Hydrology and Hydraulics Report – Scammon Bay Airport Improvements Feasibility Study

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Alaska Department of Transportation and Public Facilities, Central Region

Scammon Bay, Alaska

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Acronyms and Abbreviations

ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AWC	*Anadromous Waters Catalog*
cfs	cubic feet per second
CMP	corrugated metal pipe
DOT&PF	State of Alaska Department of Transportation and Public Facilities
DS	Downstream
°F	degrees Fahrenheit
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FPID	Fish Passage Inventory Database
GFDL-CM3	NOAA Geophysical Fluid Dynamics Laboratory - Coupled Model 3.0
GIS	Geographic Information Systems
GCM	Global Circulation Model
H&H	Hydrology and Hydraulics
HDPE	High Density Polyethylene
HEC	Hydraulic Engineering Circular
HW/D	headwater depth to culvert diameter ratio
IfSAR	Interferometric Synthetic Aperture Radar
LiDAR	Light Detection and Ranging
MHHW	mean higher-high water
MLLW	mean lower-low water
MTL	mean tide level
NAVD88	North American Vertical Datum of 1988
NCAR-CCSM4	National Center for Atmospheric Research - Atmospheric Research Community Earth System Model 4
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
PCM	*Alaska Highway Preconstruction Manual*
PIH	Plans-in-Hand
PRISM	Parameter-elevation Regression on Independent Slopes Model
Q_{50}	50-year design discharge
SCM	Scammon Bay Airport (International Air Transport Association's airport code)
SNAP	University of Alaska Fairbanks Scenarios Network for Alaska + Arctic Planning
TR-55	Technical Release 55
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

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1. Introduction

1.1 Project Overview

This Hydrology and Hydraulics (H&H) Report is prepared for the State of Alaska Department of Transportation and Public Facilities (DOT&PF) Central Region as part of a larger feasibility study to assess improvements to the airport at Scammon Bay (project).

The project is at the Scammon Bay State Airport (SCM), which is a state-owned, public use airport. The DOT&PF proposes various airport improvements to enhance safety, improve infrastructure, and bring the airport to Federal Aviation Administration standards. These improvements consist primarily of repairing elements that have been damaged by flooding or have otherwise deteriorated over time, including:

- Increasing the elevation of the runway, taxiway, apron, and access road
- Shifting the runway away from the Kun River
- Replacing the culvert under the runway
- Placing erosion protection adjacent to the Kun River and airport embankments
- Making various building and aviation-specific additions and replacements
- Obtaining additional right-of-way

1.2 Scope of Hydrologic and Hydraulic Analyses

The project involves providing H&H and coastal engineering recommendations to guide a larger feasibility study regarding the various airport improvements to better protect SCM from flooding and scour. The H&H portion consisted of looking at the removal and replacement of one 48-inch-diameter cross culvert near the center of the existing runway. The crossing conveys an unnamed tributary to the Kun River and will require hydraulic design. As of the writing of this report, Alaska Department of Fish and Game (ADF&G) had not determined if this crossing will require hydraulic design to accommodate anadromous fish passage. If anadromous fish passage requirements are established, the supplementary design considerations will need to be considered for the feasibility study.

Details specific to the coastal engineering recommendations to support this project are provided under a separate report (HDR, 2022).

HDR conducted a background review, site visit, and discussions with DOT&PF to gain an overall understanding of the project drainage and site-specific drainage issues. This was followed by basin delineations, development of flood frequencies, culvert hydraulic calculations, and tidal analyses. These are discussed in this report and detailed in its appendices.

1.3 Organization of Report

This report is organized as follows:

- Section 2 discusses existing hydrologic and hydraulic conditions.
- Section 3 discusses the project design criteria.
- Section 4 discusses the hydrologic analysis.
- Section 5 discusses the hydraulic analysis.
- Section 6 discusses floodplain management.
- Section 7 presents the summary and recommendations.
- Section 8 presents the references cited.

All elevations provided are based on the North American Vertical Datum of 1988 (NAVD88) unless otherwise specified.

2. Hydrologic and Hydraulic Conditions

2.1 General Physical Characteristics

The project is located in the community of Scammon Bay in Western Alaska, in the Kusilvak Census Area (Figure 1). Scammon Bay has a population of 594 (U.S. Census Bureau 2020) and covers 299 acres. The runway is located on the south shore of the Kun River along the northeast edge of the community.

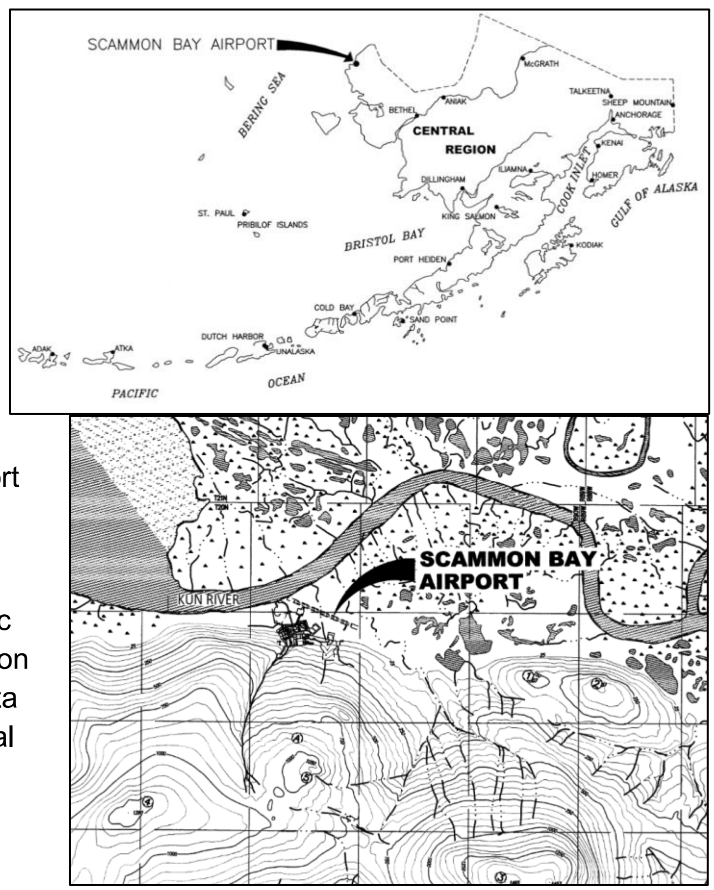

Figure 1: Location and Vicinity Map

Recreated from DOT&PF 2004 and 2013b

DOT&PF and HDR conducted a site visit in May 2021 to assess the existing runway culvert and the surrounding area. Appendix A includes HDR's site visit report with photographs.

Local topography was analyzed using publicly available Interferometric Synthetic Aperture Radar (IfSAR) and Light Detection and Ranging (LiDAR) digital elevation data (State of Alaska Geological & Geophysical Surveys 2021).

Geology of the area was interpreted from the United States Geological Survey (USGS) Geologic Map of Alaska via an online mapper (Wilson et al. 2015).

Land cover characteristics in the area were analyzed for use in hydrologic estimations and are summarized in Table 1. Land cover type and corresponding hydrologic properties were determined by analysis of vegetation that was observed during site visits, aerial photography, and cover classifications from the National Land Cover Database (NLCD) (Dewitz 2020). Water feature coverage, such as rivers, streams, and ponds, were classified by similar means and the 2021 Alaska Hydrography Database (USGS 2021).

2.1.1 Runway 10/28

The airport consists of one Type A, gravel runway (designated by 10/28). The runway sits between 10 and 17.5 feet in elevation and runs northwest to southeast at a +0.19 percent slope. It is bounded by the Kun River to the northwest, surrounded by intertidal wetlands, and connected to the community with one access road to the southwest.

The runway sits near the border of two geologic regions: uplands and wetlands. The USGS classifies the upland areas of the community as intermediate granitic rocks and the adjacent wetland areas as unconsolidated and poorly consolidated surficial deposits (Wilson et al. 2015).

2.1.2 Runway Culvert

The existing structure beneath the runway is a 48-inch-diameter, 198-foot-long, smooth interior wall, corrugated, high-density polyethylene (HDPE) pipe. The DOT&PF *2013 Scammon Bay Airport Flood Permanent Repairs DMVA/FEMA* plans show the culvert with a 0.2 percent slope, an inlet invert elevation of 4.0 feet, and an outlet invert elevation of 3.6 feet. The crossing allows flow from a perennial stream (unnamed tributary) to pass beneath the runway and discharge to the Kun River.

Upstream of the culvert, the stream meanders through the hillside, the eastern portion of the community, and tundra for approximately 1,400 feet. During the May 2021 site visit, the existing culvert was inspected and appeared to be sagging and partially collapsed in three locations. While the inlet was not visible due to mounded snow, a large pool of water (10–15 feet wide and approximately 20 feet long) was observed immediately upstream of the inlet. A noticeable foul odor was also documented and is suspected to be caused by effluent seeping from the wastewater lagoon, located next to an upstream portion of the meandering stream. This assumption was not confirmed during the site visit.

Downstream of the culvert, the stream travels approximately 1,700 feet through intertidal wetlands to its receiving waters, the Kun River. At the outlet, the stream is approximately 5 feet wide but widens to 10–14 feet immediately downstream of the outlet. Tidal influence on the stream channel is evident from the nearly vertical stream banks that range from 2 to 3 feet in depth.

2.2 Climate

The Scammon Bay area has a maritime climate and receives an average annual precipitation of 24 inches due to its coastal proximity. Climate records for the area indicate that the warmest temperatures occur in July, averaging 51 degrees Fahrenheit (°F), and the coldest temperatures occur in February, averaging 8.4°F. Precipitation varies from the driest month (February), with an average 1.0 inch of rain, to the wettest month (August), with an average 4.4 inches of rain

(SNAP 2021). Historical annual snowfall is around 68 inches and typically accumulates between October and April (Western Regional Climate Center 2021).

2.3 General Basin Hydrology

Scammon Bay is located on the Yukon-Kuskokwim Delta, 60 miles southwest of the mouth of the Yukon River. Most of the streams within the Yukon-Kuskokwim Delta are made up of shallow sloped, meandering channels flowing through tundra and wetlands that contain numerous oxbow lakes and relic channels on their way to the Bering Sea. The Scammon Bay community is located at the intersection of three distinct hydrologic features: the Kun River to the north and east, the Askinuk Mountains to the south, and the Bering Sea to the west. The airport lies along the Kun River, 0.75 mile upstream from its mouth.

2.3.1 Kun River Basin

The Kun River generally flows east to west and acts as a northern boundary for the community of Scammon Bay as it reaches its receiving waters, Scammon Bay, in the eastern Bering Sea. The Kun River's drainage basin at the Scammon Bay airport encompasses an estimated 461 square miles and contains portions of the Askinuk Mountains, perennial alpine streams, tundra, wetlands, and ponds. It is bounded by relatively flat tundra and wetlands to the north, the Black River to the east, and the Askinuk mountain range to the southwest, shown on Figure 2. The wetlands and ponds make up approximately 19 percent of the basin area and likely account for significant flow attenuation during heavy rainfall events.

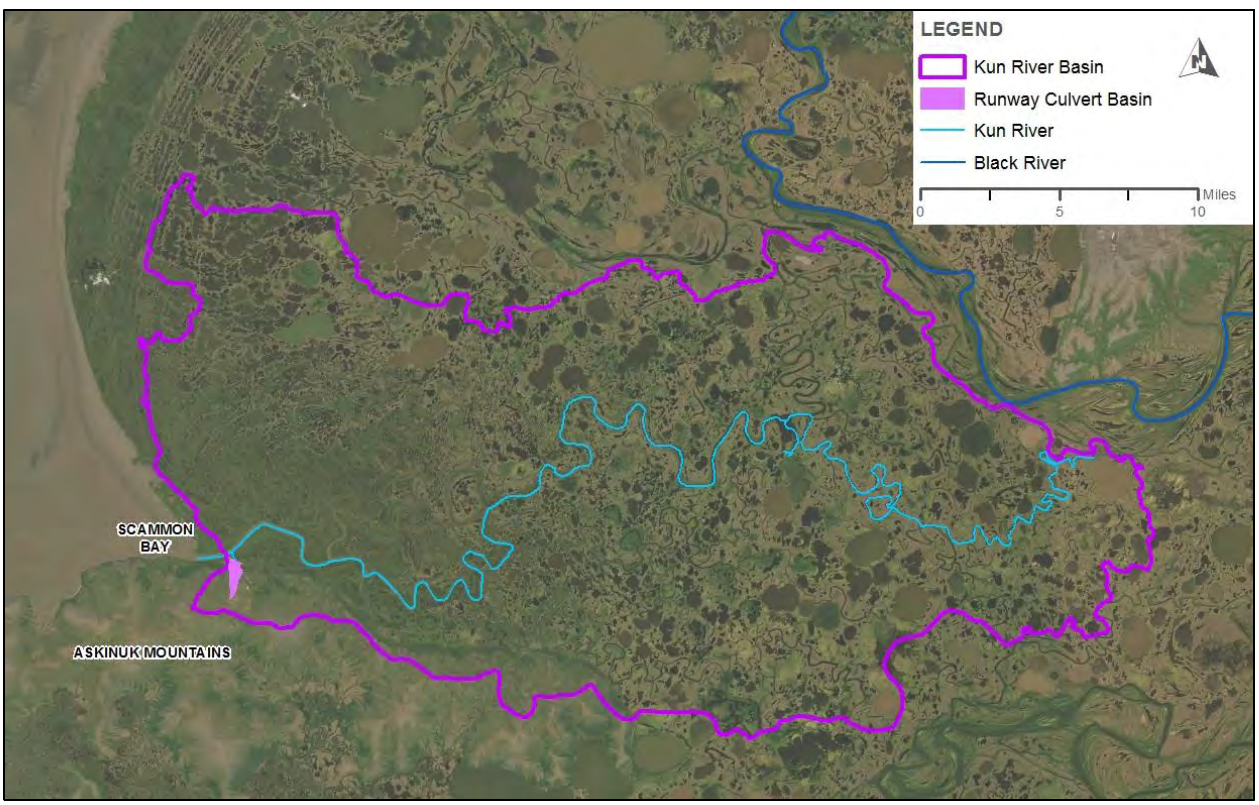

Figure 2: Kun River Basin

The Kun River is listed in the ADF&G *Anadromous Waters Catalog* (AWC) as having Arctic Char and Chum Salmon (ADF&G 2021a).

2.3.2 Runway Culvert Basin

The runway culvert basin for the unnamed tributary to the Kun River is approximately 296 acres. It receives flows from a portion of the hillside above the community, flows from the community, and (likely) small amounts of seepage from the community's sewage lagoon. It is a perennial stream that meanders through the tundra for approximately 1,400 feet before passing through the runway culvert and then traveling approximately 1,700 feet through the intertidal wetlands to the Kun River. The runway culvert basin and surrounding area are shown on Figure 3.

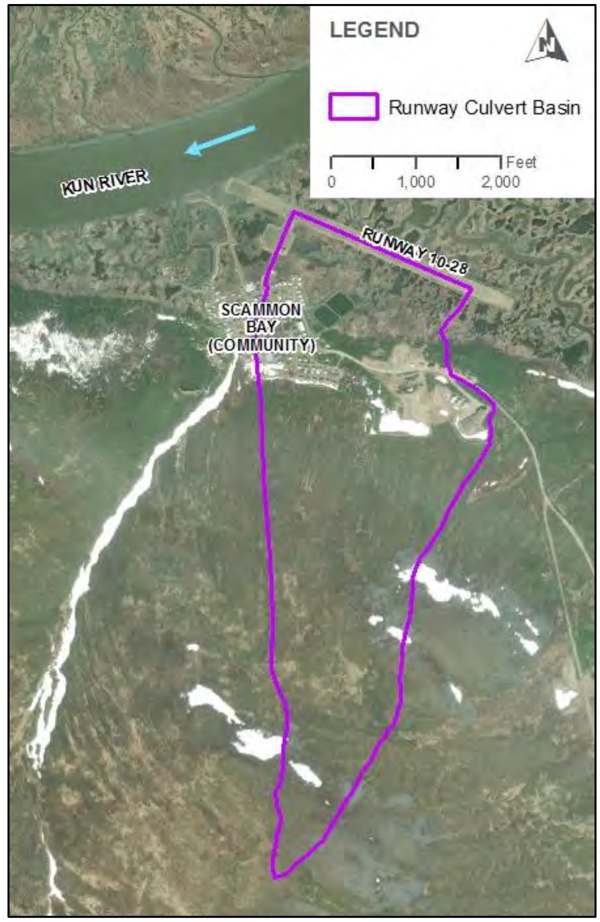

Figure 3: Runway Culvert Basin

During June 2021, discussions with ADF&G indicated that this tributary may have suitable habitat for fish species residing in the Kun River, but it is not currently listed in the AWC.

2.3.3 Basin Characteristic Summary

Table 1 summarizes standard basin characteristics for the Kun River and the runway crossing identified for analysis. These characteristics are frequently used when evaluating hydrology at ungaged sites and are included for reference. Of these characteristics, the values used to calculate design discharges are area and annual precipitation.

Table 1: Project Drainage Basin Characteristics

Feature	Runway Culvert Basin Unnamed Tributary to the Kun River	Kun River at the Scammon Bay Airport
Area (square miles)	0.46	461
Area with Lake and Pond Storage (%)	0.45	18.9
Forested Area[a] (%)	1.6	0.39
Average Stream Slope[a] (feet/feet)	0.13	0.002
Mean Elevation (feet)	363	31
1971–2000 PRISM[b] Annual Precipitation (inches)	24.5	19.0

Notes: PRISM = Parameter-elevation Regression on Independent Slopes Model.
[a] Dewitz 2020.
[b] Gibson 2009.

2.4 Additional Hydrologic Attributes

This section summarizes other hydrologic attributes as required by DOT&PF's *Alaska Highway Preconstruction Manual* for H&H reports (DOT&PF 2013a). Since the runway culvert's basin lies within the greater Kun River basin, both basins are discussed further.

2.4.1 Tidal Influence

The mouth of the unnamed tributary is approximately 2 miles upstream from where the Kun River flows into Scammon Bay in the eastern Bering Sea. The National Oceanic and Atmospheric Administration (NOAA) monitors a tidal benchmark on the Kun River (Station ID: 9467124) that is 948 feet upstream of the runway (NOAA 2021a). The mean lower low water (MLLW) and mean higher high water (MHHW) elevations recorded at this benchmark are 0.30 foot and 6.77 feet, respectively. The existing runway culvert's outlet invert elevation is 3.60 feet, which is 0.01 foot above the mean tide level (MTL) and 3.17 feet below the MHHW. It was suspected that the tributary and culvert were tidally influenced upon inspection during the May 2021 site visit and was later confirmed through coastal modeling.

The runway culvert is estimated to be tidally influenced 45 percent of the time but is never completely inundated during astronomical tides. This percentage is assumed to increase over time due to a predicted 0.64-foot increase in relative sea level over the next 50 years. The culvert can, however, become fully inundated during a coastal storm surge event, which is an abnormal rise in sea level caused by a storm. The extent to which the culvert is inundated is dependent on the severity of the event. See Table 2 for a comparison of the existing culvert outlet's elevation to typical tidal elevations.

Table 2: Kun River (NOAA Station ID: 9467124) Tidal Datums

Datum	Elevation (feet, based on NAVD88)	Elevation (feet from MLLW)
Mean Higher High Water (MHHW)	6.77	6.47
Mean High Water (MHW)	6.00	5.70
Runway Culvert Outlet Invert	3.60	3.30
Mean Tide Level (MTL)	3.59	3.29
Mean Sea Level (MSL)	3.50	3.20
Mean Low Water (MLW)	1.18	0.88
Mean Lower Low Water (MLLW)	0.30	0
NAVD88	0	-0.30

Sources: NOAA 2021b.
Notes: NAVD88 = North American Vertical Datum of 1988.

Based on the 50-year return interval storm surge model, the water surface elevation is greatest (15.7 feet) as the storm recedes the area. The velocities surrounding the inlet of the culvert were nearly identical (1.7 feet per second) during the building and receding of the storm.

2.4.2 Freshwater Streams

The project is located on the banks of the Kun River and includes one perennial freshwater stream, the unnamed tributary to the Kun River, that passes through the runway culvert. Various other perennial freshwater streams (named and unnamed tributaries of the Kun River), seasonal freshwater streams, wetlands, and ponds are located within the greater Kun River basin.

2.4.3 Navigation

The unnamed tributary of the Kun River that passes through the runway culvert is not listed in the Alaska Department of Natural Resources (ADNR) navigable waters catalog as navigable. Sections of the Kun River are listed as either undetermined or potentially navigable, with the mouth and section along the community listed as undetermined (ADNR 2021a). There is an active city-owned, seaplane landing base located at the northwest edge of the community. Additionally, the local community utilizes small boats in the surrounding area.

In a United States Army Corps of Engineers (USACE) – Alaska District 2009 report, barges were indicated to bring bulk supplies in the summer months (the Bering Sea is ice-free from late June through October). The barge landing was noted to be easy to access (USACE 2009).

2.4.4 Confluences

The confluence of the unnamed tributary is approximately 2 miles upstream of the mouth of the Kun River. There are no other confluences upstream of the crossing that would affect the site hydraulics during large flood events.

The Kun River has several named confluences and numerous other unnamed tributaries. From its headwaters to the mouth, the Iaslaktoli, Tungpuk, Kikneak, and Ear rivers converge with the Kun River before it flows into Scammon Bay and then the Bering Sea.

2.4.5 Mining Activity

Based on the ADNR mining claims map, the project extents have no active mining activity (ADNR 2021b). In the past, there may have been some mining activity along the shores of Scammon Bay, but there have been no significant historical mining operations in the project area that might affect the hydrology at the crossing site.

2.4.6 Debris Problems

Problems with debris have not been documented at the crossing, nor were they listed during the May 2021 site visit as a design concern. The flows from the unnamed tributary to the Kun River emanate from upland tundra and wetlands where debris is typically not an issue. The Kun River drains a large, predominantly boggy area that backwaters to the crossing during high-tide events. While the upstream reaches likely do not contain debris that would get stuck inside or damage the culvert, driftwood and other large floating objects brought in during incoming tides might affect the project site.

2.4.7 Icing Problems

Icing problems were not listed as a design concern or observed during the May 2021 site visit. A thaw pipe or other icing counter measures were not observed in the existing runway culvert. If there is seepage from the sewage lagoon, it would provide slightly warmer flows to the culvert, lowering icing potential.

Substantial snow accumulation was present at the runway culvert inlet and outlet. This accumulation is thought to be due to winter runway maintenance, and caution should be taken in the future to avoid plowing/stacking snow near the culvert inlet and outlet to prevent reduction of the hydraulic capacity of the culvert. In terms of icing, snow cover may act as insulation for the culvert.

2.4.8 Fish Passage

The unnamed tributary of the Kun River has not been identified or nominated for fish passage based on the ADF&G Fish Passage Inventory Database (FPID) (ADF&G 2021b). The Kun River is mapped as anadromous in the AWC and is listed with having Arctic Char and Chum Salmon (ADF&G 2021a). While no fish sampling has been conducted in the tributary, its direct connection to the Kun River with no apparent barriers to fish passage increases the likelihood that it contains fish.

Discussions with ADF&G to date indicate that while the stream is relatively small and has a small connected habitat, ADF&G desires to maintain connectivity with the Kun River. Discussion with ADF&G should be concluded, and determination should be made on design requirements.

3. Design Criteria

Specific design criteria for airport culverts are not provided in the Alaska Aviation Preconstruction Manual or the FAA Advisory Circular for Airport Drainage Design (dated 8/15/2013). Therefore, the new runway is to be designed to the standards set forth in the *Alaska Highway Preconstruction Manual* (PCM) *(*DOT&PF 2013a) and the *Alaska Highway Drainage Manual* (Drainage Manual) (DOT&PF 2006). Both documents require culverts 48 inches in diameter or greater to be hydraulically designed (PCM section 450.9.7, Drainage Manual section 9.2.2). Table 1120-1 of the PCM establishes a design flood frequency of 50 years (Q_{50}) for this type of crossing. The Drainage Manual, section 9.3.3, requires a headwater depth to culvert diameter ratio (HW/D) no greater than 1.5. The proposed culvert should have a design life of 30 to 75 years.

If required at future design stages, fish passage shall be accommodated and the structure design will follow the guidelines set forth by the *Memorandum of Agreement between ADF&G and DOT&PF for the Design, Permitting, and Construction of Culverts for Fish Passage* (DOT&PF 2001).

4. Hydrologic Analysis

4.1 Flood Frequency Analyses

The method of flood frequency analysis is typically selected by the contributing basin area. The 2016 USGS Regression Equations (USGS 2016) are typically used when the (site) basin meets the minimum area and mean annual precipitation criteria. In areas that do not meet the limitations of USGS Regression Equations, the Rational method and/or the National Resources Conservation Service (NRCS) Urban Hydrology for Small Watershed Technical Release 55 (TR-55; NRCS 1986) methods can be utilized. Between the two latter methods, the TR-55 method is typically selected for basins outside of the 2016 USGS regression equations criteria, as it tends to be the more conservative method for design discharges, producing higher estimated flows at Q_{50}. In a case in which the 2016 USGS regression equations can be used, the other methods can also be calculated, and their results compared for corroboration and consistency.

The methods considered and the basin area requirements for each method are:

- 2016 USGS regression equations (basin area greater than 0.4 square mile; between 8 and 280 inches of mean annual precipitation)
- Rational method (basin area less than 200 acres [0.31 square mile])
- NRCS TR-55 (no basin area limitation)

4.1.1 USGS Regression Equations

The USGS first introduced Regression Equations specific to Alaska (and the Yukon River) in 2003 and divided the state geographically into seven regions (Curran et al. 2003). These regions were drawn to group areas with similar hydrologic characteristics (e.g., climate, terrain) and had regression equations specific to each region. These equations were developed by analyzing the hydrologic characteristics of between 25 and 97 basins throughout each region. Basin characteristics that were used in the regression equations varied by region but typically (except for the North Slope) included basin area and mean annual precipitation, in addition to other regional characteristics such as percent storage area, elevation, percent forested area, and mean January temperature. The Regression Equations were updated and simplified in 2016, combining all seven regions into one and changing the hydrologic characteristics used in the equations to just two: basin area and mean annual precipitation (Curran et al. 2016). The basin for the runway culvert meets the 2016 Regression Equations' recommended criteria and was used for flood frequency analysis at the site.

To calculate discharges of various return intervals, basins are delineated in ArcMap using high-resolution imagery and topographic mapping. Precipitation values are developed in ArcMap by area-weighting the Mean Precipitation for Alaska 1971–2000 Parameter-elevation Regression on Independent Slopes Model (PRISM) dataset sponsored by the National Park Service (NPS) (Gibson, 2009).

4.1.2 NRCS TR-55 Method

TR-55 is a simplified version of the NRCS TR-20, which is used to estimate storm runoff and peak discharge for small basins. TR-55 uses basin geometry, 24-hour local rainfall depth, ground cover type, and peak discharge curves to estimate time of concentration and flood frequencies.

As part of the TR-55 method, the maximum flow length for each basin was determined using Geographic Information Systems (GIS) and surface LiDAR survey data obtained through the Alaska Division of Geological and Geophysical Surveys. The TR-55 method divides overland flow into three categories when estimating peak runoff: shallow sheet flow, shallow concentrated flow, and open channel flow. TR-55 states that open channel flow calculations should be used only in areas "where cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets (NRCS, 1986)."

Because limited cross sections or formal stream surveys exist for the project area, the flow lengths used to calculate times of concentration were broken down as follows. The first 300 feet of overland flow was designated as sheet flow. In basins where none of the information previously stated was available, the remaining flow length was split evenly between shallow concentrated flow and open channel flow. In basins where blue lines are present on USGS quadrangle sheets, the length of each blue line was assigned to open channel flow and the remaining flow length was assigned to shallow concentrated flow.

Local rainfall depth for the 24-hour event was obtained from the NOAA Atlas 14, Volume 7, Version 2 point precipitation frequency estimates.

4.1.3 FHWA HEC-17 Analyses

The Federal Highway Administration (FHWA) provides technical guidance for analyzing highways during extreme events in the Hydraulic Engineering Circular (HEC)-17, *Highways in the River Environment – Floodplains, Extreme Events, Risk, and Resilience* (FHWA 2016). HEC-17 lays out five varying levels of analysis to account for risk and vulnerability assessments. The appropriate level is chosen based on information available, project needs, and service life (see Chapter 7 of HEC-17 [FHWA 2016]).

A Level 2 analysis, which includes the analysis of confidence limits in addition to the Level 1 – Historical Discharge Analysis, was determined to be appropriate. The Level 1 analysis is completed and summarized in Section 4.1.4. Based on a hydrologic service life of between 30 and 75 years, the Level 2 analysis reviews the 68 percent confidence interval of the design discharge and other methods of estimating nonstationary impacts, specifically anticipated increases in precipitation due to climate change. These values allow for consideration of a larger exposure period, when the probability of extreme events and nonstationary impacts increase, and current estimates of climate change impacts.

To estimate increases to flows over the service life of the culvert (30-75 years), the University of Alaska Fairbanks Scenarios Network for Alaska + Arctic Planning (SNAP) data were used to adjust the annual PRISM precipitation data and the NOAA Atlas 14, Volume 7, Version 2 point precipitation frequency estimates.

SNAP has predicted an overall increase in annual precipitation of 9.1 percent for the years 2060–2069 and 17 percent for the years 2090–2099. The 2090–2099 precipitation values were used as they provide a more conservative estimate for the anticipated service life of the project. These increased factors were applied to the PRISM annual precipitation data used in the 2016 Regression Equations. It should be noted that the (limitations of) 2016 Regression Equations cautions users when exploring the potential for future precipitation increases from climate models within the Regression Equations because of the unknown error associated with the combination of methods. Because of this uncertainty, the SNAP adjusted results provided below are not intended for use as design flows.

Effects of climate change for the 24-hour rainfall event were also estimated based on SNAP data for the project area. SNAP currently has two Global Circulation Models (GCMs) that predict future short-duration rainfall events for the service life of the proposed structure (the years 2080–2099 were selected for this analysis): the NOAA Geophysical Fluid Dynamics Laboratory - Coupled Model 3.0 (GFDL-CM3) and the National Center for Atmospheric Research - Atmospheric Research Community Earth System Model 4 (NCAR-CCSM4). GFDL-CM3 uses an aggressive climate change model and estimates an increase in the 50-year, 24-hour rainfall depth of 299 percent. NCAR-CCSM4 uses a less aggressive but still conservative climate change model and predicts an increase in the 50-year, 24-hour rainfall depth of 59 percent, deeming it the chosen GCM for this analysis.

Table 3 shows the comparison of the design discharge for the basin (Level 1) with the upper limit of the 68 percent confidence interval and the SNAP adjusted 2016 Regression Equations. The purpose of this comparison is for design consideration, looking at the potential consequences, and mitigating where feasible and reasonable. These values are not meant to be used as design criteria.

Table 3: Level 2 HEC-17 Analyses

Stream Name	**Runway Culvert Basin Unnamed Tributary of the Kun River**		
Estimation Method	2016 USGS Regression Equations		
Adjustment	**None**	**Upper 68% Confidence Interval**	**SNAP Adjusted**
Return Period	Estimated Discharge (cfs)		
2-year	13	25	15
10-year	35	66	40
25-year	50	94	56
50-year	62	118	70
100-year	75	145	84

Notes: USGS = United States Geological Survey; cfs = cubic feet per second; SNAP = Scenarios Network for Alaska + Arctic Planning.

4.1.4 Flood Frequency Analyses Results

Table 4 and Table 5 summarize the results of the flood frequency analysis for the runway culvert and the Kun River respectively. Flood frequency analysis results for the Kun River were calculated for use in coastal analysis (see Coastal Analysis Report) and were not used to size the runway culvert. The 2016 USGS Regression Equations, and the SNAP adjusted TR-55 (only used for the runway culvert) results are included. The SNAP adjusted TR-55 results include estimates for future changes in precipitation for the service life of the culvert (30-75 years). Flood frequency analysis calculations are included in Appendix B.

Table 4: Flood Frequency Analysis Summary for the Runway Culvert

Return Period	Estimated Discharge (cfs)	
	2016 USGS Regression Equations	TR-55 with SNAP Adjustment
2-year	**13**	3.3
10-year	**35**	16
25-year	**50**	27
50-year[a]	**62**	37
100-year	**75**	49

Table 5: Flood Frequency Analysis Summary for the Kun River

Return Period	Estimated Discharge (cfs)
	2016 USGS Regression Equations
2-year	**3,235**
10-year	**5,937**
25-year	**7,403**
50-year[a]	**8,500**
100-year	**9,630**

The flood frequency results from the 2016 USGS Regression Equations will be used for design. Flood frequency analysis calculations are included in Appendix B.

4.1.5 Fish Passage Flows

Fish passage design is currently not within the project scope, as the crossing was not nominated for fish passage within the AWC prior to project initiation. Discussion with ADF&G indicates that maintaining connectivity with the anadromous Kun River is a desired project outcome. While no sampling or other methods for verifying fish residency have occurred, the unnamed tributary to the Kun River is assumed to have resident fish due to its unobstructed connection to the Kun River.

The DOT&PF and ADF&G Fish Passage Memorandum of Agreement outlines three tiers of design for fish passage: Tier 1 is stream simulation, Tier 2 is FISHPASS Program design, and Tier 3 is hydraulic engineering design. **As of the release of this report, a decision has not been made for the fish passage tier requirement.**

Once guidance from DOT&PF and ADF&G is obtained on the level of fish passage design requested, further analysis will need to be conducted to meet the chosen tier requirements. It should also be noted that the design fish species, size, and time of year will need to be supplied by ADF&G before further analysis can be conducted.

5. Hydraulic Analysis

Hydraulic calculations utilize FHWA's HY-8, version 7.60 (FHWA 2019), for hydraulic analysis at the runway culvert. HY-8 uses several essential design features for the crossing structure, tailwater, and roadway to automate culvert hydraulic calculations.

Additional hydraulic design considerations were made for this crossing, including tidal influence and fish passage. To accommodate tidal changes and floating debris, the crown of the culvert outlet should be designed 2 feet above the MHHW elevation to provide headspace in the culvert during high tide events. It should be noted that this crossing will be designed to the MHHW elevation, and not to coastal storm surge event elevations.

Fish passage requirements may change the maximum HW/D ratio and would need to be addressed. Section 5.1 presents the hydraulic characteristics and analyses for the existing and proposed structures.

5.1 Crossing Structure Sizing

The recommended structure has design criteria (tidal influence and fish passage) outside of the required hydraulic minimums that drove the structure selection. Hydraulic analysis served as a verification of the structure size selected. To accommodate tidal influence, the structure's outlet crown elevation was set at least 2 feet above the MHHW elevation with consideration for relative sea level rise of 0.63 feet (crown minimum of 9.40 feet) and the structure diameter was sized to maintain a HW/D ratio of less than 1.5 during the 50-year coastal storm surge event. To accommodate fish passage design, the inlet and outlet invert elevations were selected to maintain a constant hydraulic connection with the Kun River. Various other parameters may need to be met in the future based on a design fish and design flow required for fish passage design criteria.

A 72-inch-diameter culvert was needed to meet the minimum crown elevation requirement at MHHW. When modeling the 100-year upper 68 percent confidence interval of 145 cubic feet per second (cfs), a 72-inch-diameter culvert produces a HW/D ratio of 1.43.

The HW/D ratio for a 72-inch-diameter culvert during the 50-year return interval coastal storm surge event is 1.93. An increased structure size of a 96-inch-diameter culvert produces a HW/D of 1.44. In this case, the increase in cost and constructability of a 96-inch-diameter pipe in comparison with a 72-inch-diameter pipe is likely minimal in the overall project cost, and therefore justifies upsizing the pipe to 96-inches based on this design criteria.

See Figure 4 for a profile of the proposed culvert at the design discharge, Q_{50}, of 62 cfs. Table 6 summarizes the existing and proposed crossing structures and characteristics. Refer to Table 7 and Table 8 for summaries of the existing and proposed crossing structure hydraulics. See Appendix C for the HY-8 report and riprap apron calculations.

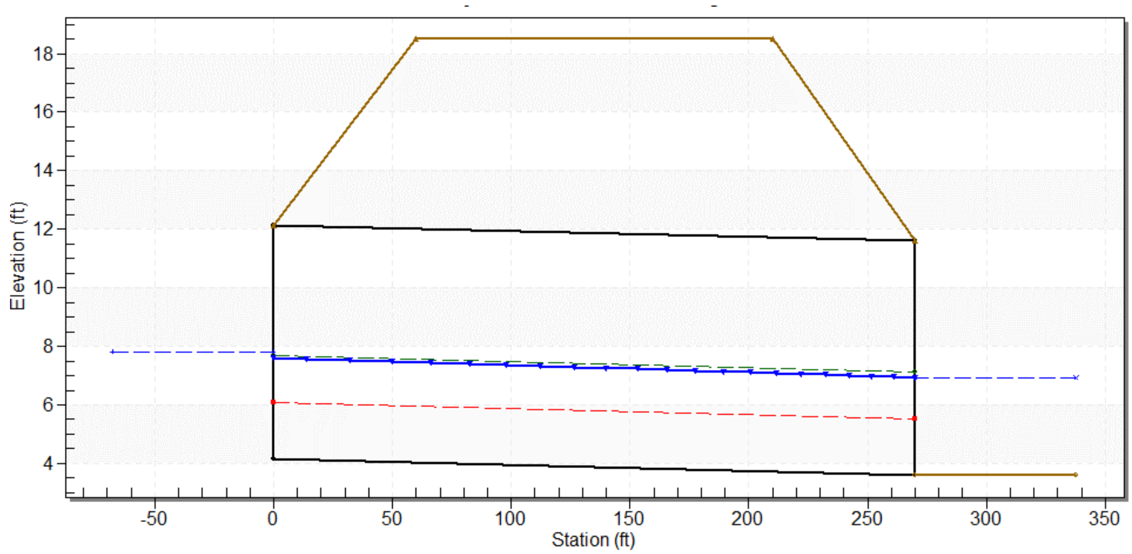

Figure 4: Proposed Culvert Profile at Q_{50} (62cfs)

Table 6: Existing and Proposed Culvert and Channel Characteristics

Culvert Name	Runway Culvert	
Structure	**Existing Structure**	**Proposed Structure**
Length (feet)	199	270
Shape and Dimension	48-inch, round, smooth-wall HDPE	96-inch, round, 8-gage[a] aluminum structural plate
Culvert Slope (%)	0.2	0.2
US Channel Slope (%)	1.3	
DS Channel Slope (%)	0.1	

Notes: HDPE = high-density polyethylene; US = upstream; DS = downstream.
[a] If 8 gage is unavailable, 10 gage is also acceptable.

Table 7: Existing Structures Hydraulic Analysis

Basin Name	Event (Q-Year)	Discharge (cfs)	Existing Structure				
			Headwater Elevation (feet)	Culvert Discharge (cfs)	Roadway Discharge (cfs)	HW/D[a]	Tailwater Elevation (feet)
Runway Culvert	2	13	5.65	13	0		4.75
	50 (Design)	62	8.08	62	0		6.93
	100	75	8.79	75	0	1.2	7.42
	Upper 68% (50)	118	12.40	118	0	2.1	7.60
	Overtopping	126	13.2	126	0	2.3	7.60

Notes: cfs = cubic feet per second; HW/D = headwater depth to culvert diameter ratio.
[a] Blank unless HW/D is greater than 1.0.

Table 8: Proposed Structures Hydraulic Analysis

Basin Name	Event (Q-Year)	Discharge (cfs)	Proposed Structure Non-tidally influenced				Proposed Structure Tidally (MHHW) influenced			
			Headwater Elevation (feet)	Culvert Discharge (cfs)	HW/D[a]	Tailwater Elevation (feet)	Headwater Elevation (feet)	Culvert Discharge (cfs)	HW/D[a]	Tailwater Elevation (feet)
Runway Culvert	2	13	5.77	13		4.75	7.43	13		7.40
	50 (Design)	62	7.80	62		6.93	8.05	62		7.40
	100	75	8.25	75		7.42	8.24	75		7.40
	Upper 68% (50)	118	9.73	118		8.94	9.03	118		7.40
	Overtopping	315 / 500	18.50	315	1.8	12.00	18.50	500	1.8	7.40

Notes: cfs = cubic feet per second; HW/D = headwater depth to culvert diameter ratio.
[a] Blank unless HW/D is greater than 1.0.

5.1.1 Runway Culvert

The existing culvert is a 48-inch, round, smooth-wall HDPE pipe, is 198.15 feet in length with a 0.2 percent slope, and has an estimated HW/D ratio of 1.02 at the 50-year discharge. Its inlet and outlet inverts are at 4.0 feet and 3.6 feet, respectively. The outlet invert is 0.01 foot above the MTL and 3.17 feet below the MHHW.

The proposed culvert is a 270-foot-long, 96-inch, 8-gage aluminum structural plate culvert, at a 0.2 percent slope. When selecting culvert material, aluminum was preferred over steel due to its increased corrosion resistance to seawater. Structural plate pipe was selected over corrugated pipe because it comes in a thicker gage (8-gage vs 10-gage) and can be shipped in stacks of 4.5-foot sheets to cut cost getting to the site. 10-gage corrugated aluminum pipe is a viable alternative to structural plate, however, it can only be shipped in 20-foot long segments and may be more expensive to barge to the site.

The proposed culvert will pass the 50-year design discharge and the 100-year discharge with a HW/D ratio of less than 1. Its proposed inlet and outlet inverts are at 4.15 feet and 3.6 feet, respectively, keeping the same outlet invert elevation as existing conditions. To accommodate tidal influence, the structure's outlet crown reaches 11.6 feet in elevation, more than accounting for the desired 2 feet above the MHHW elevation (crown minimum of 8.77 feet). This additional elevation will allow for headspace in the culvert during high tide events and allow for up to 0.63 feet of relative sea level rise (see accompanying *Coastal Report*). When considering crossing resilience through HEC-17, a 72-inch culvert was determined to provide a more conservative design and allow for greater resiliency with a minimal increase in material and construction costs.

5.2 Riprap Protection

The flows from the unnamed tributary of the Kun River are significantly smaller and slower in velocity when compared to tidal influxes. Therefore, the inlet and outlet scour protection will be based on tidal flows and velocities. The riprap protections required for the tidal flows are analyzed and calculated in the accompanying *Coastal Report* and were determined to have an average diameter of 1.4 feet and average weight of 238 pounds. The riprap protection that will be used for the coastal applications will also be used to surround the inlet and outlet and serve as riprap aprons at their entrances. A mixture of sands, gravels, and fines should be placed within the upstream and downstream channel to fill voids between riprap to allow for migration of any local fish species into and out of the runway culvert. Mixture specifications will be specified at a future stage of design.

The Drainage Manual does not include guidance on the design of energy dissipators and riprap aprons. Chapter 10 of FHWA's HEC-14: *Hydraulic Design of Energy Dissipators for Culverts and Channels* (FHWA 2006) was used for the riprap apron design. The median riprap diameter size, or D50, is calculated using input variables of the design discharge, culvert diameter, and tailwater depth. Supercritical flow requires an additional adjustment using the normal depth within the culvert. Once the size of the riprap is determined, it can be compared to standard riprap classes. The dimensions of the riprap apron are determined based on the riprap class and diameter of the culvert.

Apron calculations can be found in Appendix C, and its layout and details can be found in the plan set.

5.3 End Section Treatment

The proposed culvert is designed to pass the 50-year return interval coastal storm-surge event with a HW/D ration of less than 1.5. During these events, the culvert may contain an air pocket that would create a buoyant force, possibly displacing the culvert upward. Anchors at each end of the culvert (inlet and outlet) are proposed to restrain against these buoyant forces. Concrete headwalls are recommended due to the lack of geotechnical information at the project site.

Based on buoyant force calculations, 20,032 pounds of restraining force, located 1 foot from each culvert end, is required to overcome buoyant forces under inundated, storm-surge conditions. Based on DOT&PF's standard plans for drainage, a precast, type 1, concrete headwall for a 96-inch culvert with 2 to 1 side slopes will provide the necessary restraining force (DOT&PF 2019).

6. Floodplain Management

This project is outside the limits of any Federal Emergency Management Agency (FEMA) mapped floodplain areas. As a federally funded project, this project is subject to the requirements of Executive Order 11988, which stipulates avoidance and mitigation of potential impacts to the 100-year floodplain (FEMA 1977). In addition, the enlarged culvert at the crossing will not increase the elevation of the 100-year floodplain. The proposed design calls for additional conveyance in the form of an enlarged structure where drainage improvements are included.

7. Summary and Recommendation

Table 9 outlines the existing and proposed culverts, with notes and details specific to the crossing.

Table 9: Culvert Summary Table

Purpose	Drainage Feature	Design Flow (cfs)	Anadromous Stream	Existing Structure					Proposed Work				
				Shape/ Type	Size (inches)	Length (feet)	Inverts (feet)	Discharge at HW/D = 1 (cfs)	Shape/ Type	Size (inches)	Length (feet)	Inverts (feet)	Discharge at HW/D = 1 (cfs)
Runway Culvert	Unnamed tributary of the Kun River	62 (50-year)	No	Round / HDPE	48	199	Inlet = 4.0 Outlet = 3.6	61	Round / SP Aluminum	96	270	Inlet = 4.15 Outlet = 3.6	184

Notes: cfs = cubic feet per second, HDPE = high density polyethylene, HW/D = headwater / diameter, SP = structural plate

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Appendix A – Field Notes and Trip Report

Appendix B – Flood Frequency Estimates and Supporting Data

Appendix C – HY-8 Report and Riprap Apron Calculations

Appendix A – Field Notes and Trip Report

Site Visit Report

Date:	Tuesday, May 25, 2021
Project:	Scammon Bay Airport Improvements CFAPT00691
To:	Jenelle Brinkman, PE (DOT&PF)
From:	Ronny McPherson, PE (HDR) Irene Turletes, PE (HDR)
Subject:	Scammon Bay Coastal and H&H Site Visit

A site visit was performed to Scammon Bay, AK to support the hydraulics & hydrology (H&H) and coastal processes in the vicinity of the Scammon Bay runway. The site visit occurred on May 18th, 2021 from approximately 2:30pm to 5:30pm. Conditions at the site were considered wintery/spring breakup, however, enough of the runway, runway edge, access road, surrounding uplands, and existing culvert were exposed to allow for an adequate understanding of the site. Weather was in the upper 30s and overcast for the duration of the site visit.

Site visit attendees included the following:

- Philip Cheasebro, DOT&PF
- Rory Bryant, DOT&PF
- Bill Starn, CRW
- Irene Turletes, HDR
- Ronny McPherson, HDR

The following provides observations from the site visit.

Existing Runway Culvert

1. The existing culvert spanning the width of the runway appears to be sagging and partially collapsed in three locations. The culvert was confirmed to be 3.5 feet diameter non-metallic (HDPE). Class I riprap was placed at both inlet and outlet for approximately 10 feet.
2. The stream at the culvert outlet appears to be approximately 5 feet wide with a depth of 1 foot at the time of the site visit. Immediately downstream, the channel became 10 to 14 feet wide and 0.5 to 0.75 feet deep at the thalweg. The stream appears to be tidal as evident by the 2 to 3 feet nearly vertical stream banks.
3. The upstream side at the culvert inlet had a large pool approximately ten to fifteen feet wide and approximately twenty feet long with a depth of approximately 2 feet at the time of the site visit. There was a noticeable foul odor at the culvert inlet and is suspected to be caused by some amount of effluent from the nearby wastewater lagoon. The inlet was not visible due to snow.

East Runway Terminal

1. There were no signs of obvious erosion due to wave action that would have occurred during upland flooding nor were the obvious signs of scour due to swift currents from

filling or draining the area between the runway and the adjacent higher land elevation during a storm surge.

2. There were signs of typical upland runoff erosion (e.g., rilling) and signs of heavy equipment and ATV wheel trenches along the perimeter.
3. The remnants of a burnt snowmachine was observed just landward of the east runway terminal
4. The east runway RSA elevation undulated significantly with noticeable ATV traffic
5. The lower elevations of the terminal bank had well established thick vegetation (i.e., alders, willows, or similar).
6. The windsock spur represents the shortest distance from the runway to the adjacent higher land elevation. There were no obvious signs of erosion or scour from waves/storm surge at this location. The bank material at this location primarily consisted of 2- to 4-inch gravel with very little fines.

West Runway Terminal

1. Armor rock material is placed along the western runway terminal which appeared to be in the DOT&PF Class II Riprap size range.
2. Several armor rocks were observed to be displaced and are no longer interlocked with the structure on north side of the runway. The armor rock at the very west terminal (immediately adjacent to the Kun River) was entirely displaced leaving only small stone material and fines.
3. The Kun River was observed to have a very slow flow rate (<1 fps) at the time of the site visit.

Anecdotal Data

Scammon Bay residents provided some anecdotal data when inquired about storm surge in the area. The following summarizes their comments

1. Storm surge only happens in the Fall (September through November). The latest storm surge recalled was once in December.
2. The highest storm surge recalled was shin to knee high above the runway apron. This equates to approximately +14 feet NAVD.
3. All houses in the community are higher than historical storm surge elevations.
4. When storm surges recede, it creates very fast currents around the East Runway Terminal. Noting that the river east of the runway and the Kun River also flows very quickly during these times.

Figure 1. Runway access road. Side slopes appeared to be in good condition – no obvious signs of scour/erosion.

Figure 2. Runway apron. Anecdotal data provided noted highest surges flood entire apron up to knee high.

Figure 3. Runway, wastewater lagoon, and creek. Photo taken from hillside vantage point south of runway and within the community.

Figure 4. Creek downstream of runway culvert outlet. Nearly vertical banks indicate tidal influence.

Figure 5. Runway culvert outlet.

Figure 6. Inside runway culvert looking from outlet to inlet. The culvert was observed to have some sagging and partially collapse in three locations

Figure 7. Pool at runway culvert inlet.

Figure 8. Side slope at windsock (closest point to adjacent elevation). No obvious scour or erosion caused by storm surge/waves.

Figure 9. Side slopes at east terminal. Vegetation observed along bank with no obvious signs of scour or erosion from storms surge waves.

Figure 10. North slope of runway edge. No obvious signs of recent scour or erosion due to storm surge/waves (side slopes were noted to have been reworked/graded).

Figure 11. Armor rock protection at western terminal along north edge (looking west). Some rocks observed to be displaced.

Figure 12. Armor rock protection at western terminal along north edge (looking east). Some rocks observed to be displaced but less than at the western end.

Figure 13. Western runway terminal. No armor rock observed.

Appendix B – Flood Frequency Estimates and Supporting Data

Project Name: Scammon Bay *Updated: 7/14/21 K. Grundhauser*

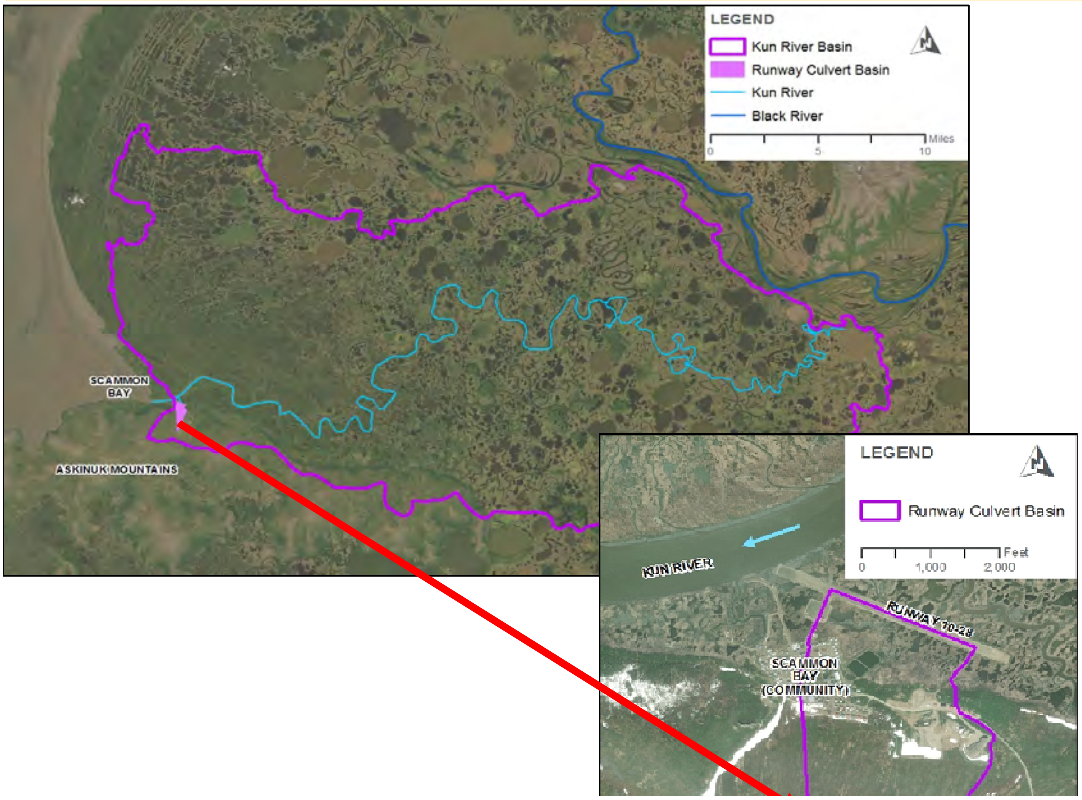
Step 1: Use basin size (ft^2) to determine which peak flow calculation methods apply by basin size.

Basin #	Basin Size	Basin Size	Basin Size	Applicable Method
	ft^2	acres	mi^2	
RW Culvert	**12,915,452**	**296**	**0.463**	**2016 USGS Regression Equations**
Kun River	**12,857,297,057**	**295163**	**461**	**2016 USGS Regression Equations**

Basin falls within 2016 USGS Regression Equation parameters

Basin falls only within NRCS TR-55 Parameters

Basin falls within Rational Method parameters and NRCS TR-55 parameters



Project Name Scammon Bay

Step 2: Calculate flows using 2016 USGS Regression Equations, flows incorporating SNAP Climate Data, and flows adjusting for local gage factors.

2016 USGS Regression Equations					% Exceedance							
					50%	20%	10%	4%	2%	1%	0.5%	0.2%
ADF&G Culvert ID #	**Basin Size**	**Basin Size**	**PRISM Precip ***	**PRISM Precip**	**2-year**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**	**200-year**	**500-year**
	ft^2	mi^2	mm*100	in	2016 Regression Flow (cfs)							
RW Culvert	**12,915,452**	**0.46**	**58,047**	**22.9**	**12**	**24**	**33**	**47**	**58**	**71**	**84**	**103**
Kun River	**12,857,297,057**	**461.19**	**48,231**	**19.0**	**3235**	**4804**	**5937**	**7403**	**8500**	**9630**	**10778**	**12312**

*Values calculated in GIS using Zonal Statistics tool with basin polygons and 1 m by 1 m resampled rainfall raster.

Source: Mean Precipitation for Alaska 1981-2010, https://prism.oregonstate.edu/projects/alaska.php

**See SNAP Data

Basin falls within 2016 Regression Equation parameters

Basin falls outside of 2016 USGS Regression Equations

ADF&G Culvert ID #	**Basin Size**	**SNAP** Adjusted PRISM Precip**	% Exceedance							
			50%	20%	10%	4%	2%	1%	0.5%	0.2%
			2-year	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**	**200-year**	**500-year**
	mi^2	in	SNAP Adjusted Flow (cfs)							
RW Culvert	**0.46**	**26.7**	**14**	**27**	**38**	**53**	**66**	**80**	**95**	**116**
Kun River	**461.19**	**22.2**	**3800**	**5548**	**6802**	**8416**	**9620**	**10860**	**12115**	**13790**

Local Stream Gage Factors

Map Identification No.	**USGS Station No.**	**USGS station Name**	**Annual exceedance probability discharge, in cubic feet per second**												**Skew coefficient used for Sta AEP**	**Skew coefficient used in appendix B**	**MSE of skew coefficient used in appendix B**
			50-percent			**20-percent**			**10-percent**			**4-percent**					
			Sta	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**			
219	15304000	Kuskokwim River at Crooked Creek, Alaska	162,000	121,000	161,000	212,000	150,000	212,000	243,000	169,000	243,000	281,000	193,000	280,000	-0.141	0.260	0.154
361	15621000	Snake River near Nome, Alaska	2,710	925	2,680	3,430	1,450	3,400	3,820	1,830	3,790	4,240	2,340	4,200	-0.555	-0.555	0.235
209	15302000	Nuyakuk River near Dillingham, Alaska	19,400	17,300	19,400	23,200	22,800	23,200	25,400	26,500	25,500	27,900	31,200	28,000	-0.203	-0.202	0.115

Map Identification No.	**USGS Station No.**	**USGS station Name**	**Annual exceedance probability discharge, in cubic feet per second**												**Skew coefficient used for Sta AEP**	**Skew coefficient used in appendix B**	**MSE of skew coefficient used in appendix B**
			2-percent			**1-percent**			**0.5-percent**			**0.2-percent**					
			Sta	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**			
219	15304000	Kuskokwim River at Crooked Creek, Alaska	308,000	210,000	306,000	334,000	226,000	331,000	359,000	243,000	355,000	392,000	264,000	385,000	-0.141	0.260	0.154
361	15621000	Snake River near Nome, Alaska	4,510	2,740	4,460	4,750	3,140	4,690	4,960	3,560	4,890	5,220	4,120	5,140	-0.555	-0.555	0.235
209	15302000	Nuyakuk River near Dillingham, Alaska	29,600	34,700	29,700	31,200	38,100	31,300	32,700	41,600	32,800	34,500	46,100	34,800	-0.203	-0.202	0.115

[Location of map identification Nos. are shown in figure 1. **Usage in this report**: Regr, used to develop regression equations; ReglSkew, used to develop regional skew; redundant, omitted from any regional analysis on the basis of hydrologic redundancy with another site; Sta, used for station analysis only. INF, infinity; No., number; PILF, potentially influential low flood; USGS, U.S. Geological Survey. ft^3/s, cubic feet per second; in., inches; mi^2, square miles]

Map identification No.	**USGS station No.**	**Station name**	**Drainage area (mi^2)**	**Mean annual precipitation (in.)**	**Kendall *tau* correlation coefficient, for sites having statistically significant trends**	**Kendall *tau* *p*-value**	**Usage in this report**	**Skew Region, for sites within applicable range of drainage area**	**Period of record used**	**Historic period length (years)[1]**	**Water year(s) for data omitted from analysis[2]**	**Number of peaks in record[3]**	**Perception threshold for water years noted (ft^3/s)[4,5]**	**Interval discharge range for noted water year (ft^3/s)[5]**	**PILF threshold (ft^3/s)[6]**	**Number of PILFs**
219	15304000	Kuskokwim River at Crooked Creek, Alaska	31100	21	--	--	Regr	--	1952-2012	61		60	1995: INF-INF (j, p)	--	--	--
361	15621000	Snake River near Nome, Alaska	86	22	--	--	Regr	--	1965-1991	27	1994 (d)	27		--	--	--
209	15302000	Nuyakuk River near Dillingham, Alaska	1510	37	--	--	Regr	--	1954-2012	59		50	1997-2002, 2005-2007: INF-INF (j, p)	--	--	--

Project Name Scammon Bay
Step 3: Calculate flows using TR-55 Method

*TR-55 Applied to all basins for comparison purposes. See TR-55 Publication for more detailed information about TR-55 Method and limitations.

Compute Watershed Runoff (Chapter 2)

Part 1: Determine Basin** area and CN
**If the basin is one homogenous basin, use only subbasin 1 and leave others blank. Otherwise break up basin into major subbasins

Basin ID*	Gravel/Dirt Road/Residential			Brush / Forest			Herbaceous / Water / Wetlands			**Product of CN x Area**
	Description	Area (sq. ft)	CN	Description	Area (sq. ft)	CN	Description	Area (sq. ft)	CN	
RW Culvert	Residential	2264152.82	82	Schrub / Forest	8762962	70	Brush	1888337	85	**74**

Part 2: Solve for Runoff Q (inches) using eq. 2-4 and eq. 2-3:
Use SNAP future estimates

Basin ID*	CN	S	P - Rainfall (inches) for 24-hour storm					Q - Runoff (inches)				
			2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
RW Culvert	74	3.5	1.77	3.12	3.89	4.5	5.15	0.26	1.00	1.54	2.00	2.51

Time of Concentration and Travel Time (Chapter 3)

Part 3: Find Time of Concentration by adding all times Travel times
Part 3A: Calculate sheet flow time using eq. 3-3

*First 300 feet of all flows are assumed to be sheet flow

	Basin Slope		
	Max El (ft)	Min El (ft)	Flow Length (ft)
	Slope Calc		
Sheet	1060	1055	300
Shallow	1055	29.5	6189.8
Open	29.5	6.1	1814.3

Time of Concentration - Sheet Flow					
Basin ID*	Manning's n	L* (ft)	P_2 (in)	S (ft/ft)	T_t (hr)
		Flow Length	*2-yr, 24-hour*	*Slope*	
RW Culvert	0.20	300	0.059	0.0162	3.97

Part 3B: Calculate shallow concentrated flow* time using eq. 3-1

Basin ID*	Surface description	L (ft)	S (ft/ft)	V (ft/s)	T_t (hr)	
		Flow Length	*Slope*	*Average Vel.*		
RW Culvert	Hillside Brush	6190	0.1656	6.7	0.26	(Est. velocity)

Part 3C: Calculate open-channel flow time using eq. 3-3, or using open channel flow calculator***.

Open channel flows lengths assumed to be in a surveyed channel, channels visable from aerial photos, or where streams appear on USGS quadrangle sheets. Assumed a 10 ft wide rectangular channel, Manning's 0.04, at bankfull, ~14 cfs.

***Useful Online open channel flow calculator Auburn Engineering Department
*** For this project open channel flows lengths were measured from USGS topo maps.

Basin ID*	A (ft^2)	P_w (ft)	r (ft)	S (ft/ft)	Manning's n	V (ft/s)	L	T_t (hr)
	XS Area	*Wetted Perimeter*	*Hydraulic Radius*	*Channel Slope*			*Flow Length*	
RW Culvert	5.39	11.08	0.486462094	0.0129	0.04	2.6	1814	0.19

Part 3D: Calculate Time of Concetration by adding Parts 3A-3C.

Time of Concentration				
Basin ID*	Part 3A	Part 3B	Part 3A	T_c (hr)
	Sheet Flow	Shallow Concentrated Flow	Open Channel Flow	
RW Culvert	3.97	0.26	0.19	4.42

Graphical Peak Discharge Method (Chapter 4)

Part 4: Compute the peak discharge using Table 4-1, eq. 4-1, and exhibit 4-I, IA, II, III, or IV

Basin ID*	A_m (sq. mi)	CN	I_a	T_c (hr)	Rainfall Distribution (I, IA, II, III)	F_p	Q (in)	I_{a-2}/P	I_{a-10}/P	I_{a-25}/P	I_{a-50}/P	I_{a-100}/P
	Drainage Area	Runoff CN		Time of Conc.		Pond Factor No = 1.0	Runoff	2-Year Event	10-Year Event	25-Year Event	50-Year Event	100-Year Event
RW Culvert	0.46	74	0.703	4.42	Type I Storm Event	0.7	See Part 2	0.40	0.23	0.18	0.16	0.14

Basin ID*	**q_{u-2} (csm/in)**	**q_{u-10} (csm/in)**	**q_{u-25} (csm/in)**	**q_{u-50} (csm/in)**	**q_{u-100} (csm/in)**
	Use T_c & I_a/P with 4-1A	*Use T_c & I_a/P with 4-1A*	*Use T_c & I_a/P with 4-1A*	*Use T_c & I_a/P with 4-1A*	*Use T_c & I_a/P with 4-1A*
RW Culvert	39	48	53	55	58

TR-55 Peak Flows					
Basin ID*	**q_{p-2} (cfs)**	**q_{p-10} (cfs)**	**q_{p-25} (cfs)**	**q_{p-50} (cfs)**	**q_{p-100} (cfs)**
	2-Year Discharge	*10-Year Discharge*	*25-Year Discharge*	*50-Year Discharge*	*100-Year Discharge*
RW Culvert	3.3	16	27	37	49

Project Nai Scammon Bay
Step: HEC-17 Upper 68% Confidence Interval Analysis

Enter a site-description name:

Scammon Bay Airport - Runway Culvert

Enter the explanatory variables:

Drainage area, in square miles	DRNAREA	0.46	Equations are valid for DRNAREA between 0.4 and 1,000 mi^2 with PRECPRIS00 between 8 and 280 inches, and for DRNAREA greater than 1,000 and less than 31,100 mi^2 with PRECPRIS00 between 10 and 111 inches.
Mean annual precipitation from 1971-2000 PRISM data, in inches	PRECPRIS00	22.9	

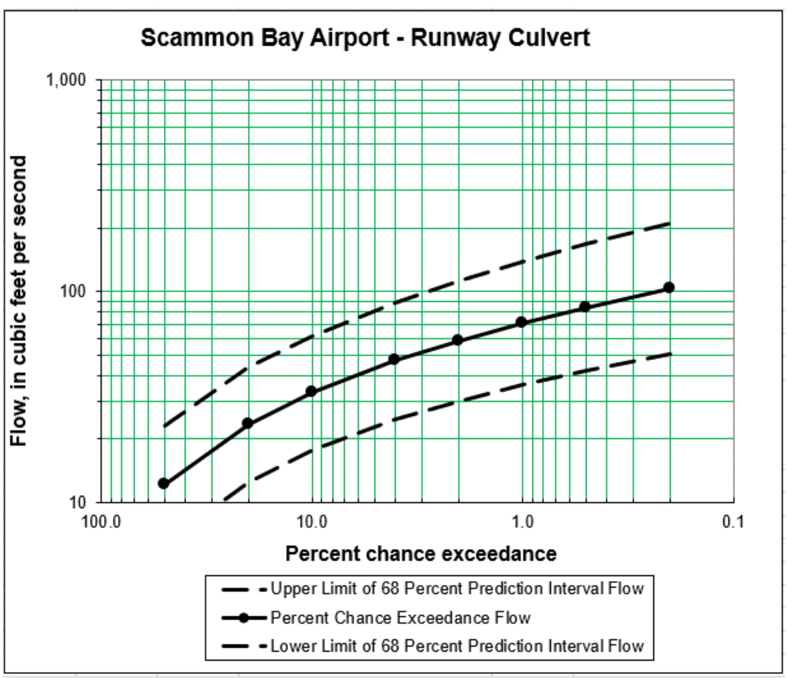
Warnings regarding range of variables:

Results:

Percent chance exceedance	Percent chance exceedance flow, in ft^3/s	Lower limit of 68 percent prediction interval flow, in ft^3/s	Upper limit of 68 percent prediction interval flow, in ft^3/s	$-SEP_{P,i}$ (percent)	$+SEP_{P,i}$ (percent)	Average $SEP_{P,i}$ (percent)
50	12.1	6.4	23.0	-47.4	90.0	71.4
20	23.5	12.5	43.9	-46.7	87.7	69.8
10	33.0	17.6	61.7	-46.8	87.8	69.8
4	46.8	24.6	88.8	-47.5	90.3	71.6
2	58.0	30.2	112	-48.1	92.8	73.4
1	70.6	36.3	138	-48.8	95.2	75.1
0.5	83.8	42.2	167	-49.8	99.3	78.0
0.2	103	50.2	211	-51.4	105.6	82.5

Notes

Differences in rounding of equation parameters can produce minor differences between the results obtained using the regression equations in table 7 and using WREG software. The estimates in this spreadsheet use the regression equations as published in table 7. The regression estimates for streamgages shown in table 4 were computed using WREG during the regression analysis.

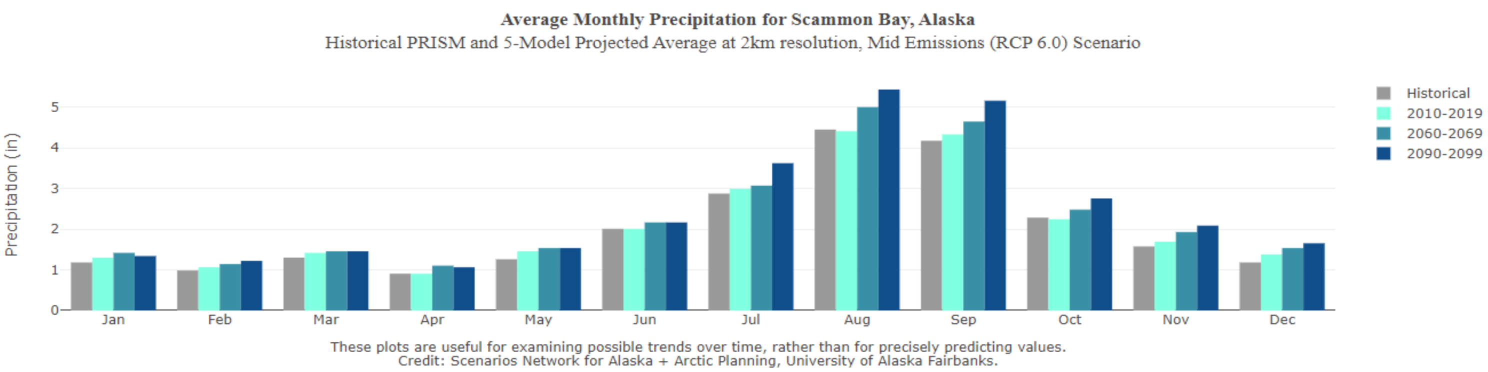


Appendix B: Flood Frequency Estimates and Supporting Data

Scammon Bay, AK SNAP Data**

Month	Precipitation (in)				2010-2099
	Historical	2010-2019	2060-2069	2090-2099	% Increase
January	1.18	1.30	1.42	1.34	3.0
February	0.98	1.06	1.14	1.22	14.8
March	1.30	1.42	1.46	1.46	2.8
April	0.91	0.91	1.10	1.06	17.4
May	1.26	1.46	1.54	1.54	5.4
June	2.01	2.01	2.17	2.17	7.8
July	2.87	2.99	3.07	3.62	21.1
August	4.45	4.41	5.00	5.43	23.2
September	4.17	4.33	4.65	5.16	19.1
October	2.28	2.24	2.48	2.76	22.8
November	1.57	1.69	1.93	2.09	23.3
December	1.18	1.38	1.54	1.65	20.0
Annual	24.17	25.20	27.48	29.49	17.0
			9.1	17.0	

Decimal Increase: 1.170



SNAP data collected from UAF Scenarios Network for Alaska + Arctic Planning website:

Data: https://www.snap.uaf.edu/tools/community-charts

About: https://uaf-snap.org/snap-story/community-charts-help-northerners-see-changes/

GFDL-CM3 Method and NCAR-CCSM4 Method Results

GFDL-CM3 Method (in)								
	2-Year	5-year	10-Year	25-Year	50-Year	100-Year	200-Year	500-Year
60-Minute	0.65	0.88	1.08	1.38	1.64	1.93	2.29	2.83
2-Hour	0.74	1.01	1.24	1.62	1.97	2.39	2.92	3.82
3-Hour	0.81	1.11	1.37	1.76	2.1	2.49	2.97	3.86
6-Hour	1.15	1.55	1.9	2.43	2.9	3.44	4.09	5.08
12-Hour	1.74	2.47	3.13	4.22	5.23	6.44	7.96	10.42
24-Hour	2.29	3.42	4.52	6.47	8.46	11.02	14.39	20.28

NCAR-CCSM4 Method (in)								
	2-Year	5-year	10-Year	25-Year	50-Year	100-Year	200-Year	500-Year
60-Minute	0.47	0.63	0.74	0.87	0.96	1.05	1.14	1.27
2-Hour	0.57	0.75	0.87	1.01	1.11	1.2	1.3	1.41
3-Hour	0.62	0.84	1	1.23	1.41	1.59	1.81	2.11
6-Hour	0.85	1.14	1.34	1.6	1.79	1.97	2.18	2.45
12-Hour	1.23	1.73	2.04	2.38	2.58	2.74	2.87	2.97
24-Hour	1.77	2.55	3.12	3.89	4.5	5.15	5.85	6.82

Predicted Change (%) using NCAR-CCSM4 Method								
	2-Year	**5-year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**	**200-Year**	**500-Year**
60-Minute	32	42	42	40	37	34	31	28
2-Hour	34	41	40	35	32	28	25	19
3-Hour	25	36	38	42	45	46	49	53
6-Hour	25	34	35	34	33	32	31	29
12-Hour	25	40	42	38	33	26	18	8
24-Hour	25	42	49	54	59	63	66	69

SNAP: Precipitation frequency estimates with future climate models
Data: https://snap.uaf.edu/tools/future-alaska-precip

Data Type: **Precipitation Intensity**
Units: English
Time Series: Partial Duration
Mountain Village **Precipitation intensity**

Precipitation Estimates (inches/hour)

Duration	Average Recurrence Interval (years)						
	2	10	25	50	100	200	500
5-min	1.49	2.18	2.62	2.95	3.29	3.67	4.16
10-min	1.00	1.46	1.76	1.98	2.21	2.46	2.80
15-min	0.780	1.14	1.37	1.55	1.72	1.92	2.18
30-min	0.518	0.760	0.910	1.03	1.14	1.27	1.45
60-min	0.355	0.520	0.623	0.703	0.782	0.873	0.992
2-hr	0.212	0.311	0.373	0.420	0.468	0.522	0.594
3-hr	0.165	0.241	0.288	0.325	0.362	0.404	0.459
6-hr	0.113	0.166	0.199	0.224	0.249	0.278	0.317
12-hr	0.082	0.120	0.144	0.162	0.181	0.202	0.230
24-hr	0.059	0.087	0.105	0.118	0.132	0.147	0.168

NOAA Atlas 14 Point Precipitation Frequency Estimates:
https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_ak.html

Appendix C – HY-8 Report and Riprap Apron Calculations

HY-8 Culvert Analysis Report

48-inch Aluminum Round Culvert

Existing Culvert

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Scammon Bay Runway Culvert

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
5.06	40% Q2	5.60	5.60	0.00	1
5.71	Q2	14.00	14.00	0.00	1
8.28	Q50	66.00	66.00	0.00	1
9.19	Q100	80.00	80.00	0.00	1
11.85	Q50 U68%	112.00	112.00	0.00	1
13.28	Q100 U68%	138.00	121.42	16.33	12
13.20	Overtopping	126.46	126.46	0.00	Overtopping

Rating Curve Plot for Crossing: Scammon Bay Runway Culvert

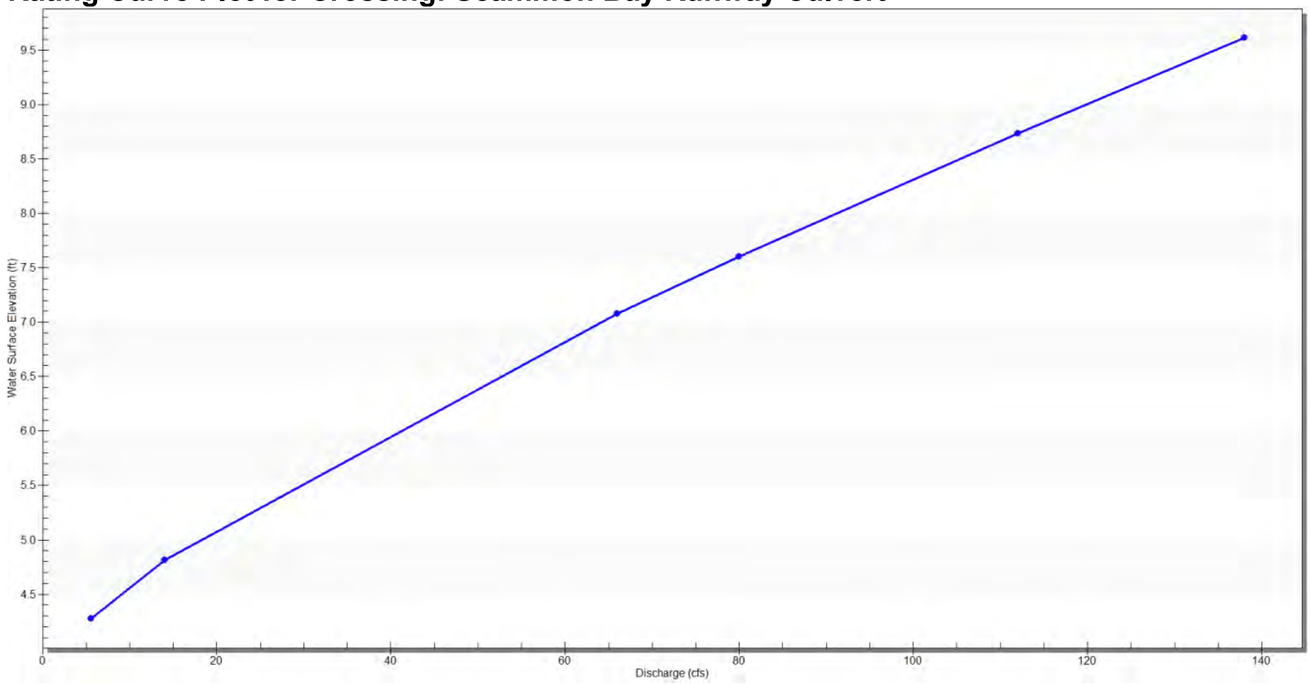


Table 2 - Culvert Summary Table: 48-inch Culvert

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
40% Q2	5.60	5.60	5.06	0.97	1.06	2-M2c	0.76	0.69	0.69	0.67	3.91	0.83
Q2	14.00	14.00	5.71	1.56	1.71	3-M2t	1.21	1.09	1.21	1.21	4.36	1.16
Q50	66.00	66.00	8.28	3.82	4.28	7-M1t	3.09	2.45	3.48	3.48	5.69	1.90
Q100	80.00	80.00	9.19	4.48	5.19	7-M2t	4.00	2.71	4.00	4.00	6.37	2.00
Q50 U68%	112.00	112.00	11.85	6.46	7.85	4-FFf	4.00	3.20	4.00	5.13	8.91	2.18
Q100 U68%	138.00	121.42	13.28	7.18	9.28	4-FFf	4.00	3.31	4.00	6.01	9.66	2.29

****

Straight Culvert

Inlet Elevation (invert): 4.00 ft, Outlet Elevation (invert): 3.60 ft

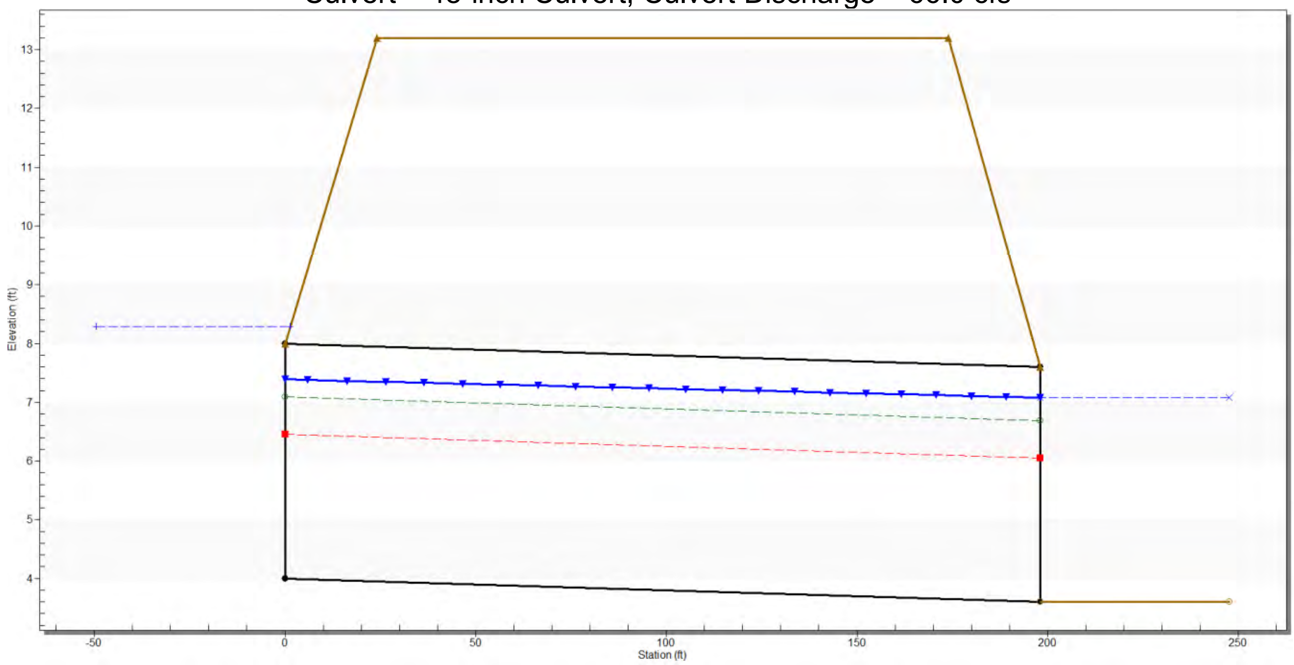
Culvert Length: 198.15 ft, Culvert Slope: 0.0020 ft/ft

****

Water Surface Profile Plot for Culvert: 48-inch Culvert

Crossing – Scammon Bay Runway Culvert, Design Discharge – 66.0 cfs

Culvert – 48-inch Culvert, Culvert Discharge – 66.0 cfs



Site Data - 48-inch Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4.00 ft

Outlet Station: 198.15 ft

Outlet Elevation: 3.60 ft

Number of Barrels: 1

Culvert Data Summary - 48-inch Culvert

Shape: Circular

Diameter: 4.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Runway Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
5.600	4.274	0.674	0.830
14.000	4.812	1.212	1.155
66.000	7.079	3.479	1.897
80.000	7.599	3.999	2.000
112.000	8.731	5.131	2.183
138.000	9.614	6.014	2.295

Tailwater Channel Data: Scammon Bay Runway Culvert

Channel Type: Rectangular Channel

Bottom Width: 10.00 ft

Channel Slope: 0.0010 ft/ft

Manning’s n (channel): 0.040

Channel Invert Elevation: 3.60 ft

Roadway Data for Crossing: Scammon Bay Runway Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 13.20 ft

Roadway Surface: Gravel

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report

66-inch Aluminum Round Structural Plate Culvert

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Scammon Bay Runway Culvert

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
5.35	40% Q2	5.60	5.60	0.00	1
6.03	Q2	14.00	14.00	0.00	1
8.54	Q50	66.00	66.00	0.00	1
9.18	Q100	80.00	80.00	0.00	1
11.39	Q50 U68%	112.00	112.00	0.00	1
13.69	Q100 U68%	138.00	138.00	0.00	1
18.50	Overtopping	185.23	185.23	0.00	Overtopping

Rating Curve Plot for Crossing: Scammon Bay Runway Culvert

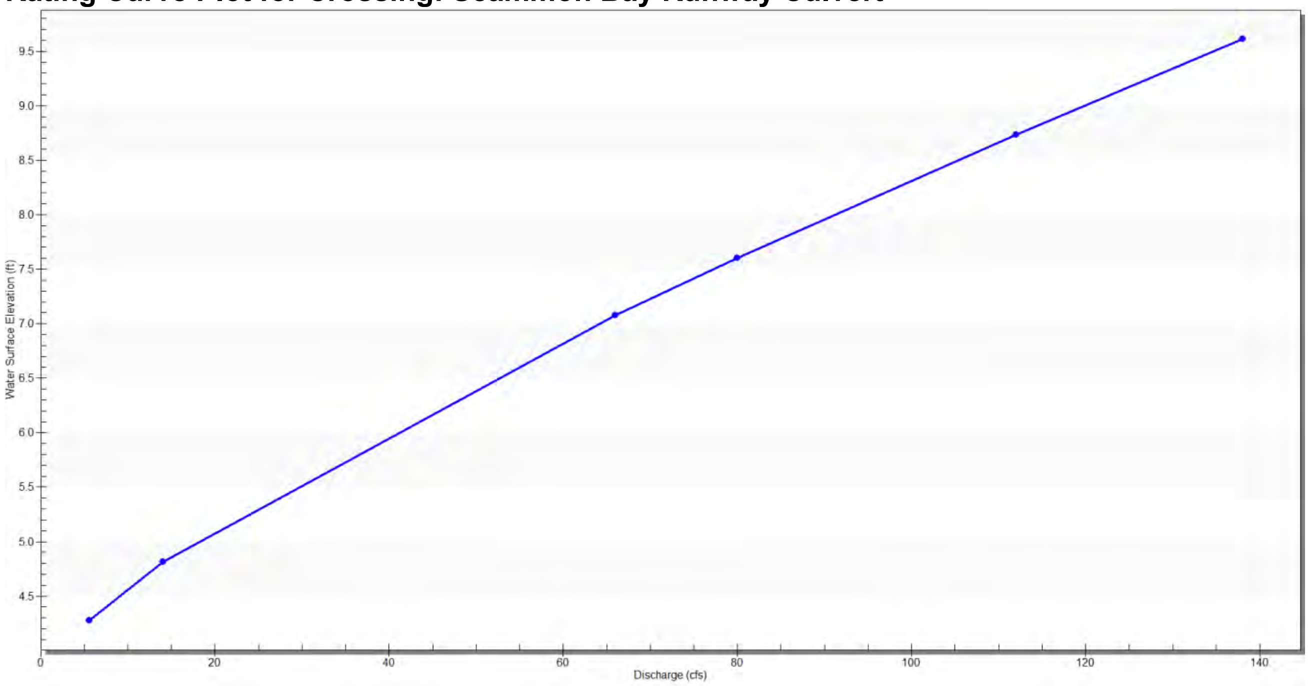


Table 2 - Culvert Summary Table: 66-inch Culvert

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
40% Q2	5.60	5.60	5.35	0.85	1.20	3-M2t	1.17	0.63	0.67	0.67	3.36	0.83
Q2	14.00	14.00	6.03	1.37	1.88	3-M2t	1.87	1.00	1.21	1.21	3.61	1.16
Q50	66.00	66.00	8.54	3.12	4.39	3-M2t	5.50	2.22	3.48	3.48	4.17	1.90
Q100	80.00	80.00	9.18	3.49	5.03	3-M2t	5.50	2.46	4.00	4.00	4.32	2.00
Q50 U68%	112.00	112.00	11.39	4.28	7.24	7-M2t	5.50	2.93	5.13	5.13	4.85	2.18
Q100 U68%	138.00	138.00	13.69	4.90	9.54	4-FFf	5.50	3.27	5.50	6.01	5.81	2.29

****

Straight Culvert

Inlet Elevation (invert): 4.15 ft, Outlet Elevation (invert): 3.60 ft

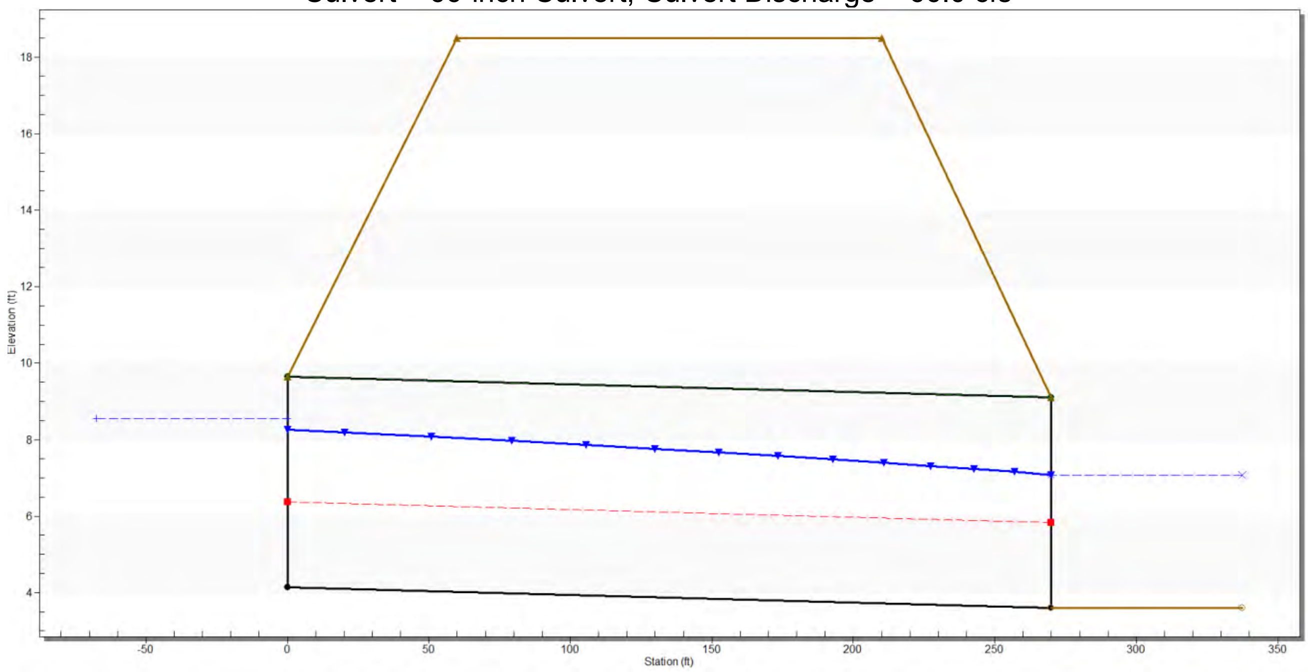
Culvert Length: 270.0 ft, Culvert Slope: 0.0020 ft/ft

****

Water Surface Profile Plot for Culvert: 66-inch Culvert

Crossing – Scammon Bay Runway Culvert, Design Discharge – 66.0 cfs

Culvert – 66-inch Culvert, Culvert Discharge – 66.0 cfs



Site Data - 66-inch Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4.15 ft

Outlet Station: 270.00 ft

Outlet Elevation: 3.60 ft

Number of Barrels: 1

Culvert Data Summary - 66-inch Culvert

Shape: Circular

Diameter: 5.50 ft

Barrel Material: Corrugated Aluminum

Embedment: 0.00 in

Manning's n: 0.0350

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Runway Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
5.600	4.274	0.674	0.830
14.000	4.812	1.212	1.155
66.000	7.079	3.479	1.897
80.000	7.599	3.999	2.000
112.000	8.731	5.131	2.183

Tailwater Channel Data: Scammon Bay Runway Culvert

Channel Type: Rectangular Channel

Bottom Width: 10.00 ft

Channel Slope: 0.0010 ft/ft

Manning's n (channel): 0.040

Channel Invert Elevation: 3.60 ft

Roadway Data for Crossing: Scammon Bay Runway Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 18.50 ft

Roadway Surface: Gravel

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report

72-inch Aluminum Round Structural Plate Culvert

(Preferred Alternative)

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Scammon Bay Runway Culvert

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
5.34	40% Q2	5.60	5.60	0.00	1
5.98	Q2	14.00	14.00	0.00	1
8.35	Q50	66.00	66.00	0.00	1
8.91	Q100	80.00	80.00	0.00	1
10.36	Q50 U68%	112.00	112.00	0.00	1
12.23	Q100 U68%	138.00	138.00	0.00	1
18.50	Overtopping	215.25	215.25	0.00	Overtopping

Rating Curve Plot for Crossing: Scammon Bay Runway Culvert

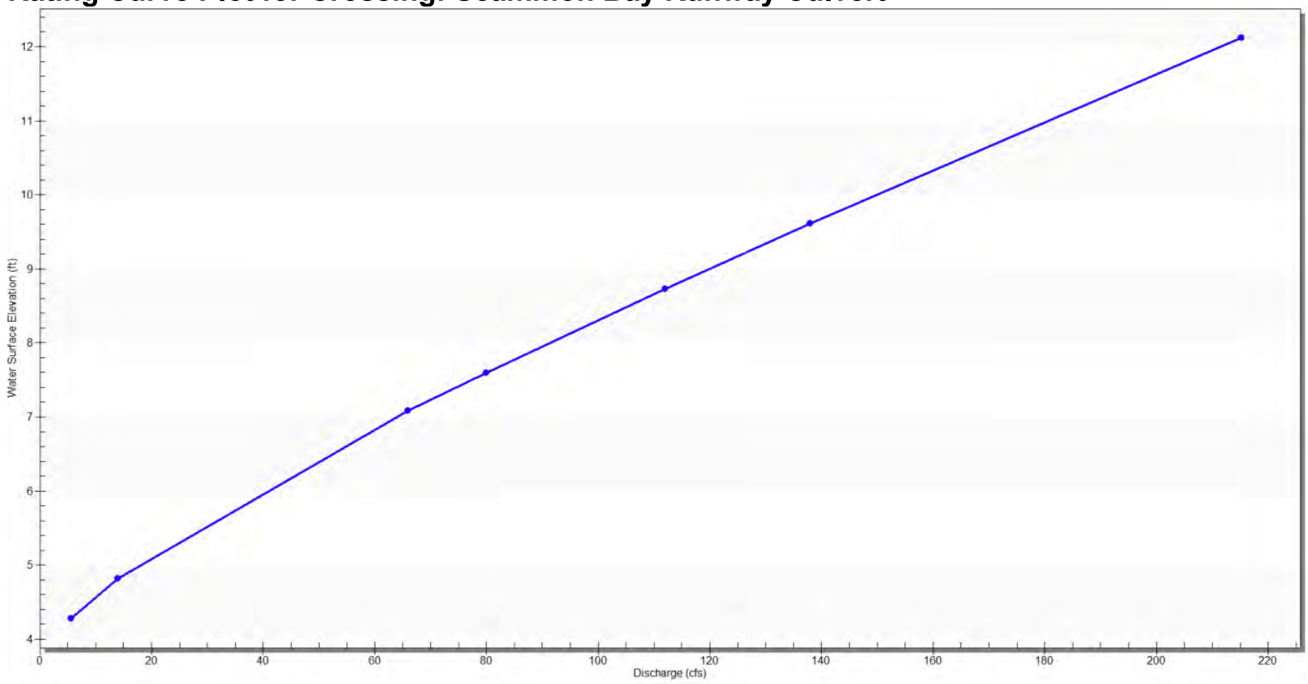


Table 2 - Culvert Summary Table: 72-inch Culvert

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
40% Q2	5.60	5.60	5.34	0.83	1.19	3-M2t	1.14	0.61	0.67	0.67	3.21	0.83
Q2	14.00	14.00	5.98	1.33	1.83	3-M2t	1.80	0.98	1.21	1.21	3.43	1.16
Q50	66.00	66.00	8.35	3.01	4.20	3-M2t	4.57	2.17	3.48	3.48	3.88	1.90
Q100	80.00	80.00	8.91	3.35	4.76	3-M2t	6.00	2.39	4.00	4.00	4.00	2.00
Q50 U68%	112.00	112.00	10.36	4.09	6.21	3-M2t	6.00	2.85	5.13	5.13	4.35	2.18
Q100 U68%	138.00	138.00	12.23	4.64	8.08	4-FFf	6.00	3.18	6.00	6.01	4.88	2.29

****

Straight Culvert

Inlet Elevation (invert): 4.15 ft, Outlet Elevation (invert): 3.60 ft

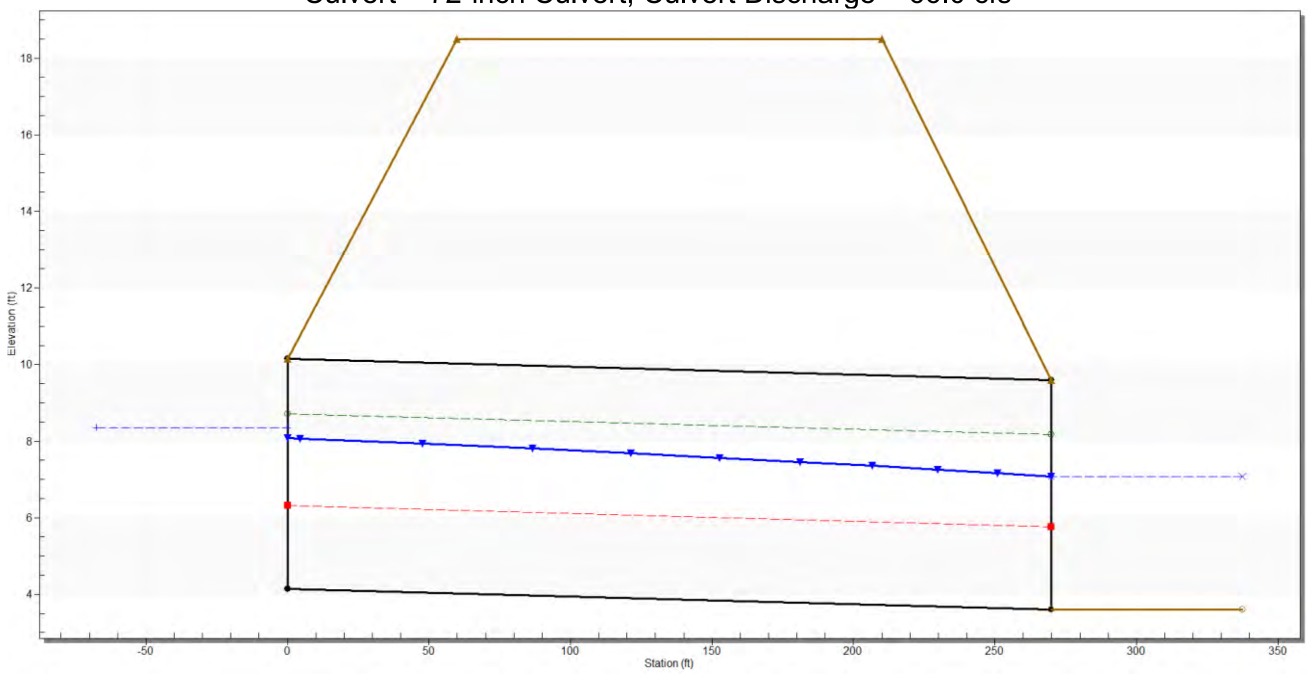
Culvert Length: 270.0 ft, Culvert Slope: 0.0020 ft/ft

****

Water Surface Profile Plot for Culvert: 72-inch Culvert

Crossing – Scammon Bay Runway Culvert, Design Discharge – 66.0 cfs

Culvert – 72-inch Culvert, Culvert Discharge – 66.0 cfs



Site Data - 72-inch Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4.15 ft

Outlet Station: 270.00 ft

Outlet Elevation: 3.60 ft

Number of Barrels: 1

Culvert Data Summary - 72-inch Culvert

Shape: Circular

Diameter: 6.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 0.00 in

Manning's n: 0.0350

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Runway Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
5.600	4.274	0.674	0.830
14.000	4.812	1.212	1.155
66.000	7.079	3.479	1.897
80.000	7.599	3.999	2.000
112.000	8.731	5.131	2.183
138.000	9.614	6.014	2.295

Tailwater Channel Data: Scammon Bay Runway Culvert

Channel Type: Rectangular Channel

Bottom Width: 10.00 ft

Channel Slope: 0.0010 ft/ft

Manning’s n (channel): 0.040

Channel Invert Elevation: 3.60 ft

Roadway Data for Crossing: Scammon Bay Runway Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 18.50 ft

Roadway Surface: Gravel

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report

72-inch Aluminum Round Structural Plate Culvert under Tidally Influence Conditions

(Preferred Alternative)

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Scammon Bay Runway Culvert

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
6.79	40% Q2	5.60	5.60	0.00	1
6.89	Q2	14.00	14.00	0.00	1
8.26	Q50	66.00	66.00	0.00	1
8.67	Q100	80.00	80.00	0.00	1
9.64	Q50 U68%	112.00	112.00	0.00	1
10.51	Q100 U68%	138.00	138.00	0.00	1
18.50	Overtopping	265.81	265.81	0.00	Overtopping

Rating Curve Plot for Crossing: Scammon Bay Runway Culvert

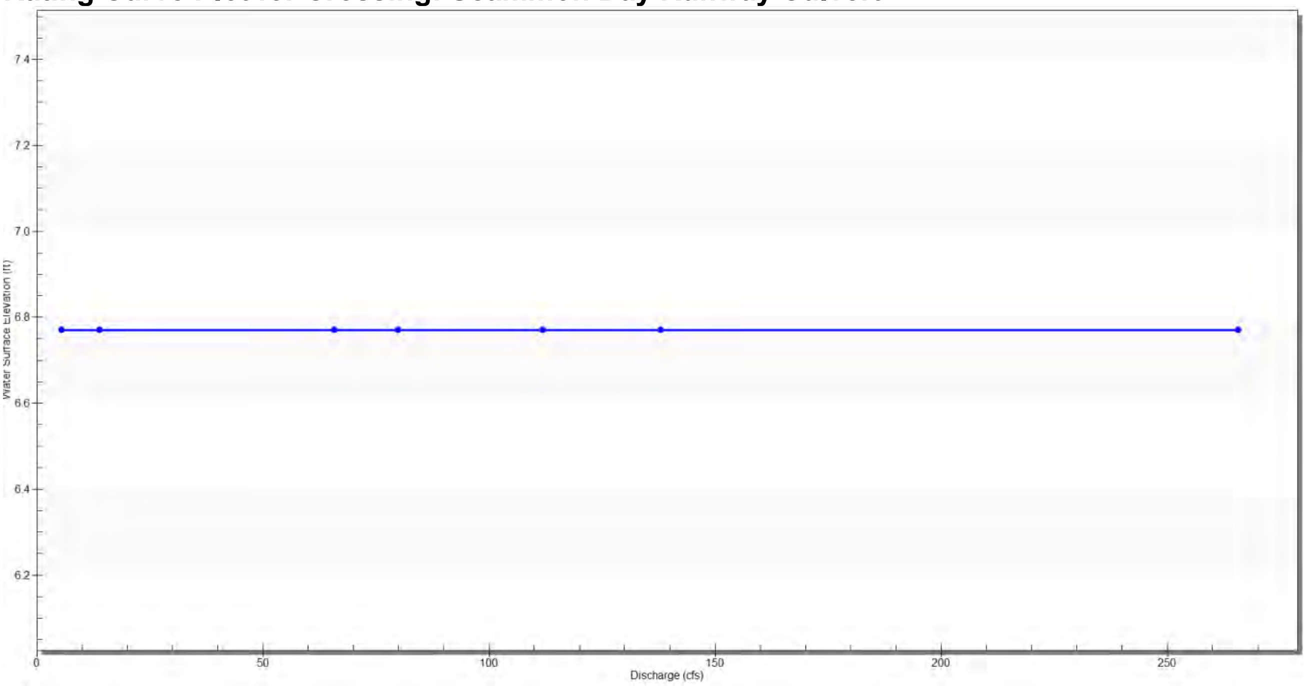


Table 2 - Culvert Summary Table: 72-inch Culvert

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
40% Q2	5.60	5.60	6.79	0.83	2.64	3-M1t	1.14	0.61	3.17	3.17	0.37	0.00
Q2	14.00	14.00	6.89	1.33	2.74	3-M1t	1.80	0.98	3.17	3.17	0.92	0.00
Q50	66.00	66.00	8.26	3.01	4.11	3-M2t	4.57	2.17	3.17	3.17	4.35	0.00
Q100	80.00	80.00	8.67	3.35	4.52	3-M2t	6.00	2.39	3.17	3.17	5.28	0.00
Q50 U68%	112.00	112.00	9.64	4.09	5.49	3-M2t	6.00	2.85	3.17	3.17	7.39	0.00
Q100 U68%	138.00	138.00	10.51	4.64	6.36	7-M2c	6.00	3.18	3.18	3.17	9.05	0.00

****

Straight Culvert

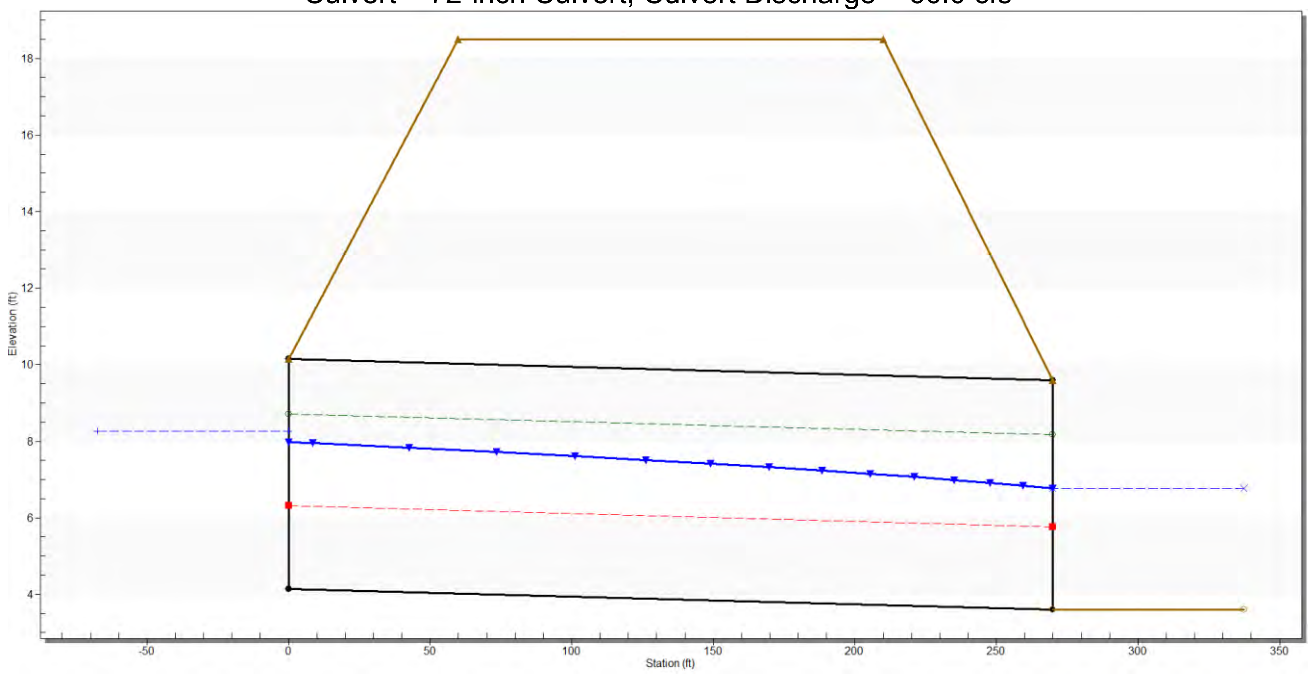
Inlet Elevation (invert): 4.15 ft, Outlet Elevation (invert): 3.60 ft

Culvert Length: 270.0 ft, Culvert Slope: 0.0020 ft/ft

****

Water Surface Profile Plot for Culvert: 72-inch Culvert

Crossing – Scammon Bay Runway Culvert, Design Discharge – 66.0 cfs
Culvert – 72-inch Culvert, Culvert Discharge – 66.0 cfs



Site Data - 72-inch Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4.15 ft

Outlet Station: 270.00 ft

Outlet Elevation: 3.60 ft

Number of Barrels: 1

Culvert Data Summary - 72-inch Culvert

Shape: Circular

Diameter: 6.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 0.00 in

Manning's n: 0.0350

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Runway Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
5.600	6.770	3.170	0.000
14.000	6.770	3.170	0.000
66.000	6.770	3.170	0.000
80.000	6.770	3.170	0.000
112.000	6.770	3.170	0.000
138.000	6.770	3.170	0.000

Tailwater Channel Data: Scammon Bay Runway Culvert

Channel Type: Constant Tailwater Elevation

Channel Invert Elevation: 3.60 ft

Constraint Tailwater Elevation: 6.77 ft (Mean Higher-High Water Elevation [MHHW])

Roadway Data for Crossing: Scammon Bay Runway Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 18.50 ft

Roadway Surface: Gravel

Roadway Top Width: 150.00 ft

Riprap Bed Sizing for Proposed Runway Culvert

Updated 7/21/2021 K. Grundhauser

Inputs
Set by Specs
Calculated

Step 1

From HEC-RAS or HY-8 enter values for depth and velocity of Q100 flows and select D85/15 and stability coefficients

This will produce the course fraction gradations for rip rap sizing at the bottom of the table

Using Corps of Engineers Equations - FHWA Circular on Development in the River System - Page 6.25.
FHWA NHI 01-004; River Engineering for Highway Encroachments, 2001
http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=8&id=20

Safety Factor	**1.5**			
Stability Coefficient for Incipient Failure	0.3	Round or Angular Rock?	Angular	(0.36 round rock, 0.3 angular rock)
Vertical Velocity Distribution Coeff	1.00	(1.0 for straight channels)		
Blanket Thickness Coeff	1	(1xD100 or 1.5 or D50 max, whichever is greater)		
Local depth of flow	4	ft for 100-year event		
Unit Weight of water	62.4	lb/ft^3	(assumed)	
Unit weight of rock	165	lb/ft^3	(assumed)	
Local depth-average velocity	4	ft/s from 100-year event avg. velocity in pipe		
Side Slope correction factor	1			
Gravitational Acceleration	32.2	ft/s^2		
D85/D15	3.4	(1.7-5.2)	IN RANGE	
D50/D30	2			

Note: This method is based on the minimum D30 size

Riprap Design Method - Selecting Proper Gradation, Page 131.
Design Hydrology and Sedimentology for Small Catchments, Haan, Barfield and Hayes, 1981.

D15	0.0	ft	1.0	inches
D30	0.1	ft	1.0	inches
D50	0.1	ft	2.0	inches
D85	0.2	ft	3.0	inches
D100	0.2	ft	3.0	inches

Using D50 size, used FHWA circular for Rip Rap design to spec out D100, D85 and D15.
D100 = 2.0D50

Buoyancy Force Calculations for Scammon Bay Runway Culvert *Updated:* *K. Grundhauser* *7/9/2021*

Resistance = Weight of pipe + Weight of water (in pipe) + Weight of fill (over pipe), lbs/ft.
Hydrostatic Uplift (Buoyant) Force = Weight of water displaced by the pipe, lb/ft.

Assumed (from Virginia DOT):

Weight of dry fill =	F_d =	100	lb/ft^3	
Weight of coastal protection =	F_s =	160	lb/ft^3	<- D50 - 1.4' diameter, 238 lb. We calculated a 300-400 lb d50 with an average density of 160 lbs/ft3. The density can range from 155 into the 170s.
Unit weight of water =	γ =	62.43	lb/ft^3	

Provide:

Weight of pipe =	W_p =	47.6	lb/ft	(72-inch, 10-gage thickness, aluminum, CMP)
Flow =	Q =	138	cfs	@ Q100 68%
Headwater =	H =	12.1	ft	@ avg Q50 storm surge, 15.7 NAVD88
Diameter of the pipe =	D =	6	ft	
Radius of the pipe =	R =	3	ft	
Critical depth =	**y_c =**	**3.13**	**ft**	@ Q100 68%
Normal depth =	y_n =	6	ft	@ Q100 68%
Length of pipe =	L =	274.5	ft	
Length of pipe per unit =	$L_{(unit)}$ =	1		
Cross section area =	A_{xc} =	28.27	ft^2	

Calculate:	**At Critical Depth**		
Buoyant force = $L_{(unit)}$*A*	Buoy =	1,765.2	lb/ft

Section 1 (Inlet)

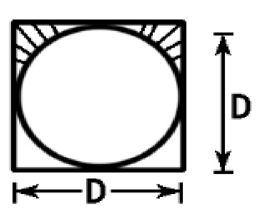
Surcharge (lbs./ft.) = Wt. of Fill + Wt. of Water + Wt. of Pipe

Area of Fill =	A_F =	0.00	ft^2					
Weight of Fill =	W_F =	0.0	lb/ft					
Area of Water =	A_W =	14.9	ft^2					
Weight of Water =	W_W =	931.3	lb/ft					
Weight of pipe =	W_p =	47.6	lb/ft					
Surcharge (lbs./ft.) =		978.9	lb/ft					
At Section 1 -	Weight	979	lb/ft	<	Buoy =	1,765	lb/ft	**Unstable**

Section 2 (Inlet to 12 ft)

Surcharge (lbs./ft.) = Wt. of Fill + Wt. of Water + Wt. of Pipe

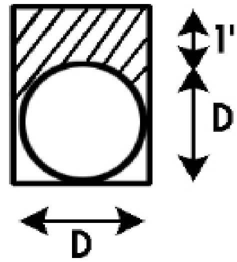
Area of Fill =	A_F =	3.86	ft^2
Weight of Fill =	W_F =	618.1	lb/ft
Area of Water =	A_W =	14.9	ft^2
Weight of Water =	W_W =	931.3	lb/ft
Weight of pipe =	W_p =	47.6	lb/ft



Surcharge (lbs./ft.) =		1596.9 lb/ft					
At Section 2 -	Weight	1,597 lb/ft	<	Buoy =	1,765	lb/ft	**Unstable**

Section 3 (12 ft to 16 ft)

Surcharge (lbs./ft.) = Wt. of Fill + Wt. of Water + Wt. of Pipe

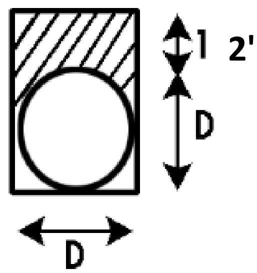


Area of Fill =	A_F =	9.86	ft^2
Weight of Fill =	W_F =	1578.1	lb/ft
Area of Water =	A_W =	14.9	ft^2
Weight of Water =	W_W =	931.3	lb/ft
Weight of pipe =	W_p =	47.6	lb/ft
Surcharge (lbs./ft.) =		2556.9	lb/ft

At Section 3 -	Weight	2,557 lb/ft	>	Buoy =	1,765	lb/ft	**Stable**

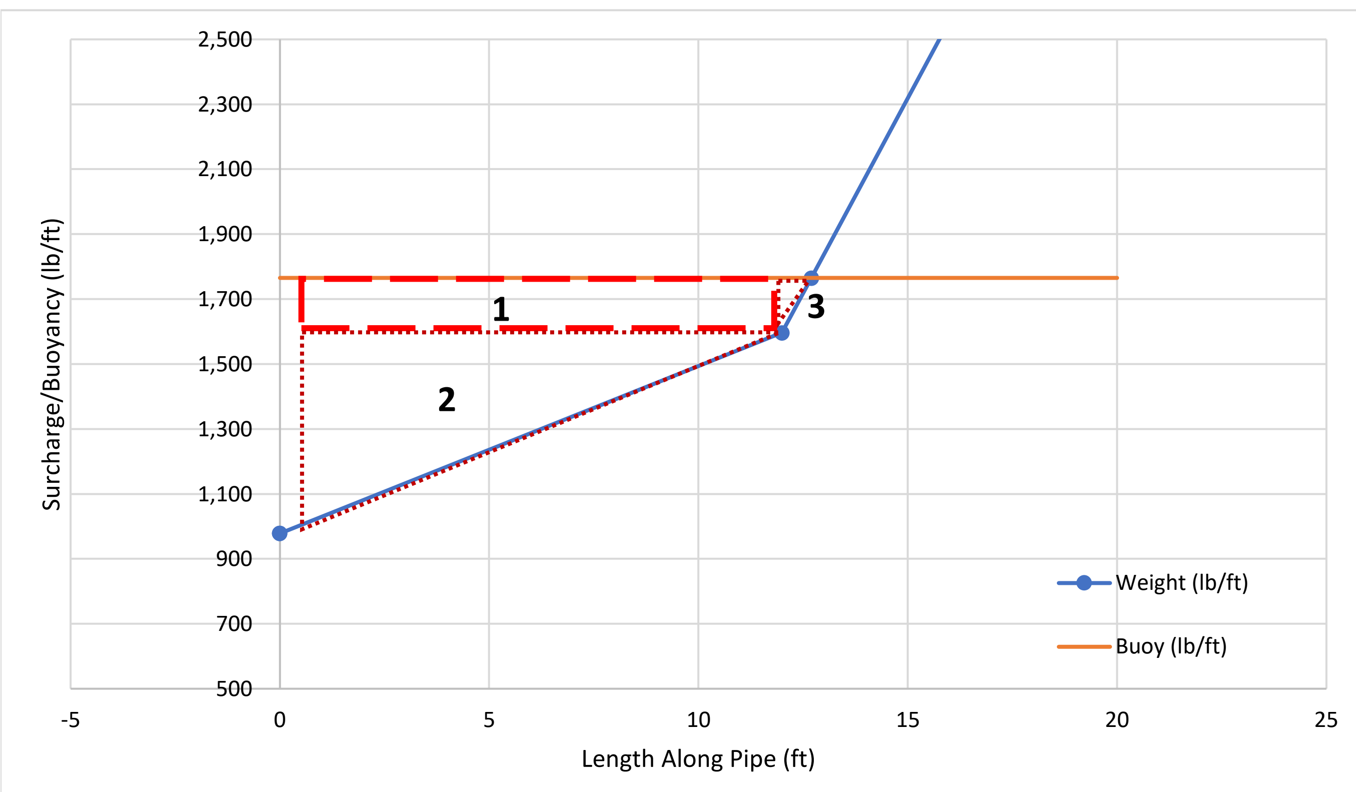
Section 4 (16 ft to 20 ft)

Surcharge (lbs./ft.) = Wt. of Fill + Wt. of Water + Wt. of Pipe



Area of Fill =	A_F =	15.86	ft^2
Weight of Fill =	W_F =	2538.1	lb/ft
Area of Water =	A_W =	14.9	ft^2
Weight of Water =	W_W =	931.3	lb/ft
Weight of pipe =	W_p =	47.6	lb/ft
Surcharge (lbs./ft.) =		3516.9	lb/ft

At Section 4 -	Weight	3,517 lb/ft	>	Buoy =	1,765	lb/ft	**Stable**



y= 240 x + -1283

Distance from Inlet (ft)	Weight (lb/ft)	Buoy (lb/ft)
0	979	1,765
0	979	1,765
12	1,597	1,765
12.700	1,765	1,765
16	2,557	1,765
20	3,517	1,765

Area			X Centroid	
1	2,017	lbs.	6	ft
2	3,708	lbs.	4.00	ft
3	59	lbs.	12.23	ft
Sum	5,784	lbs.	2.40	ft

Hinge Point =	12.700	ft			
Buoyancy Force =	59,561	lb*ft	Restrain =	59,561	lb*ft
Location of restraint =	1.00	ft (from Inlet)			
Required Restraining Forc	5,091	lb			

Minimum Restraining Force*	**5,091**	lbs. at	**1**	ft from Inlet.
	5,566		**2**	
	6,846		**4**	

Assume Concrete Toe Wall		**Wall**		**Toe**	
Width =	B_C =	11.0	ft	11.00	ft
Depth =	D_C =	1	ft	4.00	ft
Height =	H_C =	4	ft	1.00	ft
Unit Weight of Concrete	W_C =	165	lb/ft^3		
Unit weight of water =	γ =	62.43	lb/ft^3		
Concrete weight =	13,612.50	lb	**>**	Buoy =	6,846.09 **lb**

Passes

*Analysis is for non-rigid pipe. Additional restraining force may not be needed for a rigid pipe.

Recommend

At the inlet and outlet, install a DOT standard toe wall, see detail for dimensions.

Sources:

Virginia DOT Procedure:	http://www.virginiadot.org/business/resources/LocDes/DrainageManual/chapter8.pdf
Pipe Weight:	https://www.conteches.com/Portals/0/Documents/Design%20Guides/CMP-Design-Guide.pdf?ver=2018-05-16-083622-383
General Soil Weights:	http://www.geotechnicalinfo.com/soil_unit_weight.html
Saturated Soil Weight:	https://www.concretepipe.org/wp-content/uploads/2014/09/DD_22M.pdf
Equation of a line:	https://planetcalc.com/8110/
DOT Standard Toe wall:	https://dot.alaska.gov/stwddes/dcsprecon/assets/pdf/stddwgs/eng/d3101p1.pdf