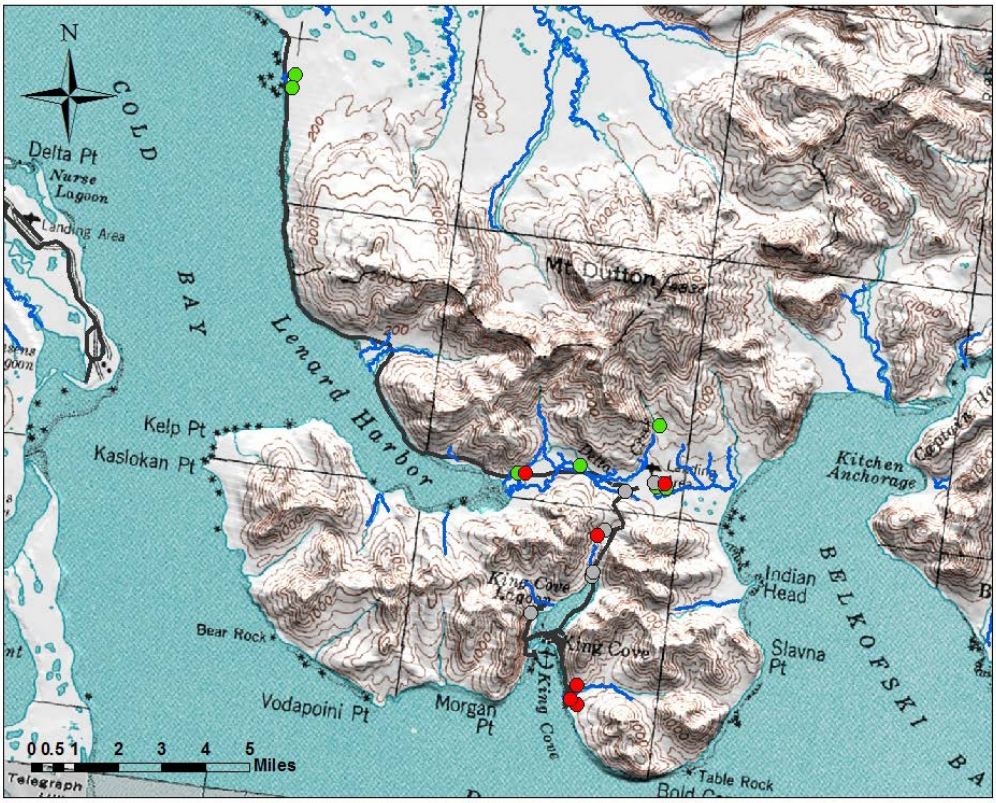

Figure 8.–Site map showing assessed site locations and their ratings on the road system in King Cove.

Culvert Type and Dimensions

Most of the culverts on the King Cove road system were circular, made of corrugated steel, short (between 40 and 50 feet long), and had an inlet width between 2 and 4 feet (Tables 23–26). The assessment crew also found 2 sites with multiple culverts (Table 27). Note: Not all measurements could be taken at every site due to inaccessibility and/or safety.

Table 23.–Culvert lengths for culverts assessed on the King Cove road system. Not all culverts could be measured due to lack of access or damage.

Culvert Length (ft)	No. of Culverts	% of Culverts
20-30	1	5.9%
30-40	0	0.0%
40-50	7	41.2%
50-60	4	23.5%
60-70	3	17.6%
70-80	0	0.0%
80-90	0	0.0%
90-100	0	0.0%
100-110	0	0.0%
110-120	0	0.0%
120-130	0	0.0%
130-140	0	0.0%
140-150	0	0.0%
150-160	0	0.0%
160-170	0	0.0%
170-180	0	0.0%
180-190	2	11.8%
Total	17	100.0%

Table 24.–Culvert widths for culverts assessed on the King Cove road system.

Culvert Width	No. of Culverts	% of Culverts
1-1.5	1	4.5%
1.5-2	0	0.0%
2-2.5	4	18.2%
2.5-3	0	0.0%
3-3.5	6	27.3%
3.5-4	3	13.6%
4-4.5	0	0.0%
4.5-5	1	4.5%
5-5.5	0	0.0%
5.5-6	1	4.5%
6-6.5	1	4.5%
6.5-7	0	0.0%
7-7.5	2	9.1%
7.5-8	0	0.0%
8-8.5	0	0.0%
8.5-9	0	0.0%
9-9.5	0	0.0%
9.5-10	0	0.0%
10-10.5	1	4.5%
10.5-11	0	0.0%
11-11.5	2	9.1%
Total	22	100.0%

Table 25.–Culvert type (shape) for culverts assessed on the King Cove road system.

Culvert Type	No. of Culverts	% of Culverts
Circular pipe	18	81.8%
Pipe-arch	4	18.2%
Total	22	100%

Table 26.–Culvert construction material for culverts assessed on the King Cove road system.

Culvert Material	No. of culverts	% of Culverts
Corrugated aluminum	2	9.1%
Corrugated steel	19	86.4%
Structural steel plate	1	4.5%
Total	22	100%

Table 27.–Number of culverts at assessed sites on the King Cove road system.

No. of Culverts at Site	No. of Sites	% of Sites
1	18	90.0%
2	2	10.0%
Total	20	100%

Factors Affecting Fish Passage

The most common factors affecting fish passage on the King Cove road system were Red gradients and Gray outfall heights. Short culverts, inlet perches, Red outfall heights, and Gray constriction ratios were also significant problems found on assessed culverts (Table 28).

Table 28.–Factors affecting fish passage for culverts assessed on the road system of King Cove.

Factors Affecting Fish Passage	No. of Culverts with Factor	No. of Culverts Assessed for Factor	% of Culverts with Factor
Culvert Gradient Red	7	16	43.8%
Outfall Height Gray	5	19	26.3%
None (No factors recorded)	5	22	22.7%
Culvert too short	4	22	18.2%
Inlet Perch	4	22	18.2%
Outfall Height Red	3	19	15.8%
Constriction Ratio Gray	3	12	25.0%
Road Bank Erosion	3	22	13.6%
Structural Problem	3	22	13.6%
Constriction Ratio Red	2	12	16.7%
Compound Gradient	2	22	9.1%
Culvert sagging in middle	2	22	9.1%
Hydrualic Flow Exceed Capacity	2	22	9.1%
Mechanical damage or joint parting	2	22	9.1%
Other	2	22	9.1%
Culvert Gradient Gray	1	16	6.3%
Inlet apron too steep	1	22	4.5%
Material Inadequate for designed use	1	22	4.5%

Critical Values

The ADF&G Level 1 assessment uses three critical values to assign ratings to culverts in the Fish Passage Matrix (Figure 3). These include outfall height, culvert gradient, and constriction. Some culverts accessed during this project may have more than one Red critical value and additional noted factors affecting passage. Level 1 assessments rate culverts based on the swimming ability of a 55 mm juvenile coho salmon, but data collected can also provide potential adult barriers. The project considers culverts with an outfall height greater than one foot and/or having a gradient (slope) greater than 4% to be a potential barrier to adult salmon and trout.

Outfall Height and Type

The project found that most culverts in King Cove to be At Grade (53%), meaning they have no discernable outfall and are not perched above the stream. The most common type of outfall was free fall into pool (Table 29). The project found 4 culverts with an outfall larger than 4 inches, but no culverts had an outfall larger than one foot (Table 30).

Table 29.–Outfall types for culverts assessed on the King Cove road system. 3 outfall heights were not measured because they were not accessible.

Outfall Type	No. of Culverts	% of Culverts
At Grade	10	45.45%
Cascade Over Rip-Rap	1	4.55%
Free Fall into Pool	9	40.91%
Free Fall onto Rip Rap	1	4.55%
Hydraulic Jump	1	4.55%
Total	22	

Table 30.–Outfall Height for culverts assessed on the King Cove road system.

Outfall Height (in.)	No. of Culverts	% of Culverts	Rating
At grade	10	52.6%	Green
>0-4	5	26.3%	Gray
4-12	4	21.1%	Red
Total	19	100.0%	

Culvert Gradient

Culvert gradient is calculated as the difference in elevation of the inlet and outlet divided by the culvert length. It reflects the overall slope of the culvert as installed. Gradient was not calculated at every site due to inaccessibility or other inability to carry out a complete survey (fencing that prevented access and presence of bears). Half (50%) of the 16 culverts assessed for gradient had a gradient over 2%. Any culvert that has a gradient over 2% is considered Red, unless it is embedded or backwatered (Table 31).

Constriction Ratio

Constriction ratio refers to the degree to which a culvert constricts or narrows a stream as it passes under the road. Constriction ratio is calculated by dividing the culvert inlet width by the average stream width at OHW and is measured at sites where a consistent natural channel exists. The smaller the number the more constricted a site is (ADF&G Culvert Matrix, Figure 3). Channel width cannot be collected at sites that connect ponds or wetlands, many tidal sites and heavily modified channels and are excluded from this part of the analysis. The project found most sites assessed did not have an issue with constriction. Of the 12 sites assessed for constriction only 1 had a Red constriction ratio and 2 sites were rated Gray (Table 32). Additionally, 2 other sites were visually assessed to be under sized and 1 rated Red and one rated Gray (Table 28 and Table 43).

Table 31.–Culvert gradients for culverts assessed on the King Cove Road system.

Culvert Gradient (%)	No. of Culverts	% of Culverts
-0.25-0	1	6.3%
>0-.25	0	0.0%
0.25-0.5	1	6.3%
0.5-0.75	1	6.3%
0.75-1	0	0.0%
1-1.25	1	6.3%
1.25-1.5	3	18.8%
1.5-1.75	0	0.0%
1.75-2	1	6.3%
2-2.25	2	12.5%
2.25-2.5	1	6.3%
2.5-2.75	0	0.0%
2.75-3	2	12.5%
3-3.25	0	0.0%
3.25-3.5	1	6.3%
3.5-3.75	0	0.0%
3.75-4	2	12.5%
Total	16	100.0%

Table 32.–Constriction ratios of assessed sites on the King Cove road system.

Constriction Ratio	No. of Culverts	% of Culverts	Rating
0.25-0.5	1	8.3%	Red
0.5-0.75	2	16.7%	Gray
0.75-1	2	16.7%	Green
1-1.25	1	8.3%	
1.25-1.50	0	0.0%	
1.5-1.75	2	16.7%	
1.75-2	0	0.0%	
2-2.25	2	16.7%	
2.25-2.5	2	16.7%	
Total	12	100.0%	

Other Culvert and Site Data

Assessments found that 6 culverts met the project standards for being embedded. Additionally, the project also found 2 sites to be backwatered, 2 sites to have tidal influence, and 1 site to have baffles. The project also found most culverts on the King Cove road system to be in good shape, with 8 culverts rated as 3 or Fair, 8 culverts rated 4 or Good, and 2 culverts rated 5 or Excellent (Tables 33–37, ADF&G Fish Passage Matrix, Figure 3).

Table 33.–Number of sites that meet the project requirements for embeddedness on the King Cove road system.

Embedded?	No. of Culverts	% of Culverts
No	16	72.7%
Yes	6	27.3%
Total	22	100%

Table 34.–Number of assessed sites that meet project criteria for being backwatered on the King Cove road system.

Backwatered?	No. of Sites	% of Sites
No	18	90.0%
Yes	2	10.0%
Total	20	100%

Table 35.–Number of assessed sites that have tidal influence on the King Cove road system.

Tidal Influence?	No. of Sites	% of Sites
No	18	90.0%
Yes	2	10.0%
Total	20	100%

Table 36.–Number of assessed culverts with baffles on the King Cove road system.

Baffles?	No of Culverts	% of Culverts
No	21	95.4%
Yes	1	4.6%
Total	22	100%

Table 37.–Condition rating of culverts assessed on the King Cove road system.

Condition Rating	No. of Culverts	% of Culverts
1	2	9.1%
2	2	9.1%
3	8	36.4%
4	8	36.4%
5	2	9.1%
Total	22	100%

Stream Characteristics

Most of the road system in King Cove, barring Delta Creek Valley, runs along the slope break of large mountains with roads built along the coastline and on valley floors (Figure 8). At assessed sites where stream gradient was calculated, stream slope ranged from almost flat to near 4% (Table 38). Most larger streams on the King Cove road system are bridged, with the average assessed stream being between 1 and 6 feet at OHW. Project crew encountered medium stream flows with the majority of culvert water depth at outlet between 0.25 and 0.5 feet in depth (Tables 39–41).

Table 38.–Stream gradients for sites assessed on the King Cove road system.

Stream Gradient (%)	No of Sites	% of Streams
0-0.5	2	18.2%
0.5-1	1	9.1%
1-1.5	0	0.0%
1.5-2	2	18.2%
2-2.5	1	9.1%
2.5-3	1	9.1%
3-3.5	2	18.2%
3.5-4	2	18.2%
Total	11	100.0%

Table 39.–Water depth at outlet for assessed culverts on the King Cove road system.

Water Depth at Outlet (ft)	No. of Culverts	% of Culverts
0 (Dry)	1	6.7%
>0-0.25	7	46.7%
0.25-0.5	5	33.3%
0.5-0.75	1	6.7%
0.75-1	1	6.7%
Total	15	100%

Table 40.–Stream stage at assessed sites on the King Cove road system.

Stream Stage	No. of Streams	% of Streams
High	4	26.7%
Low	1	6.7%
Medium	10	66.7%
Total	15	100%

Table 41.–Average stream widths for sites assessed on the King Cove road system.

Average Stream Width (ft)	No. of Streams	% of Streams
1.5-2	1	7.7%
2-2.5	1	7.7%
2.5-3	1	7.7%
3-3.5	1	7.7%
3.5-4	2	15.4%
4-4.5	1	7.7%
4.5-5	2	15.4%
5-5.5	0	0.0%
5.5-6	2	15.4%
6-6.5	1	7.7%
6.5-7	0	0.0%
7-7.5	0	0.0%
7.5-8	0	0.0%
8-8.5	0	0.0%
8.5-9	0	0.0%
9-9.5	0	0.0%
9.5-10	0	0.0%
10-10.5	0	0.0%
10.5-11	0	0.0%
11-11.5	0	0.0%
11.5-12	0	0.0%
12-12.5	0	0.0%
12.5-13	0	0.0%
13-13.5	0	0.0%
13.5-14	1	7.7%
Total	13	100.0%

Fish Collection Data

No trapping was done during this project, but the assessment crew made visual observations on spawning adults and juvenile salmonids when encountered. 2015 was a very strong year for the pink salmon run in the King Cove area. The crew encountered adult pink salmon at 12 assessed sites, adult chum salmon at 3 sites, and adult sockeye salmon at 1 site, as well as noting visual observation of juvenile salmonids at 3 sites and Dolly Varden char at 4 sites. The project nominated all salmon information to the AWC, with 6 back-up nominations, 2 correction nominations, and 8 new nominations.

DISCUSSION

The results indicate that fish passage for juvenile salmonids and other weak swimming fish is widely impacted on the King Cove and Cold Bay road systems. The project found that 90% of the culverts assessed in Cold Bay and 60% of those assessed in King Cove were either rated as Red, crossings likely to be inadequate for fish passage, or Gray, or crossings that may be inadequate for fish passage (Tables 2 and 22). This can be problematic in an area like King Cove where roads

are built on a slope break near coast lines and follow valley floors and most potential fish habitat lies upstream of the crossing (Figure 8).

In addition to the three Critical Values used for the Level 1 assessments the data collected during the surveys allows additional refinement and classification, such as the identification of culverts that are potentially adult barriers due to perched outlets or are at imminent risk of failure due to damage. This information is available for all sites online at the ADF&G Fish Resource Monitor: https://www.adfg.alaska.gov/sf/SARR/AWC/index.cfm?ADFG=main.interactive

Information includes culvert dimensions and measurements, longitudinal profile and stream channel dimensions as outlined in the Culvert Inventory and Assessment Manual for Fish Passage in the State of Alaska (Eisenman and O'Doherty 2014).

No culverts assessed in King Cove were found to be potential adult barriers, having an outfall over 1 foot or a gradient over 4%. However, the assessment crew was not able to fully assess all sites, due to the presence of bears and the airport's security fencing limiting creek accessibility. Only 1 culvert in Cold Bay, Site 30103340, was found to have an outfall over 1 foot and a gradient over 4%. However, this site is also above the known uppermost point of anadromy and the potential fish habitat upstream is unknown.

Most culverted streams on the King Cove and Cold Bay road systems are small- to medium-sized (Tables 18 and 42). These small- and medium-sized creeks are important to juvenile salmonids that will utilize non-natal streams for rearing for up to two years (Kahler & Quinn, 1998). Additionally, many of the small streams in the area have resident populations of Dolly Varden char, grayling, three- and nine-spine stickleback, sculpin, and lamprey, and it has been observed that these fish utilize the entire length of usable habitat in their streams when flows allow. Providing road crossings that maintain favorable flow conditions are critical for maintaining habitat connectivity (Bryant et al. 2009).

The Level 1 Assessment method is useful in classifying culverts into categories based on the measurements taken during surveys, especially "Green" culverts or those of low concern. However, it should be noted that the Level 1 Assessment was designed as a quick assessment, focused on juvenile salmonids, over a large geographic area. Prior to selection of restoration sites, the restoration practitioner should review the available information and consider factors such as species and life stage of interest, channel type, and flow conditions at the site. Remote areas like King Cove and Cold Bay have an abundance of sites that lack habitat or fish information, or the information is incomplete. The recommendations made below were made with the data collected from this project and available upstream habitat was calculated from the AWC and satellite imagery. Ground truthing conditions at sites is recommended early on in any kind of replacement or selection process. Finally, conditions at any site are subject to change without notice to the Fish Passage Improvement Program.

There are some improvements and refinements that would make future Level 1 assessment projects more useful. These include the following:

- The development of separate criteria for different types of streams.
- The development of criteria for the passage of other species such as Dolly Varden, trout, adult salmon, grayling, and other juvenile salmon.
- Testing the existing and newly developed criteria in the field.

- Investigating the effects of additional factors such as the length of culvert and culvert size and incorporating that information into assessments.

RECOMMENDATIONS

COLD BAY

Of the 6 Red and 3 Gray assessed culverts, the project identified 4 culvert sites of concern and high priority for replacement and restoration (Table 2, Figure 9). These recommendations are based on culvert condition, severity of the barrier, estimated upstream habitat, cataloged anadromous habitat above site, and identified species usage. Except for site 30103338, which was replaced with a stream simulation culvert in 2009 (ADF&G 2009), the remaining sites all show signs of significant deterioration and it is recommended that these culverts be replaced for proper road maintenance and that those replacements consider fish passage for resident species found in those systems.

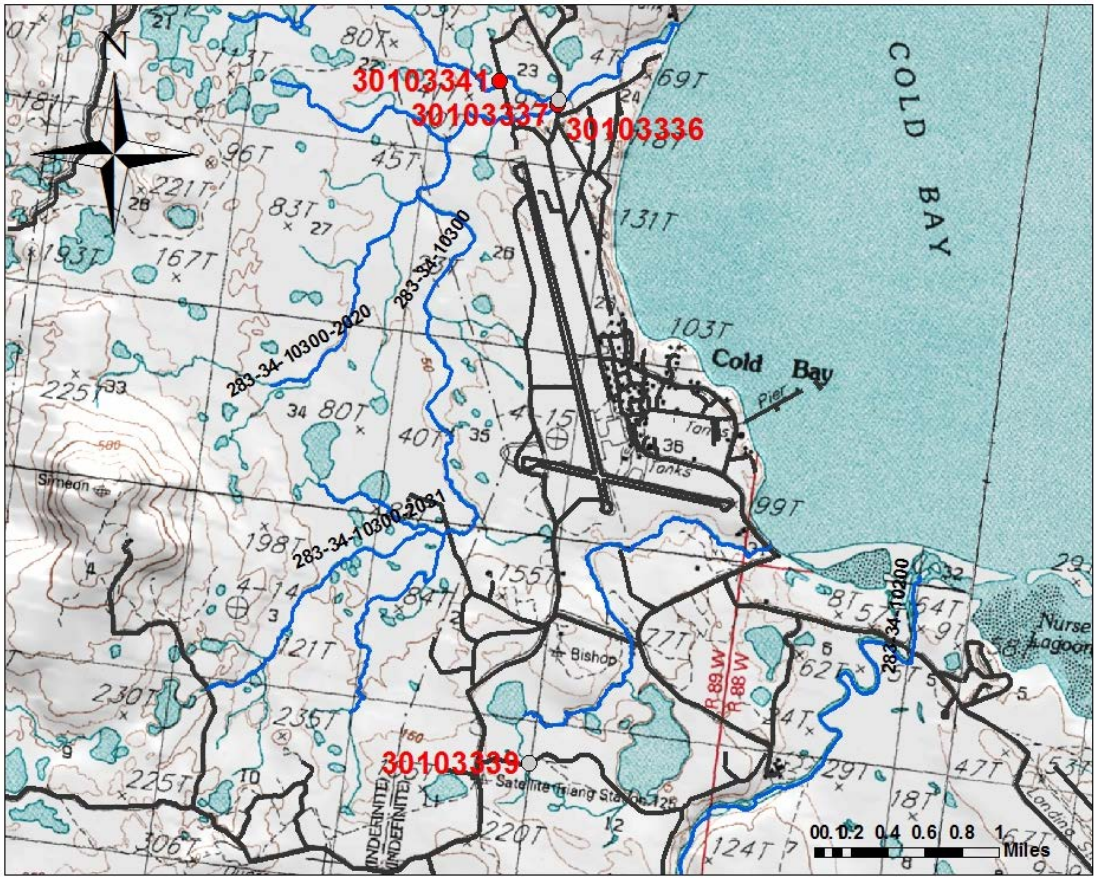

Figure 9.–Map showing culvert of concern on the Cold Bay and Izembek NWR road systems

Site 30103341, Unnamed Tributary to Trout Creek, AWC #283-34-10300-2008

This site is approximately 0.40 miles upstream from another culvert of concern at site 30103337. The culvert is located on airport property on an access road to the runway approach lights on the north end of runway 14 (Figure 9).

At the time of assessment, the inlet was bent downward and partially separated. Water was being funneled around the invert, which was submerged, and entering the culvert at the point of separation (Figures 10 and 11). Above the culvert is 3 miles of AWC-documented stream habitat and over 62 acres of lake habitat. The assessment crew also observed adult sockeye and coho salmon, juvenile coho salmon, and threespine stickleback below the culvert, but no fish were observed or captured above. Damage to the inlet appears to be blocking any upstream movement.

It is recommended that this culvert be replaced with a stream simulation culvert to restore unimpeded access to upstream spawning areas and allow juvenile salmonids and resident fish seasonal movement.

Figure 10.–Site 30103341, unnamed tributary to Trout Creek on the airport runway light access road, damaged inlet.

Figure 11.–Site 30103341, unnamed tributary to Trout Creek on the airport runway light access road, outlet. *Note*: Adult sockeye salmon below outlet.

Site 30103339, Upper Stapp Creek, AWC #283-34-10250

This site is on a small road off Frosty Mountain Road, labeled 4WD Trail, and consists of an old wooden box culvert that likely dates back to World War II. During the site assessment it was noted that the culvert did not have a bottom, and it was unclear if the crossing was designed as a three-sided structure or if the bottom had rotted away (Figure 9). The assessment also noted that there were multiple grade drops inside the culvert, but how severe those drops were could not be determined. Water surface gradient though culvert was calculated at 1.73% (Figures 12–14).

The creek is small, averaging 1.2 feet wide at OHW, but it had excellent habitat consisting of undercut banks, small pools, and riffles. Satellite imagery shows that this creek extends about another 0.3 miles upstream and drains multiple kettle ponds. During the assessment one juvenile coho salmon was caught upstream, nine juvenile coho salmon were caught downstream, and small unidentified fish were observed in the upstream kettle ponds. At the time of assessment this creek was not included in the AWC but was nominated and accepted in 2015 (ADF&G 2015).

It is recommended that this crossing be either removed and the road decommissioned or replaced with a stream simulation culvert.

Figure 12.–Site 30103339, inlet.

Figure 13.–Site 30103339, looking upstream inside the culvert from outlet.

Figure 14.–Site 30103339, outlet.

Site 30103336, Trout Creek, AWC #283-34-10300

This site is located on Grant Point Road on the north side of Cold Bay. This site consists of five 8 to 9-foot diameter fuel tanks that were installed in the 1980's to replace a failing bridge (M. Miller, ADF&G, Sport Fish Biologist, Anchorage, personal communication) (Figure 9). The tank ends had been cut out and the tanks placed end to end. The way the openings were cut left about a 1 to 2-foot-high lip between sections that act like baffles. The cut-out pieces from the tanks were used as wing walls for the outlet. Overall length of the culvert is 156 feet. Upstream OHW measurements averaged 23.3 feet, and the pipes constrict the stream with a ratio of 0.37. There is a noticeable hydraulic inlet perch. This creek has been cataloged as supporting sockeye, coho, chum, and pink salmon runs and resident three spine stickleback and Dolly Varden char (Figures 15-18). This culvert shares its outlet pool with site 30103337 (Stream No. #283-34-10300-2008) with the outlet located downstream about 20 feet.

It is recommended that this site be replaced along with site 30103337 with a bridge or large stream simulation culvert.

Figure 15.–Site 30103336, inlet.

Figure 16.–Site 30103336, stream constriction at inlet creating a hydraulic jump, inlet.

Figure 17.–Site 30103336 inside culvert looking upstream from outlet showing internal structural problems and internal baffles from tank lips.

Figure 18.–Outlets of site 30103336 (left) and 30103337 (right)

Site 30103337, Unnamed Tributary to Trout Creek, AWC #283-34-10300-2008.

This site is about 0.40 miles downstream from site 30103341 and converges with Trout Creek (AWC #293-34-10300) directly downstream of the culvert outlet (Figure 9). It was constructed of old fuel tanks in the same manner as Site 30103336. The culvert is 78 feet long and about 8 feet in diameter. It is perched at the outlet (Figures 19–21). This stream is considerably smaller than Trout Creek with an average OHW of 8.23 feet. We caught 1 juvenile coho salmon and 1 juvenile Dolly Varden char upstream, as well as threespine sticklebacks up- and downstream. There were also adult coho salmon observed milling below the culvert.

It is recommended that this site be replaced in conjunction with site 30103336 with a bridge or stream simulation culvert.

Figure 19.–Site 30103337, inlet with metal wingwalls.

Figure 20.–Site 30103337, outlet showing outfall.

Figure 21.–Site 30103337, looking upstream inside culvert from outlet.

KING COVE

The project identified 6 Red and 7 Gray sites on the King Cove road system, although none blocked more than 0.9 miles of habitat (Table 43). No culverts in the area met project standards of an adult barrier, having a 1-foot outfall height (Table 30), but one site was observed by project's staff to be a partial barrier to adult fish at high flows. Due to the low number of sites, a full prioritization was not performed on these sites. The site restoration recommendations below are based on culvert condition, severity of barrier, potential upstream habitat, documented upstream anadromy, and species usage. Recommendations listed below are meant to be a guide to identifying and selecting sites, but it is not meant to be a prescriptive order of replacement. Sites that are not identified as high priority should nonetheless be replaced with stream simulation or other fish-friendly crossings during the normal course of road maintenance or upgrade. Any tidal culverts that appear to impede fish passage should be further examined to determine the extent of impacts and the quality and influence of replacement on habitat upstream. It is normal for fish to only be able to enter creek mouths during part of the tidal cycle, and that in itself does not constitute a significant impact to fish passage.

Table 43.–Red and Gray culverts on the King Cove Road. Extent of upstream habitat was estimated from topographic maps, the USGS National Hydrography Dataset, AWC, and aerial photographs.

Site ID	Rating	Est. U/S Miles	AWC Miles	Lake Acres	AWC?	Fish	No. Species	Outfall Height	Gradient	Constriction	Condition	Notes
30103446	Gray	0.9	0.33	0	Yes	Pink, chum	2	0.16	0.63		4	Insufficient water depth in culvert for passage during low water.
30103445	Red	0.88	0.04	0	Yes	Pink, coho, chum	3	0		Yes	4	Culvert observed to be undersized, CR not measured
30103444	Gray	0.55	0.09	0	Yes	Pink, coho, chum	3	0		Yes	3	Culvert looks constricted, CR not calculated
30103443	Gray	0.47	0.02	0	Yes	Pink, coho, chum	3	0	Steep, not measured		3	Insufficient water depth in culvert for passage
30103448	Red	0.44	0	0	No	Dolly Varden	1	0.18	1.41	0.43	4	
30103447	Gray	0.25		0	Nominated	Dolly Varden	1	0.25	Steep, not measured		3	
30103461	Red	0.22	0.22	0	Nominated	Pink	1	0.8	2.83	0.8	1	Perched flared outlets, only one culvert taking flow
30103459	Red	0.15	0	0	No	Dolly Varden	1	0.7	2.15	0.66	3	Flared outlet perched
30103457	Gray	0.14	0.14	0	Nominated	Pink, chum	2	0.2			1	
30103460	Red	0.12	0.06	0	Nominated	Pink	1	0.22	3.29		3	Only one culvert taking flow
30103450	Gray	0.06	0.01	0	Nominated	Pink	1	0.19	3.83	No	3	Culvert does not appear undersized
30103455	Red	0.03	0	0	No	Dolly Varden	1	0.66	1.96		3	
30103449	Gray	0	0	3.95	Nominated	Sockeye, pink, chum	3	0.59		0.81	2	Tidal

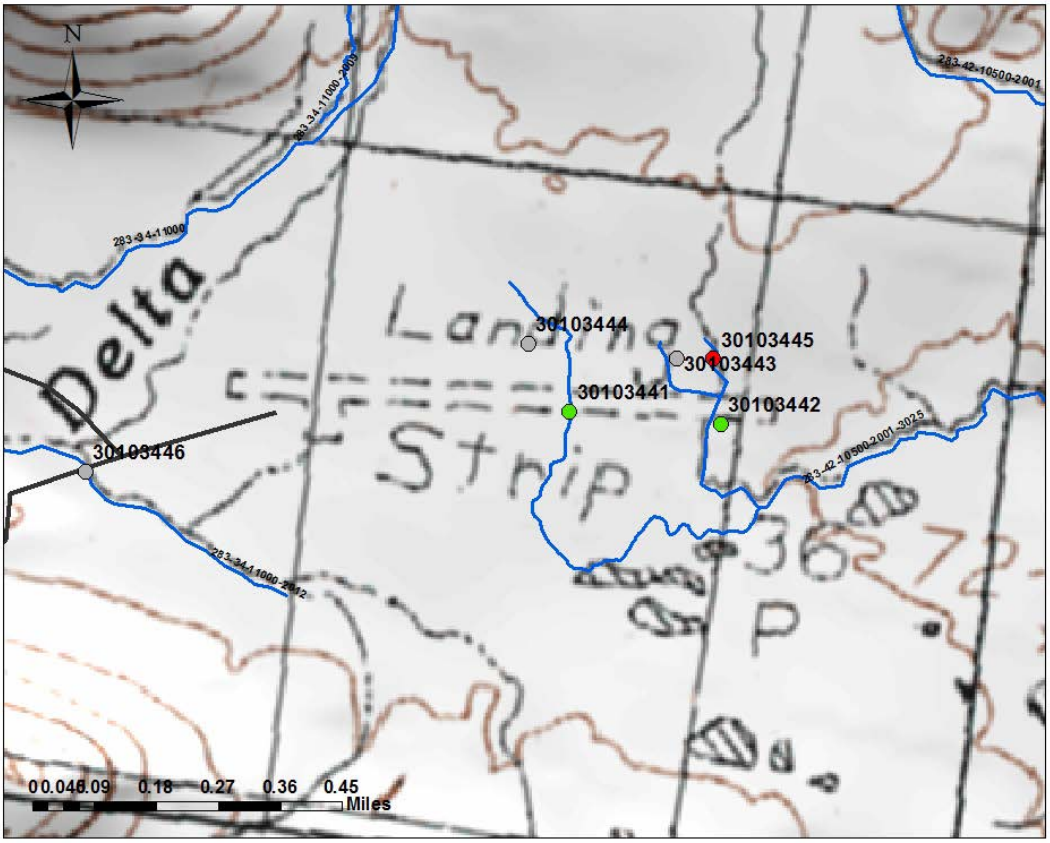

Figure 22.–Map of the culverts around the King Cove airport.

The King Cove airport has 2 anadromous streams that pass under the runway. Both sites 30103441 (AWC # 283-42-10500-2001-3025-4019) and 30103442 (AWC# 283-42-10500-2001-3025-4020) were rated Green by assessment crews, but there are also 3 culverts upstream on an airport access road that are of concern for fish passage (Figure 22). A very large number of spawning pink salmon were observed to be using these streams at the time of survey.

Site 30103444, Unnamed Stream, AWC # 283-42-10500-2001-3025-4019

This site is about 500 feet upstream from site 30103441 (Figure 22). This creek has been cataloged for pink, coho, and chum salmon and Dolly Varden char. Cataloged anadromy extends 500 feet upstream beyond the crossing and satellite imagery shows an additional half mile of potential habitat upstream above the end of anadromy. Assessment crews noted that the culvert was undersized for the creek but were unable to access the inlet or upstream habitat because of the airport security fence. Adult pink salmon were observed above and below the culvert. The project recommends replacement with a stream simulation type culvert (Figures 23 and 24).

Figure 23.–Site 30103444, outlet.

Figure 24.–Site 30103444, upstream channel with adult pinks.

Site 30103443, Unnamed Stream, AWC # 283-42-10500-2001-3025-4020-5013

This site is about 550 feet upstream from site 30103442. The stream in documented for pink salmon and is a tributary to a known coho and chum salmon stream about 1000 feet downstream (Figure 22). The assessment crew was unable to access the culvert inlet or upstream habitat due to a security fence but noted that the culvert appeared to be a potential gradient barrier and that it had inadequate water depth for adult passage. Adult pink salmon were observed downstream of the culvert. The stream is cataloged for pink salmon for a few hundred feet above the crossing, but satellite imagery shows about a half mile of estimated upstream habitat. The project recommends replacement with a stream simulation type culvert (Figures 25 and 26).

Figure 25.–Site 30103443, looking upstream inside culvert from outlet.

Figure 26.–Site 30103443, downstream habitat with adult pink salmon.

Site 30103445, Unnamed Stream, AWC # 283-42-10500-2001-3025-4020

This site is about 400 feet upstream from site 30103442 and merges with a small tributary (AWC #283-42-10500-2001-3025-4020-5013) about 300 feet downstream (Figure 22). Stream is documented for pink salmon another 200 feet above site and the assessment crew encountered many spawning pink salmon during assessment. Satellite imagery shows an estimated 0.88 miles of potential habitat upstream above the current uppermost point of anadromy, and it has been documented for coho and chum salmon downstream. The airport security fence prevented the assessment crew from assessing culvert inlet and upstream habitat. The culvert is undersized, and the site is severely constricted. The project recommends replacement with a stream simulation type culvert (Figures 27–29).

Figure 27.–Site 30103445, culvert outlet side view with spawned-out pink salmon.

Figure 28.–Site 30103445, culvert outlet from directly downstream.

Figure 29.–Site 30103445, above culvert outlet looking downstream.

Site 30103446, Unnamed Tributary to Delta Creek, AWC # 283-34-11000-2012

Site is located on Airport Road about 4 miles north of the city center and a quarter mile from the airport (Figure 22). A large number of adult spawning pink and chum salmon were observed to move through or attempt to move through this culvert at the time of survey.

The stream is cataloged for pink salmon 0.33 miles above culvert and was nominated for chum by project staff. Satellite imagery shows approximately 0.9 miles of stream habitat above the crossing. The culvert was somewhat undersized, had an outfall of 0.19 inches at time of assessment, and was observed to be partially impassable to adult fish after a rain event due to high water velocities. Additionally, low water levels may not allow for adequate water depth through culvert for fish passage. The project recommends replacing with a stream simulation type culvert in the long term; in the short term, a correctly installed grade control structure installed downstream may backwater the inlet and improve passage (Figures 30–33).

Figure 30.–Site 30103446, culvert outlet showing outfall.

Figure 31.–Site 30103446, interior of culvert showing water level and rust line.

Figure 32.–Site 30103446, culvert inlet.

Site 30103448, Unnamed Creek, not cataloged in the AWC to this crossing

Site is on the shooting range off Airport Road about 3 miles from King Cove (Figure 33). The stream is cataloged in the AWC for chum and pink salmon about 0.3 miles downstream of this culvert. Assessment crews observed fish at the site, most likely Dolly Varden char. Satellite imagery shows about another half mile of potential habitat upstream. Recommend replacement with a stream simulation culvert (Figures 34-36).

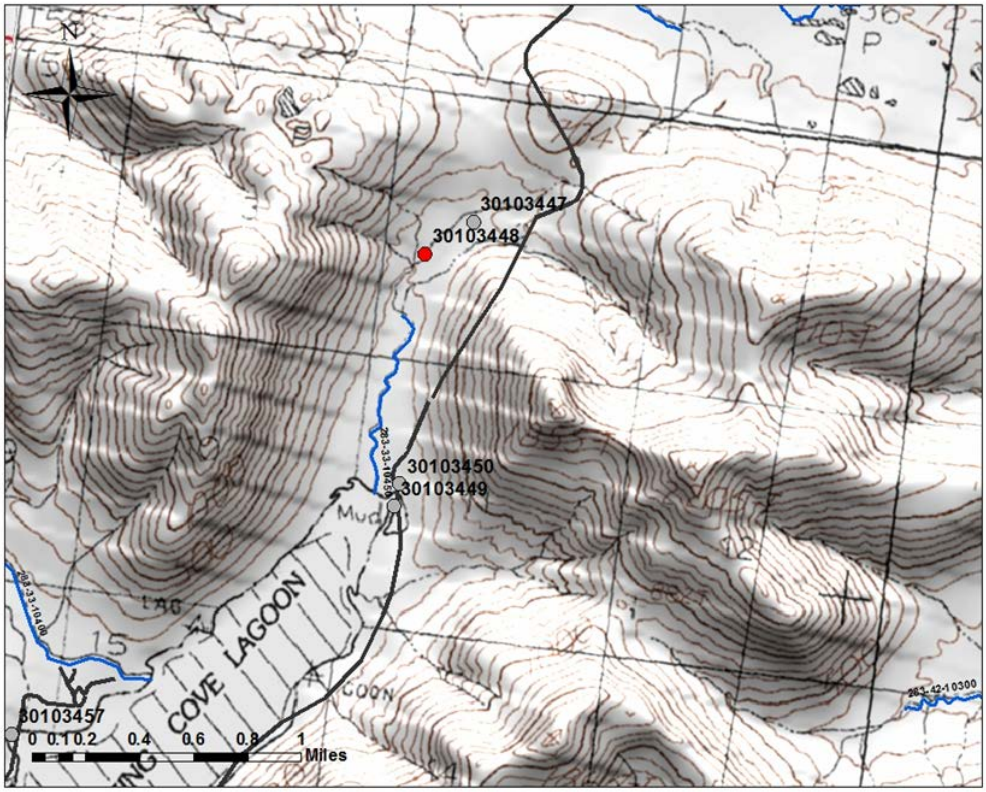

Figure 33.–Map of culverts on the northern end of King Cove Lagoon.

Figure 34.–Site 30103448, culvert outlet showing outfall.

Figure 35.–Site 30103448, inlet perch.

Figure 36.–Site 30103448, constricted culvert inlet.

Site 30103461, Unnamed Tributary to Ram Creek, Nominated to AWC

Site is about 1000 feet upstream from the confluence with Ram Creek (AWC # 283-33-10500) and about 950 feet downstream of site 30103460 (Figure 37). The assessment crew observed adult pink salmon and Dolly Varden char up- and downstream from this site. Site consists of 2 culverts, with one capturing all the flow at the time of survey. Culvert has a Red outfall and adult fish were observed leaping to pass through the crossing and stacking up below the culvert. Recommend replacing culverts with a stream simulation culvert (Figures 38–40).

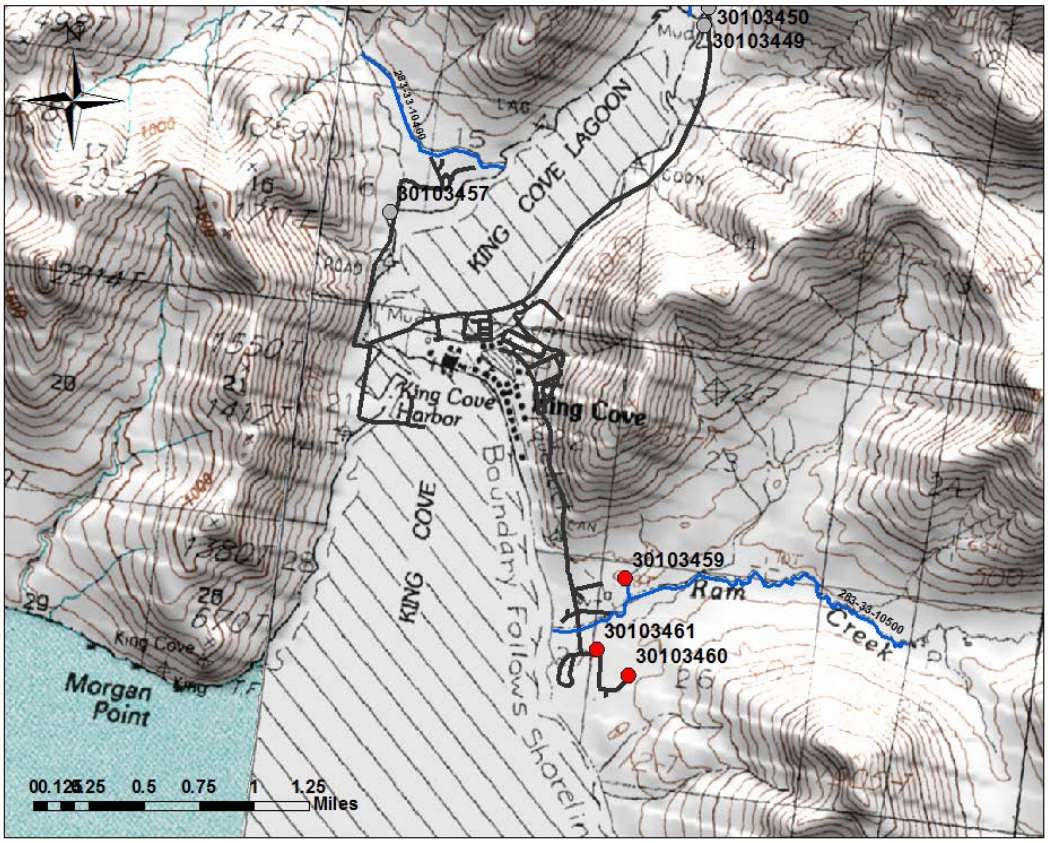

Figure 37.–Map of culverts around the City of King Cove and western King Cove Lagoon

Figure 38.–Site 30103461, outlets showing outfall.

Figure 39.–Site 30103461, outlet of C1 showing outfall and adult pink salmon attempting to transit.

Figure 40.–Site 30103461 culvert inlets.

Site 30103460, Unnamed Tributary to Ram Creek, Nominated to AWC

Site is about a quarter mile upstream from site 30103461 and a half mile from the confluence with Ram Creek (Figure 37). Site consists of two culverts with flared inlets. Almost all flow is being directed into the C1 culvert, or the first culvert starting from the left streambank looking downstream. Both culverts have Gray outfall and Red gradients, and the site also has a Gray constriction ratio. The assessment crew observed Dolly Varden char above culvert, adult pink salmon above and below the culvert, and adult pink salmon over 400 feet upstream of the crossing. The project recommends replacing these culverts with a stream simulation culvert (Figures 41–43).

Figure 41.–Site 30103460, culvert inlets, C1 (left hand side) taking almost all flow.

Figure 42.–Site 30103460, culvert outlets.

Figure 43.–Site 30103460, outlet of C1 showing outfall.

Site 30103459, Unnamed Tributary to Ram Creek, AWC # 283-33-10500-2011.

This site is about 700 feet upstream from the confluence with Ram Creek (AWC#283-33-10500) (Figure 37). The creek is documented for pink salmon up to the road crossing. The culvert has a Red outfall and gradient and a Gray constriction ratio. The assessment crew observed fish upstream and downstream of site, likely Dolly Varden char. Creek flows under the new King Cove school about 300 feet downstream of the culvert. The project recommends replacement with a stream simulation culvert (Figures 44–47).

Figure 44.–Site 30103459, flared outlet showing Red outfall.

Figure 45.–Site 30103459, culvert inlet, showing inlet perch.

Figure 46.–Site 30103459, 300 feet downstream of culvert showing creek flowing under new King Cove school.

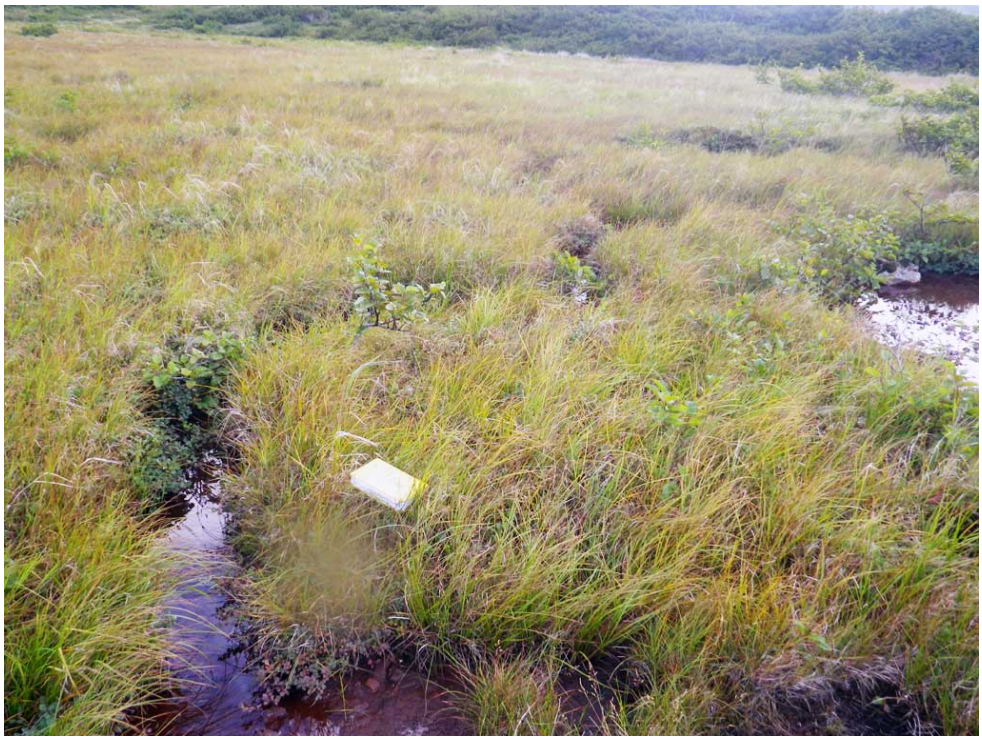

Figure 47.–Site 3013459, habitat 400 feet upstream from culvert.

ACKNOWLEDGMENTS

The project would like to thank the individuals and organizations that made this project possible. They include: the US Fish and Wildlife Service, the National Wildlife Refuge System, the Alaska Sustainable Salmon Fund, the City of King Cove, the City of Cold Bay, Neil Durco, and Jeanette Alas.

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APPENDIX A. FORMS

Appendix A1.–Field data form (front).

Survey ID		**Date**	
Site ID		**Time**	
Road Name		**Book #**	
Milepost		**Crew**	
Watershed		**Lat.**	
Stream Name		**Long.**	

Site Classification (Red/Gray/Green) _____

(Complete all applicable sections of this form before leaving survey site!)

Failure Codes	1	2	3	4	5	6
from table						

Resurvey? (Y/N)	
Backwatered? (Y/N)	

Old Survey ID (if known)_____

Step Pools ❑ Baffles ❑ Tidal ❑

Culvert Description: pipes numbered left to right facing downstream

	Units	1	2	3	4	5
Culvert Type (CIR, PA, etc.)						
Culvert Material (CSP, SSP, etc.)						
Structure Type (from matrix)	1 to 5					
Inlet Type (PRO, HDW, ect)						
Inlet Apron Length	ft					
Inlet Width	ft					
Inlet Height	ft					
Substrate Depth Inlet	ft					
Rust Line Height Inlet	ft					
Sedimentation at Inlet?	Y/N					
Outlet Type (PRO, HDW, ect.)						
Outlet Apron Length	ft					
Outlet Width	ft					
Outlet Height	ft					
Outfall Type (AG, F, C, etc.)						
Substrate Depth Outlet	ft					
Corrugation Depth	in					
Corrugation Width	in					
Culvert Length	ft					
Embedded?	Y/N					
Embedded Depth	ft					
Condition Rating (5=best)	1 to 5					
Outfall Height	ft					
Pipe Gradient	%					
Water Depth at Outlet	ft					
Max Gradient	%					
Length of Max Gradient	ft					
Stream Gradient	%					
Backwatered?	Y/N					
Individual Culvert Rating (Red, Gray, Green)						

Habitat Elements	**Upstream**	**Downstream**	**Inlet**	**Outlet**
Dominant substrate				
Subdominant substrate				

Stream Measurements

	Dist.	**OHW**
Upstream width		
Upstream width		
Upstream width		
Upstream width		
Downstream width		
Downstream width		
Downstream width		

Avg u/s width	
Avg d/s width	
Constriction Ratio	

Stream Stage (High, Med, or Low)	

Stream Approach Angle	

Fish data:	Sheet #		Line #s	
Trap	Loc/Dist	Time In	Time out	Soak Time
A				
B				

Notes: (Fish observations, damage, oddities, ect)

Appendix A2.–Field data form (back).

	Structure Type	Green *Conditions may be adequate to pass juvenile fish*	Gray *Conditions unlikely to pass juvenile fish, additional analysis required*	Red *Conditions assumed inadequate to pass juvenile fish, additional analysis required*
1	Bottomless pipe arch, embedded pipe arch, CMP, box culvert or other embedded structure that functions in a similar fashion to an embedded pipe arch.	Installed at channel gradient (+/- 1% gradient), AND culvert span to OHW width ratio greater than or equal to 0.75 OR fully backwatered	Structure not installed at channel gradient (+/- 1%), OR culvert span to OHW width ratio of 0.5 to 0.75	Culvert span to OHW width ratio less than 0.5
2	Culverts (all span widths) with 2 X 6 inch corrugations or greater, not embedded.	Culvert gradient less than 1.0%, AND outfall hgt.= 0, AND culvert span to OHW width ratio greater than 0.75 OR fully backwatered	Culvert gradient 1.0 to 2.0%, OR less than or equal to 4-inch outfall hgt., OR culvert span to OHW width ratio of 0.5 to 0.75	Culvert gradient greater than 2.0%, OR outfall hgt. greater than 4 inches, OR span to OHW width ratio less than 0.5
3	Pipe arch or circular CMP (span width greater than 4 feet), less than 2 X 6 inch corrugations, not embedded	Culvert gradient less than 0.5%, AND outfall hgt. = 0, AND culvert span to OHW width ratio greater than 0.75 OR fully backwatered	Culvert gradient 0.5 to 2.0%, OR less than or equal to 4-inch outfall hgt., OR culvert span to OHW width ratio of 0.5 to 0.75	Culvert gradient greater than 2.0%, OR outfall hgt. greater than 4 inches, OR culvert span to OHW width ratio less than 0.5
4	Pipe arch or circular CMP (span width less than or equal to 4 feet), less than 2 X 6 inch corrugations, not embedded	Culvert gradient less than 0.5%, AND outfall hgt.= 0, AND culvert span to OHW width ratio greater than 0.75 OR fully backwatered	Culvert gradient 0.5 to 1.0%, OR less than or equal to 4-inch outfall hgt., OR culvert span to OHW width ratio of 0.5 to 0.75	Culvert gradient greater than 1.0%, OR outfall hgt. greater than 4 inches, OR span to OHW width ratio less than 0.5.
5	Non-embedded box culverts, culverts with non-standard configurations or materials, culverts with baffles or downstream weirs or step pools, fish ladders, bridges with aprons.	Fully backwatered as described below.	All others	Outfall height at downstream end of structure greater than 4 inches.
6	Multiple Structure Installations	Individual culverts all classified as Green as above	Individual culverts all classified as Gray or as some mix of Green, Gray or Red as above.	Individual culverts all classified as Red as above.

1. These criteria are not design standards, but rather indicate whether the structure is likely to provide fish passage for juvenile salmonids based on a one-time evaluation.
2. Ordinary high water (OHW) is the mean stream width measured either upstream or downstream of the culvert beyond the hydraulic influence of the culvert. .
3. An embedded culvert must have 100% bedload coverage. Circular and box culverts must be embedded at least 20% of their height. A pipe-arch must be embedded so that the mean bedload depth is greater than or equal to the vertical distance from the bottom of the pipe to the point of maximum horizontal dimension of the culvert (haunch height) or is 1 foot deep, whichever is greater.
4. A culvert is considered backwatered if one of the following conditions is met: 1) elevation of the tailwater control exceeds the elevation of the invert at both the outlet and inlet of the culvert and the of any aprons or other inlet or outlet structures 2) the culvert is located in a pond, slough or other area with slow moving or still water and the tailwater and headwaters surface are equivalent and water surface is continuous throughout the entire structure and at least 0.1 feet in depth at the shallowest point. Culvert gradient, span to OHW ratio, and outfall height criteria are not considered in the assessment of fish passage in backwatered culverts. A culvert is not backwatered if a hydraulic jump occurs within the barrel.
5. Outfall height is the difference between the water surface elevation at the outlet and in the outlet pool (or the equivalent tailwater surface).

Site Observations

OHG	Outfall height gray
OHR	Outfall height red
GRDG	Culvert gradient gray
GRDR	Culvert gradient red
CRG	Constriction ratio gray
CRR	Constriction ratio red
AL	Culvert is poorly aligned
BV	Beaver Activity
CG	Compound gradient in pipe
CS	Cut-slope sliding into culvert
DF	Debris Flow
EC	Hydraulic flows exceeded capacity
IAS	Inlet apron too steep
IB	Improper bedding
IC	Damage associated with ice problems
IP	Inlet perch
MP	Mechanical damage or joints parting
MT	Material inadequate for designed use
OAS	Outlet apron too steep
OT	Other - vibrations, cavitation, etc.
RD	Road bank erosion
RF	Road Fill (pushed off road by grader)
SD	Sediment accumulation
SF	Shallow fill above culvert
SG	Culvert sagging in middle
SS	Subsidence
ST	Structural Problem
TS	Culvert is too short
WD	Woody Debris
NO	None of this type

Inlet/Outlet Type

PRO	Projecting
MIT	Mitered
HDW	Headwall
FLA	Flared
APR	Apron
WIN	Wing Wall

Culvert Material

SSP	Structural steel plate (bolted)
SAP	Structural aluminum plate (bolted)
CSP	Corrugated steel
CAP	Corrugated aluminum
WOD	Wood
RCP	Reinforced concrete
CPP	Corrugated plastic
NCP	Non-corrugated metal
UNK	Unknown/Other

Culvert Type

CIR	Circular pipe
OVL	Oval
AO	Open-bottom arch
BOX	Box culvert
PA	Pipe-arch
BR	Bridge
OT	Other
RM	Removed structure
FBO	Flat-bottom Oval

Substrate Types

Code	Descriptio	Size Guidelines
MD	Silt/ Clay	0.08mm to less than 2mm
SA	Sand	2mm to less than 5mm
GRV	Gravel	5mm to less than 80mm
CBL	Cobble	80mm to less than 250mm
BO	Boulder	250mm to less than 1 meter
BD	Bedrock	1 meter or greater
OR	Organics	n/a
NO	None	n/a

Outfall Type

AG	At Stream Grade
F	Free Fall In To Pool
C	Cascade Over Rip-Rap
SF	Smooth Flow Over Apron
OP	Overflow Pipe
HJ	Hydraulic Jump
FR	Free Fall on To Rip Rap
PS	Fish Passage Structue

Appendix A3.–Photo site field data form.

Fish Passage Survey Photo Site Only Form

(Remember to fill out a section in the Survey Notebook for this site as well)

Survey ID:	_____	Date:	_____
Site ID:	_____	Time:	_____
Road Name:	_____	Book #	_____
Milepost	_____	Crew:	_____
Watershed	_____	Latitude	_____
Stream Name	_____	Longitude:	_____

Photo Log

Comments: (Include why this is a photo site only: bridge, safty concern, ect.)

1 _____
2 _____
3 _____
4 _____
5 _____
6 _____
7 _____
8 _____
9 _____
10 _____

ALASKA DEPARTMENT OF FISH AND GAME

*All Site ID's for Photo Sites should begin with the prefix PS to denote a photosite.
(Example:PSARD01)
**This Form should only be filled out if you were unable to take any physical measurements at the site or if you are documenting a site as a bridge replacement.

Appendix A4.–Fish data form.

Fish Passage Culvert Assessment Sheet ____ of _____

Fish Sampling Form

Date _____ **Project** _____

	Site ID	Trap #	Distance from culvert	U/S or D/S	Species	Size category	Number	Comments
1								
2								
3								
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APPENDIX B. SITE LIST

Appendix B1.–Site list.

Site ID	Date of Survey	Stream Name	Latitude	Longitude	Site Rating	Condition Rating	Site Observations
30103336	10/2/14	Trout Creek	55.22721	-162.73399	Red	1	Inlet perch, constriction ratio red, mechanical damage or joints parting, structural problem, hydraulic flows exceeded capacity
30103337	10/2/14	Little Trout Creek	55.22755	-162.73398	Gray	2	Material inadequate for designed use, outfall height gray, structural problem
30103338	10/3/14	Unnamed	55.18615	-162.71428	Gray	4	Culvert gradient red
30103339	10/3/14	Unnamed	55.17554	-162.72604	Gray	1	Mechanical damage or joints parting, compound gradient in pipe
30103340	10/4/14	Unnamed Tributary to Trout Creek	55.17806	-162.77119	Red	2	Culvert gradient red, mechanical damage or joints parting, hydraulic flows exceeded capacity, outfall height red
30103341	10/4/14	Little Trout Creek	55.22844	-162.74231	Red	1	Compound gradient in pipe, mechanical damage or joints parting, culvert gradient red, constriction ratio gray, hydraulic flows exceeded capacity
30103342	10/4/14	Unnamed	55.28966	-162.78822	Red	1	Mechanical damage or joints parting, material inadequate for designed use, shallow fill; inadequate roadfill volume above culvert, culvert gradient red
30103343	10/4/14	Lake Hess Complex	55.28223	-162.78543	Red	1	Shallow fill; inadequate roadfill volume above culvert, mechanical damage or joints parting, material inadequate for designed use, culvert gradient red
30103344	10/5/14	Unnamed	55.26235	-162.85826	Green	3	Mechanical damage or joints parting
30103345	10/5/14	Simeon Lake Complex	55.25172	-162.77667	Red	2	Road fill (pushed off road by grader), culvert gradient red
30103441	9/1/15	Unnamed	55.11620	162.26430	Green	4	None of this type
30103442	9/2/15	Unnamed	55.11633	-162.25873	Green	4	None of this type
30103443	9/2/15	Unnamed	55.11758	-162.26063	Gray	3	Unable to survey, likely gradient barrier
30103444	9/2/15	Unnamed	55.11751	-162.26611	Gray	3	Unable to survey, culvert appears undersized for creek
30103445	9/2/15	Unnamed	55.11767	-162.25931	Red	5	Culvert is too short, constriction ratio red, hydraulic flows exceeded capacity
30103446	9/3/15	Unnamed	55.11369	-162.28165	Gray	4	Outfall height gray, Inlet perch
30103447	9/3/15	Unnamed	55.10003	-162.29069	Black	3	Outfall height gray

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Appendix B1.–Page 2 of 2.

Site ID	Date of Survey	Stream Name	Latitude	Longitude	Site Rating	Condition Rating	Site Observations
30103448	9/3/15	Unnamed	55.09801	-162.29482	Red	4	Constriction ratio red, outfall height gray, culvert gradient red, Inlet perch, Hydraulic flows exceeded capacity
30103449	9/3/15	Unnamed	55.08435	-162.29478	Gray	2	Compound gradient in pipe, mechanical damage or joints parting; other, including vibrations, cavitation, etc.
30103450	9/3/15	Unnamed	55.08558	-162.29451	Gray	3	Outfall height gray
30103451	9/2/15	Unnamed Tributary to Delta Creek	55.13646	-162.26691	Green	3	Culvert gradient gray
30103452	9/2/15	Munson Creek North Fork	55.23672	-162.50177	Green	4	Other, including vibrations, cavitation, etc.
30103453	9/2/15	Munson Creek South Fork	55.23213	-162.50261	Green	4	None of this type
30103454	9/2/15	Unnamed	55.11512	-162.34468	Green	4	None of this type
30103455	9/2/15	Unnamed	55.11553	-162.34087	Red	4	Outfall height red, Inlet perch, culvert gradient red
30103456	9/2/15	Unnamed	55.12025	-162.30981	Green	5	None of this type
30103457	9/3/15	Unnamed	55.06966	-162.32768	Gray	1	Structural Problem, culvert is too short, material inadequate for designed use, road bank erosion
30103459	9/4/15	Unnamed	55.04786	-162.29590	Red	3	Inlet perch, inlet apron too steep, outfall height red, culvert gradient red, constriction ratio gray, mechanical damage or joints parting
30103460	9/4/15	Unnamed	55.04159	-162.29416	Red	3	Culvert gradient red, outfall height gray, constriction ratio gray, culvert is too short, road bank erosion, culvert sagging in middle
30103461	9/4/15	Unnamed	55.04300	-162.29808	Red		Culvert gradient red, outfall height red, compound gradient in pipe, structural problem, culvert is too short

APPENDIX C. GLOSSARY

Appendix C1.–Glossary of terms used in this report.

Anadromous Waters Catalog: The Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes specifies which Alaskan streams, rivers, and lakes are important to anadromous fish species and therefore afforded protection under AS 16.05.871. Water bodies that are not "specified" within the Catalog are not afforded that protection. To be protected under AS 16.05.871, water bodies must be documented as supporting some life function of an anadromous fish species (salmon, trout, char, whitefish, sturgeon, etc.)

Approach angle: The angle at which the stream flows into the culvert inlet.

Apron: A length of non-erosive material designed to prevent scour holes developing at the outlet ends of culverts, outlet pipes, grade stabilization structures, and other water control devices

Arch culvert: Corrugated steel pipe formed in an arch shape that spans the stream and sits on footers of concrete, bedrock or wood. A bottomless arch culvert is built across the natural streambed.

Azimuth: A horizontal angle measured clockwise from any fixed reference plane or easily established base direction line

Bankfull flow: A condition where flow completely fills the stream channel to the top of the bank but does not spill over into the floodplain.

Baffle: Structures, usually metal plates, installed inside a culvert to deflect and/or slow the flow of water to aid upstream fish passage.

Bedload: Sediment moving on or near the streambed and frequently in contact with it.

Benchmark: A marked point of known elevation from which other elevations may be established.

Box culvert: An enclosed culvert, mainly rectangular in cross-section, typically made of corrugated steel or aluminum but wood or concrete box culverts are also found.

Channel: A natural or artificial waterway of perceptible extent that periodically or continuously contains moving water. It has a definite bed and banks, which serve to confine the water.

Channelization: Straightening of a stream or the dredging of a new channel to which the stream is diverted.

Culvert: A closed conduit used for the passage of surface water under or through a road or other embankment.

Diameter: Inside diameter, measured between inside crests of corrugations.

Drainage area: Total land area draining to any point in a stream, as measured on a map, aerial photograph, or other horizontal plane. Also called catchment area, watershed, and basin.

Embedded culvert: Any culvert that has substrate throughout its length, typically with an invert lower than the streambed elevation. Embedded culverts include geomorphic, stream simulation, and other types of embedment design methodologies or design standards to meet fish passage criteria.

Fish migration: The movement of individual fish and/or fish populations for any purpose, including feeding, spawning, etc.

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Flood: Any flow that exceeds the bankfull capacity of a stream or channel and flows out on the floodplain; greater than bankfull discharge.

Floodplain: Any flat or nearly flat lowland that borders a stream and is covered by its waters at flood stage. Land immediately adjoining a stream which is inundated when the discharge exceeds the conveyance of the normal channel. The channel proper and the areas adjoining the channel which have been or hereafter may be covered by the regulatory or 100-year flood. Any normally dry land area that is susceptible to being inundated by water from any natural source.

Ford: A road crossing a stream where a hard causeway is provided or naturally occurs in the bed of the stream.

Fry: Juvenile salmon and trout in their first few months of life.

Gabion: A patented woven or welded wire basket filled with rocks of such a size that they do not pass through the openings in the basket. Individual baskets are stacked in place like building blocks and filled with rock to form erosion resistant structures.

Glide: A stream facet feature that is commonly indicated by smooth, relatively fast-flowing water and is the transition zone of a pool to a riffle as water moves downstream. Stretch of stream that typically separates pools from riffles. The streambed of a glide has an adverse slope.

Gradient (slope): The rate of rise or fall of a slope, expressed as a percentage or ratio as determined by a change in elevation to the length.

Head of riffle: The upstream end of a riffle and downstream end of a glide.

Headwall: A retaining wall located at either the inlet or outlet of a culvert.

Headwater: The height of water at the inlet of a culvert.

Headwater elevation: The water surface elevation upstream from a culvert entrance invert, typically measured relative to the benchmark.

Hydraulic capacity: The effective carrying ability of a drainage structure. Measured as volume per time.

Hydraulic Unit Code (HUC): A geographic area representing part of all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature.

Inlet: Point where water enters a culvert.

Invert: The lowest internal point of any cross section in a culvert.

Level 1 culvert assessment: Rapid assessments based on physical measurements of the culvert and stream channel and focused on juvenile salmonid fish passage. The culvert is assessed for type, slope, outfall height, constriction, and other physical parameters and then classified as green, gray, or red using a decision matrix.

Longitudinal profile: A survey taken down the length of a stream that is used to illustrate the gradient and other features of that stream.

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Ordinary high water: This is the line between upland and bottomland that persists through successive changes in water levels, below which the presence of water is so common or recurrent that the character of the soil and vegetation is markedly different from the upland.

Outfall height: The difference between the culvert outlet water surface and the tail water surface when a perch exists at a culvert's outlet.

Outfall types: The conditions that exist at the outlet of a culvert as water exits.

Outlet: Point of culvert at which water exits the structure after passing through it.

Perch: The development of a fall or cascade at a culvert outlet due to the erosion of the stream channel downstream from a culvert barrel, bridge, apron, or ford.

Pipe arch: A corrugated metal pipe that is shaped so that it is wider than it is tall with the widest part being located near the bottom of the culvert.

Pool: Deeper stream feature characterized by still or slow-moving water and a smooth surface. Pools can typically be 2-3 times the depth of a riffle.

Resident fish: Fish that spend their entire life cycle in freshwater. In Alaska, resident fish include landlocked anadromous fish (e.g., kokanee and coho salmon), as well as traditionally defined resident fish species such as Arctic grayling or rainbow trout.

Riffle: Stream feature characterized by shallow, fast-moving water broken by the presence of rocks and boulders. Typically the steepest part of a stream.

Rise: The maximum vertical height inside a culvert, usually measured at the centerline.

Roughness: A measure of the friction exerted on the moving water by the channel bed and banks as well as other elements such as vegetation and woody debris.

Run: Stream feature characterized by fast-moving water that is not broken by the presence of rocks or boulders and is the transition zone of a riffle to a pool. Deeper than a riffle, a run will often have a well-defined thalweg.

Rust line: A well-defined line separating rusted and unrusted metal inside the barrel of a metal culvert that marks the extent of ordinary high water.

Salmonid: Fish belonging to the family Salmonidae, such as salmon and trout.

Scour: Channel degradation, typically at the culvert outlet resulting from erosive velocities.

Skew: The angle formed by the intersection of the line normal to the centerline of the road with the centerline of a culvert.

Snout-fork measurement: The length from the tip of the snout to the end of the middle caudal fin rays. Also known as *fork length*.

Soak Time: The amount of time a baited trap is left in the water to capture fish.

Streamflow: The rate at which water passes a given point in a stream, usually expressed in cubic feet per second (cfs).

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Stream gradient: The overall gradient of the stream through a reach.

Stream stage: Stage is the water level above some arbitrary point in the river.

Structural multi-plate: Multi-plate or structural plate culverts assembled on a treated timber or concrete foundation. Because of their size (normally in excess of 2 m in diameter) and the fact that they are placed on a foundation, they are normally assembled on site. A series of interlocking steel plates are bolted together to make the required shape and length.

Substrate: Bed material in a stream channel or culvert.

Tailwater control (tailcrest): a geomorphic feature that controls the elevation of the tailwater, which is the water immediately downstream of the culvert.

Tailwater depth: The depth of water immediately downstream from a culvert, measured from the culvert outlet invert.

Tailwater elevation: The water surface elevation at the downstream side of a hydraulic structure (i.e., culvert, bridge), usually measured from a datum.

Thalweg: The deepest continuous channel in a stream, generally marking the line of fastest flow.

Trash rack: A structural device used to prevent debris from entering a culvert or other hydraulic structure.

Water surface profile: A profile plot of water surface elevation through a culvert or open channel.

Watershed: The region drained by or contributing water to a specific point that could be along a stream, lake, or other stormwater facilities.

Weir: Small dam in a stream that causes water to back up behind it, and flow over or through it. (a) A notch or depression in a levee, dam, embankment, or other barrier across or bordering a stream, through which the flow of water is measured or regulated. (b) A barrier constructed across a stream to divert fish into a trap. (c) A dam (usually small) in a stream to raise the water level or divert its flow.

Wingwall: The retaining wall that provides a transition from the culvert headwall to the channel.