18 MILE FISH PASSAGE IMPROVEMENT PROJECTS

Hydrologic and Hydraulic Report

Cordova, Alaska

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ACRONYMS

ADF&G .... Alaska Department of Fish and Game
cfs .... cubic feet per second
CRWP .... Copper River Watershed Project
DOT&PF .... Alaska Department of Transportation and Public Facilities
FPID .... Fish Passage Inventory Database
fps .... feet per second
HW/D .... headwater-to-depth ratio
NOAA .... National Oceanic and Atmospheric Administration
OHW .... ordinary high water
Q/A .... flow versus area
ROW .... right-of-way
USDA .... United States Department of Agriculture
USFWS .... United States Fish and Wildlife Service
USFS .... United States Forest Service
USGS .... United States Geological Survey

1.0 INTRODUCTION

1.1 Objective

The objective of this project is to design one low water crossing and three culvert replacements for fish passage sites along the Copper River Highway in the Copper River Watershed and Delta near Cordova, Alaska. The replacement culverts will enhance flood and fish passage and ecologic function at the Copper River Highway crossings of the West, Middle, and East Fork of 18 Mile Creek by simulating the natural creek channel and provide conveyance of at least the 100-year flood flow. The culverts will also enhance maintenance conditions at each crossing and reduce the likelihood of future infrastructure damage caused by flooding along the Copper River Highway. The 18 Mile Creek system is an anadromous stream with various stems, originating from glacial outwash plains to mountain headwaters and flowing south to the Alaganik Slough. The Copper River Watershed and Delta is a system of relic channels, connected upstream and downstream, with base flows that are continuously changing over time. The four project crossing drainage basins are shown in Figures 1 through 4.

West, Middle, and East Fork 18 Mile Creek are identified in the Alaska Department of Fish and Game's (ADF&G) Anadromous Waters Catalog as number 212-10-10010-2041-3015, 212-10-10010-2041, and 212-10-10010-2041-3010, respectively. The stream crossings have been identified as No. 20100486 (COP 20), No. 20100488 (COP 22), No. 20100491 (COP 25), respectively, in the ADF&G's Fish Passage Inventory Database (FPID) and given two Red ratings (COP 20 and COP 25) and one Green rating (COP 22) with a Red constriction ratio. The low water crossing site is currently a small, crushed culvert on Goat Camp Road draining a Sheridan River tributary marsh-wetland area. This crossing is identified as No. 20101902 (SHER 02) in the FPID and given a Gray rating. All four crossings have been identified by ADF&G, United States Fish and Wildlife Service (USFWS), Copper River Watershed Project (CRWP), United States Forest Service (USFS), and the National Oceanic and Atmospheric Administration (NOAA) as an impediment and barrier to upstream fish migration as well as causing disruption to the Delta's hydrology, reducing its ecological function.

1.2 Existing Conditions

The 18 Mile Creek system provides habitat for coho salmon, pink salmon, and Dolly Varden char and spawning habitat for cutthroat trout. The existing culvert at COP 20 consists of one 5-foot diameter round culvert with poor alignment, apparent beaver activity, and damage at the culvert inlet. The culvert is undersized and has minor corrosion. There is a scour pool and sediment accumulation at the culvert outlet. The culvert is approximately 57 feet long with a slope of -0.3 percent and constricts the stream by 16 percent according to the ADF&G report. Stream constriction leads to excessive velocities at the culvert outlets and through the pipes, hindering the ability of fish to swim through the structure. The existing culvert at COP 22 consists of one 6-foot diameter round culvert with poor alignment, apparent beaver activity, and minor corrosion. There is a scour pool and sediment accumulation at the culvert outlet. The culvert is approximately 61 feet long with a slope of -0.7 percent and constricts the stream by 26 percent according to the ADF&G report. The existing culverts at COP 25 consist of two 6-foot diameter round culverts with corrosion and damage at the inlets and outlets. There is apparent beaver activity and the culverts have debris grates at the inlets. There is a pool at the inlet and a large scour pool at the outlet. The culverts are approximately 61 feet long with a slope of -1.8 and 1 percent and constrict the stream by 65 percent according to the ADF&G report. The existing culvert at SHER 02 consists of one 3-foot diameter round culvert that is submerged and crushed. The culvert is corroded and approximately 17 feet long with a slope of -0.18 percent.

To meet project objectives, a topographic survey of the project area was completed to facilitate hydraulic modeling. Stream gauge data was collected by USFWS and CRWP between September 2018 and November 2019 to determine peak flow estimates. Additional hydrologic and hydraulic computations, including the synthetic width method, were performed as a comparison and to determine fish passage design flows and required flood flow capacity. A geomorphic analysis was used to assess sediment transport and to incorporate natural channel characteristics into the final design. A geotechnical analysis, completed in April 2019 by others, was used to investigate subsurface soil conditions at the three fish passage crossings. Design alternatives were evaluated to determine the most economical means of replacing the existing structures to improve ecological function and flood conveyance.

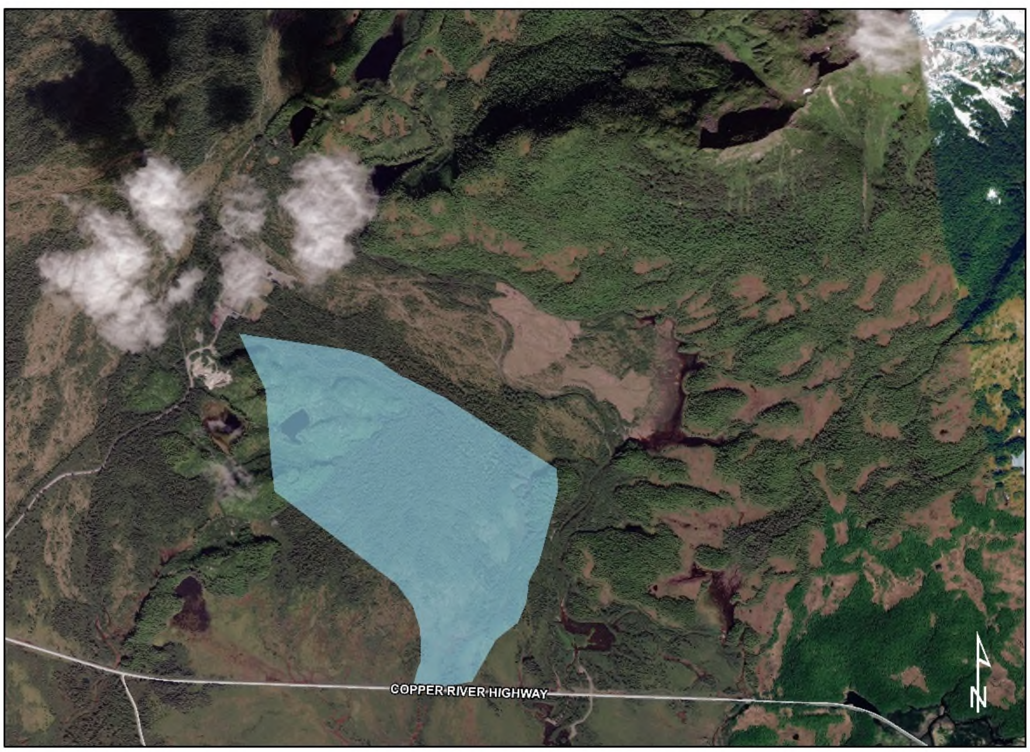

Figure 1: COP 20 Drainage Basin

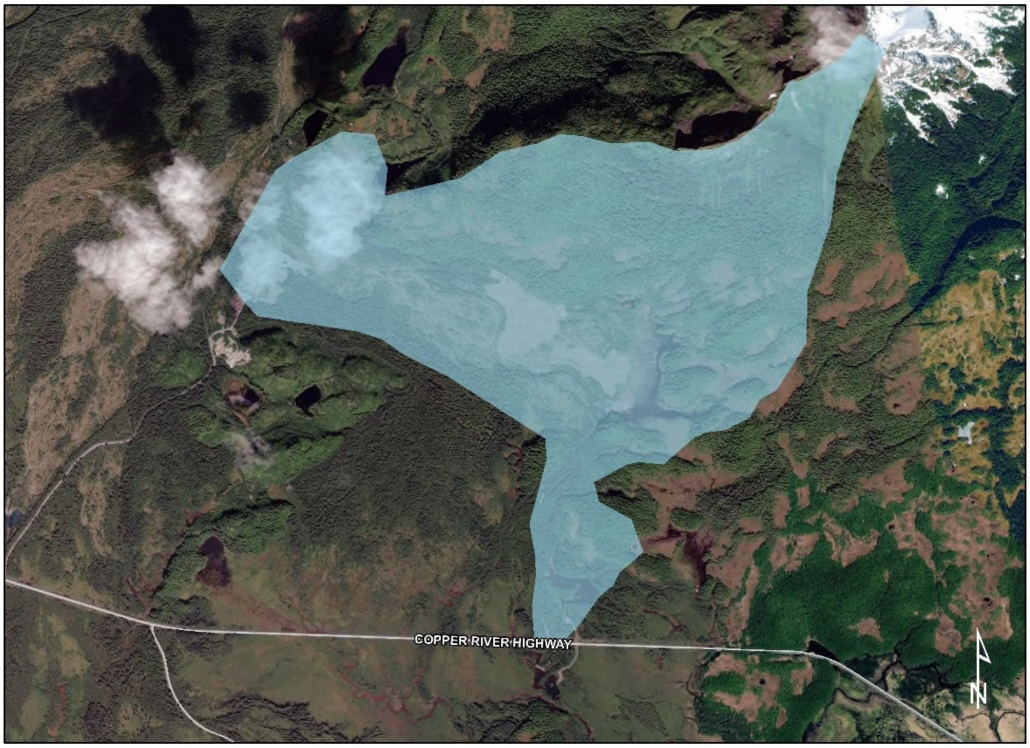

Figure 2: COP 22 Drainage Basin

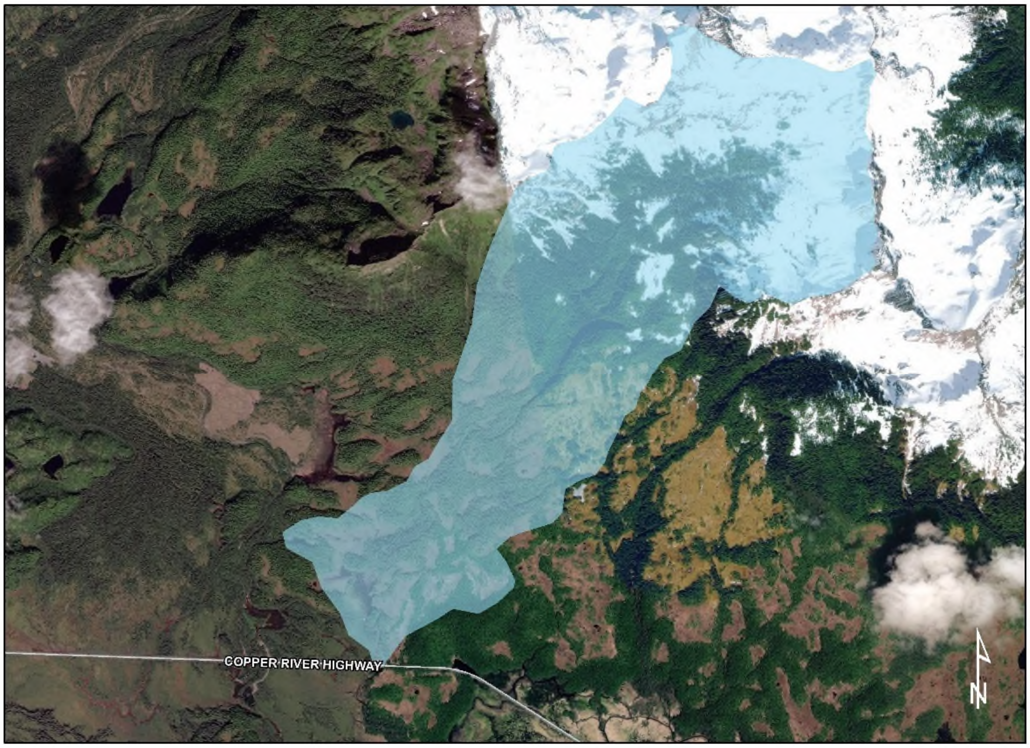

Figure 3: COP 25 Drainage Basin

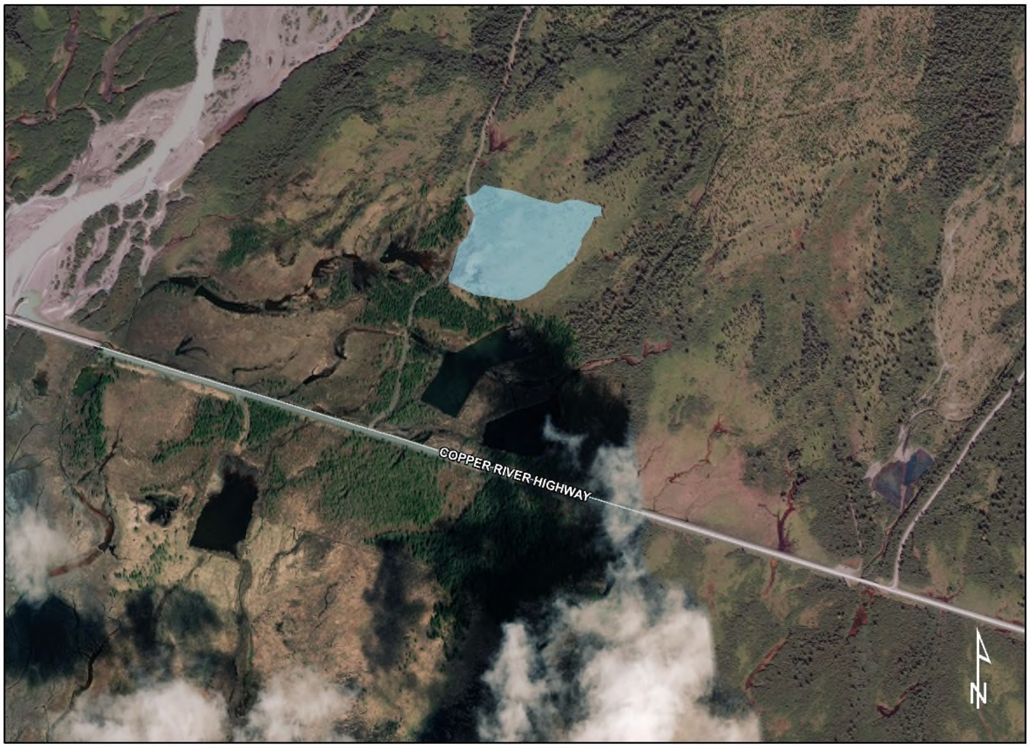

Figure 4: SHER 02 Drainage Basin

1.3 Design Criteria

The geomorphic analog method and synthetic width method are the preferred design approaches for the COP 20, COP 22, and COP 25 crossings of 18 Mile Creek. The design of the proposed fish passage culverts is based on criteria and guidelines contained in the United States Fish and Wildlife Service (USFWS) Fish Passage Design Guidelines (Revision 5) released February 2020, which follows the United States Forest Service (USFS) stream simulation approach with modifications. The USFS stream simulation approach is described in the 2008 *Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings*. Key criteria from the sources include:

- The constructed channel within the crossing shall not differ from the reference reach condition under normal flow conditions regarding channel width, cross-sectional area, gradient, substrate, and ability to pass floating debris;
- In relic channels or sloughs, with no defining bankfull features, a synthetic width may be estimated for culvert sizing by utilizing a calculated 2-year flood event with an average cross-sectional velocity of less than 4 feet per second (fps) and ideally similar to adjacent water velocities and water depth;
- The culvert width shall be at least 1.0 times bankfull width, with a minimum diameter of 5 feet;
- The embedment depth shall be the greater of 40 percent of the diameter or two feet for circular culverts;
- Embedment depth shall be the greater of 20 percent of the rise or two feet for all other culverts;
- Substrate material within the crossing shall be dynamically stable up to and including the 50-year flood;
- Stream banks inside the culvert shall be stable up to and including the 100-year flood;
- A continuous low flow channel that simulates the reference reach shall be incorporated in the substrate material;
- Culvert gradient shall be within 25% of the natural channel grade;
- Culverts shall be corrugated; and
- Structures shall be designed to accommodate at least the 100-year flood flow, preferably with a headwater-to-depth (HW/D) ratio of 0.8.

The design approach used for the SHER 02 low water crossing is based on criteria and guidelines contained in the 2006 U.S. Department of Agriculture (USDA) Forest Service *Low-Water Crossings: Geomorphic, Biological, and Engineering Design Considerations.* Key criteria from the sources include:

- Use 4:1 or flatter foreslopes on embankments;
- Provide two- to four-feet of freeboard armoring above the 100-year flood flow height;
- Must pass the 50- or 100-year flood flow through the armored cross section;
- Ideal grade into and out of the ford is 10 percent; and
- Riprap layer should be 1.5 times the maximum rock size for the depth of the riprap layer.

1.4 Right-of-Way

The Copper River Highway is owned by Alaska Department of Transportation and Public Facilities and Goat Camp Road is owned by USFS. The Copper River Highway is centered within a 200-foot-wide right-of-way (ROW) and Goat Camp Road is centered within a 60-foot road easement. Utilities

There are no known utilities located at any of the crossings of Goat Camp Road and the Copper River Highway.

2.0 GEOTECHNICAL CONDITIONS

A geotechnical investigation consisting of two borings at each crossing was conducted at the three fish passage crossing locations by Northern Geotechnical Engineering, Inc. in April 2019. The geotechnical report for USFWS Fish Passage Improvements was completed by Northern Geotechnical Engineering, Inc. The subsurface conditions encountered, soil bearing capacity, and site-specific geotechnical construction recommendations are summarized below.

2.1 COP 20

2.1.1 Upstream

- 0 to 5 feet: Poorly graded gravel with sand.
- 5 to 7 feet: Well graded gravel with silt and sand. Groundwater encountered at approximately 5 feet.
- 7 to 9 feet: Well graded sand with gravel.
- 9 to 20 feet: Well graded gravel with sand.

2.1.2 Downstream

- 0 to 7 feet: Well graded sand with silt and gravel. Groundwater encountered at approximately 6 feet.
- 7 to 9 feet: Poorly graded sand with gravel.
- 9 to 15 feet: Well graded gravel with sand.
- 15 to 21.5 feet: Well graded sand with gravel.

2.1.3 Soil Bearing Capacity

The allowable soil bearing capacity of 3,900 pounds per square foot may be used for a box culvert foundation on undisturbed sand and gravel or compacted structural fill.

2.1.4 Construction Recommendations

Site bearing soils approximately 12 to 13 feet below the road surface consist of loose to medium dense well graded gravel with sand. Excavation is required a minimum of 2 feet below the bottom of the culvert and backfilled with geotextile material and Subgrade Type F material.

2.2 COP 22

2.2.1 Upstream

- 0 to 7 feet: Well graded sand with silt and gravel.
- 7 to 12 feet: Well graded gravel with silt and sand. Groundwater encountered at approximately 7 feet.
- 12 to 20 feet: Well graded gravel with sand.

2.2.2 Downstream

- 0 to 5 feet: Well graded gravel with silt and sand.
- 5 to 10 feet: Well graded sand with silt and gravel. Groundwater encountered at approximately 7 feet.
- 10 to 12 feet: Well graded gravel with sand.
- 12 to 21.5 feet: Poorly graded sand with gravel.

2.2.3 Soil Bearing Capacity

The allowable soil bearing capacity of 3,900 pounds per square foot may be used for a box culvert foundation on undisturbed sand and gravel or compacted structural fill.

2.2.4 Construction Recommendations

Site bearing soils approximately 12 to 13 feet below the road surface consist of medium dense well graded gravel with sand. Excavation is required a minimum of 1 foot below the bottom of the culvert and backfilled with geotextile material and Subgrade Type F material.

2.3 COP 25

2.3.1 Upstream

- 0 to 5 feet: Well graded gravel with sand.
- 5 to 7 feet: Well graded sand with silt and gravel. Groundwater encountered at approximately 5 feet.
- 7 to 9 feet: Well graded sand with gravel.
- 9 to 15 feet: Well graded gravel with sand.
- 15 to 21.5 feet: Poorly graded sand and sand with silt and gravel.

2.3.2 Downstream

- 0 to 7 feet: Poorly graded sand with silt and gravel.
- 7 to 15 feet: Poorly graded sand with gravel to well graded sand with gravel. Groundwater encountered at approximately 7 feet.
- 15 to 16 feet: Poorly graded sand with silt.

- 16 to 21.5 feet: Peat and poorly graded sand with silt.

2.3.3 Soil Bearing Capacity

The allowable soil bearing capacity of 3,900 pounds per square foot may be used for a box culvert foundation on undisturbed sand and gravel or compacted structural fill.

2.3.4 Construction Recommendations

Site bearing soils approximately 12 to 13 feet below the road surface consist of loose well graded to poorly graded sand and gravel. Excavation is required a minimum of 2 feet below the bottom of the culvert. Organic material observed at the south side of Copper River Highway must be completely removed and inspected to ensure all organic materials have been removed. The excavation may be backfilled with Type A material up to two feet below the bottom of the culvert. Then placement of geotextile material and Subgrade Type F material is required, as described in the next section.

2.4 Summary

Additional recommendations provided in the appended geotechnical report include using culvert embedment material Subgrade Type F, extended one foot below the bottom of the culvert, 18 inches to both sides of the culvert, and a minimum of one foot above the culvert. A layer of Type 2 geotextile fabric should be placed between the Subgrade Type F material and the native soil or Type A material. A layer of Type 2 geotextile fabric should be placed between each one-foot layer of Subgrade Type F material.

3.0 GEOMORPHIC ANALYSIS

A site investigation was conducted on September 23 through 26, 2019. During the site visit, DOWL engineers and a USFWS hydrologist took channel measurements, conducted pebble counts, and observed bedform features. The reconnaissance level map, field notes, and pebble count data from the site investigation are included in Appendix A.

3.1 Stream Morphology and Crossing Characteristics

The 18 Mile Creek is a system of relic channels that are dynamic due to geomorphic processes such as erosion and deposition of sediments from the mountains and glacial outwash plains. The connected system is located on the edge of an inactive glacier outwash and is separated from the Sheridan River by a dike but still receives groundwater flows. The measured bankfull widths and depths may not be representative of the current channel flow regime. Along with field data, the synthetic width method was used to inform channel design and is described in Section 5.2 Synthetic Width Method.

3.1.1 COP 20

West Fork 18 Mile Creek originates on the edge of a glacial outwash, north of the Copper River highway and flows south to the Alaganik Slough.

Upstream of the COP 20 Copper River Highway crossing, West Fork 18 Mile Creek is meandering and is primarily precipitation driven with groundwater influence from the Sheridan

River. The predominant bedform features consist of slow, long pools with occasional rock riffles and woody debris steps and ponded areas. Upstream is low gradient and the banks are undercut, but vegetation, rocks and woody debris provide bank stabilization. There are signs of erosion including vegetated midchannel bars and areas of grassy terraces. The stream substrate consists of a various range of gravel sizes. Riparian vegetation includes grasses, moss, alder, willow, hemlock, and spruce trees. The floodplain is extensive and unconfined.

Downstream of the COP 20 Copper River Highway crossing, West Fork 18 Mile Creek has a large scour pool and sediment wedge and is a fairly linear system that merges with the Alaganik Slough tributary north of the COP 20 crossing and eventually merges with the Middle Fork 18 Mile Creek and East Fork 18 Mile Creek. The predominant bedform features consist of slow pools with riffles and scattered between sections of ponded areas. The banks are undercut, but willow and alder vegetation provide bank stabilization. There are signs of erosion including vegetated bars and areas of grassy terraces. The stream substrate consists of gravel and small cobble. Riparian vegetation includes grasses, moss, alder, willow, hemlock, and spruce trees. The floodplain is extensive and unconfined.

A reference reach was not defined at this crossing, but various cross sections were measured upstream and downstream of the crossing. Observed bankfull widths ranged from 10.5 feet to 12 feet, with an average bankfull depth of approximately 1.5 feet. The surveyed water surface elevation (WSE) slope is approximately 0.20 percent. The surveyed WSE slope was compared to the slope of the line connecting grade control features. Riffles and small steps provide grade control along the longitudinal profile, consisting of course gravels and small cobbles, and woody debris. Sediment and debris transport are high upstream and downstream of the crossing. There is evidence of beaver activity along West Fork 18 Mile Creek and within the vicinity of the crossing.

The observed stream characteristics of West Fork 18 Mile Creek at COP 20 are summarized in Table 1. Ordinary high water (OHW) widths and channel constriction were taken from the ADF&G FPID report.

Table 1: Stream Characteristics of West Fork 18 Mile Creek at COP 20

Stream Parameter	Existing Conditions
Surveyed WSE Slope	0.20 percent
Measured Bankfull Width	10.5-12 feet
Measured Bankfull Depth	1.5+/- feet
Channel Constriction	12-16 percent per ADF&G FPID
Bedform Features	Riffle-Pools

The Copper River Highway roadway embankment at COP 20 is well vegetated. No end sections or headwalls are present at the West Fork 18 Mile Creek COP 20 culvert. There is between 0.5 and 1.25 feet of roadway cover over the existing culvert.

3.1.2 COP 22

Middle Fork 18 Mile Creek originates on the edge of a glacial outwash, east of the COP 20 crossing, north of the Copper River highway and flows south to the Alaganik Slough.

Upstream of the COP 22 Copper River Highway crossing, Middle Fork 18 Mile Creek is meandering and is primarily precipitation driven with groundwater influence from Sheridan River. The predominant bedform features consist of riffles, pools, and runs with ponded areas and areas of split flow. Gravel bars and banks are present with several locations of grassy terraces. Upstream is low gradient and the banks are undercut, but vegetation and rocks provide bank stabilization. The stream substrate consists of a various range of gravel sizes to small cobbles. Riparian vegetation includes grasses, moss, alder, willow, hemlock, and spruce trees. The floodplain is extensive and unconfined.

Downstream of the COP 22 Copper River Highway crossing, Middle Fork 18 Mile Creek has a large scour pool and sediment wedge and is a fairly linear system that flows into a manmade pond and eventually merges with the East Fork 18 Mile Creek and West Fork 18 Mile Creek. The predominant bedform features consist of long pools and riffles, ponded areas, and gravel bars. There are gravel and undercut banks, but willow and alder vegetation provide bank stabilization. The stream substrate consists of gravel and small cobble. Riparian vegetation includes grasses, moss, alder, willow, hemlock, and spruce trees. The floodplain is extensive and unconfined.

A reference reach was not defined at this crossing, but various cross sections were measured upstream and downstream of the crossing. Observed bankfull widths ranged from 15 feet to 23 feet, with an average bankfull depth of approximately 2 feet. The surveyed water surface elevation (WSE) slope is approximately 0.44 percent. The surveyed WSE slope was compared to the slope of the line connecting grade control features. Riffles provide grade control along the longitudinal profile, consisting of course gravels and small cobbles, and woody debris. Sediment and debris transport are high upstream and downstream of the crossing. There is evidence of beaver activity along Middle Fork 18 Mile Creek and within the vicinity of the crossing.

The observed stream characteristics of Middle Fork 18 Mile Creek at COP 22 are summarized in Table 2. OHW widths and channel constriction were taken from the ADF&G FPID report.

Table 2: Stream Characteristics of Middle Fork 18 Mile Creek at COP 22

Stream Parameter	Existing Conditions
Surveyed WSE Slope	0.44 percent
Measured Bankfull Width	15-23 feet
Measured Bankfull Depth	2+/- feet
Channel Constriction	26-33 percent per ADF&G FPID
Bedform Features	Riffle-Pools

The Copper River Highway roadway embankment at COP 22 is well vegetated. No end sections or headwalls are present at the Middle Fork 18 Mile Creek COP 22 culvert. There is between 1.25 and 2.5 feet of roadway cover over the existing culvert.

3.1.3 COP 25

East Fork 18 Mile Creek originates on the piedmont of the Chugach Mountains to the north of the crossing, at the edge of the glacier outwash.

Upstream of the COP 25 Copper River Highway crossing, East Fork 18 Mile Creek is meandering. The predominant bedform features consist of riffles and pools with ponded areas. Gravel bars and banks are present with several locations of grassy terraces. Upstream is low gradient and the banks are undercut, but willow and alder vegetation provide bank stabilization. The stream substrate consists of gravel ranging from very fine to very coarse gravel. Riparian vegetation includes grasses, moss, alder, willow, hemlock, and spruce trees. The floodplain is extensive and unconfined.

Downstream of the COP 25 Copper River Highway crossing, East Fork 18 Mile Creek has a large scour pool and sediment wedge and is meandering. It eventually merges with the Middle Fork 18 Mile Creek and West Fork 18 Mile Creek. The predominant bedform features consist of pools and riffles with woody debris and gravel bars. There are undercut banks, but willow and alder vegetation provide bank stabilization. The stream substrate consists of coarse gravel to small cobble. Riparian vegetation includes grasses, moss, alder, willow, hemlock, and spruce trees. The floodplain is extensive and unconfined.

A reference reach was not defined at this crossing, but various cross sections were measured upstream and downstream of the crossing. Observed bankfull widths ranged from 23 feet to 34 feet, with an average bankfull depth of approximately 2 feet. The surveyed water surface elevation (WSE) slope is approximately 0.13 percent. The surveyed WSE slope was compared to the slope of the line connecting grade control features. Riffles provide grade control along the longitudinal profile, consisting of course gravels and small cobbles, and woody debris. Sediment and debris transport are low upstream and downstream of the crossing. There is evidence of beaver activity along East Fork 18 Mile Creek and within the vicinity of the crossing.

The observed stream characteristics of East Fork 18 Mile Creek at COP 25 are summarized in Table 3. OHW widths and channel constriction were taken from the ADF&G FPID report.

Table 3: Stream Characteristics of East Fork 18 Mile Creek at COP 25

Stream Parameter	Existing Conditions
Surveyed WSE Slope	0.13 percent
Measured Bankfull Width	23-34 feet
Measured Bankfull Depth	2+/- feet
Channel Constriction	26-35 percent per ADF&G FPID
Bedform Features	Riffle-Pools

The Copper River Highway roadway embankment at COP 25 is not vegetated and is eroding at the inlets and outlets. No end sections or headwalls are present at the East Fork 18 Mile Creek COP 22 culvert, but the inlets have makeshift pipe inlet debris guards. There is between 2.2 and 4 feet of roadway cover over the existing culverts.

3.1.4 SHER 02

The Sheridan River tributary flowing to the SHER 02 crossing originates in the marsh-wetlands southeast of the Sheridan River.

Upstream of the Goat Camp Road crossing, the Sheridan River tributary is a ponded wetland with various channel stems and areas of channelized flow. The predominant bedform features consist of slow, long pools with ponded water. Upstream is low gradient and the banks are undercut, grassy terraces. The stream substrate consists of mobile sand and small gravel. Riparian vegetation includes grasses, moss, alder, willow, hemlock, and spruce trees. The floodplain is extensive and unconfined.

Downstream of the Goat Camp Road crossing, the Sheridan River tributary is a ponded wetland with no clear stems or channelized flow. There are gravel bars and undercut banks, vegetated with alder and willow immediately downstream of the crossing. The stream substrate consists of mobile sand and small gravel and areas of organics over gravel. Riparian vegetation includes grasses, moss, alder, willow, hemlock, and spruce trees. The floodplain is extensive and unconfined.

A reference reach was not defined at this crossing, but one cross section was measured upstream of the crossing. Observed bankfull width was 5 feet, with a bankfull depth of approximately 10 inches. The channel slope is approximately 0.26 percent. There is evidence of beaver activity along the Sheridan River tributary and within the vicinity of the crossing.

The observed stream characteristics of Sheridan River Tributary at SHER 02 are summarized in Table 4.

Table 4: Stream Characteristics of Sheridan River Tributary at SHER 02

Stream Parameter	Existing Conditions
Slope	0.26 percent
Measured Bankfull Width	5 feet
Measured Bankfull Depth	10+/- inches
Bedform Features	Pools

The Goat Camp Road roadway embankment at SHER 02 is partially vegetated and eroding at the inlets and outlets. No end sections or headwalls are present at the Sheridan River Tributary SHER 02 culvert and the culvert is submerged, crushed, and corroded. There is less than half a foot of roadway cover over the existing culvert.

3.2 Substrate Analysis

3.2.1 COP 20

Two pebble counts were conducted at COP 20 approximately 650 feet and 800 feet upstream of the West Fork 18 Mile Creek crossing inlet. The pebble counts were performed at two surveyed cross section locations. The average D_{84} particle size at COP 20 was 60 millimeters (2.4 inches). The armor layer at the COP 20 crossing was found to range from fine gravel to small cobble, with most of the stream substrate consisting of very coarse gravel. A summary of the pebble counts is shown in Figure 5.

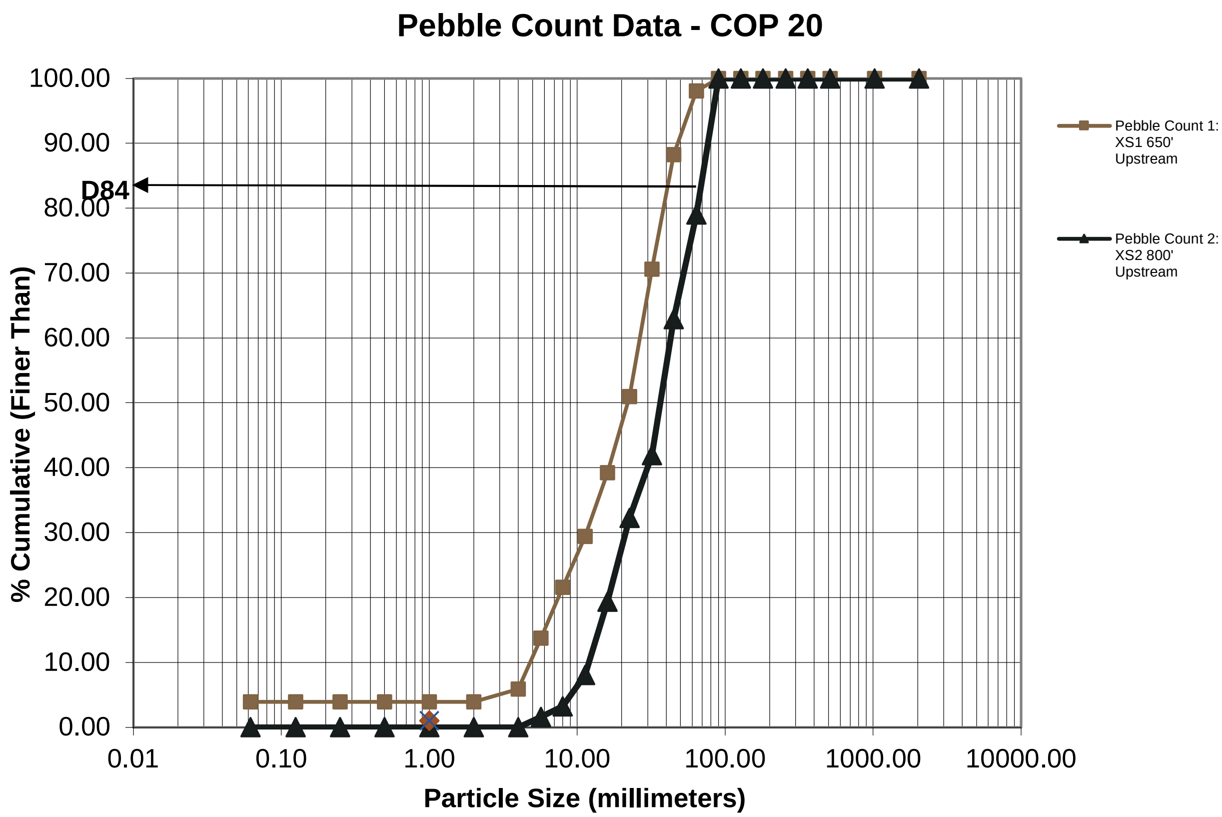

Figure 5: Summary of COP 20 Pebble Count

The observed D_{100}, D_{84}, and D_{50} particle sizes for COP 20 are summarized in Table 5. For stream substrate design, a stream bed mix will be specified based on the particle size distribution of the natural substrate observed onsite and to mitigate entrainment of bed material during Q_{100} flows. This will allow for natural sediment transport through the proposed culvert. The Fuller-Thompson equations will be used to size particles smaller than the D50 to provide adequate fines to fill voids and seal the simulation stream bed. Substrate design is included in Appendix B.

Table 5: COP 20 Pebble Count Summary

Particle Size	Count 1 650 feet Upstream	Count 2 800 feet Upstream
D_{100} (mm)	90	90
D_{84} (mm)	45	70
D_{50} (mm)	22	37

3.2.2 COP 22

One pebble count was conducted at COP 22 approximately 350 feet upstream of the Middle Fork 18 Mile Creek crossing. The pebble count was completed at one of the surveyed cross section locations. The average D_{84} particle size at COP 22 was 58 millimeters (2.3 inches). The armor layer at the COP 22 crossing was found to range from fine gravel to small cobble, with most of the stream substrate consisting of very coarse cobble. A summary of the pebble count is shown in Figure 6.

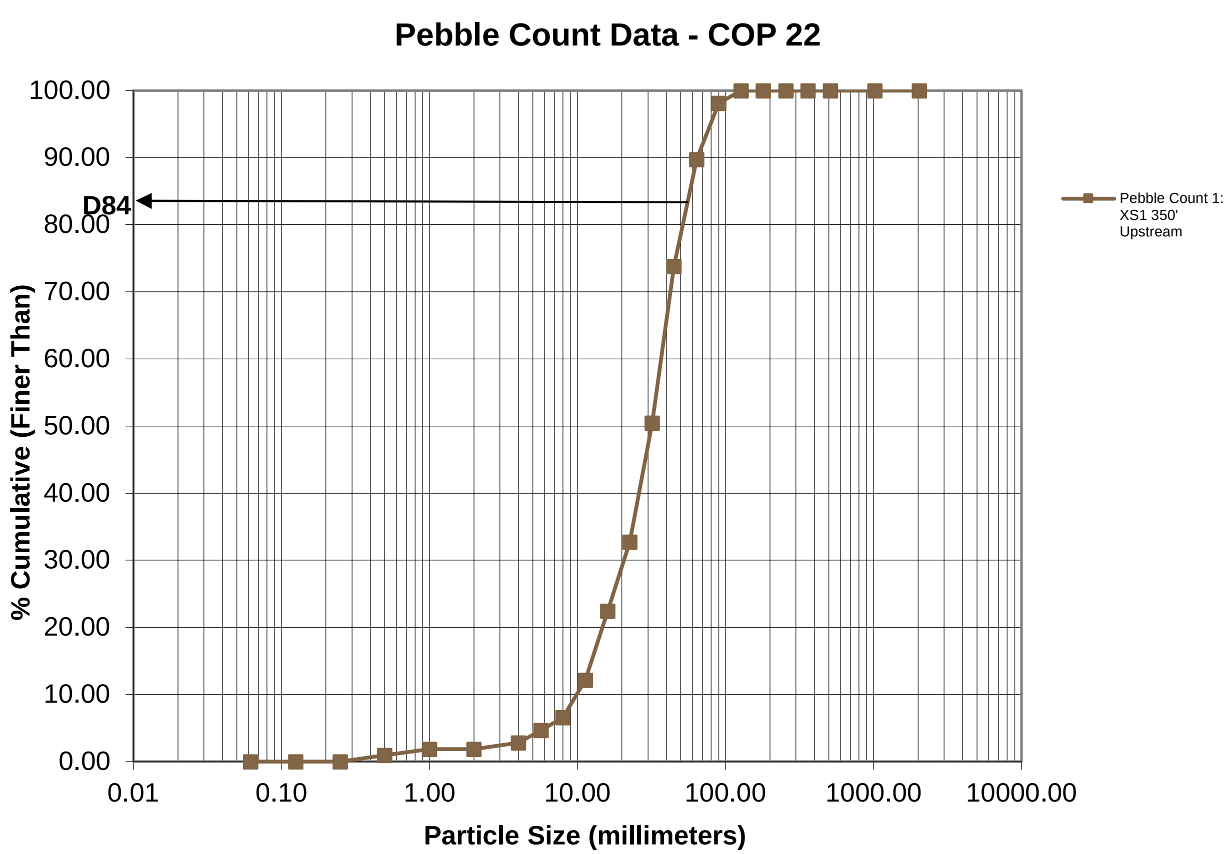

Figure 6: Summary of COP 22 Pebble Count

The observed D_{100}, D_{84}, and D_{50} particle sizes for COP 22 are summarized in Table 6. For stream substrate design, a stream bed mix will be specified based on the particle size distribution of the natural substrate observed onsite and to mitigate entrainment of bed material during Q_{100} flows. This will allow for natural sediment transport through the proposed culvert. The Fuller-Thompson equations will be used to size particles smaller than the D_{50} to provide adequate fines to fill voids and seal the simulation stream bed. Substrate design is included in Appendix B.

Table 6: COP 22 Pebble Count Summary

Particle Size	**Count 1**
	350 feet Upstream
D_{100} (mm)	128
D_{84} (mm)	58
D_{50} (mm)	32

3.2.3 <u>COP 25</u>

Three pebble counts were conducted at COP 25 approximately 55 feet and 155 feet upstream of the East Fork 18 Mile Creek crossing inlet and 500 feet downstream of the crossing outlet. The pebble counts were performed at the three surveyed cross section locations. The average D_{84} particle size at COP 25 upstream was 28 millimeters (1.1 inches) and downstream was 48 millimeters (1.9 inches). The armor layer at the COP 25 crossing upstream was found to range from medium sand to very coarse gravel, with the majority of the stream substrate consisting of medium to coarse gravel and the crossing downstream was found to range from fine gravel to very small cobble, with the majority of the stream substrate consisting of very coarse gravel. A summary of the pebble counts is shown in Figure 7.

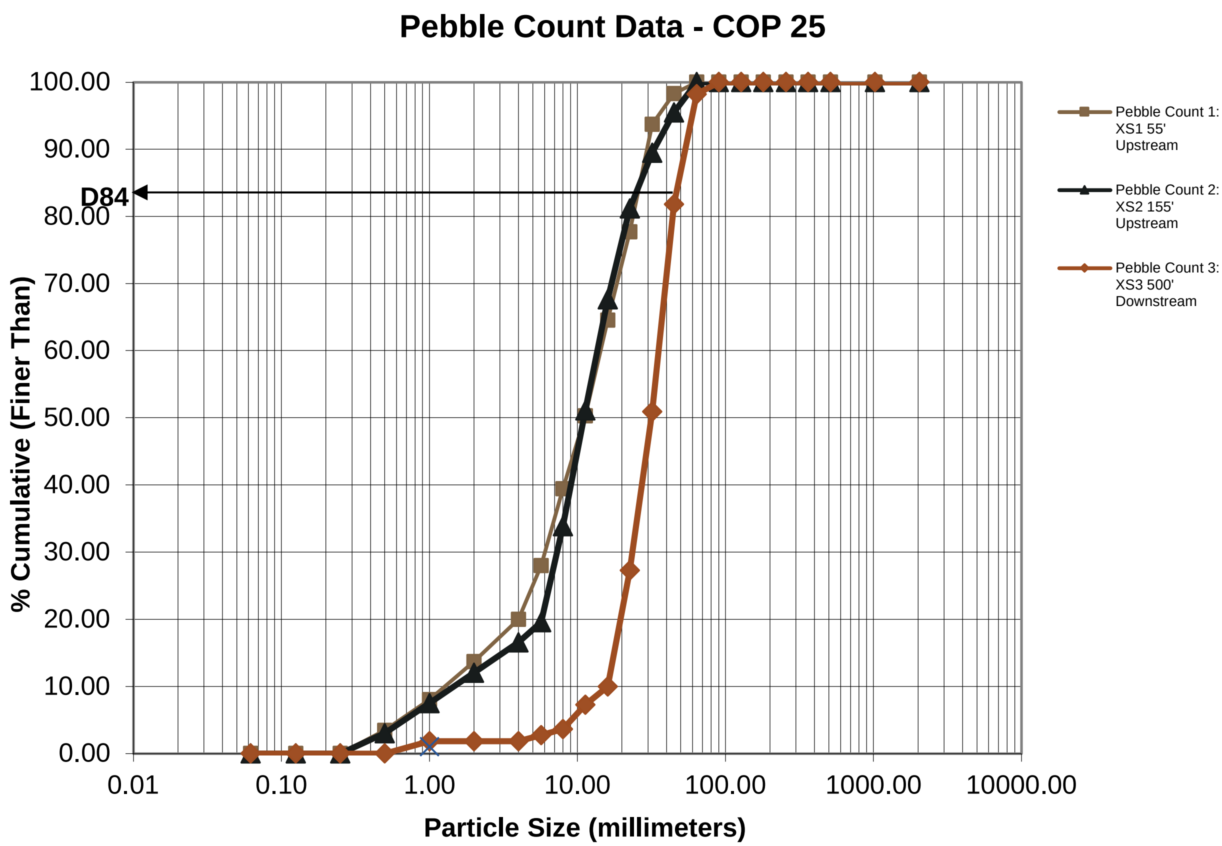

Figure 7: Summary of COP 25 Pebble Count

The observed D_{100}, D_{84}, and D_{50} particle sizes for COP 25 are summarized in Table 7. For stream substrate design, a stream bed mix will be specified based on the particle size distribution of the natural substrate observed onsite and to mitigate entrainment of bed material during Q_{100} flows. This will allow for natural sediment transport through the proposed culvert. The Fuller-Thompson equations will be used to size particles smaller than the D_{50} to provide adequate fines to fill voids and seal the simulation stream bed. Substrate design is included in Appendix B.

Table 7: COP 25 Pebble Count Summary

Particle Size	Count 1	Count 2	Count 3
	55 feet Upstream	155 feet Upstream	500 feet Downstream
D_{100} (mm)	64	64	90
D_{84} (mm)	28	28	48
D_{50} (mm)	11	11	32

3.2.4 SHER 02

One pebble count was conducted at SHER 02 approximately 90 feet upstream of the existing culvert crossing inlet. The average D_{84} particle size at SHER 02 was 35 millimeters (1.4 inches). The armor layer at the SHER 02 crossing was found to range from fine gravel to very coarse gravel, with most of the stream substrate consisting of coarse gravel. A summary of the pebble count is shown in Figure 8.

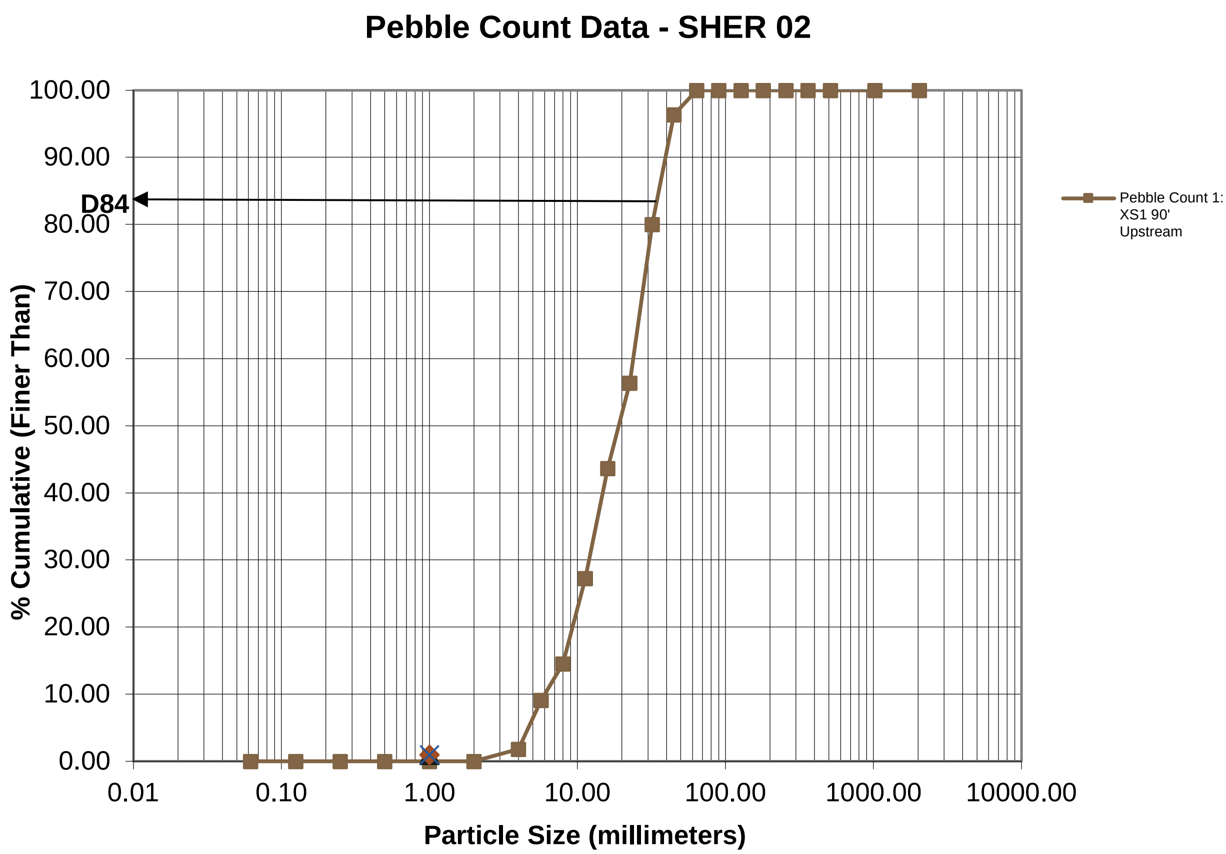

Figure 8: Summary of SHER 02 Pebble Count

The observed D_{100}, D_{84}, and D_{50} particle sizes for SHER 02 are summarized in Table 8. For the low flow channel substrate design, a stream bed mix will be specified based on the particle size distribution of the natural substrate observed onsite and to mitigate entrainment of bed material during Q_{100} flows. This will allow for natural sediment transport through the low flow crossing. The Fuller-Thompson equations will be used to size particles smaller than the D_{50} to provide adequate fines to fill voids and seal the simulation stream bed. The substrate will be used as the drivable surface of the low flow crossing. The drivable surface will extend from the channel bed to the existing road surface elevation to provide the maximum available freeboard for the crossing. Substrate design is included in Appendix B.

Table 8: SHER 02 Pebble Count Summary

Particle Size	Count 1
	90 feet Upstream
D_{100} (mm)	64
D_{84} (mm)	35
D_{50} (mm)	18

All pebble counts were performed on September 24 and 25, 2019. The D_{84} particle represents that size of which 84 percent of the streambed particles are expected to be smaller in size and is typically used as the basis for sizing rock that is only transported downstream during large flood events. Visual observations in the vicinity of the crossings agree with the pebble count results.

4.0 HYDROLOGIC ANALYSIS

4.1 Drainage Area Characteristics

The West Fork 18 Mile Creek COP 20 drainage basin flowing to Copper River Highway is approximately 345 acres (0.54 square miles) in size. The drainage basin is undeveloped and consists of wetlands and forested area within the glacial outwash area.

The Middle Fork 18 Mile Creek COP 22 drainage basin flowing to Copper River Highway is approximately 1,209 acres (1.9 square miles) in size. The drainage basin is undeveloped and consists of wetlands, forested area, and some mountain runoff within the glacial outwash area and includes Snag Lake and Holbrook Pond.

The East Fork 18 Mile Creek COP 25 drainage basin flowing to Copper River Highway is approximately 1,584 acres (2.5 square miles) in size. The drainage basin is undeveloped and consists of wetlands, forested area, and mountain runoff at the edge of the glacial outwash area and includes an upstream pond called Dead Tree Lake.

The Sheridan River tributary SHER 02 drainage basin flowing to Goat Camp Road is approximately 20 acres (0.03 square miles) in size. The drainage basin is undeveloped and consists of wetlands and forested area within the glacial outwash area.

4.2 Methodology

Several methods were used to estimate peak discharges for the 18 Mile Creek crossings including the 2003 and the 2016 Regional Regression Equations, and correlations to the USGS Gauge’s 8 peak flow measurements.

USFWS and CRWP collected discharge measurements at sites COP 20, 22, and 25 and two local pressure transducer gauges recorded stage at COP 22 and 25 between September 2018 and September 2019. USFWS provided a data summary report with the tentative peak streamflow estimates based on correlations to the USGS Gauge’s 8 peak flow measurements

(2013-2019). With the initial data, the COP 20 and COP 22 rating curves were flatter and more linear compared to the steeper rating curve for COP 25 which may be a result of not having higher flow data. An analysis was performed to remove two high March flows from the COP 25 rating curve to determine the percent increase in the flood frequency estimate by including the higher flows in the rating curve. The percent increase was applied to the flows for COP 20 for comparison. Peak flows for COP 22 were updated with the longer gauge record including information through March 2020. Additional flood frequency estimates were derived from USGS Glacier River Trib. gauge using curves that related 18 Mile Creek flow measurements to the USGS gauge discharge. The Summary of Hydrology Data Collected for COP 20, 22 & 25 report is included in Appendix C.

The 2016 Regional Regression Equations published by the United States Geological Survey (USGS) in the Scientific Investigations Report 2016-5024 were used to estimate peak discharges for each crossing. The USGS PRISM data for the drainage areas was used to find a mean annual precipitation value of 116.7 inches for COP 20, 116.9 for COP 22, 134.9 inches for COP 25, and 104.8 inches for SHER 02. The drainage basins for COP 20, 22, and 25 are within the 0.4 square mile lower limit area and 1,000 square mile upper limit area and the annual precipitations are within the range of 8 to 280 inches on which the regression equations were developed; therefore, the regression equations are expected to return reasonable flow estimates. Results of the 2016 Regional Regression Equations were compared to the results of the 2003 USGS Regional Regression Equations. The USGS Regional Regression Equation computations are included in Appendix C.

Through discussions with USFWS, USFS, and Alaska Department of Transportation and Public Facilities (DOT&PF), it was determined that due to the upstream floodplain connectivity of the system, the correlated peak flow analysis from the collected 2018 to 2020 gauge data provide the best estimate for peak flows on COP 20, 22, and 25. Further evaluation of the existing culverts was performed to determine their flow capacity and resulting headwater depths. When comparing those elevations to the floodplain elevations, floodplain connectivity between culverts was verified. This would also coincide with the USFS and DOT&PF having few issues with road overtopping though the culvert hydraulics show them undersized.

The drainage basin for SHER 02 is not within the applicable drainage basin size range for the regression equations but the flows were evaluated and used for comparison. A flow versus area (Q/A) comparison method was also used to estimate peak discharges for SHER 02. The Q/A comparison was made against the flows calculated for COP 25 based on correlations to the USGS Gauge's 8 peak flow measurements.

4.3 Results of Flood Flow Analysis

4.3.1 <u>COP 20</u>

The peak runoff flows for each analysis method for COP 20 are shown in Table 9.

Table 9: Estimated Peak Flows for COP 20

Storm Event (year)	Increase with March Flows for COP 25 (cfs)	COP 20 Flow Measurements Correlation to USGS Gauge Discharge (cfs)	2016 Regional Regression (cfs)	2003 Regional Regression (cfs)
2	148	**128**	68	82
5	171	**144**	111	109
10	182	**152**	143	127
25	196	**161**	188	151
50	205	**168**	222	168
100	214	**174**	260	185

Notes: cfs = cubic feet per second

The estimated peak flows from the COP 20 flow measurements correlation to USGS Gauge Discharge were used for the hydraulic analyses for COP 20. See the Summary of Hydrology Data Collected for COP 20, 22 & 25 report included in Appendix C for additional information. Per the criteria identified in the project objectives, culverts for COP 20 have been evaluated for hydraulic capacity based on the 100-year peak flow of 174 cubic feet per second (cfs).

4.3.2 COP 22

The peak runoff flows for each analysis method for COP 22 are shown in Table 10.

Table 10: Estimated Peak Flows for COP 22

Storm Event (year)	COP 22 Gauge Correlation to USGS Gauge 8 Peak Flow Measurements (2013-2019) (cfs)	COP 22 Flow Measurements Correlation to USGS Gauge Discharge (cfs)	2016 Regional Regression (cfs)	2003 Regional Regression (cfs)
2	**319**	691	210	189
5	**355**	773	321	248
10	**375**	819	404	288
25	**398**	871	514	340
50	**413**	905	598	380
100	**427**	938	690	418

Notes: cfs = cubic feet per second

The estimated peak flows from the COP 22 Gauge Correlation to USGS Gauge 8 Peak Flow Measurements were used for the hydraulic analyses for COP 22. See the Summary of Hydrology Data Collected for COP 20, 22 & 25 report included in Appendix C for additional information. Per the criteria identified in the project objectives, culverts for COP 20 have been evaluated for hydraulic capacity based on the 100-year peak flow of 427 cubic feet per second (cfs).

4.3.3 COP 25

The peak runoff flows for each analysis method for COP 25 are shown in Table 11.

Table 11: Estimated Peak Flows for COP 25

Storm Event (year)	COP 25 Gauge Correlation to USGS Gauge 8 Peak Flow Measurements (2013-2019) (cfs)	COP 25 Flow Measurements Correlation to USGS Gauge Discharge (cfs)	2016 Regional Regression (cfs)	2003 Regional Regression (cfs)
2	**705**	962	305	294
5	**801**	1075	454	388
10	**857**	1139	564	452
25	**919**	1210	709	533
50	**962**	1258	819	595
100	**1002**	1302	940	654

Notes: cfs = cubic feet per second

The estimated peak flows from the COP 25 Gauge Correlation to USGS Gauge 8 Peak Flow Measurements were used for the hydraulic analyses. See the Summary of Hydrology Data Collected for COP 20, 22 & 25 report included in Appendix C for additional information. Per the criteria identified in the project objectives, culverts are evaluated for hydraulic capacity based on the 100-year peak flow of 1,002 cfs.

4.3.4 SHER 02

The peak runoff flows for each analysis method for SHER 02 are shown in Table 12.

Table 12: Estimated Peak Flows for SHER 02

Storm Event (year)	Q/A Method to COP 25 Correlation to USGS Gauge 8 Peak Flow Measurements (cfs)	2016 Regional Regression (cfs)	2003 Regional Regression (cfs)
2	9.1	**5.9**	14
5	10.3	**10.8**	19
10	11.1	**14.8**	22.4
25	11.9	**20.6**	26.6
50	12.4	**25.3**	29.7
100	12.9	**30.6**	32.7

Notes: cfs = cubic feet per second

The peak flows from the 2016 Regional Regression Equations were used for the hydraulic analyses. Per the criteria identified in the project objectives, the low water crossing must pass the 50- or 100-year peak flow of 25.3 cfs and 30.6 cfs, respectively, through the armored cross section.

5.0 HYDRAULIC ANALYSIS

5.1 HY-8 Analysis

The Federal Highway Administration's HY-8 software was used for the hydraulic analysis of proposed culverts. The software was used to model the hydraulic capacity at the 50-year and 100-year flow and calculate the overtopping flow. Results of the HY-8 analyses for the proposed culvert options are included in Section 7.0 Recommendations. Supporting calculations are included in Appendix D. Structures were selected for analysis based on span dictated by the measured bankfull widths, synthetic widths, and HW/D ratios.

5.2 Synthetic Width Method

The USFWS Fish Passage Design Guidelines (Revision 5) released February 2020 recommends using the synthetic width method in areas where geomorphic data shows as existing stream in a relic channel with no defining bankfull features. A synthetic width can be estimated for culvert sizing by using the 2-year peak flow with an average cross-sectional velocity of less than 4 fps with similar adjacent water velocities and depths. Calculated synthetic widths are shown in Table 13 and calculations can be found in Appendix D.

Table 13: Synthetic Width Method

Stream	Calculated Synthetic Width
COP 20	11.3 feet
COP 22	17.9 feet
COP 25	26.2 feet

5.3 Low Flow Channel

5.3.1 COP 20, 22, and 25

The low flow channels for the COP 20, 22, and 25 crossings were calculated based on guidance from the USFWS Fish Passage Design Guidelines (Revision 5). A "V" shaped thalweg with a cross sectional area of 15 to 30 percent of the bankfull cross sectional area and a minimum depth of four inches for small streams and up to twelve inches for later streams was used for design of the low flow channels.

5.3.2 SHER 02

The USDA Forest Service Low Water Crossings: Geomorphic, Biological, and Engineering Design Considerations (2006) was used as guidance to determine site hydraulic factors needed for design of the low water crossing at SHER 02. Manning's equation was used to determine flow depth and velocity through the respective components of the ford. Supporting calculations are included in Appendix D. The geometry of the crossing was selected for analysis based existing measured bankfull widths and to enable passage of a vehicle safety through the ford.

6.0 DESIGN ALTERNATIVES

Design guidelines recommend that culvert span for proposed replacement structures should be at least 1.0 times bankfull width. Since measured bankfull widths may not reflect channel characteristics, Synthetic Width Method was used in addition to the measured widths to develop crossing structure dimensions. One of the main design parameters in the analysis of design options is the HW/D: a numerical representation of the depth of the water at the culvert inlet to the height of the culvert relative to the stream bed. For stream simulation design, a HW/D of 0.8 or less is desirable when economically reasonable to reduce the likelihood for scour of bed material within the culvert during flood events and to provide freeboard for passing debris during flood events. A combination of measured bankfull information, synthetic width, and HW/D ratios was used to determine acceptable structures for the crossings.

Due to the 18 Mile system being connected upstream and downstream, an additional consideration for the design of the crossings included channel changes caused by downcutting or beaver activity.

Several replacement alternatives have been evaluated including various structural steel plate box culverts and aluminum box culvert sizes with floodplain relief culverts. Round and pipe arch culvert options are not practical due to the limited available cover and groundwater elevations at the project locations.

Culvert replacement options considered for COP 20 include:

- A 12-foot, 11-inch span by 6-foot, 0-inch rise aluminum box culvert embedded 2.6 feet with a 49-inch span by 33-inch rise aluminum pipe arch overflow culvert (Q100 HW/D=0.94),
- A 12-foot, 11-inch span by 6-foot, 0-inch rise aluminum box culvert embedded 2.6 feet with a 57-inch span by 38-inch rise aluminum pipe arch overflow culvert (Q100 HW/D=0.92),
- A 15-foot, 6-inch span by 7-foot, 3-inch rise aluminum box culvert embedded 3.8 feet with a 57-inch span by 38-inch rise aluminum pipe arch overflow culvert and headwalls and wingwalls (Q100 HW/D=0.80), and
- A 16-foot, 8-inch span by 7-foot, 4-inch rise steel box culvert embedded 3.9 feet (Q100 HW/D=0.94).

Culvert replacement options considered for COP 22 include:

- A 15-foot, 4-inch span by 6-foot, 5-inch rise aluminum box culvert embedded 1.5 feet with a 57-inch span by 38-inch aluminum pipe arch overflow culvert (Q100 HW/D=1.03),
- A 15-foot, 4-inch span by 6-foot, 5-inch rise aluminum box culvert embedded 1.5 feet with a 64-inch span by 43-inch aluminum pipe arch overflow culvert (Q100 HW/D=1.00),
- A 19-foot, 10-inch span by 7-foot, 8-inch rise aluminum box culvert embedded 2.7 feet with a 64-inch span by 43-inch aluminum pipe arch overflow culvert and headwalls and wingwalls (Q100 HW/D=0.85), and
- A 16-foot, 8-inch span by 7-foot, 4-inch rise steel box culvert embedded 3.9 feet (Q100 HW/D=1.14).

Culvert replacement options considered for COP 25 include:

- A 19-foot, 10-inch span by 7-foot, 8-inch rise aluminum box culvert embedded 1.5 feet with a 64-inch span by 43-inch aluminum pipe arch overflow culvert (Q100 HW/D=1.33),
- A 19-foot, 10-inch span by 7-foot, 8-inch rise aluminum box culvert embedded 1.5 feet with a 71-inch span by 47-inch aluminum pipe arch overflow culvert (Q100 HW/D=1.30),
- A 29-foot span by 8-foot, 3-inch rise aluminum box culvert embedded 3 feet with a 71-inch span by 47-inch steel pipe arch overflow culvert and headwalls and wingwalls (Q100 HW/D=1.06), and
- A 19-foot, 7-inch span by 7-foot, 5-inch rise steel box culvert embedded 1.5 feet with a 71-inch span by 47-inch steel pipe arch overflow culvert (Q100 HW/D=1.29).

7.0 RECOMMENDATIONS

7.1.1 COP 20

Replacing the 5-foot diameter round culvert at the COP 20 Copper River Highway crossing with a 15-foot, 6-inch span by 7-foot, 3-inch rise aluminum box culvert with a 57-inch span by 38-inch rise aluminum pipe arch and headwalls and wingwalls is the recommended option for improving fish passage and flood conveyance at the West Fork 18 Mile Creek crossing.

This replacement option is anticipated to convey the Q_{100} of 174 cfs and the Q_{50} of 168 with a HW/D ratio of approximately 0.80 and 0.78, respectively. The box culvert will be embedded 3.8 feet. Minimum allowable cover over the culvert is approximately 1.4 feet and maximum allowable cover over the culvert is approximately 4 feet. Roadway overtopping would occur at a flow of approximately 303 cfs.

The box culvert will provide an adequate span to facilitate construction of an approximately 12-foot wide channel plus one- to two-feet of reconstructed stream bank on each side of the channel which meets the criteria of 1.5 times the D_{100} of the proposed substrate (12") for the stream banks. The culvert will be embedded with waterway bed material to mimic natural substrate. The simulated stream channel will be constructed as a roughened riffle and the downstream scour hole pool will be filled, tying into the downstream sediment wedge. Rock weirs will be placed at the stream tie-in points. Rock clusters will be constructed within the culvert using Class I riprap with a meandering low flow channel. Reconstructed stream banks upstream and downstream from the culvert will consist of woody debris bank reconstruction, vegetated mats, and willow staking. The embankment slopes will be stabilized with Class I riprap to provide erosion protection.

7.1.2 COP 22

Replacing the 6-foot diameter round culvert at the COP 22 Copper River Highway crossing with a 19-foot, 10-inch span by 7-foot, 8-inch rise aluminum box culvert with a 64-inch span by 43-inch rise aluminum pipe arch and headwalls and wingwalls is the recommended option for improving fish passage and flood conveyance at the Middle Fork 18 Mile Creek crossing.

This replacement option is anticipated to convey the Q_{100} of 427 cfs and the Q_{50} of 413 with a HW/D ratio of approximately 0.85 and 0.83, respectively. The box culvert will be embedded 2.7 feet. Minimum allowable cover over the culvert is approximately 1.4 feet and maximum allowable cover over the culvert is approximately 4 feet. Roadway overtopping would occur at a flow of approximately 650 cfs.

The box culvert will provide an adequate span to facilitate construction of an approximately 16.5-foot wide channel plus one- to two-feet of reconstructed stream bank on each side of the channel which meets the criteria of 1.5 times the D_{100} of the proposed substrate (12") for the stream banks. The culvert will be embedded with waterway bed material to mimic natural substrate. The simulated stream channel will be constructed as a roughened riffle and the downstream scour hole pool will be filled, tying into the downstream sediment wedge. Rock weirs will be place at the stream tie-in points. Rock clusters will be constructed within the culvert using Class I riprap with a meandering low flow channel. Reconstructed stream banks upstream and downstream from the culvert will consist of woody debris bank reconstruction, vegetated mats, and willow staking. The embankment slopes will be stabilized with Class I riprap to provide erosion protection.

7.1.3 COP 25

Replacing the two 6-foot diameter round culverts at the COP 25 Copper River Highway crossing with a 29-foot, 0-inch span by 8-foot, 3-inch rise aluminum box culvert with a 71-inch span by 47-inch rise steel pipe arch and headwalls and wingwalls is the recommended option for improving fish passage and flood conveyance at the East Fork 18 Mile Creek crossing.

This replacement option is anticipated to convey the Q_{100} of 1,002 cfs and the Q_{50} of 962 with a HW/D ratio of approximately 1.06 and 1.04, respectively. The box culvert will be embedded 3 feet. Minimum allowable cover over the culvert is approximately 1.4 feet and maximum allowable cover over the culvert is approximately 4 feet. Roadway overtopping would occur at a flow of approximately 1,611 cfs.

The box culvert will provide an adequate span to facilitate construction of an approximately 26-foot wide channel plus one- to two-feet of reconstructed stream bank on each side of the channel which meets the criteria of 1.5 times the D_{100} of the proposed substrate (12") for the stream banks. The culvert will be embedded with waterway bed material to mimic natural substrate. The simulated stream channel will be constructed as a roughened riffle and the downstream scour hole pool will be filled. Rock weirs will be place at the stream tie-in points. Rock clusters will be constructed within the culvert using Class I riprap with a meandering low flow channel. Reconstructed stream banks upstream and downstream from the culvert will consist of woody debris bank reconstruction, vegetated mats, and willow staking. The embankment slopes will be stabilized with Class I riprap to provide erosion protection.

7.1.4 SHER 02

Replacing the 3-foot diameter round culvert at the SHER 02 Goat Camp Road crossing with a low water ford the recommended option for improving fish passage and flood conveyance at the Goat Camp Road crossing.

This replacement option is anticipated to convey the 100-year peak flow of 30.6 cfs and the Q_{50} of 25.3. The low flow crossing will provide an adequate area of flow through a 5-foot-wide channel, one to two feet deep, with side slopes at 10H:1V that daylight at the existing road surface to accommodate vehicle traffic. The ford channel geometry will mimic the downstream reach, with waterway bed material to mimic natural substrate and provide a wearable driving surface. The embankment slopes will be stabilized with Class I riprap to provide erosion protection. Signage for the low water crossing will be included as appropriate.

7.2 Rejected Alternatives

7.2.1 COP 20

The 12-foot, 11-inch span by 6-foot, 0-inch rise aluminum box culvert embedded 2.6 feet and 13-foot, 3-inch span by 6-foot, 9-inch rise aluminum box culvert embedded 3.3 feet were considered for the crossing but the use of an overflow, floodplain culvert allows for additional flow capacity to reduce the HW/D ratio as well as providing use for the stream diversion. An aluminum structure is recommended over steel due to the lower weight of material, higher corrosion resistance and the potential for faster installation reducing the traffic restrictions on the

Copper River Highway. Pipe arch and round structures were considered but due to the limited available cover over the pipe, both structure shapes were eliminated.

7.2.2 COP 22

The 15-foot, 4-inch span by 6-foot, 5-inch rise aluminum box culvert embedded 1.5 feet and 16-foot, 6-inch span by 6-foot, 8-inch rise aluminum box culvert embedded 1.7 feet were considered for the crossing but the use of an overflow, floodplain culvert allows for additional flow capacity to reduce the HW/D ratio as well as providing use for the stream diversion. An aluminum structure is recommended over steel due to the lower weight of material, higher corrosion resistance and the potential for faster installation reducing the traffic restrictions on the Copper River Highway. Pipe arch and round structures were considered but due to the limited available cover over the pipe, both structure shapes were eliminated.

7.2.3 COP 25

An aluminum structure is recommended over steel due to the lower weight of material ,higher corrosion resistance and the potential for faster installation reducing the traffic restrictions on the Copper River Highway. Pipe arch and round structures were considered but due to the limited available cover over the pipe, both structure shapes were eliminated.

8.0 REFERENCES

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APPENDIX A: GEOMORPHIC ANALYSIS

Stream Crossing Site Assessment **DOWL**

Reference Reach Data Sheet **Revised RDP 08212015**

Project: CRWP/USFWS Cordova FP	**Project Number:**
Date: 9/24/19 & 9/25/19	**Assessed by:** ROBUCK / MELOCIK - DOWL FRANKLIN DEKKER - USFWS
Crossing ID: COP 20 18 M	
Weather Conditions: 50° CLOUDY	

CROSSING CHARACTERISTICS:

Existing Culvert/Crossing:

6 Foot

REFERENCE REACHES WERE NOT FOUND. REPRESENTATIVE XS WERE FOUND TO REPRESENT ADEQUATE CULVERT SECTIONS

Geomorphology/Stream Type/Bedform Features:

Beaver dam upstream

Substrate/Bed Mobility:

Glacier Outwash Channel ~ 20-23 feet

Floodplain Characteristics/Entrenchment:

Wide Floodplain

Flow/Velocity Estimates: 3 cfs @ 0.4 to 0.5 fps

Tie-in Points:

PEBBLE COUNT

Site: COP 20

Party: ROBUCK / MELOCIK

Reach:

Date:

PEBBLE COUNT — Reach: US — Date: 9/25/19

PEBBLE COUNT — Reach: — Date:

Inches	PARTICLE	Millimeters		PARTICLE COUNT 1 (XS 1 US)	2 (XS 2 US)	3	TOT #	ITEM %	% CUM	TOT #	ITEM %	% CUM	TOT #	ITEM %	% CUM
	Silt / Clay	< .062	S/C	II											
	Very Fine	.062 - .125	SAND												
	Fine	.125 - .25	SAND												
	Medium	.25 - .50	SAND												
	Coarse	.50 - 1.0	SAND												
.04 - .08	Very Coarse	1.0 - 2	SAND												
.08 - .16	Very Fine	2 - 4	GRAVEL	I											
.16 - .22	Fine	4 - 5.7	GRAVEL	IIII	I										
.22 - .31	Fine	5.7 - 8	GRAVEL	IIII	I										
.31 - .44	Medium	8 - 11.3	GRAVEL	IIII	III										
.44 - .63	Medium	11.3 - 16	GRAVEL	卌	卌 II										
.63 - .89	Coarse	16 - 22.6	GRAVEL	卌 I	卌 III										
.89 - 1.26	Coarse	22.6 - 32	GRAVEL	卌 卌	卌 I										
1.26 - 1.77	Very Coarse	32 - 45	GRAVEL	卌 IIII	卌 卌 III										
1.77 - 2.5	Very Coarse	45 - 64	GRAVEL	卌	卌 卌										
2.5 - 3.5	Small	64 - 90	COBBLE	I	卌 卌 III										
3.5 - 5.0	Small	90 - 128	COBBLE												
5.0 - 7.1	Large	128 - 180	COBBLE												
7.1 - 10.1	Large	180 - 256	COBBLE												
10.1 - 14.3	Small	256 - 362	BOULDER												
14.3 - 20	Small	362 - 512	BOULDER												
20 - 40	Medium	512 - 1024	BOULDER												
40 - 80	Large-Vry Large	1024 - 2048	BOULDER												
	Bedrock		BDRK												
						TOTALS →									

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Stream Crossing Site Assessment
Reference Reach Data Sheet

DOWL
Revised RDP 08212015

Date: COP 22	Project Number:

UPSTREAM REFERENCE REACH: @ Beaver Dam Outlet (NOT R[illegible])

Channel Cross Section Shape:	Channel Slope:

Δ from Xing	Bankfull Width	Bankfull Depth	Bed Width	Floodplain Width	Riffles		Channel Stability Notes:
					Δ Xing	Length	
700' FROM culvert	10.5 @ outlet of Beaver dam	9" to WS 17" to BF	10 feet	> 50			U/s Cross Section - 200' Long Pro Downstream D/s cross section 10' - 6" Water depth 15" to BF Stability: 1 = lowest (very temporary) 5 = highest (permanent)

Pools			Steps				Ribs		Notes:
Δ Xing	Length	Depth	Δ Xing	Height	Type	Stability	Δ Xing	Stability	
Check Long Pro									250' u/s from culvert 200' d/s from culvert

Vegetation: Willow / Alder

Bedrock Observed: None

DOWNSTREAM REFERENCE REACH: NONE

Channel Cross Section Shape:	Channel Slope:

Δ from Xing	Bankfull Width	Bankfull Depth	Bed Width	Floodplain Width	Riffles		Channel Stability Notes:
					Δ Xing	Length	
	12	6 to 10"	9'	> 50			Stability: 1 = lowest (very temporary) 5 = highest (permanent)

Pools			Steps				Ribs		Notes:
Δ Xing	Length	Depth	Δ Xing	Height	Type	Stability	Δ Xing	Stability	

Vegetation:

Bedrock Observed:

Stream Crossing Site Assessment
Reference Reach Data Sheet

DOWL
Revised RDP 08212015

Project: CRWP/USFWS Cordova FT Round	**Project Number:**
Date: 9/24/19	**Assessed by:** HCR / BMM
Crossing ID: COP 22 - 18 mile campground	
Weather Conditions: 44°F, partly cloudy, Rain	

CROSSING CHARACTERISTICS:

Existing Culvert/Crossing: 6' Round

Geomorphology/Stream Type/Bedform Features: glacial outwash, riffle/pools, no steps, little woody debris

Substrate/Bed Mobility:
gravel/cobbles

Floodplain Characteristics/Entrenchment:
wide floodplain

Flow/Velocity Estimates:
~1 ft/s

Tie-in Points:

PEBBLE COUNT

Site:
Party:
Reach:
Date:

Inches	PARTICLE	Millimeters		PARTICLE COUNT 1 (US 150 · x-sec)	2	3	TOT #	ITEM %	% CUM	PEBBLE COUNT (Reach: / Date:) TOT #	ITEM %	% CUM	PEBBLE COUNT (Reach: / Date:) TOT #	ITEM %	% CUM
	Silt / Clay	< .062	S/C												
	Very Fine	.062 - .125	SAND												
	Fine	.125 - .25	SAND												
	Medium	.25 - .50	SAND	|											
	Coarse	.50 - 1.0	SAND	|											
.04 - .08	Very Coarse	1.0 - 2	SAND												
.08 - .16	Very Fine	2 - 4	GRAVEL	|											
.16 - .22	Fine	4 - 5.7	GRAVEL	||											
.22 - .31	Fine	5.7 - 8	GRAVEL	||											
.31 - .44	Medium	8 - 11.3	GRAVEL	卌 |											
.44 - .63	Medium	11.3 - 16	GRAVEL	卌 卌 |											
.63 - .89	Coarse	16 - 22.6	GRAVEL	卌 卌											
.89 - 1.26	Coarse	22.6 - 32	GRAVEL	卌 卌 卌 |||											
1.26 - 1.77	Very Coarse	32 - 45	GRAVEL	卌 卌 卌 卌 卌											
1.77 - 2.5	Very Coarse	45 - 64	GRAVEL	卌 卌 卌 ||											
2.5 - 3.5	Small	64 - 90	COBBLE	卌 卌 |											
3.5 - 5.0	Small	90 - 128	COBBLE	||											
5.0 - 7.1	Large	128 - 180	COBBLE												
7.1 - 10.1	Large	180 - 256	COBBLE												
10.1 - 14.3	Small	256 - 362	BOULDER												
14.3 - 20	Small	362 - 512	BOULDER												
20 - 40	Medium	512 - 1024	BOULDER												
40 - 80	Large-Vry Large	1024 - 2048	BOULDER												
	Bedrock		BDRK												
						TOTALS →									

Stream Crossing Site Assessment
Reference Reach Data Sheet

DOWL
Revised RDP 08212015

Date: 9/25/19	Project Number:

UPSTREAM REFERENCE REACH:

Channel Cross Section Shape:	Channel Slope:

Δ from Xing	Bankfull Width	Bankfull Depth	Bed Width	Floodplain Width	Riffles		Channel Stability Notes:
					Δ Xing	Length	
	19	1'9"					
	23						
145	16'	~~13~~	13'				
	29		>10-12'				
350'	15'	25"	WSE 13"	>50'			Stability: 1 = lowest (very temporary) 5 = highest (permanent)

Pools			Steps				Ribs		Notes:
Δ Xing	Length	Depth	Δ Xing	Height	Type	Stability	Δ Xing	Stability	

Vegetation:

Bedrock Observed:

DOWNSTREAM REFERENCE REACH:

Channel Cross Section Shape:	Channel Slope:

Δ from Xing	Bankfull Width	Bankfull Depth	Bed Width	Floodplain Width	Riffles		Channel Stability Notes:
					Δ Xing	Length	
							Stability: 1 = lowest (very temporary) 5 = highest (permanent)

Pools			Steps				Ribs		Notes:
Δ Xing	Length	Depth	Δ Xing	Height	Type	Stability	Δ Xing	Stability	

Vegetation:

Bedrock Observed:

Stream Crossing Site Assessment
Reference Reach Data Sheet

DOWL
Revised RDP 08212015

Project: CRWP/USFWS Cordova FP	**Project Number:**
Date: 9/24/19 & 9/25/19 & 9/26/19	**Assessed by:** BMM & HCR Franklin Dekker
Crossing ID: COP 25 - 18 mile east fork	
Weather Conditions: 52°F cloudy	

CROSSING CHARACTERISTICS:

Existing Culvert/Crossing: (2) 6' Round - pipes installed to control beaver debris

Geomorphology/Stream Type/Bedform Features:

C Channel - Beaver dam donstream.

Substrate/Bed Mobility:

high in reference reach - low u/s of culvert + downstream due to backwater effects

Floodplain Characteristics/Entrenchment:

Wide floodplain / low entrenchment

Flow/Velocity Estimates:

less than 1 fps

Tie-in Points:

PEBBLE COUNT

Site:
Party:
Reach:
Date:

Inches	PARTICLE	Millimeters		PARTICLE COUNT 1 XS 1 US 55' US	2	3 XS#2 US 55'	TOT #	ITEM %	% CUM	PEBBLE COUNT Reach: Date: TOT #	ITEM %	% CUM	PEBBLE COUNT Reach: Date: TOT #	ITEM %	% CUM
	Silt / Clay	< .062	S/C				XS#3 DS ~ 500-550'								
	Very Fine	.062 - .125	SAND												
	Fine	.125 - .25	SAND												
	Medium	.25 - .50	SAND												
	Coarse	.50 - 1.0	SAND												
.04 - .08	Very Coarse	1.0 - 2	SAND												
.08 - .16	Very Fine	2 - 4	GRAVEL												
.16 - .22	Fine	4 - 5.7	GRAVEL												
.22 - .31	Fine	5.7 - 8	GRAVEL												
.31 - .44	Medium	8 - 11.3	GRAVEL												
.44 - .63	Medium	11.3 - 16	GRAVEL												
.63 - .89	Coarse	16 - 22.6	GRAVEL												
.89 - 1.26	Coarse	22.6 - 32	GRAVEL												
1.26 - 1.77	Very Coarse	32 - 45	GRAVEL												
1.77 - 2.5	Very Coarse	45 - 64	GRAVEL												
2.5 - 3.5	Small	64 - 90	COBBLE												
3.5 - 5.0	Small	90 - 128	COBBLE												
5.0 - 7.1	Large	128 - 180	COBBLE												
7.1 - 10.1	Large	180 - 256	COBBLE												
10.1 - 14.3	Small	256 - 362	BOULDER												
14.3 - 20	Small	362 - 512	BOULDER												
20 - 40	Medium	512 - 1024	BOULDER												
40 - 80	Large-Vry Large	1024 - 2048	BOULDER												
	Bedrock		BDRK												
						TOTALS →									

THE REFERENCE REACH FIELD BOOK 112

Survey - 400' d/s

Stream Crossing Site Assessment
Reference Reach Data Sheet

DOWL
Revised RDP 08212015

Date: 9/24/19	**Project Number:**

UPSTREAM REFERENCE REACH: FLAGGED FOR SURVEY

Channel Cross Section Shape: | **Channel Slope:**

	Δ from Xing	Bankfull Width	Bankfull Depth	Bed Width	Floodplain Width	Riffles Δ Xing	Riffles Length
XS2	155 u/s Ref	2 : 31 (29')	2'-5"	ws 24'	>50		
XS1	55' us Ref	3-26 (23')	@ STA 7 2'-1"	ws @ 13" 23'	>50'		
	~900' straight line	27-29	2'-11"	27'	>50'		20'
		25'	1'-3"	25'	>50'		

Channel Stability Notes: Upstream beaver dam - broken out - meandering c channel

Stability: 3 — 1 = lowest (very temporary), 5 = highest (permanent)

Pools Δ Xing	Pools Length	Pools Depth	Steps Δ Xing	Steps Height	Steps Type	Steps Stability	Ribs Δ Xing	Ribs Stability	Notes:
	30'	3'-11"							

Vegetation: ALDER / SPRUCE

Bedrock Observed: None

DOWNSTREAM REFERENCE REACH:

Channel Cross Section Shape: | **Channel Slope:**

Δ from Xing	Bankfull Width	Bankfull Depth	Bed Width	Floodplain Width	Riffles Δ Xing	Riffles Length
~550'	34	1'-6"	33	>50		

Channel Stability Notes:

Stability: 1 = lowest (very temporary), 5 = highest (permanent)

Pools Δ Xing	Pools Length	Pools Depth	Steps Δ Xing	Steps Height	Steps Type	Steps Stability	Ribs Δ Xing	Ribs Stability	Notes:
		3'-1"							

Vegetation:

Bedrock Observed:

Stream Crossing Site Assessment
Reference Reach Data Sheet

DOWL
Revised RDP 08212015

Project: CRWP Copper River Highway Fish Passages	**Project Number:**
Date: 9/24/19 & 9/25/19	**Assessed by:** HCR + BMM, Franklin Dekker
Crossing ID: Sher 02	
Weather Conditions: Cloudy 50°F	

CROSSING CHARACTERISTICS:

Existing Culvert/Crossing:
3' Culvert → Remove & harden crossing

Geomorphology/Stream Type/Bedform Features:
Wetland

Substrate/Bed Mobility:
3" of Organics over gravel

Floodplain Characteristics/Entrenchment:
Type E Low Flow wetland - Downstream Beaver Dam - 3'foot drop
2.5' water Drop

Flow/Velocity Estimates:

Tie-in Points:

PEBBLE COUNT

Site:
Party:
Reach:
Date:

Inches	PARTICLE	Millimeters		PARTICLE COUNT 1 (US90')	2	3	TOT #	ITEM %	% CUM	PEBBLE COUNT Reach: Date: TOT #	ITEM %	% CUM	PEBBLE COUNT Reach: Date: TOT #	ITEM %	% CUM
	Silt / Clay	< .062	S/C												
	Very Fine	.062 - .125	SAND												
	Fine	.125 - .25	SAND												
	Medium	.25 - .50	SAND												
	Coarse	.50 - 1.0	SAND												
.04 - .08	Very Coarse	1.0 - 2	SAND												
.08 - .16	Very Fine	2 - 4	GRAVEL	I											
.16 - .22	Fine	4 - 5.7	GRAVEL	IIII											
.22 - .31	Fine	5.7 - 8	GRAVEL	III											
.31 - .44	Medium	8 - 11.3	GRAVEL	卌 II											
.44 - .63	Medium	11.3 - 16	GRAVEL	卌 IIII											
.63 - .89	Coarse	16 - 22.6	GRAVEL	卌 II											
.89 - 1.26	Coarse	22.6 - 32	GRAVEL	卌 卌 III											
1.26 - 1.77	Very Coarse	32 - 45	GRAVEL	卌 IIII											
1.77 - 2.5	Very Coarse	45 - 64	GRAVEL	II											
2.5 - 3.5	Small	64 - 90	COBBLE												
3.5 - 5.0	Small	90 - 128	COBBLE												
5.0 - 7.1	Large	128 - 180	COBBLE												
7.1 - 10.1	Large	180 - 256	COBBLE												
10.1 - 14.3	Small	256 - 362	BOULDER												
14.3 - 20	Small	362 - 512	BOULDER												
20 - 40	Medium	512 - 1024	BOULDER												
40 - 80	Large-Vry Large	1024 - 2048	BOULDER												
	Bedrock		BDRK												
						TOTALS →									

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Stream Crossing Site Assessment
Reference Reach Data Sheet

DOWL
Revised RDP 08212015

Date: 9/24 + 9/25	Project Number:
UPSTREAM REFERENCE REACH: NONE Section taken 275' upstream	
Channel Cross Section Shape:	Channel Slope:

Δ from Xing	Bankfull Width	Bankfull Depth	Bed Width	Floodplain Width	Riffles		Channel Stability Notes:
					Δ Xing	Length	Bankfull + Section marked upstream
90'	5'	10"	4'5"	750'			Stability: 1 = lowest (very temporary) 5 = highest (permanent)

Pools			Steps				Ribs		Notes:
Δ Xing	Length	Depth	Δ Xing	Height	Type	Stability	Δ Xing	Stability	

Vegetation:

Bedrock Observed:

DOWNSTREAM REFERENCE REACH:

Channel Cross Section Shape:	Channel Slope:

Δ from Xing	Bankfull Width	Bankfull Depth	Bed Width	Floodplain Width	Riffles		Channel Stability Notes:
					Δ Xing	Length	
							Stability: 1 = lowest (very temporary) 5 = highest (permanent)

Pools			Steps				Ribs		Notes:
Δ Xing	Length	Depth	Δ Xing	Height	Type	Stability	Δ Xing	Stability	

Vegetation:

Bedrock Observed:

USFWS/CRWP Cordova FP Projects 9/24/19
Luca, Kristi, Franklin, Chantel, Kristin C, Kate, Brad, Me

18 mile Campground - COP 22

- Flow patterns impacted, connected upstream & ds
  - dike upstream?
- groundwater loss @ sites
- flow up @ this visit
- precip. / flashy systems
- Waterfalls up upstream, flows over FS Road through next pipe west
- Kristi says this one has high velocities causing ds scour hole
- do we want to excavate sed. wedge
  → worth re-grading, removing
  → use material within wedge within channel current as substrate
- Kristi, Luca believe still bed load coming down, blowouts, etc.

- Check alignment: update aligment
  - ↳ straighten, skew
- traffic diversion
  - → keep Moose season, fishing, hunting seasons in mind
  - → design vehicles
  - → Road closures
    - DOT no more than 36 hours of closure
      - 25 mile Recommendation
      - → don't use half/half

one eyed pond → gravel pit
Road across → dead end

- keep slopes in mind for raising Road

- DOT wants geotextile under Riprap Road Bank stabilization or use smaller Riprap filter layer

Cop 25 - 18 mile Fork

(2) 8' or 6' Round $\boxed{\text{VAP}}$

- pinks
- mostly coho
- cutthroat

Aug 04 flooding

beaver guard on pipes - thaw pipe?

- beaver dam ds
  - → all ponded, Riffle sequence ds
- ds Riffle crest pretty stable (grade control)
  - * Flag for Willie
  - ↳ take ds of beaver dam
- larger flows (flood)
- lower base flows than cop 22
- very flashy, mountain flows, quick Runoff headwaters, losing Reach
- use floodplain culverts, overflow pipes
  - → use for diversion
- more cover @ this site
  - * downstream (east) haystack pond ditch flowing into keep connectivity
- bedrock under peat ds, left bank stable
- will move ds Right bank
- spawning Riffle ds
- edge of glacial outwash
  - icing, freezing
  - * Ask Bobby ice jam
- us shallow pond 200 yds us. dead tree lake

COP 20   18 mile West Fork

US - open glacier outwash
→ Rapid succession

less flashy
- smaller drainage area
- water was typ. 2' deep in pipe all summer
- undersized
→ doesn't get too overwhelmed
- not large drainage basin
- Refridgerator creek upstream
- less freezing but still freezes
- low fill: may need to raise Road
↳ 300'-500' Road survey

SHER 02 - Recently maintained, bladed

CRWP wasn't aware why this is being done w/ this project

- low water ford crossings (hardened)
- Remove pipe
- winter → freezes, people drive around
- keep ice conditions in mind
- no snow removal on goat camp Road
- use signage?
- prevent people from driving around frozen ford
- get (survey) Riffle elevations to know what elevation to set ford
- BFW off Q2 flows to know Ford width
- all juveniles here
- pressure transducer in this pond (WWA)
- well established beaver pond
- all wetland

NOTES

Box culvert - Mile 17

Moose Meadow - Mile 20

Maybe look @ Sher 1, Cop 9?

*get in touch w/ DOT M&O (Robby)

-beaver grates causing dams, FP issues

*digital globe imagery

*Sher2 WSE shots important

-Document existing Rd condit. to show we aren't worsening or making dangerous (more)

-understanding relic channel vs. proposed section BFW

↓ Raising Rd etc

-no discussion on pipe material

Sher02

- wetland DS beaver dam - waist height

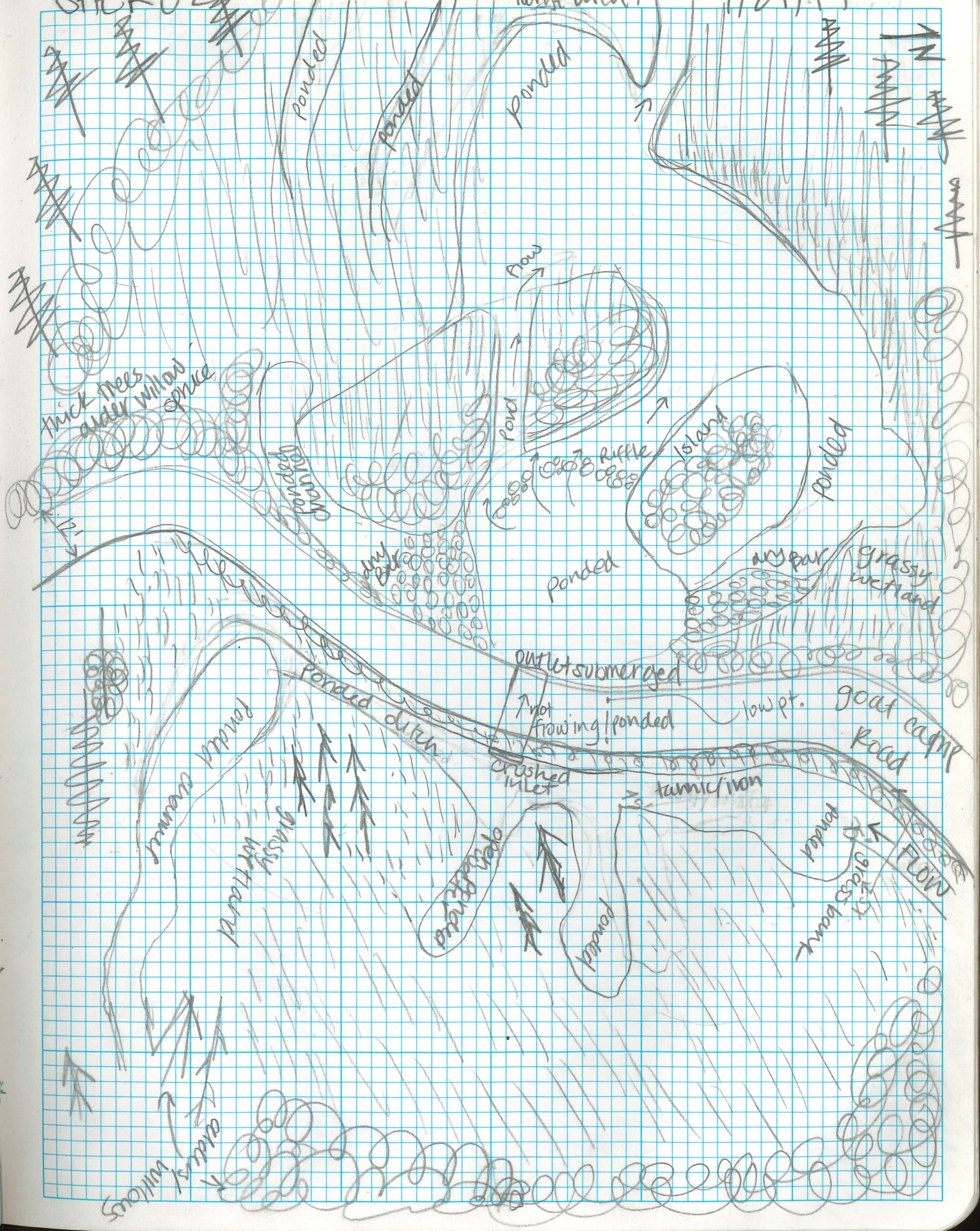
↳ grass

- close Rd.

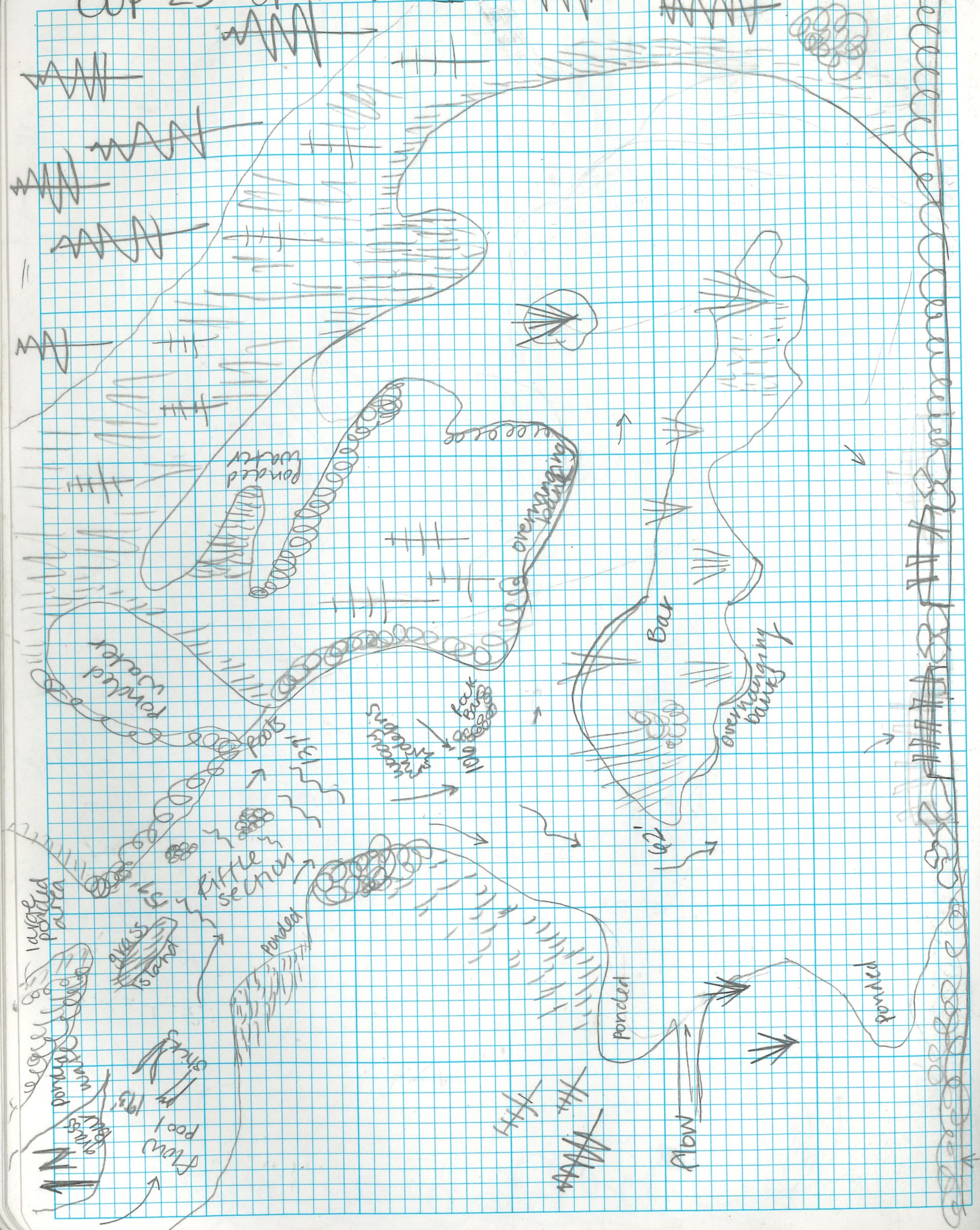
Cop25

- US FS Land

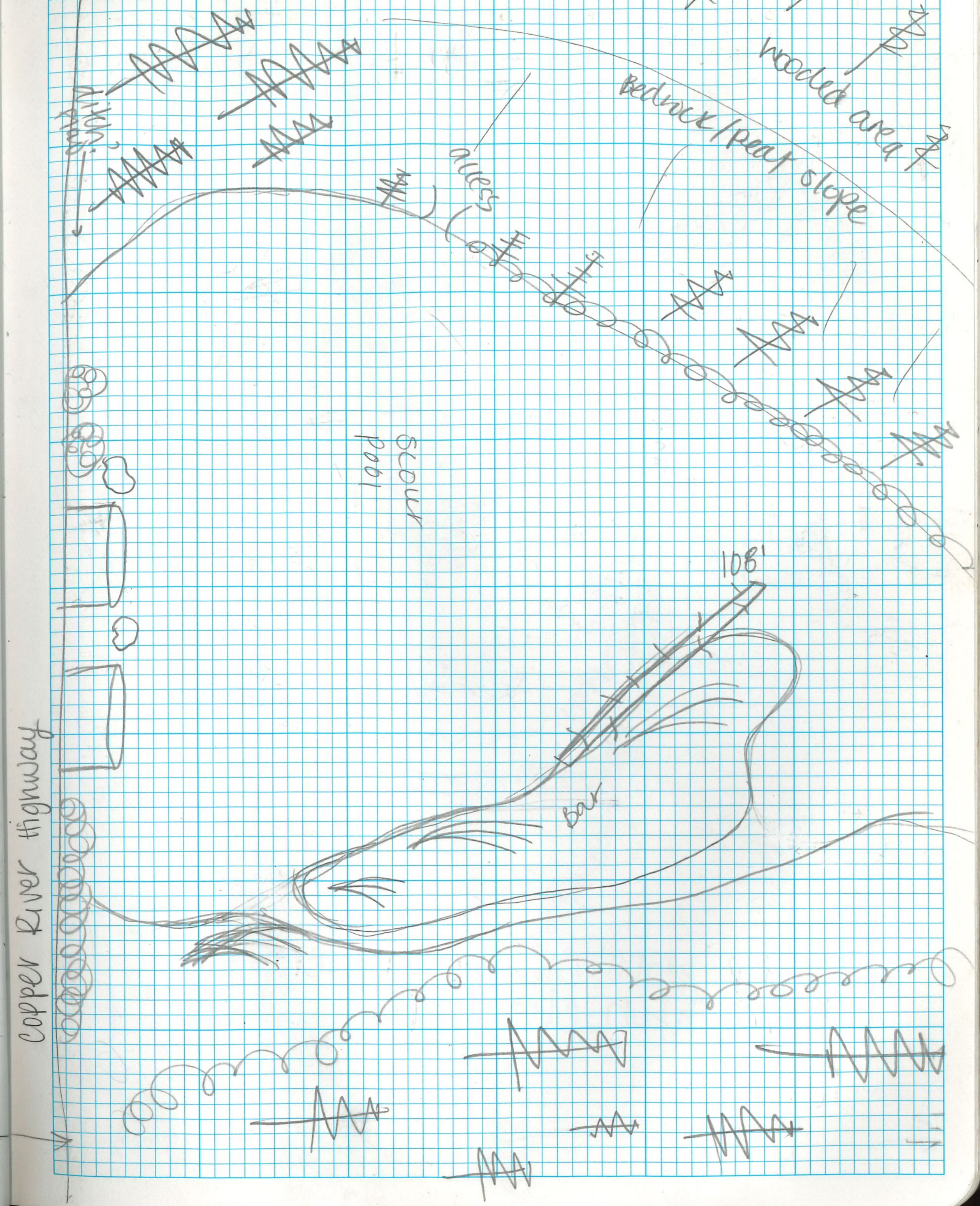
SHER02 9/24/19



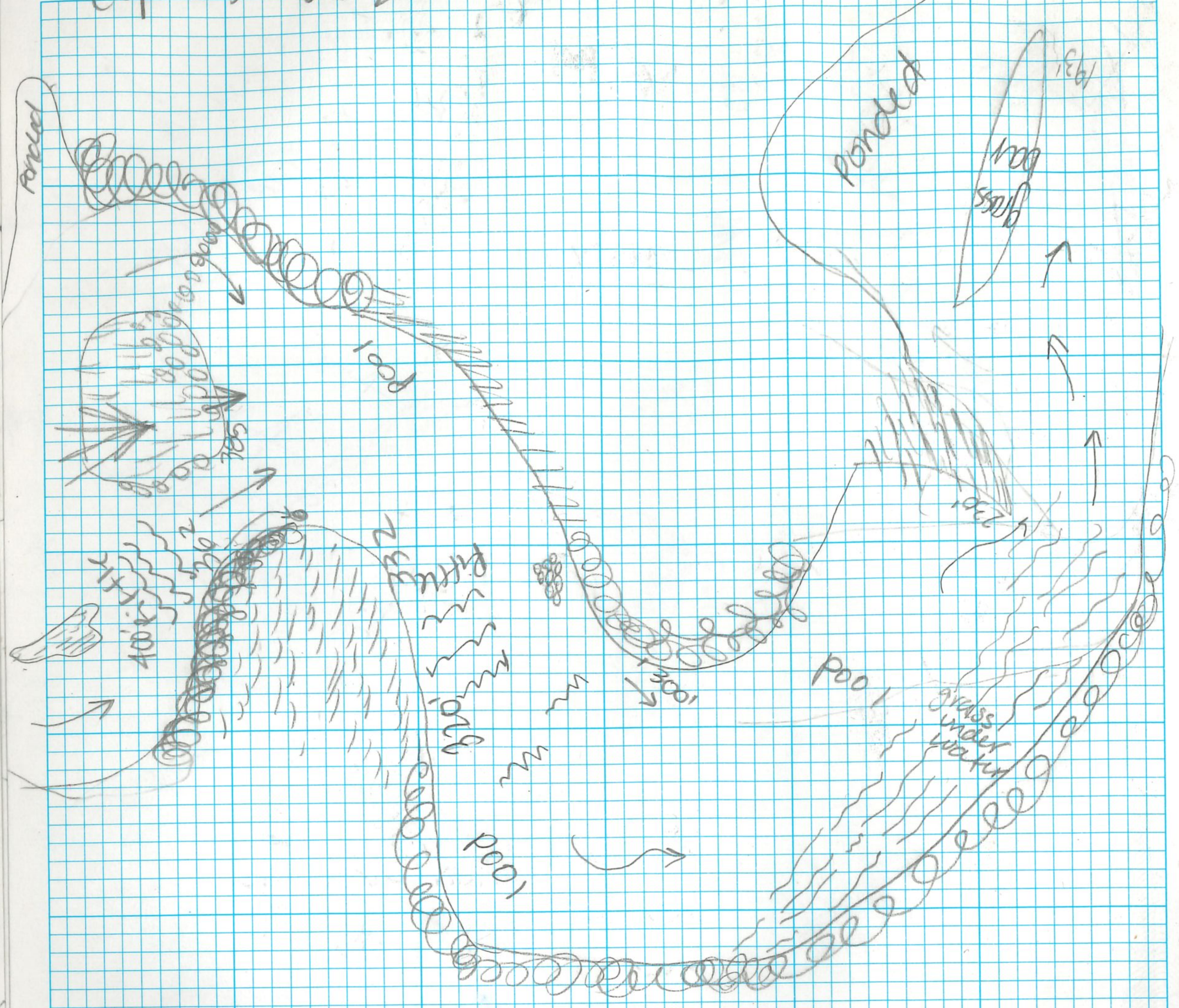
COP 25 - upstream 1



downstream 1



COP 25 - US 2

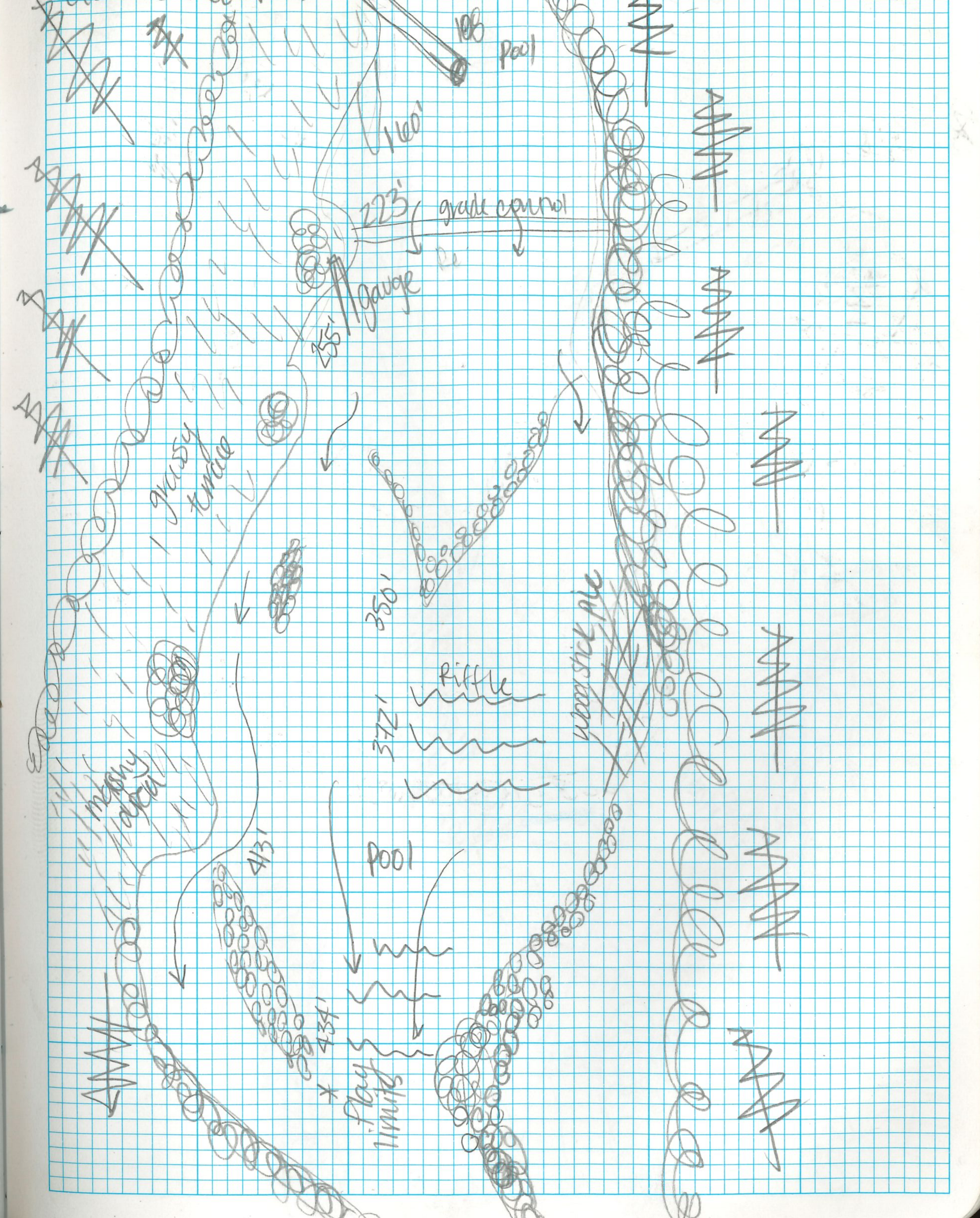


Maybe tie ~500' US into culvert, straighten channel

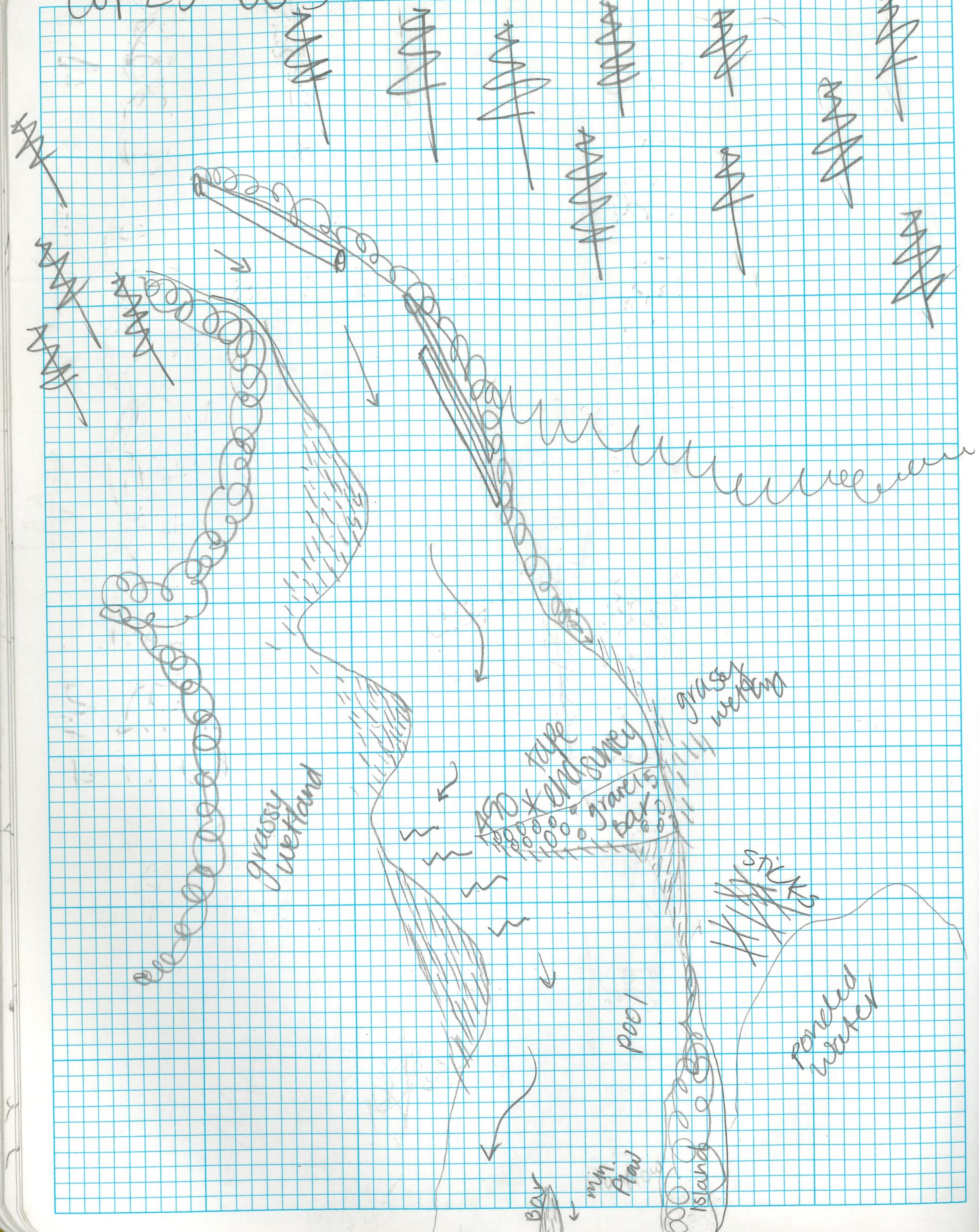
~10-20cfs
9/24/19

N

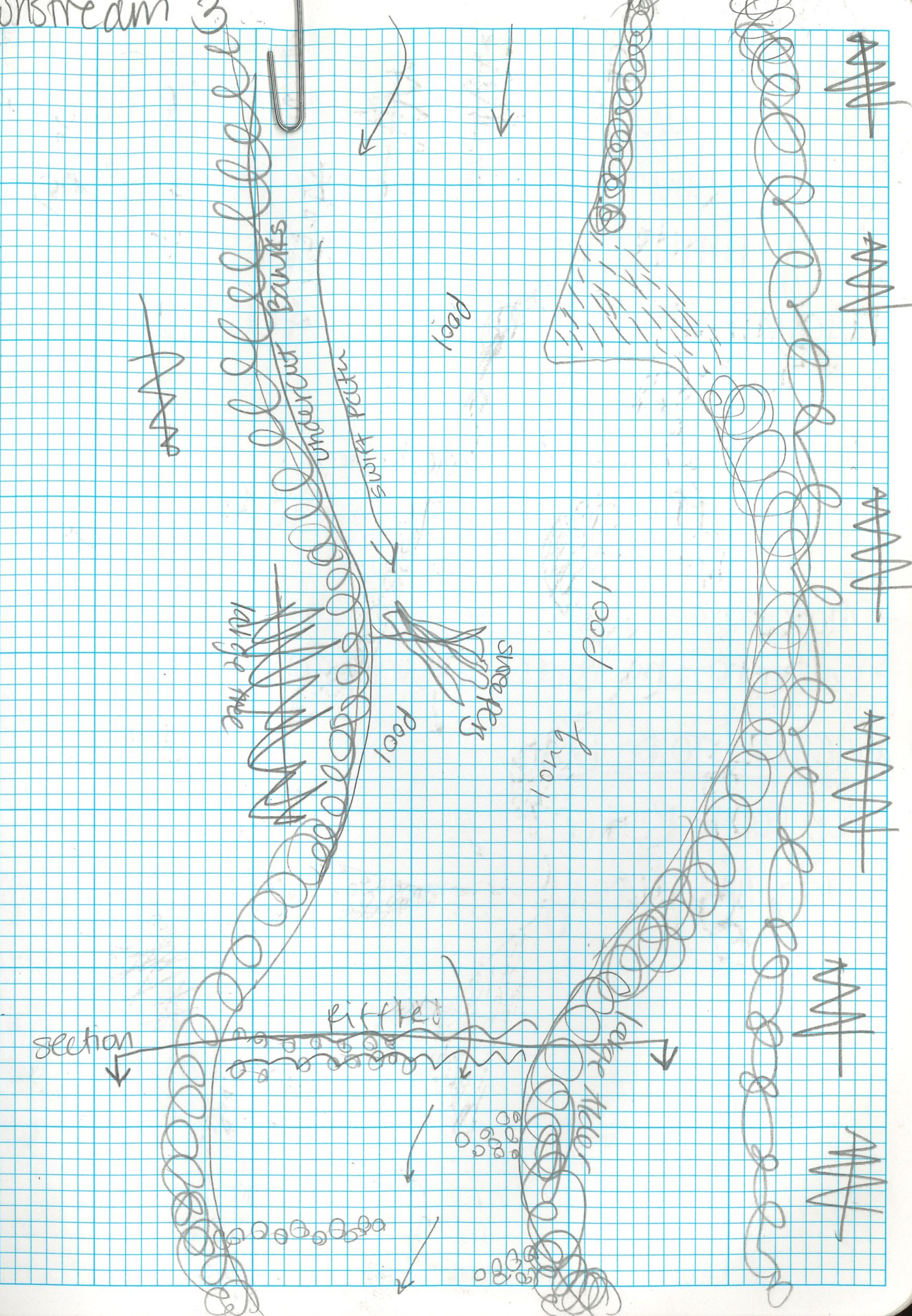
downstream 2



COP 25 - US 3



downstream 3



COP 25 To Do List

- (2) Peb counts US → @ flagged Ref. reach
- (1) Peb count DS → @ good cross section flagged
- flag limits of survey upstream
- flag limits or tell Willie 400' downstream survey
- Double check Ref Reach:
  BFW, BF depth, low flow, tie in pts.
- Photos
- Downstream side ditch (east)

Sher 02 To Do List

- Peb count Riffle?
- Flag for survey

COP 22 TO DO LIST

9/24/19

- Pebble counts upstream
- pick Ref. Reach upstream (cross sections) @ 15' width location

COP20 TODO LIST

250' US & DS survey

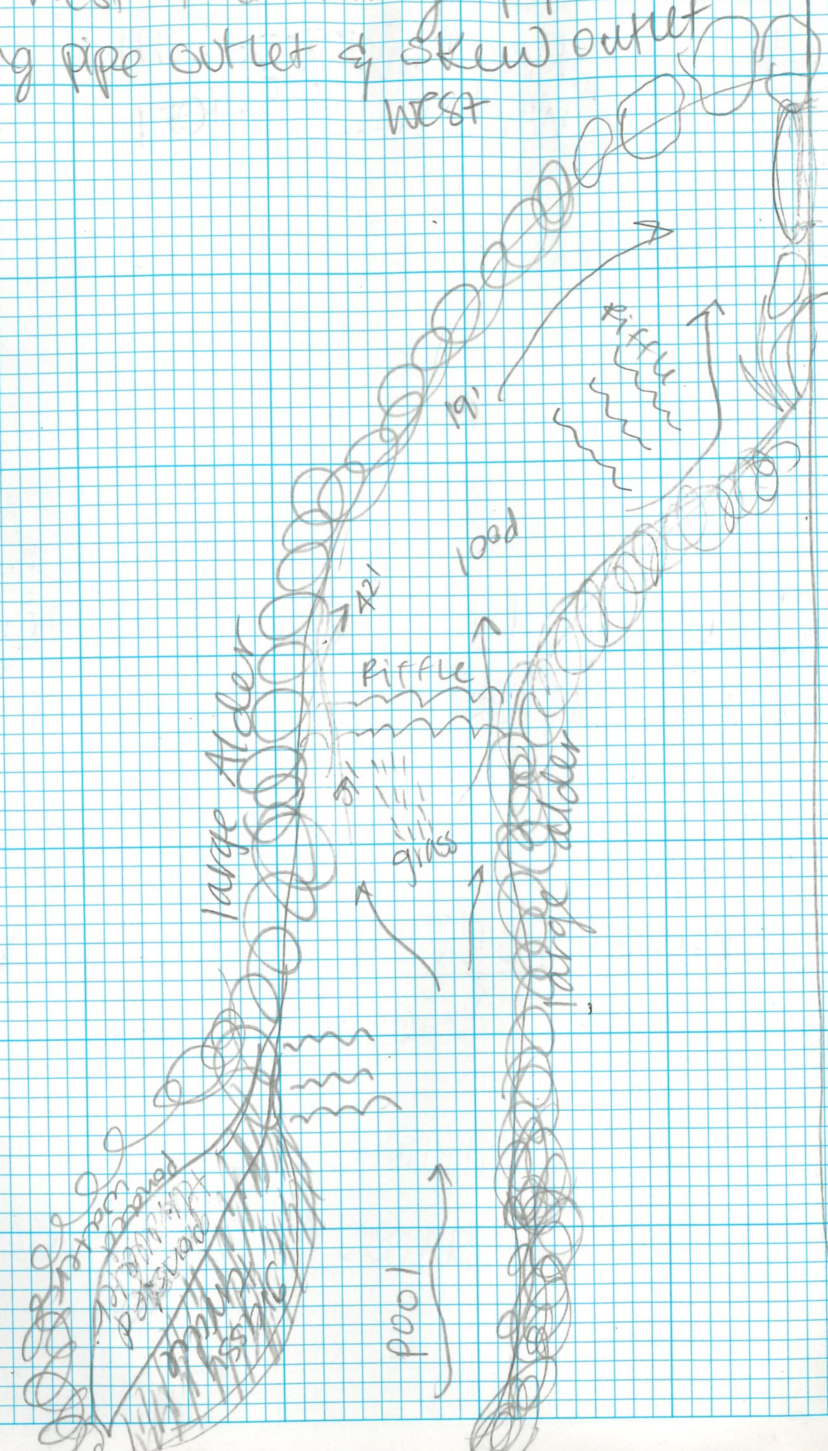
- pebble count US

Questions for DOT

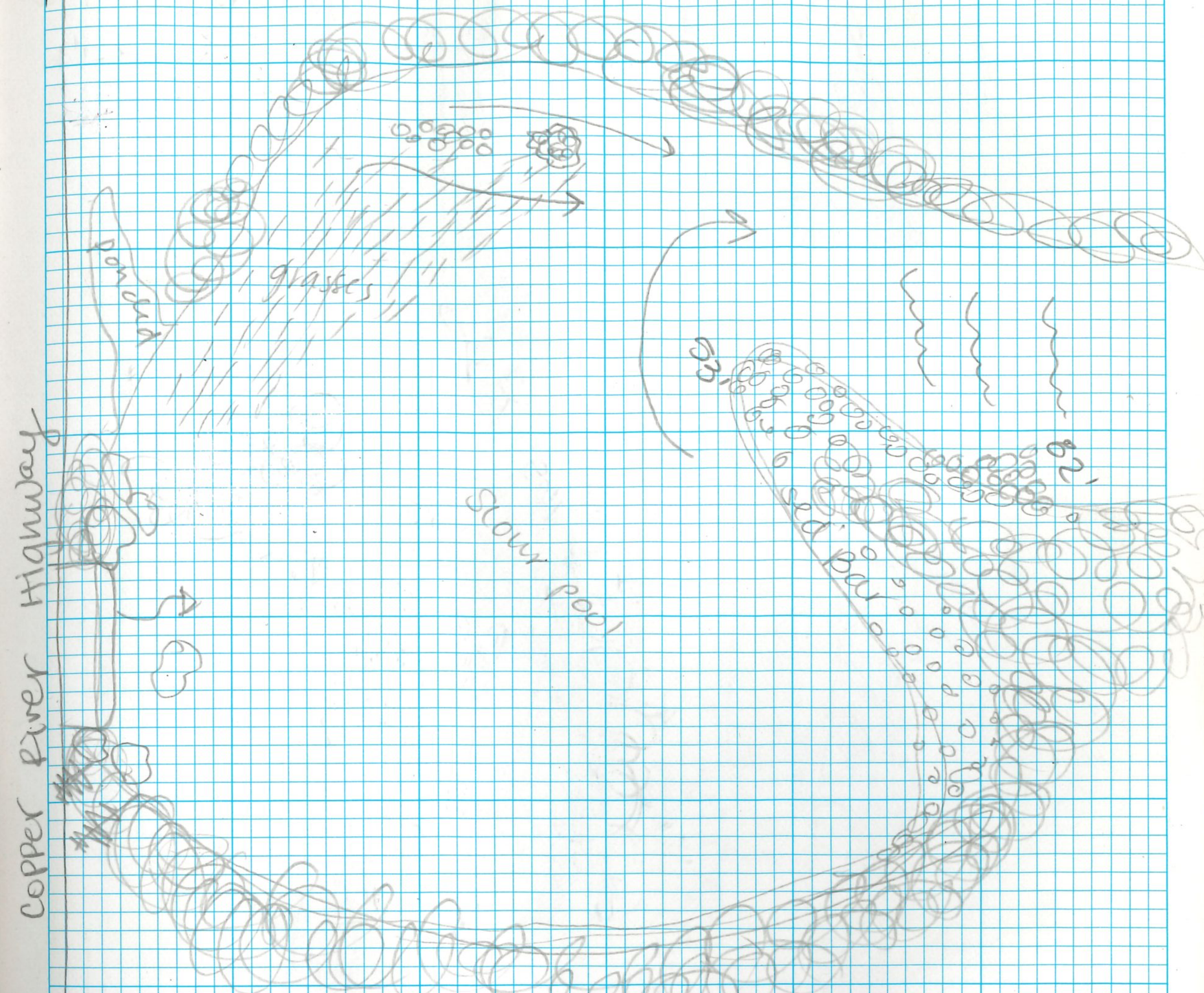
- Icing issues
- Beavers
- Road grading, maintenance
- Road users / closures / design vehicles

COP 22 - upstream 6' Round

put new pipe west of existing pipe or @ existing pipe outlet & skew outlet west

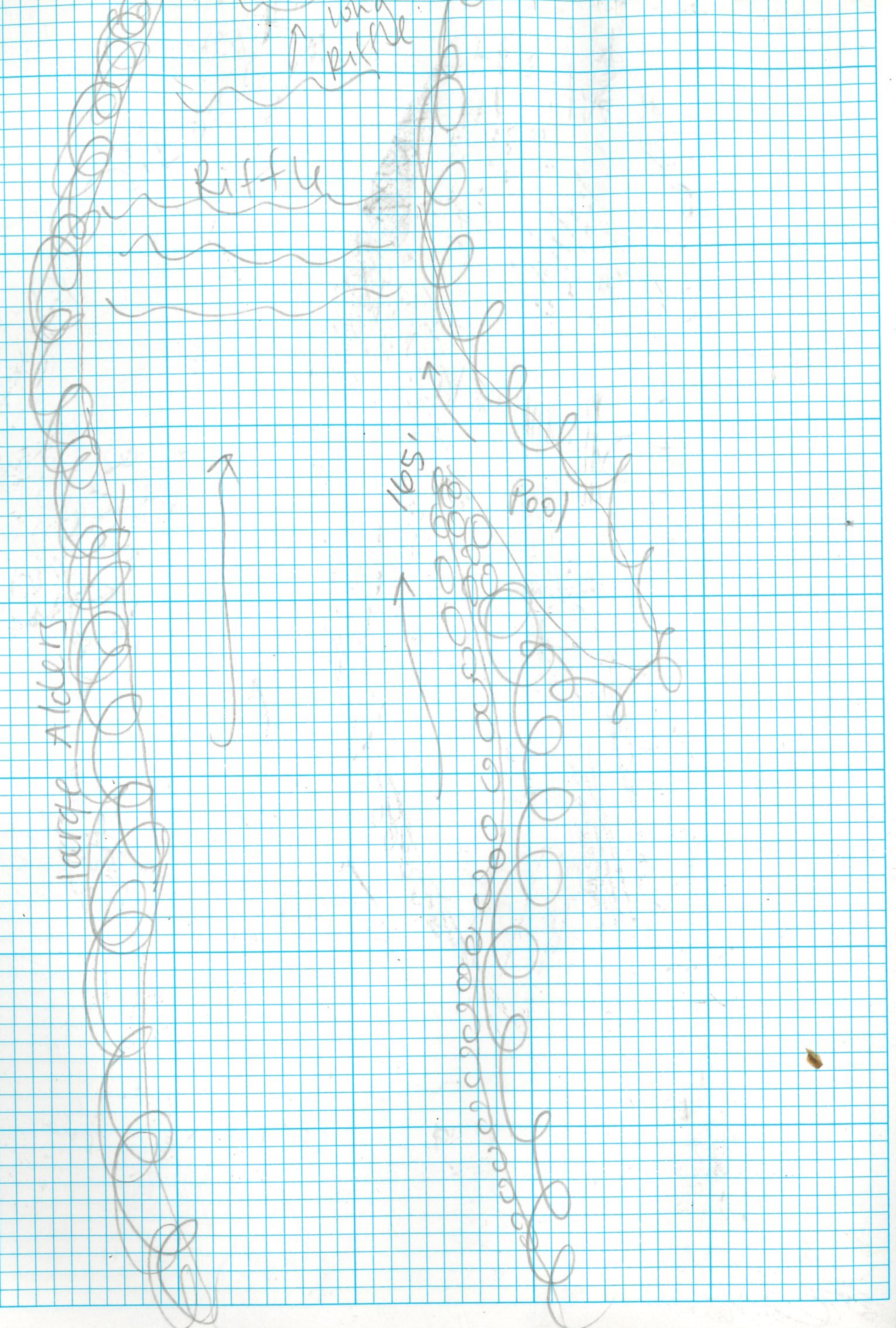


downstream 1

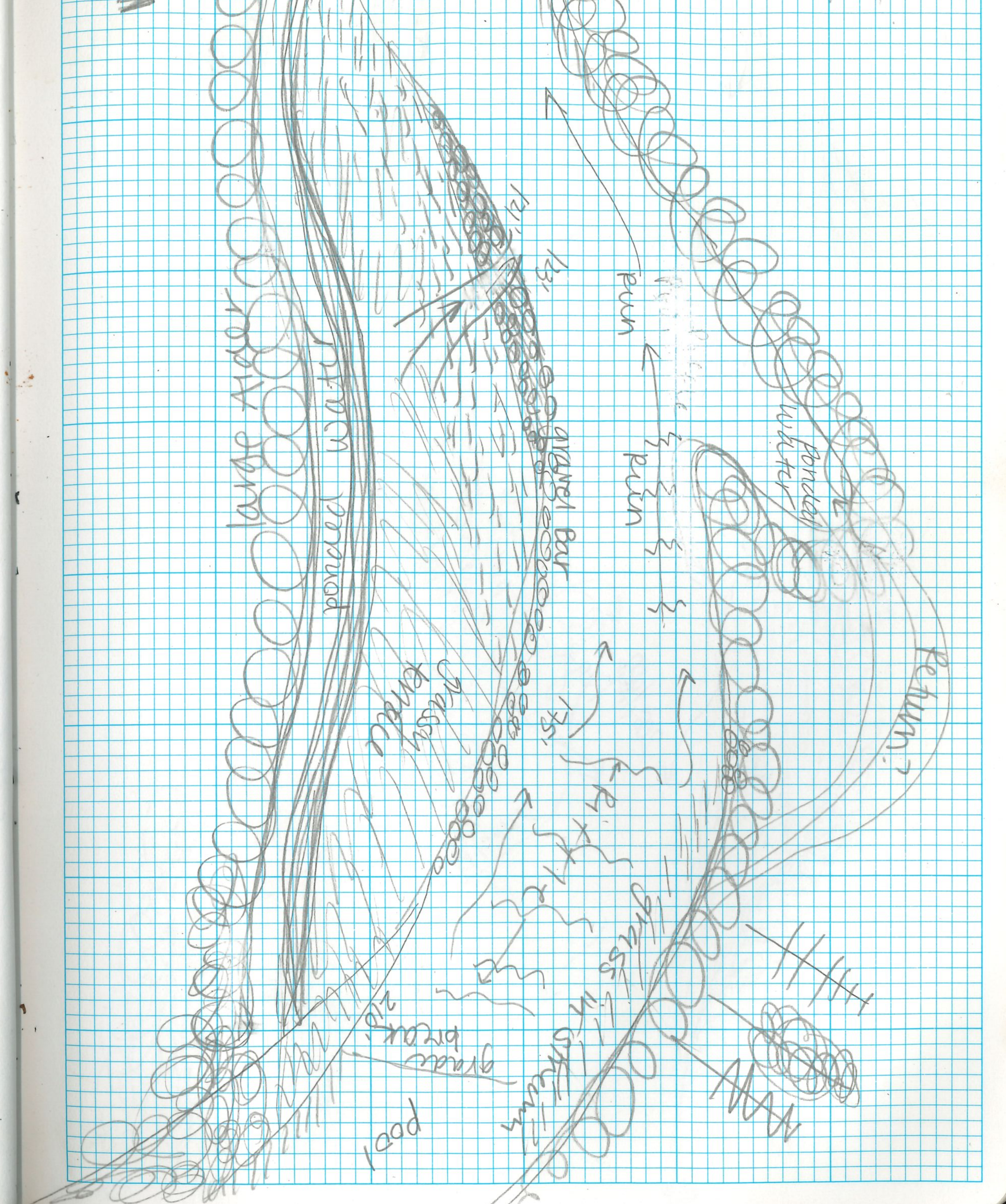


CCR 22 - upstream 2 8/24/19

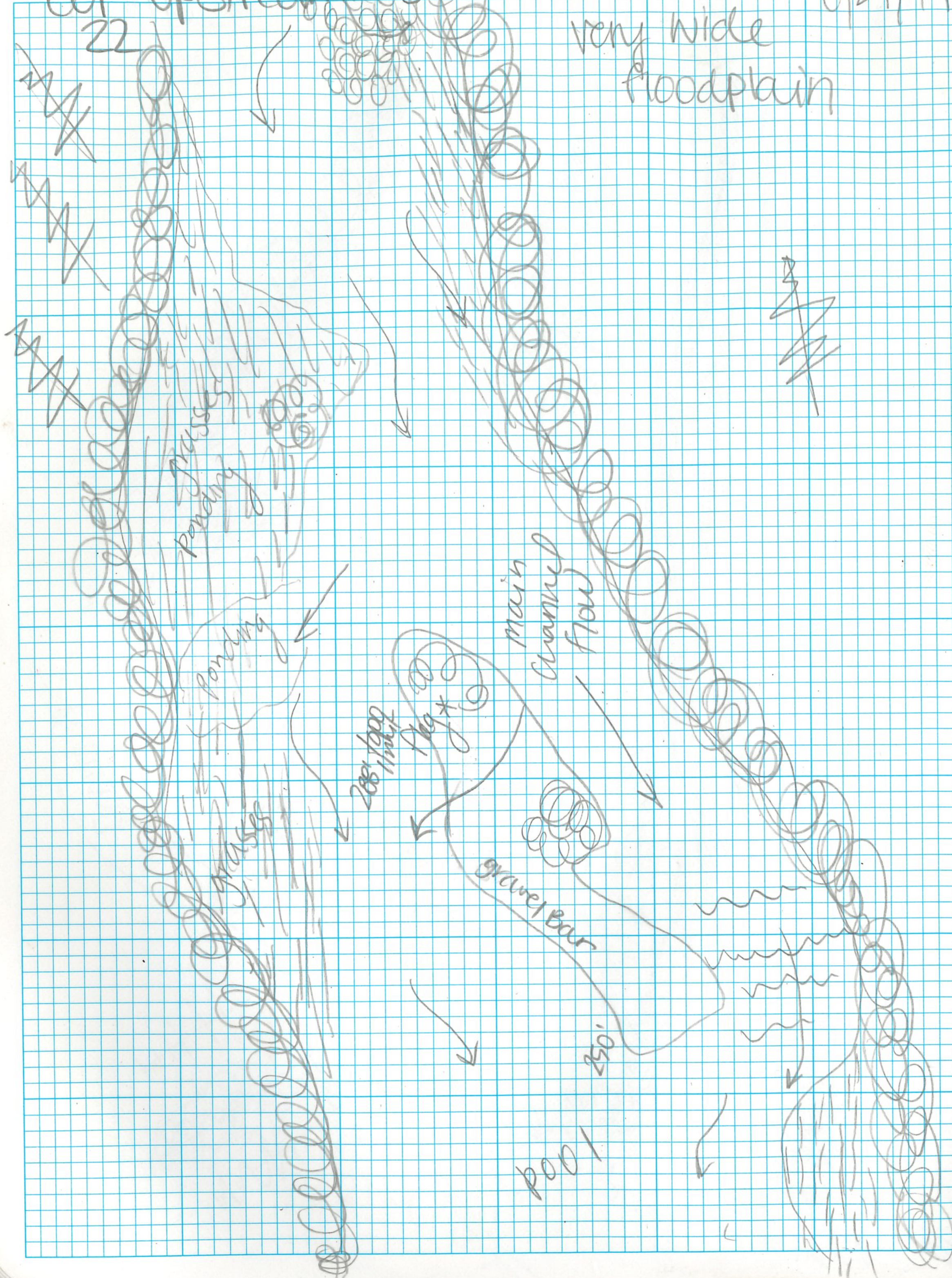
downstream 2



8/24/19



cop upstream 3 8/24/19
22



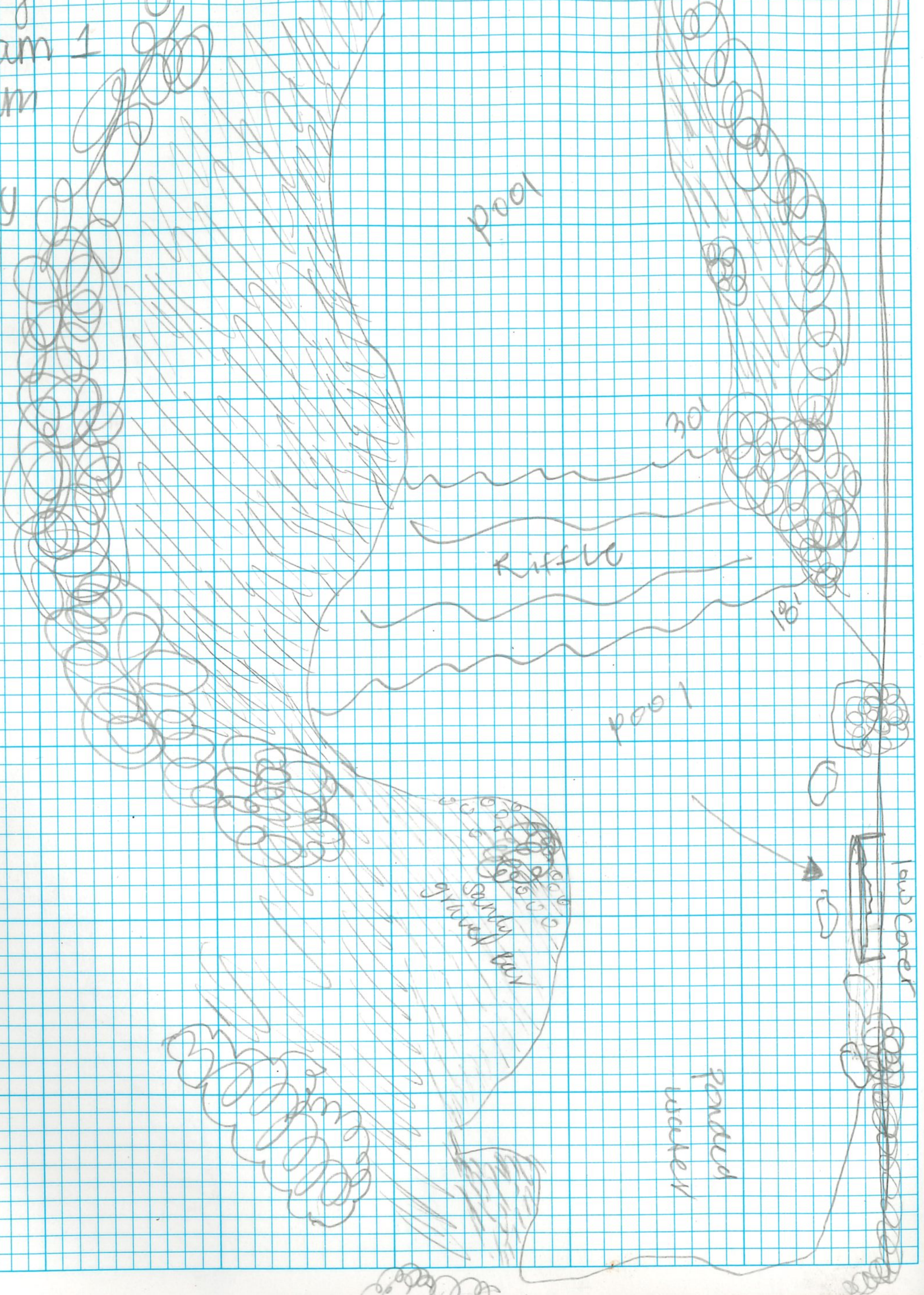
COP 20 - 18 Mile West Fork 9/25/19

Q today = Avg 3 cfs (pump?)

Upstream 1

Beaver dam (old) partially breached US

8 am - 12 pm

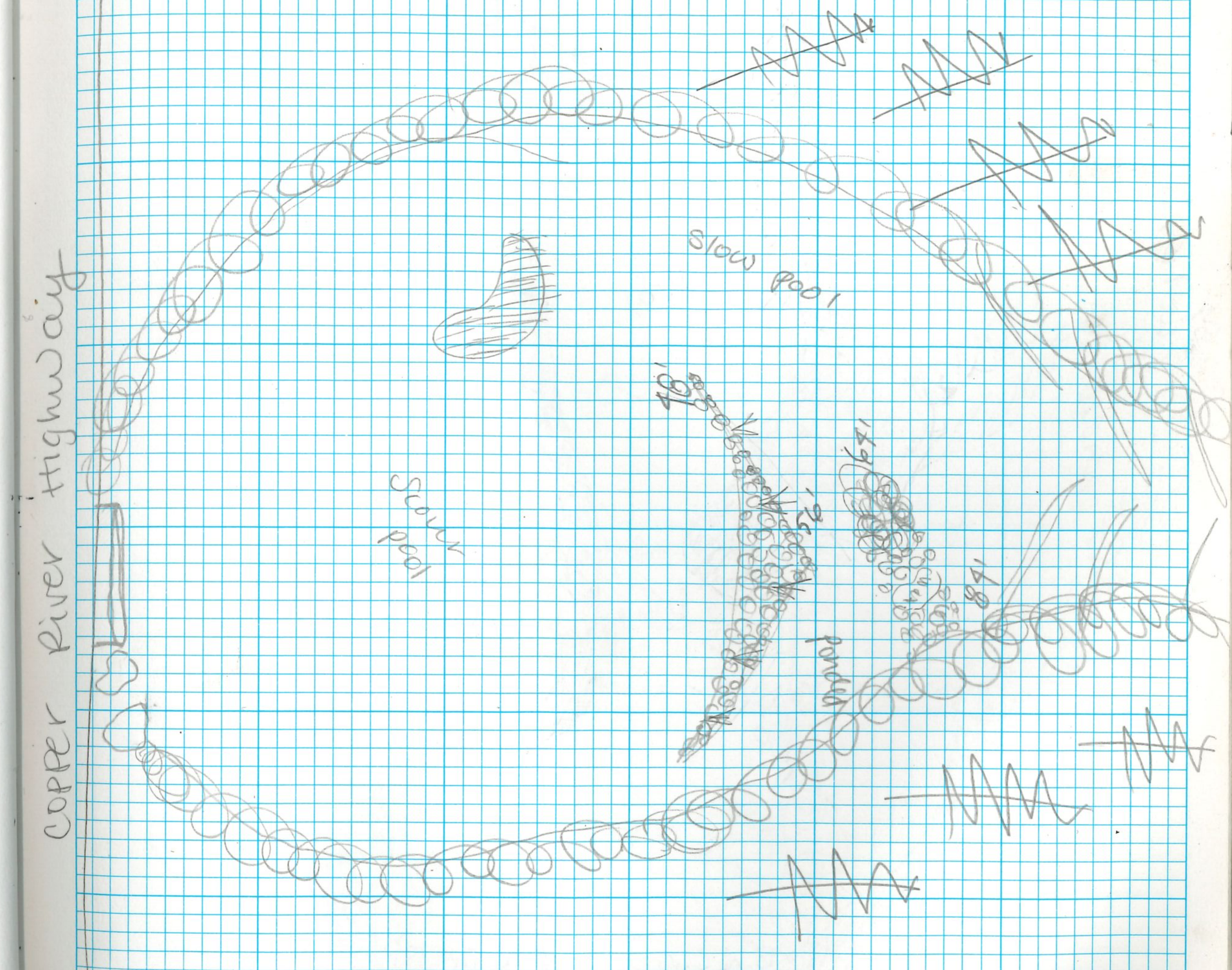


COP 20 downstream 1

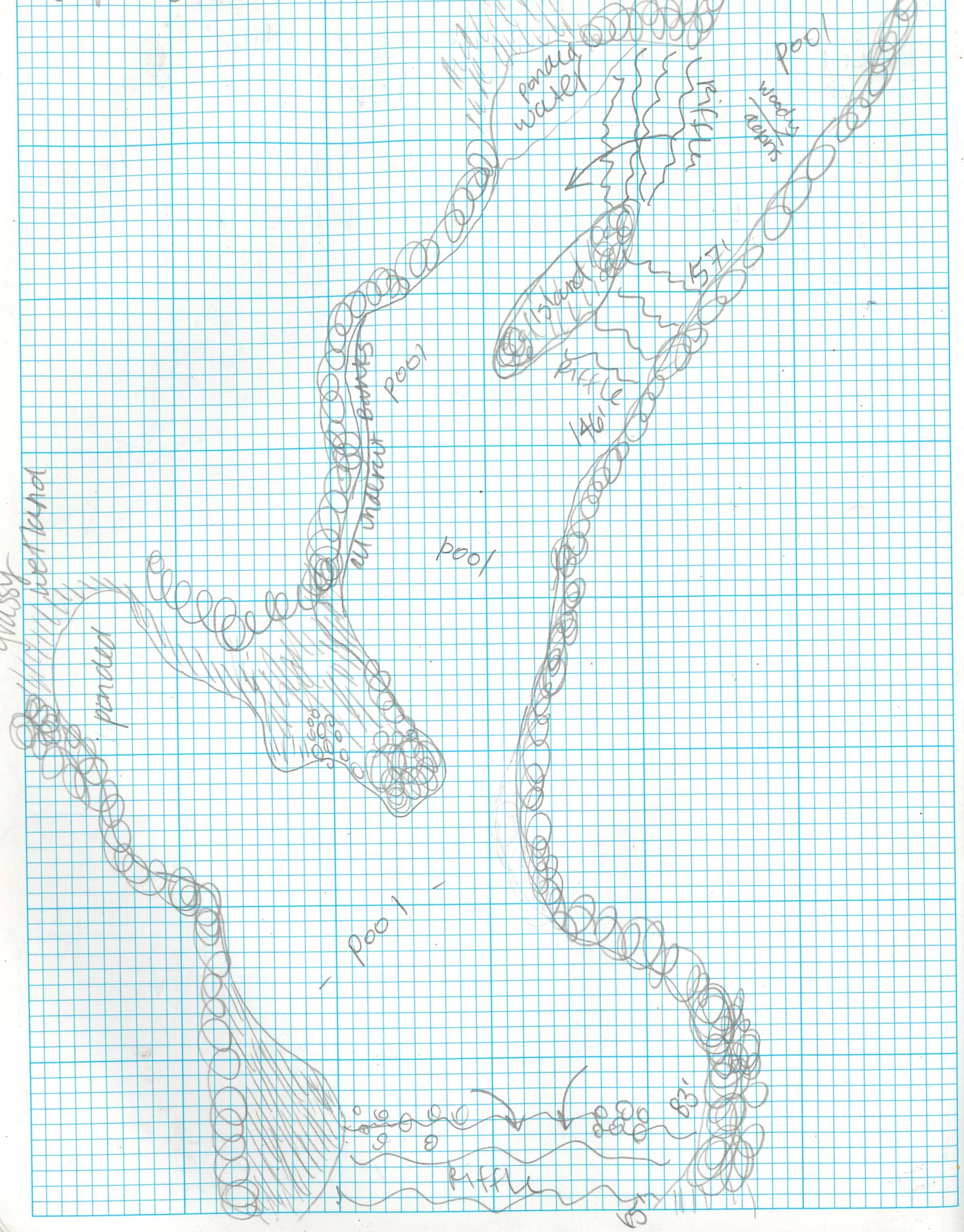
- Realign culvert to east of existing
- use existing for diversion

Peb count 1 @ XS1 ~ 600-700' US inlet

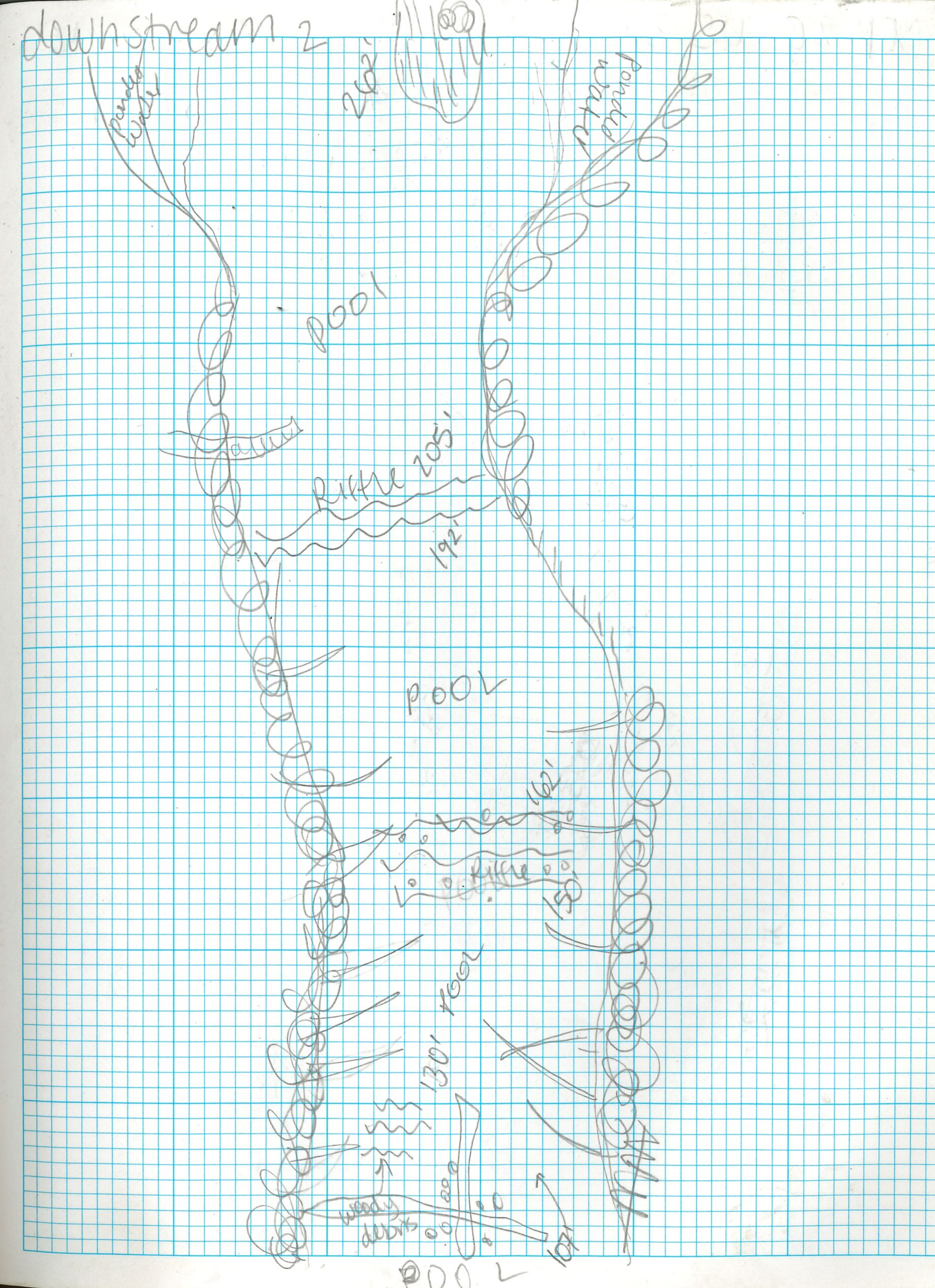
Peb count 2 @ XS2 ~ 800' US @ beaver dam breach US inlet



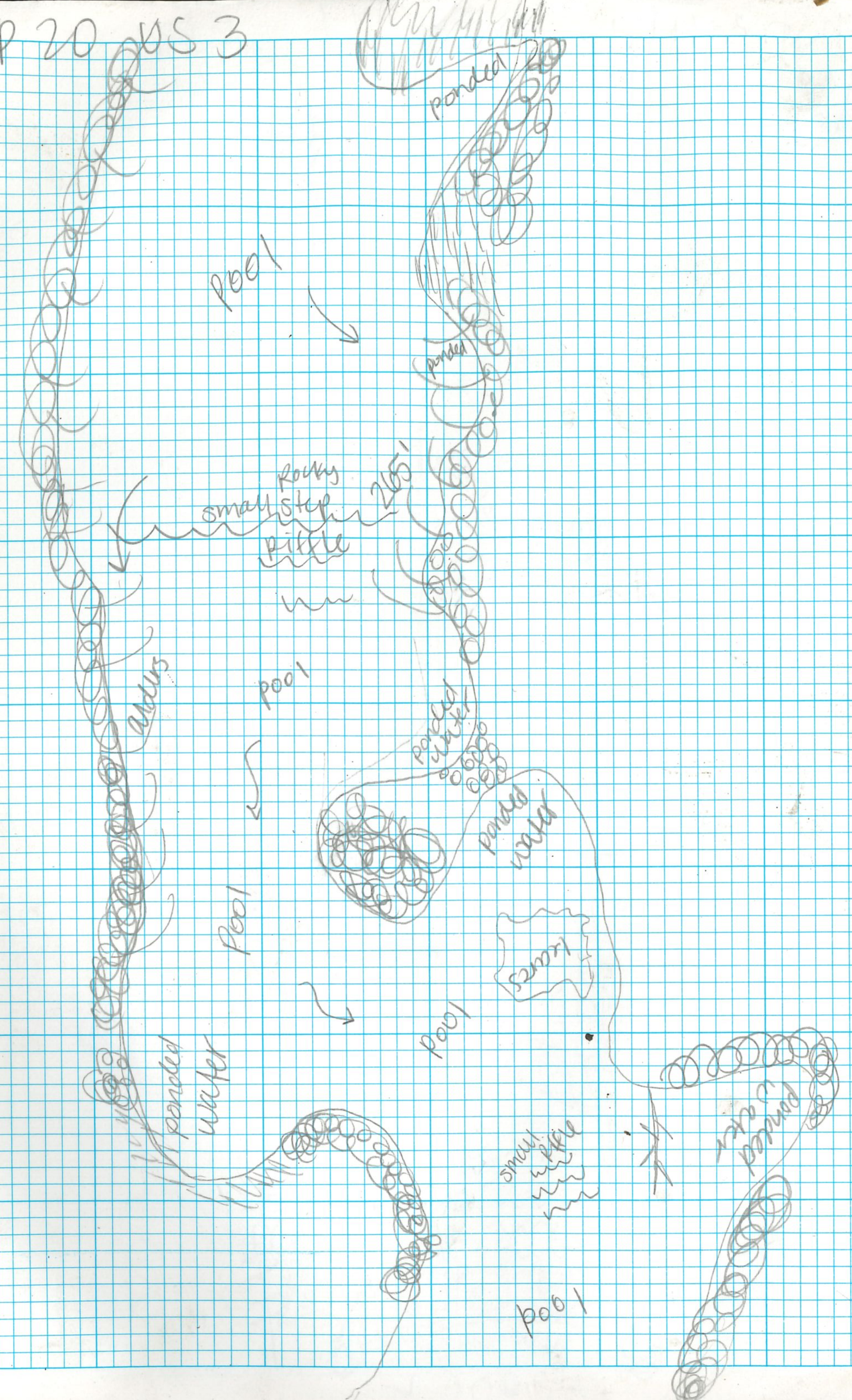
COP 20 US 2



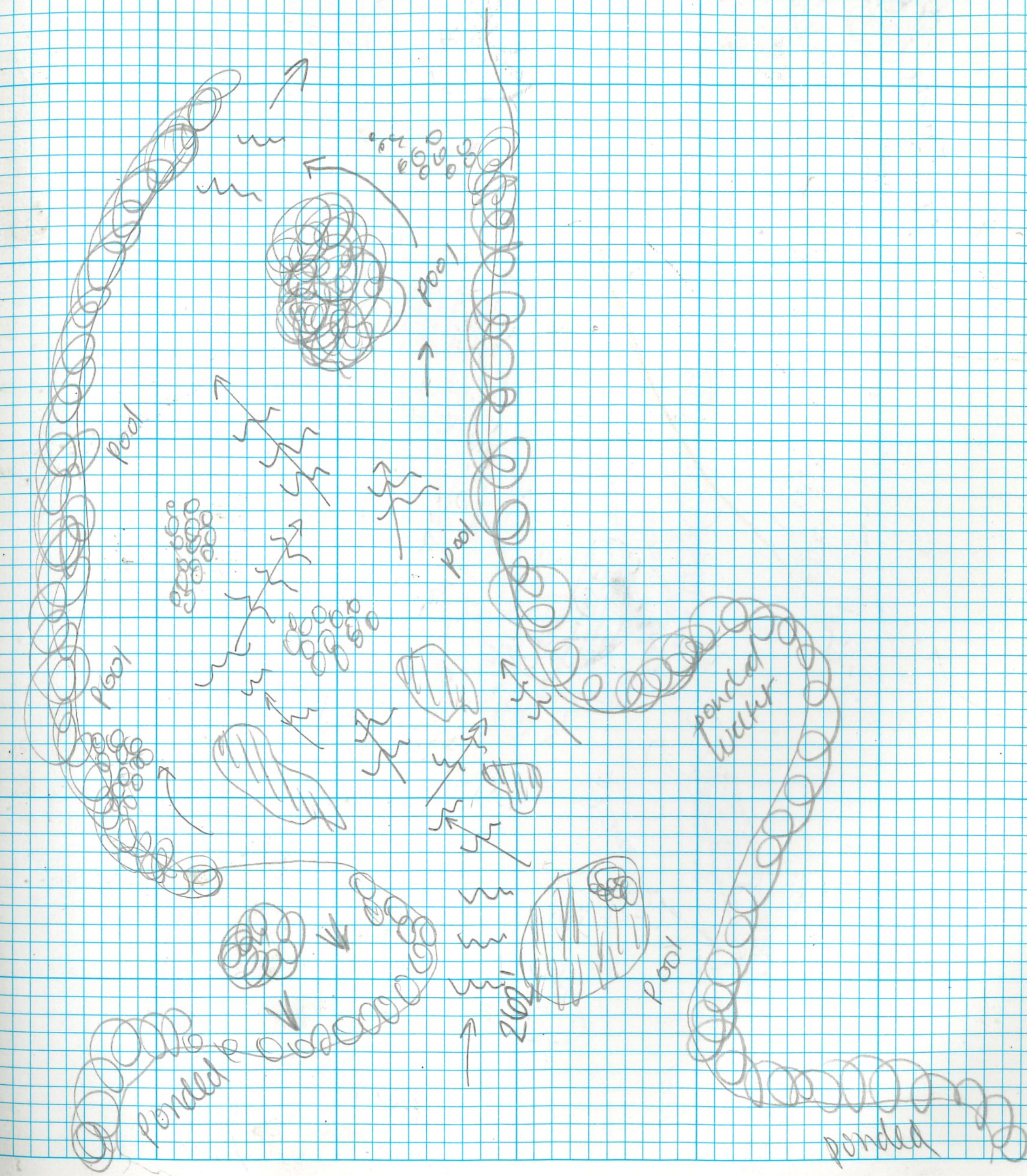
downstream 2



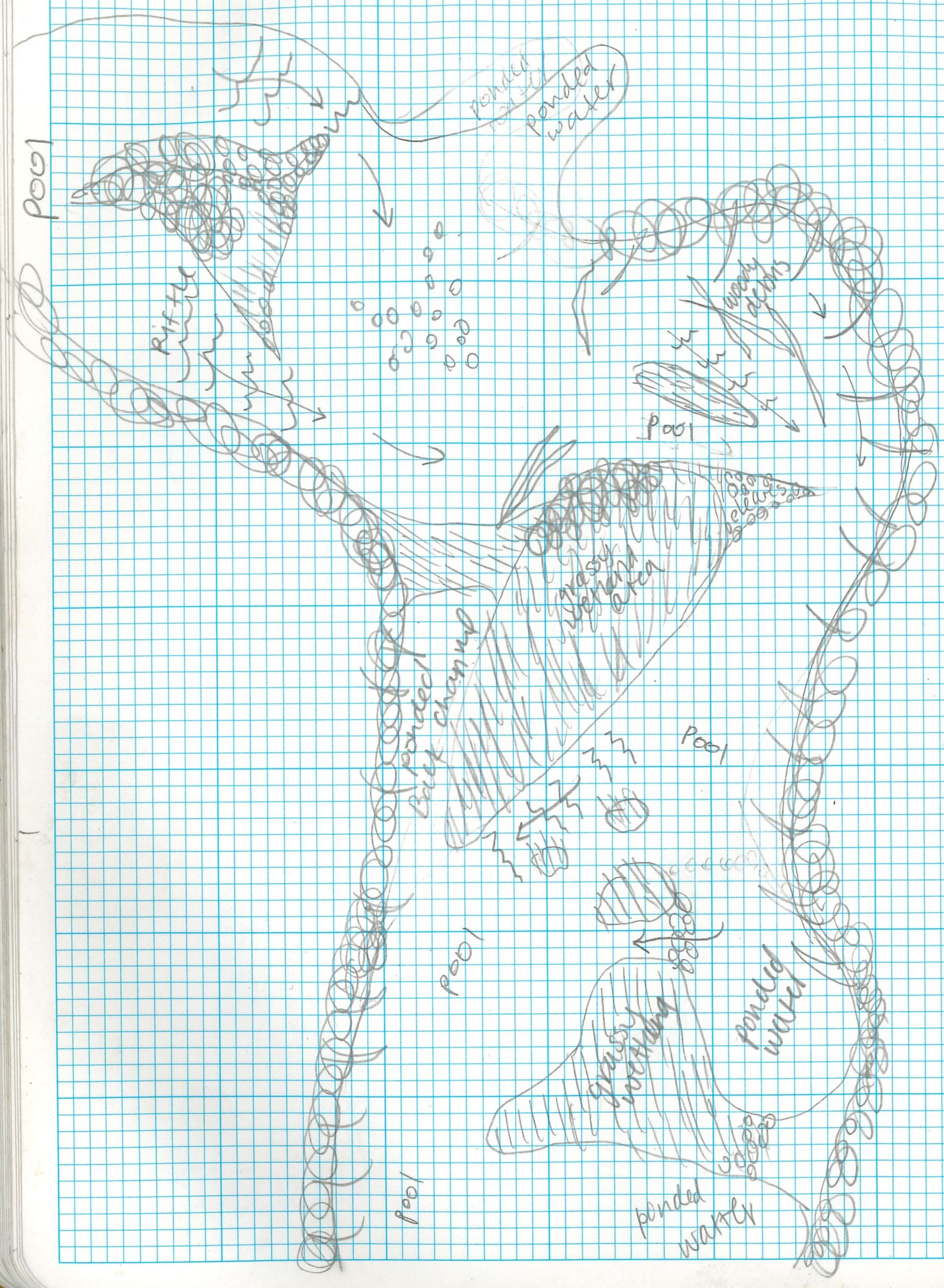
COP 20 US 3



DS 3



COP 20 US 4


Pool
Riffle
ponded water
ponded water
woody debris
Pool
boulders
grassy wetland area
ponded/back channel
Pool
Pool
ponded water
grassy wetland
Pool
ponded water

COP 20 upstream survey info for Willie

- 250' topo (survey) flagged upstream/ds
  - WSE
  - BFW/Depth
  - Riffle/Pools, etc.

8/25 8am-12pm

- (2) X-sections ~ 600'-700' US
  800?

longitudinal profile US from flagging ~~[illegible]~~ to beaver dam, cross section #2

8/25 12:20-12:50

Sher 02 → 275' US: Xsection & topo from culvert

- US/DS flagged for survey (topo)
- Roadway flagged 300'-500'

8/25 1:00-2:00pm

COP 22

- US: 300' topo (survey) flagged
- 1 XS @ ~ 350' US
  maybe just move survey limits US of Xsection @ ~350'
- DS: 300' topo (survey) flagged

* Buy Ray tape 300'

COP 25 survey info 2:15-4:00? 9/25/19

- US: 400' ~ 450' to grass/gravel Bar US. flagged
  topo survey
- DS: 400' → 434' flagged

9/26/19 8-9am

- 2 flagged Ref Reach US start & stop ~ 1000' US flagged @ eagle lake, Bend in stream
- 1 flagged ds
  → DS of 450' flagged end survey → Ref. Reach long profile, etc. 200' end @ Riffle
- (2) X-sections (flagged)
  US 155' #2
  55' #1
  US of start of Ref. Reach @ Bend/lake

DS (1)
X-section flagged → Just x-section
→ get long profile from end survey 190' to DS X-section

- May need raft for survey @ DS Pool

COP 33-37 → designed as 16' saddle glacier

APPENDIX B: SUBSTRATE DESIGN

New Stream Channel Design (Culvert, Rock Ramp) - COP 20

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

YELLOW ARE INPUTS				
Safety Factor	**1.5**			
Stability Coefficient for Incipient Failure	0.3	(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	2	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	4.3774	ft/s from 100-year event avg. velocity in pipe		Approximate depth average flow for outlet velocities
Side Slope correction factor	1			
Gravitational Acceleration	32.2	ft/s^2		
D85/D15	5	(1.7-5.2)		
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	0.1	ft	1.0	inches
D30	0.1	ft	2.0	inches
D50	0.2	ft	3.0	inches
D85	0.3	ft	4.0	inches
D100	0.4	ft	5.0	inches

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

Fuller-Thompson Estimating for Maximum Density: D100 (inches) **12.0**

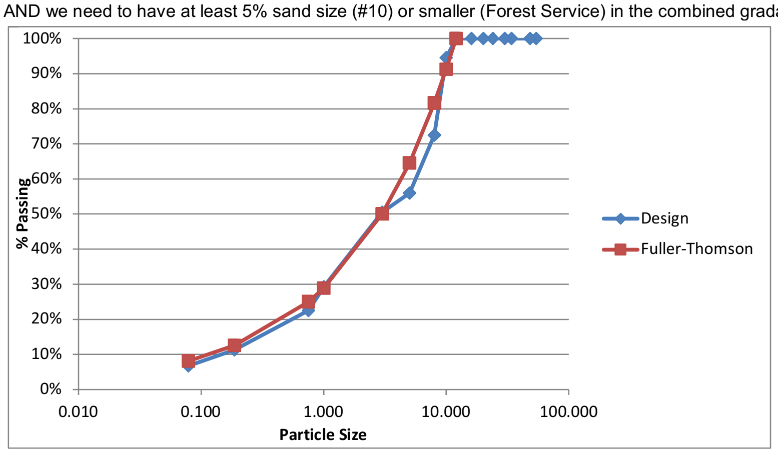
Method Adapted from US Forest Service Stream Simulation Guidelines D30 5.0 | Stability (D30): **OK**

D30 Req'd 2.0

YELLOW ARE INPUTS		COARSE MATERIAL					FINES	
		Type IV Rip Rap	Type III Rip Rap	Type II Rip	Type I Rip Ra	FA	Combined %	F-T EQN
	RELATIVE % =	0	0	0.0000	0.5500	0.4500	1.0000	
Size (inches)	Sieve Size	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing
54	54 in	1.00	1.00	1.00	1.00	1.00	100%	212%
48	48 in	0.90	1.00	1.00	1.00	1.00	100%	200%
34	34 in	0.50	1.00	1.00	1.00	1.00	100%	168%
30	30 in	0.35	0.90	1.00	1.00	1.00	100%	158%
24	24 in	0.25	0.50	1.00	1.00	1.00	100%	141%
20	20 in	0.15	0.15	0.90	1.00	1.00	100%	129%
16	16 in	0.00	0.00	0.50	1.00	1.00	100%	115%
12	12 in	0.00	0.00	0.15	1.00	1.00	100%	100%
10	10 in	0.00	0.00	0.00	0.90	1.00	95%	91%
8	8 in	0.00	0.00	0.00	0.50	1.00	73%	82%
5	5 in	0.00	0.00	0.00	0.20	1.00	56%	65%
3	3 in	0.00	0.00	0.00	0.10	1.00	51%	50%
1	1 in	0.00	0.00	0.00	0.00	0.65	29%	29%
0.75	0.75 in	0.00	0.00	0.00	0.00	0.50	23%	25%
0.187	#4	0.00	0.00	0.00	0.00	0.25	11%	12%
0.0787	#10 Sand	0.00	0.00	0.00	0.00	0.15	7%	8%

FA: Porous Backfill

Gradation values should be within +/-5% of this gradation (Rice)
AND we need to have at least 5% sand size (#10) or smaller (Forest Service) in the combined gradation



DATA for Graph & Fuller-Thomson Eqn

Size (in)	Combined % pa	F-T equation
54.000	100%	212%
48.000	100%	200%
34.000	100%	168%
30.000	100%	158%
24.000	100%	141%
20.000	100%	129%
16.000	100%	115%
12.000	100%	100%
10.000	95%	91%
8.000	73%	82%
5.000	56%	65%
3.000	51%	50%
1.000	29%	29%
0.750	23%	25%
0.187	11%	12%
0.079	7%	8%

New Stream Channel Design (Culvert, Rock Ramp) - COP 22

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

YELLOW ARE INPUTS		
Safety Factor	**1.5**	
Stability Coefficient for Incipient Failure	0.3	(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	2.65	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	6.2952	ft/s from 100-year event avg. velocity in pipe
Side Slope correction factor	1	
Gravitational Acceleration	32.2	ft/s^2
D85/D15	5	(1.7-5.2)
D50/D30	2	

Approximate depth-average flow for outlet velocities

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	0.2	ft	3.0	inches
D30	0.2	ft	3.0	inches
D50	0.4	ft	6.0	inches
D85	0.7	ft	9.0	inches
D100	0.8	ft	11.0	inches

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

Fuller-Thompson Estimating for Maximum Density: D100 (inches) 12.0

Method Adapted from US Forest Service Stream Simulation Guidelines D30 5.0

D30 Req'd 3.0

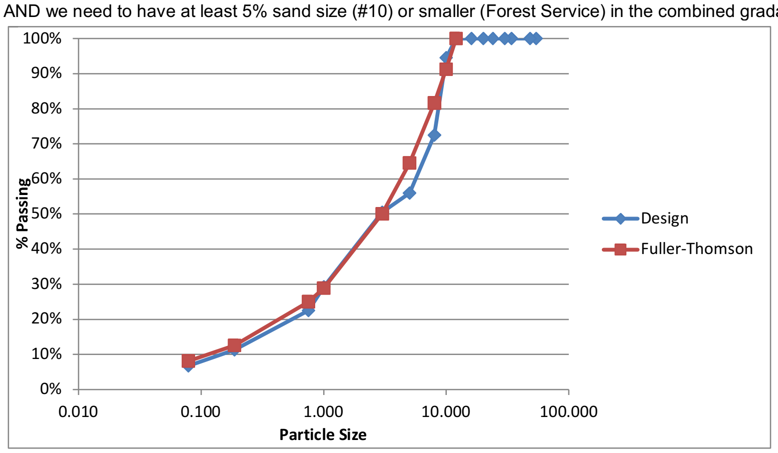
Stability (D30): OK

YELLOW ARE INPUTS

		COARSE MATERIAL					FINES	
		Type IV Rip Rap	Type III Rip Rap	Type II Rip	Type I Rip Ra	FA	Combined %	F-T EQN
	RELATIVE % =	0	0	0.0000	0.5500	0.4500	1.0000	
Size (inches)	Sieve Size	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing
54	54 in	1.00	1.00	1.00	1.00	1.00	100%	212%
48	48 in	0.90	1.00	1.00	1.00	1.00	100%	200%
34	34 in	0.50	1.00	1.00	1.00	1.00	100%	168%
30	30 in	0.35	0.90	1.00	1.00	1.00	100%	158%
24	24 in	0.25	0.50	1.00	1.00	1.00	100%	141%
20	20 in	0.15	0.15	0.90	1.00	1.00	100%	129%
16	16 in	0.00	0.00	0.50	1.00	1.00	100%	115%
12	12 in	0.00	0.00	0.15	1.00	1.00	100%	100%
10	10 in	0.00	0.00	0.00	0.90	1.00	95%	91%
8	8 in	0.00	0.00	0.00	0.50	1.00	73%	82%
5	5 in	0.00	0.00	0.00	0.20	1.00	56%	65%
3	3 in	0.00	0.00	0.00	0.10	1.00	51%	50%
1	1 in	0.00	0.00	0.00	0.00	0.65	29%	29%
0.75	0.75 in	0.00	0.00	0.00	0.00	0.50	23%	25%
0.187	#4	0.00	0.00	0.00	0.00	0.25	11%	12%
0.0787	#10 Sand	0.00	0.00	0.00	0.00	0.15	7%	8%

FA: Porous Backfill

Gradation values should be within +/-5% of this gradation (Rice)
AND we need to have at least 5% sand size (#10) or smaller (Forest Service) in the combined gradation



DATA for Graph & Fuller-Thomson Eqn

Size (in)	Combined % pa	F-T equation
54.000	100%	212%
48.000	100%	200%
34.000	100%	168%
30.000	100%	158%
24.000	100%	141%
20.000	100%	129%
16.000	100%	115%
12.000	100%	100%
10.000	95%	91%
8.000	73%	82%
5.000	56%	65%
3.000	51%	50%
1.000	29%	29%
0.750	23%	25%
0.187	11%	12%
0.079	7%	8%

New Stream Channel Design (Culvert, Rock Ramp) - COP 25

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

YELLOW ARE INPUTS				
Safety Factor	**1.5**			
Stability Coefficient for Incipient Failure	0.3	(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	4.6	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	5.6502	ft/s from 100-year event avg. velocity in pipe		Approximate depth-average flow for outlet velocities
Side Slope correction factor	1			
Gravitational Acceleration	32.2	ft/s^2		
D85/D15	5	(1.7-5.2)		
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	0.1	ft	2.0	inches
D30	0.2	ft	2.0	inches
D50	0.3	ft	4.0	inches
D85	0.5	ft	6.0	inches
D100	0.6	ft	7.0	inches

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

Fuller-Thompson Estimating for Maximum Density: D100 (inches) **12.0**

Method Adapted from US Forest Service Stream Simulation Guidelines D30 5.0

D30 Req'd 2.0

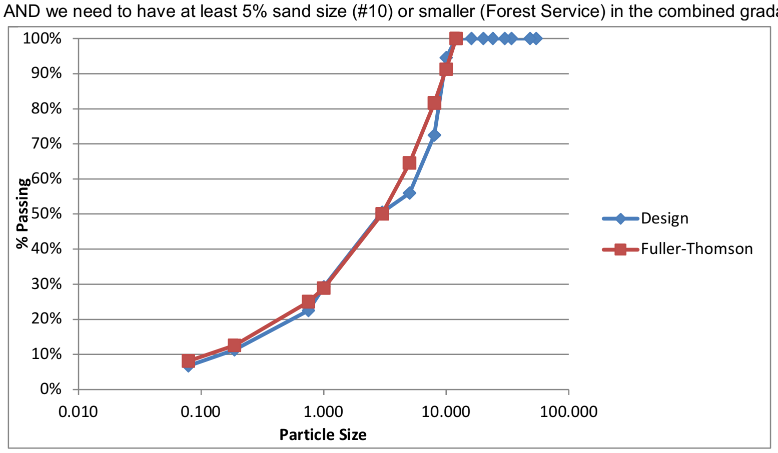
Stability (D30): **OK**

YELLOW ARE INPUTS

		COARSE MATERIAL					FINES	
		Type IV Rip Rap	Type III Rip Rap	Type II Rip	Type I Rip Ra	FA	Combined %	F-T EQN
	RELATIVE % =	0	0	0.0000	0.5500	0.4500	1.0000	
Size (inches)	Sieve Size	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing
54	54 in	1.00	1.00	1.00	1.00	1.00	100%	212%
48	48 in	0.90	1.00	1.00	1.00	1.00	100%	200%
34	34 in	0.50	1.00	1.00	1.00	1.00	100%	168%
30	30 in	0.35	0.90	1.00	1.00	1.00	100%	158%
24	24 in	0.25	0.50	1.00	1.00	1.00	100%	141%
20	20 in	0.15	0.15	0.90	1.00	1.00	100%	129%
16	16 in	0.00	0.00	0.50	1.00	1.00	100%	115%
12	12 in	0.00	0.00	0.15	1.00	1.00	100%	100%
10	10 in	0.00	0.00	0.00	0.90	1.00	95%	91%
8	8 in	0.00	0.00	0.00	0.50	1.00	73%	82%
5	5 in	0.00	0.00	0.00	0.20	1.00	56%	65%
3	3 in	0.00	0.00	0.00	0.10	1.00	51%	50%
1	1 in	0.00	0.00	0.00	0.00	0.65	29%	29%
0.75	0.75 in	0.00	0.00	0.00	0.00	0.50	23%	25%
0.187	#4	0.00	0.00	0.00	0.00	0.25	11%	12%
0.0787	#10 Sand	0.00	0.00	0.00	0.00	0.15	7%	8%

FA: Porous Backfill

Gradation values should be within +/-5% of this gradation (Rice)
AND we need to have at least 5% sand size (#10) or smaller (Forest Service) in the combined gradation



DATA for Graph & Fuller-Thomson Eqn

Size (in)	Combined % pa	F-T equation
54.000	100%	212%
48.000	100%	200%
34.000	100%	168%
30.000	100%	158%
24.000	100%	141%
20.000	100%	129%
16.000	100%	115%
12.000	100%	100%
10.000	95%	91%
8.000	73%	82%
5.000	56%	65%
3.000	51%	50%
1.000	29%	29%
0.750	23%	25%
0.187	11%	12%
0.079	7%	8%

New Stream Channel Design (Culvert, Rock Ramp) - SHER02

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

YELLOW ARE INPUTS			
Safety Factor	**1.5**		
Stability Coefficient for Incipient Failure	0.3	(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	0.63	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	4.36	ft/s from 100-year event avg. velocity in pipe	
Side Slope correction factor	1		
Gravitational Acceleration	32.2	ft/s^2	
D85/D15	5	(1.7-5.2)	
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	0.1	ft	2.0	inches
D30	0.1	ft	2.0	inches
D50	0.2	ft	3.0	inches
D85	0.4	ft	5.0	inches
D100	0.5	ft	6.0	inches

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

Fuller-Thompson Estimating for Maximum Density: D100 (inches) 12.0

Method Adapted from US Forest Service Stream Simulation Guidelines D30 5.0

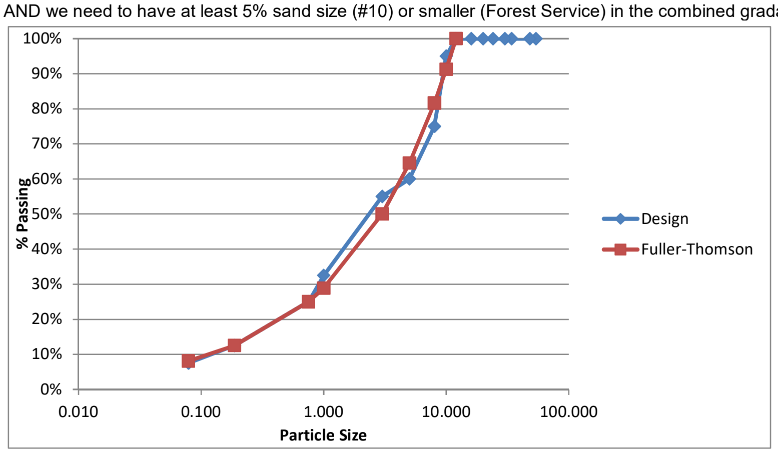
D30 Req'd 2.0

Stability (D30): OK

YELLOW ARE INPUTS		COARSE MATERIAL					FINES	
		Type IV Rip Rap	Type III Rip Rap	Type II Rip	Type I Rip R	FA	Combined %	F-T EQN
	RELATIVE % =	0	0	0.0000	0.5000	0.5000	1.0000	
Size (inches)	Sieve Size	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing
54	54 in	1.00	1.00	1.00	1.00	1.00	100%	212%
48	48 in	0.90	1.00	1.00	1.00	1.00	100%	200%
34	34 in	0.50	1.00	1.00	1.00	1.00	100%	168%
30	30 in	0.35	0.90	1.00	1.00	1.00	100%	158%
24	24 in	0.25	0.50	1.00	1.00	1.00	100%	141%
20	20 in	0.15	0.15	0.90	1.00	1.00	100%	129%
16	16 in	0.00	0.00	0.50	1.00	1.00	100%	115%
12	12 in	0.00	0.00	0.15	1.00	1.00	100%	100%
10	10 in	0.00	0.00	0.00	0.90	1.00	95%	91%
8	8 in	0.00	0.00	0.00	0.50	1.00	75%	82%
5	5 in	0.00	0.00	0.00	0.20	1.00	60%	65%
3	3 in	0.00	0.00	0.00	0.10	1.00	55%	50%
1	1 in	0.00	0.00	0.00	0.00	0.65	33%	29%
0.75	0.75 in	0.00	0.00	0.00	0.00	0.50	25%	25%
0.187	#4	0.00	0.00	0.00	0.00	0.25	13%	12%
0.0787	#10 Sand	0.00	0.00	0.00	0.00	0.15	8%	8%

FA: Porous Backfill

Gradation values should be within +/-5% of this gradation (Rice)
AND we need to have at least 5% sand size (#10) or smaller (Forest Service) in the combined gradation



DATA for Graph & Fuller-Thomson Eqn

Size (in)	Combined % pa	F-T equation
54.000	100%	212%
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30.000	100%	158%
24.000	100%	141%
20.000	100%	129%
16.000	100%	115%
12.000	100%	100%
10.000	95%	91%
8.000	75%	82%
5.000	60%	65%
3.000	55%	50%
1.000	33%	29%
0.750	25%	25%
0.187	13%	12%
0.079	8%	8%

APPENDIX C: HYDROLOGIC ANALYSIS

Cordova Hydrology - SHER 02				
Percent chance exceedance	Recurrance interval	Q/A to USFWS Analysis COP 25 (cfs)	2016 Regression (cfs)	2003 Regression (cfs)
50	2	9.1	**5.9**	14.0
20	5	10.3	**10.8**	19.0
10	10	11.1	**14.8**	22.4
4	25	11.9	**20.6**	26.6
2	50	12.4	**25.3**	29.7
1	100	12.9	**30.6**	32.7
0.5	200	13.4	**36.1**	35.8
0.2	500	-	**44.1**	39.8

Cordova Hydrology - COP 20					
Percent chance exceedance	Recurrance interval	Percent increase with March Flows for COP 25 (cfs)	COP 20 Flow Measurements Correlation to USGS Gauge Discharge (cfs)	2016 Regression (cfs)	2003 Regression (cfs)
50	2	148	**128**	68	82
20	5	171	**144**	111	109
10	10	182	**152**	143	127
4	25	196	**161**	188	151
2	50	205	**168**	222	168
1	100	214	**174**	260	185
0.5	200	221	**179**	299	203
0.2	500	-	**-**	353	226

Cordova Hydrology - Cop 22					
Percent chance exceedance	Recurrance interval	COP 22 Gauge Correlation to USGS Gauge 8 Peak Flow Measurements (2013-2019) (cfs)	COP 22 Flow Measurements Correlation to USGS Gauge Discharge (cfs)	2016 Regression (cfs)	2003 Regression (cfs)
50	2	**319**	691	210	189
20	5	**355**	773	321	248
10	10	**375**	819	404	288
4	25	**398**	871	514	340
2	50	**413**	905	598	380
1	100	**427**	938	690	418
0.5	200	**440**	968	783	459
0.2	500	**-**	-	911	512

Cordova Hydrology - Cop 25					
Percent chance exceedance	Recurrance interval	COP 25 Gauge Correlation to USGS Gauge 8 Peak Flow Measurements (2013-2019) (cfs)	COP 25 Flow Measurements Correlation to USGS Gauge Discharge (cfs)	2016 Regression (cfs)	2003 Regression (cfs)
50	2	**705**	962	305	294
20	5	**801**	1075	454	388
10	10	**857**	1139	564	452
4	25	**919**	1210	709	533
2	50	**962**	1258	819	595
1	100	**1002**	1302	940	654
0.5	200	**1040**	1344	1060	717
0.2	500	**-**	-	1230	799

Summary of Hydrology Data Collected for Cop 20, 22 & 25
3/20/2020
Franklin Dekker, USFWS

Between 9/5/2018 to 11/22/2019, USFWS and Copper River Watershed Project collected discharge measurements at sites COP 20, 22 and 25 and two local pressure transducer gages recorded stage at COP 22 and 25 between 9/4/2018 and 9/25/2019 (Table 1). This data summary report includes tentative peak streamflow estimates. All correlations used for stage-discharge relationships and synthetic records with the USGS gage are tentative and will improve with future flow measurements and gage data. Between 6 & 8 flow measurements were used for correlations. The USGS gaged used with the Glacier River Trib Near Cordova # 15215900.

Table 1. Flow Measurements from 18 Mile sites and gage data available for analysis. The largest and smallest measured flows are shown in bold for each site.

Site	Discharge Measurement Date	Discharge Measurement Time	Discharge Measurement (ft^3/s)	COP 22 Gage Height (ft)	COP 25 Gage Height (ft)	USGS Gage Q (ft^3/s)
COP20	9/5/2018	16:34	3.0		2.12	6.2
COP20	10/10/2018	14:17	7.1		2.36	4.7
COP20	12/17/2018	15:45	8.6		2.58	23.0
COP20	12/18/2018	11:30	5.3		2.40	15.6
COP20	7/10/2019	12:09	1.6	1.41	2.07	7.0
COP20	**8/22/2019**	**14:17**	**0.8**	1.37	2.04	1.7
COP20	9/13/2019	16:16	7.1	1.51	2.36	22.3
COP20	9/25/2019	7:58	3.0		2.36	25.0
COP20	**11/22/2019**	**9:52**	**20.7**			59.8
COP22	9/5/2018	15:48	6.9			6.2
COP22	10/10/2018	13:41	7.0			4.4
COP22	12/10/2018	15:00	11.3			17.5
COP22	3/19/2019	8:17	61.4	2.23		40.5
COP22	7/2/2019	16:30	9.0	1.45		12.0
COP22	7/10/2019	10:17	9.0	1.41		7.2
COP22	**8/21/2019**	**14:00**	**6.4**	1.37		1.6
COP22	9/13/2019	11:28	30.5	1.63		18.5
COP22	9/25/2019	10:43	10.7	1.68		22.7
COP22	10/11/2019	11:35	77.1	2.34		59.0
COP22	11/14/2019	14:15	39.1	2.20		16.5
COP22	**11/22/2019**	**11:14**	**114.7**	2.77		58.6
COP25	9/5/2018	14:35	5.5		2.12	6.4
COP25	10/10/2018	13:09	11.8		2.27	4.0
COP25	12/10/2018	14:00	23.7		2.42	17.8
COP25	**3/17/2019**	**18:57**	**186.7**		3.59	64.6
COP25	3/17/2019	16:00	125.7		3.26	40.5
COP25	7/10/2019	11:31	6.9		2.06	7.0
COP25	**8/21/2019**	**14:49**	**5.0**		2.03	1.6
COP25	9/13/2019	12:50	83.1		2.51	17.8
COP25	10/11/2019	12:40	92.6			53.8
COP25	11/14/2019	15:11	42.0			15.6
COP25	11/22/2019	12:45	94.7			58.6

Peak flow Estimates

Peak flow estimates were based on correlations to the USGS Gage's 8 peak flow measurements (2013 - 2019). The local gage discharge records were used to correlate to the USGS Gage in the case of COP22 and COP25, but for COP20 which did not have local gage, flow measurements were correlated directly to the USGS gage. Peak flows calculated from those correlations were entered into a Log Pearson Type III Distribution with weighted regional skew values from Curran et al. 2016 to determine flood frequency estimates. These peak flow estimates should be evaluated in conjunction with other available methods, such as the regional regression equations. The COP20 and COP22 sites appear like they would benefit from addition flow measurements at larger flows to improve correlations.

Table 2. Peak Flow Estimates based on correlation to USGS Gage's 8 peak flow measurements (2013 - 2019). COP20 measured discharge was used for correlations while local gage records were used in the case of COP22 and COP25.

RI	**COP20 (cfs)**	**COP22 (cfs)**	**COP25 (cfs)**
2	128	319	705
5	144	355	801
10	152	375	857
25	162	398	919
50	168	413	962
100	**174**	**427**	**1002**
200	180	440	1040

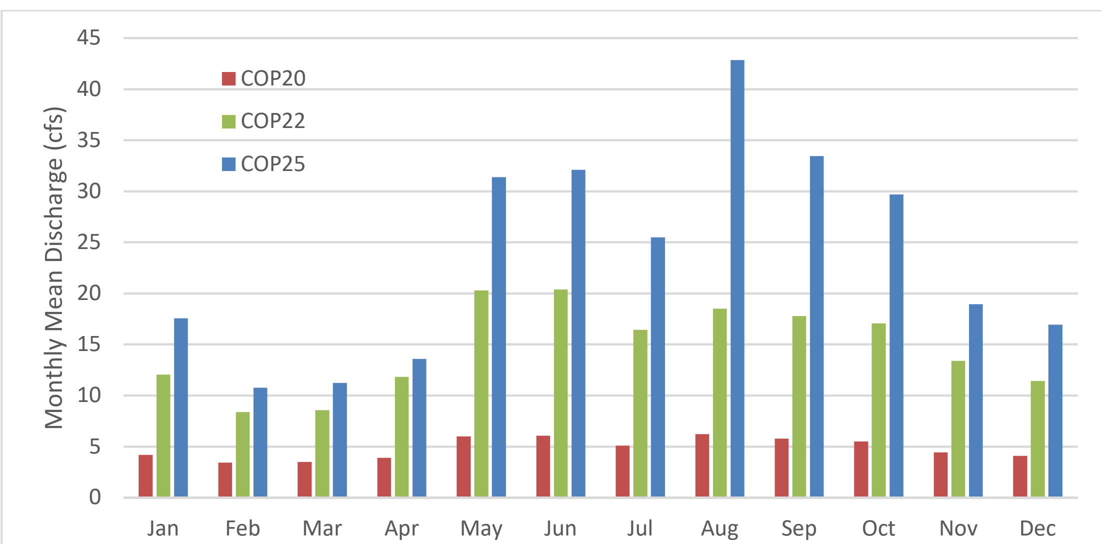


Figure 1. Mean monthly discharge from 2013- 2020 calculated from synthetic record with USGS gage.

[Type here]

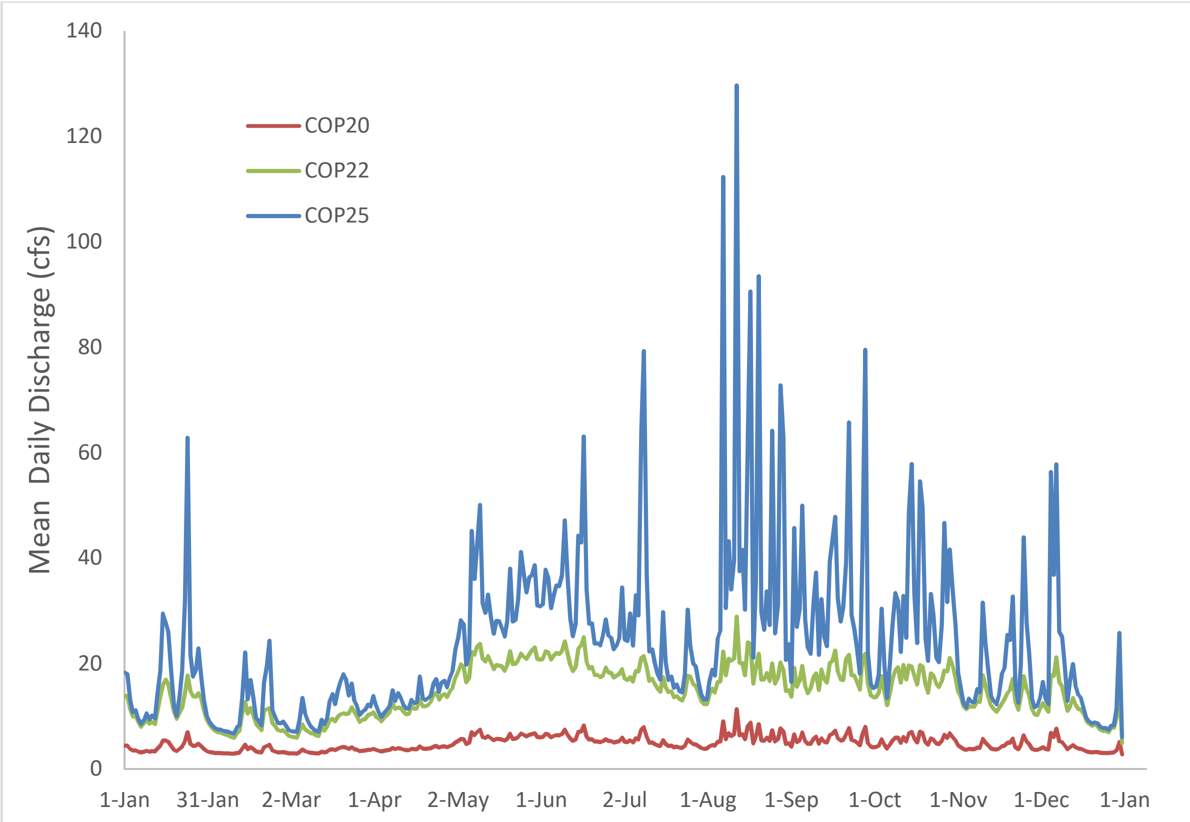


Figure 2. Mean daily discharge from 2013 – 2020 calculated from synthetic record with USGS gage.

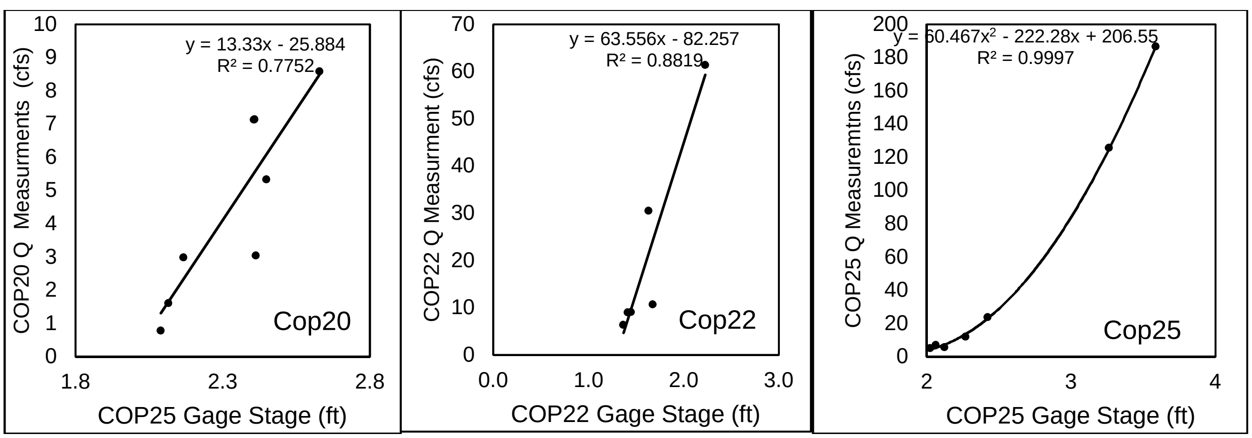


Figure 3. Discharge measurements to local gage relationships for local gage discharge records.

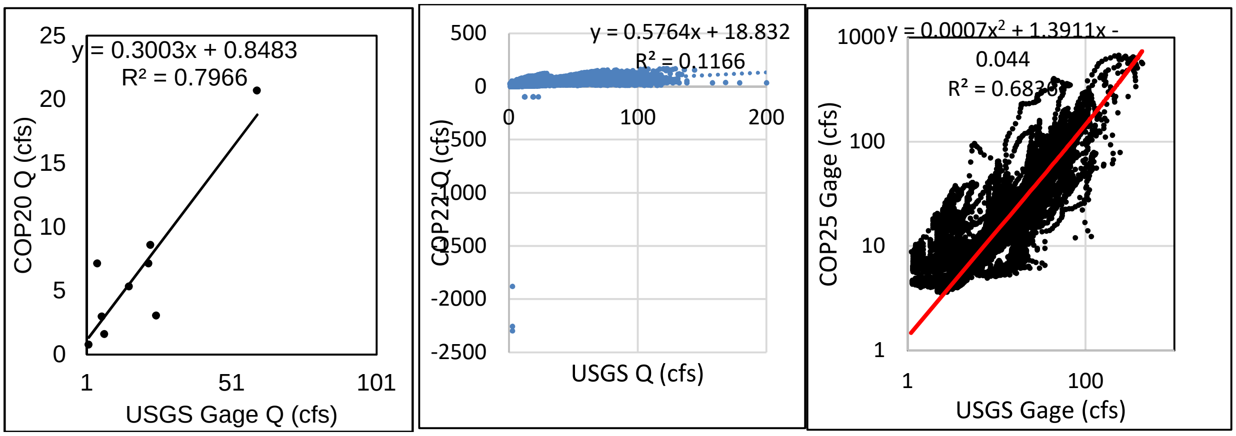


Figure 4. Correlations to USGS gage used to create 2013- 2020 synthetic record.

UPDATE 4/22/2020

Correlations to the USGS Gage for another Flood Frequency estimate that uses all possible flow measurements taken at 18 Mile sites.

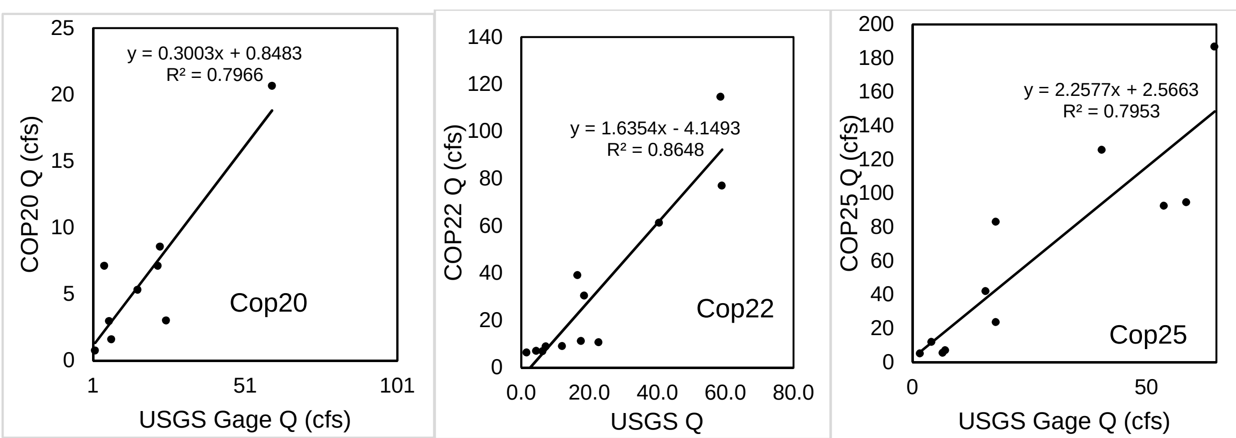


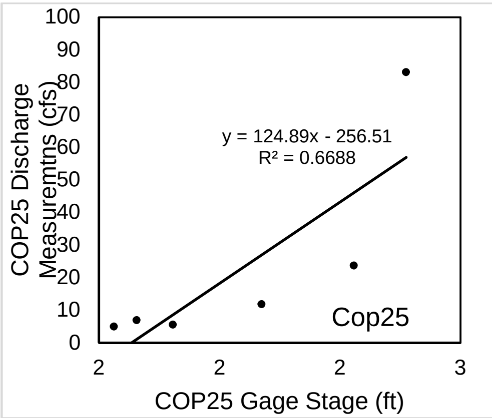
Figure 5. Correlations of 18 Mile site discharge measurements to USGS Gage discharge.

Table 3. Flood frequency estimates derived from USGS Glacier River Trib Gage using curves that related 18mile flow measurements to USGS gage discharge.

RI	COP20 (cfs)	COP22 (cfs)	COP25 (cfs)
2	128	691	962
5	144	773	1,075
10	152	819	1,139
25	161	871	1,210
50	168	905	1,258
100	174	938	1,302
200	179	968	1,344

What if 2 large March 2019 events are removed from the COP25 Rating Curve?

Table 4. COP25 flood frequency with and without March flows in rating curve.



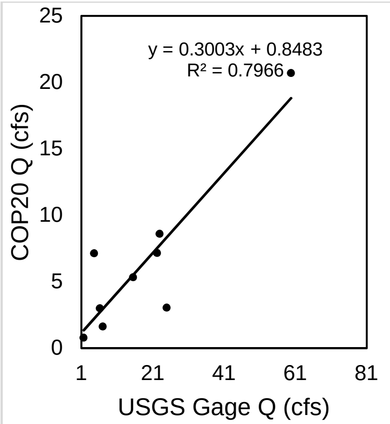
RI	**COP25 Q With March flows (cfs)**	**COP25 Q without March flows (cfs)**	with March / without March
2	705	606	116%
5	801	676	119%
10	857	715	120%
25	919	759	121%
50	962	789	122%
100	1002	816	123%
200	1040	842	123%

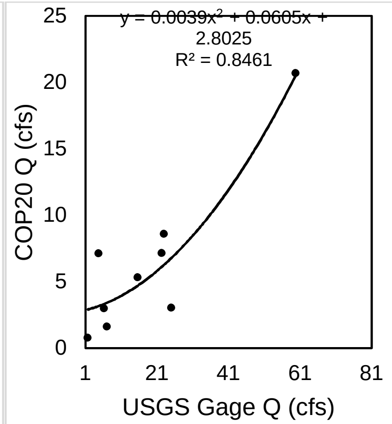
References

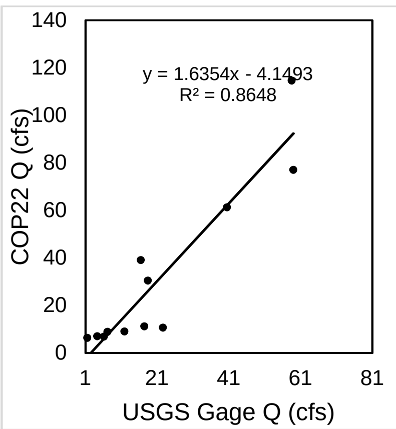
Curran, J.H., Barth, N.A., Veilleux, A.G., and Ourso, R.T., 2016, Estimating flood magnitude and frequency at gaged and ungaged sites on streams in Alaska and conterminous basins in Canada, based on data through water year 2012: U.S. Geological Survey Scientific Investigations Report 2016–5024, 47 p., http://dx.doi.org/10.3133/sir20165024.

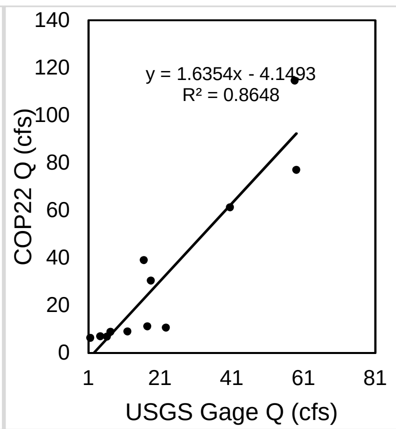
USGS. Glacier River Trib Near Cordova # 15215900. url: https://waterdata.usgs.gov/nwis/uv/?site_no=15215900

[Type here]


y = 0.3003x + 0.8483
R² = 0.7966
COP20 Q (cfs)
USGS Gage Q (cfs)


y = 0.0039x² + 0.0605x + 2.8025
R² = 0.8461
COP20 Q (cfs)
USGS Gage Q (cfs)


y = 1.6354x - 4.1493
R² = 0.8648
COP22 Q (cfs)
USGS Gage Q (cfs)


y = 1.6354x - 4.1493
R² = 0.8648
COP22 Q (cfs)
USGS Gage Q (cfs)

Flood-frequency applications tool for use on unregulated streams in Alaska and conte

This spreadsheet computes the regression estimate of the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent ch exceedance flows for an unregulated stream in Alaska or conterminous basins in Canada. The spreadsh includes the 90 percent prediction intervals, the minus and plus standard error of prediction intervals, a average standard error of prediction. To use the spreadsheet, enter requested information in the yellow below.

Enter a site-description name:

Cop 20 - Cordova, AK

Enter the explanatory variables:

Drainage area, in square miles	DRNAREA	0.54	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	108.3169291	
Warnings regarding range of variables:			

Results:

Percent chance exceedance	Percent chance exceedance flow, in ft^3/s	Lower limit of 90 percent prediction interval flow, in ft^3/s	Upper limit of 90 percent prediction interval flow, in ft^3/s	$-SEP_{P,i}$ (percent)	$+SEP_{P,i}$ (percent)	Average $SEP_{P,i}$ (percent)
50	68.0	23.7	196	-47.3	89.6	71.1
20	111	39.3	311	-46.6	87.3	69.5
10	143	50.8	403	-46.6	87.3	69.5
4	188	65.2	540	-47.3	89.8	71.3
2	222	75.5	653	-48.0	92.2	73.0
1	260	86.8	781	-48.6	94.6	74.7
0.5	299	96.4	928	-49.7	98.6	77.6
0.2	353	108	1,150	-51.2	104.9	82.0

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.

Flood-frequency applications tool for use on unregulated streams in Alaska and conte

This spreadsheet computes the regression estimate of the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent ch exceedance flows for an unregulated stream in Alaska or conterminous basins in Canada. The spreadsh includes the 90 percent prediction intervals, the minus and plus standard error of prediction intervals, a average standard error of prediction. To use the spreadsheet, enter requested information in the yellow below.

Enter a site-description name:

Cop 22 - Cordova, AK

Enter the explanatory variables:

Drainage area, in square miles	DRNAREA	1.89	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	116.8807087	
Warnings regarding range of variables:			

Results:

Percent chance exceedance	Percent chance exceedance flow, in ft^3/s	Lower limit of 90 percent prediction interval flow, in ft^3/s	Upper limit of 90 percent prediction interval flow, in ft^3/s	$-SEP_{P,i}$ (percent)	$+SEP_{P,i}$ (percent)	Average $SEP_{P,i}$ (percent)
50	210	73.1	601	-47.2	89.4	71.0
20	321	114	902	-46.5	87.0	69.3
10	404	144	1,130	-46.5	87.1	69.3
4	514	179	1,480	-47.2	89.5	71.0
2	598	204	1,750	-47.9	91.9	72.8
1	690	231	2,070	-48.5	94.3	74.5
0.5	783	253	2,420	-49.6	98.3	77.3
0.2	911	280	2,970	-51.1	104.5	81.7

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.

Flood-frequency applications tool for use on unregulated streams in Alaska and conte

This spreadsheet computes the regression estimate of the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent ch exceedance flows for an unregulated stream in Alaska or conterminous basins in Canada. The spreadsh includes the 90 percent prediction intervals, the minus and plus standard error of prediction intervals, a average standard error of prediction. To use the spreadsheet, enter requested information in the yellow below.

Enter a site-description name:

Cop 25 - Cordova, AK

Enter the explanatory variables:

Drainage area, in square miles	DRNAREA	2.48	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	134.8784449	
Warnings regarding range of variables:			

Results:

Percent chance exceedance	Percent chance exceedance flow, in ft^3/s	Lower limit of 90 percent prediction interval flow, in ft^3/s	Upper limit of 90 percent prediction interval flow, in ft^3/s	$-SEP_{P,i}$ (percent)	$+SEP_{P,i}$ (percent)	Average $SEP_{P,i}$ (percent)
50	305	106	874	-47.2	89.4	71.0
20	454	162	1,280	-46.5	87.0	69.3
10	564	201	1,590	-46.5	87.1	69.3
4	709	247	2,040	-47.2	89.5	71.0
2	819	279	2,400	-47.9	91.9	72.8
1	940	314	2,810	-48.5	94.3	74.5
0.5	1,060	343	3,280	-49.6	98.3	77.3
0.2	1,230	377	3,990	-51.1	104.5	81.7

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.

Flood-frequency applications tool for use on unregulated streams in Alaska and conte

This spreadsheet computes the regression estimate of the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent ch exceedance flows for an unregulated stream in Alaska or conterminous basins in Canada. The spreadsh includes the 90 percent prediction intervals, the minus and plus standard error of prediction intervals, a average standard error of prediction. To use the spreadsheet, enter requested information in the yellow below.

Enter a site-description name:

Sher 2 - Cordova, AK

Enter the explanatory variables:

Drainage area, in square miles	DRNAREA	0.03	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	104.7783465	

Warnings regarding range of variables:

WARNING: DRAINAGE AREA IS NOT WITHIN APPLICABLE RANGE. ACCURACY OF ESTIMATES ARE UNKNOWN.

Results:

Percent chance exceedance	Percent chance exceedance flow, in ft^3/s	Lower limit of 90 percent prediction interval flow, in ft^3/s	Upper limit of 90 percent prediction interval flow, in ft^3/s	$-SEP_{P,i}$ (percent)	$+SEP_{P,i}$ (percent)	Average $SEP_{P,i}$ (percent)
50	5.9	2.0	17.0	-47.6	90.7	71.9
20	10.8	3.8	30.6	-46.9	88.3	70.2
10	14.8	5.2	42.1	-46.9	88.4	70.3
4	20.6	7.1	59.9	-47.6	91.0	72.1
2	25.3	8.5	75.0	-48.3	93.5	73.9
1	30.6	10.1	92.8	-49.0	95.9	75.6
0.5	36.1	11.5	113	-50.0	100.0	78.5
0.2	44.1	13.3	146	-51.5	106.4	83.1

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.

Table 3. Regression equations for estimating 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year peak streamflows for unregulated streams in Regions 1-7, Alaska and conterminous basins in Canada

[Q_T, T-year peak streamflow, in cubic feet per second; A, drainage area, in square miles; ST, area of lakes and ponds (storage), in percent; P, mean annual precipitation, in inches; J, mean minimum January temperature, in degrees Fahrenheit; E, elevation, in feet; F, area of forest, in percent]

Enter a site-description name:

Cop 20 - Cordova, AK

	Constant	Exponent for A	Exponent for ST	Exponent for P	Exponent for J	Average standard error of prediction (log units)	Average standard error of prediction (percent)	Average equivalent years of record	Estimate of recurrence interval Q_T using user-supplied characteristics	
									User: Enter values in shaded area for this region (9999 indicates a dummy value that must be replaced)	
	Region 1, Region 3 (93 gaging stations)								**A=**	0.54
	Applicable range of variables:								**ST=**	5
	A: 0.720-571; ST: 0-26; P: 70-300; J: 0-32								**P=**	180
									J=	16
Q2	0.004119	0.8361	-0.3590	0.9110	1.635	0.158	38	0.88	82.238	
Q5	0.009024	0.8322	-0.3670	0.8128	1.640	0.156	37	1.3	109.003	
Q10	0.01450	0.8306	-0.3691	0.7655	1.622	0.157	37	1.8	127.427	
Q25	0.02522	0.8292	-0.3697	0.7165	1.588	0.161	38	2.4	150.618	
Q50	0.03711	0.8286	-0.3693	0.6847	1.559	0.166	40	2.8	168.121	
Q100	0.05364	0.8281	-0.3683	0.6556	1.527	0.171	41	3.1	184.971	
Q200	0.07658	0.8276	-0.3669	0.6284	1.495	0.178	43	3.4	203.147	
Q500	0.1209	0.8272	-0.3646	0.5948	1.449	0.188	45	3.6	226.414	

Table 3. Regression equations for estimating 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year peak streamflows for unregulated streams in Regions 1-7, Alaska and conterminous basins in Canada

[Q_T, T-year peak streamflow, in cubic feet per second; A, drainage area, in square miles; ST, area of lakes and ponds (storage), in percent; P, mean annual precipitation, in inches; J, mean minimum January temperature, in degrees Fahrenheit; E, elevation, in feet; F, area of forest, in percent]

Enter a site-description name: Cop 22 - Cordova, AK

Enter a site-description name: Cop 22 - Cordova, AK

	Constant	Exponent for A	Exponent for ST	Exponent for P	Exponent for J	Average standard error of prediction (log units)	Average standard error of prediction (percent)	Average equivalent years of record	Estimate of recurrence interval Q_T using user-supplied characteristics	
									User: Enter values in shaded area for this region (9999 indicates a dummy value that must be replaced)	
	Region 1, Region 3 (93 gaging stations)								**A=**	1.89
	Applicable range of variables:								**ST=**	10
	A: 0.720-571; ST: 0-26; P: 70-300; J: 0-32								**P=**	180
									J=	16
Q2	0.004119	0.8361	-0.3590	0.9110	1.635	0.158	38	0.88	188.566	
Q5	0.009024	0.8322	-0.3670	0.8128	1.640	0.156	37	1.3	247.514	
Q10	0.01450	0.8306	-0.3691	0.7655	1.622	0.157	37	1.8	288.405	
Q25	0.02522	0.8292	-0.3697	0.7165	1.588	0.161	38	2.4	340.172	
Q50	0.03711	0.8286	-0.3693	0.6847	1.559	0.166	40	2.8	379.508	
Q100	0.05364	0.8281	-0.3683	0.6556	1.527	0.171	41	3.1	417.536	
Q200	0.07658	0.8276	-0.3669	0.6284	1.495	0.178	43	3.4	458.667	
Q500	0.1209	0.8272	-0.3646	0.5948	1.449	0.188	45	3.6	511.656	

Table 3. Regression equations for estimating 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year peak streamflows for unregulated streams in Regions 1-7, Alaska and conterminous basins in Canada

[Q_T, T-year peak streamflow, in cubic feet per second; A, drainage area, in square miles; ST, area of lakes and ponds (storage), in percent; P, mean annual precipitation, in inches; J, mean minimum January temperature, in degrees Fahrenheit; E, elevation, in feet; F, area of forest, in percent]

Enter a site-description name:

Cop 25 - Cordova, AK

	Constant	Exponent for A	Exponent for ST	Exponent for P	Exponent for J	Average standard error of prediction (log units)	Average standard error of prediction (percent)	Average equivalent years of record	Estimate of recurrence interval Q_T using user-supplied characteristics	
									User: Enter values in shaded area for this region (9999 indicates a dummy value that must be replaced)	
	Region 1, Region 3 (93 gaging stations)								**A=**	2.48
	Applicable range of variables:								**ST=**	5
	A: 0.720-571; ST: 0-26; P: 70-300; J: 0-32								**P=**	180
									J=	16
Q2	0.004119	0.8361	-0.3590	0.9110	1.635	0.158	38	0.88	294.184	
Q5	0.009024	0.8322	-0.3670	0.8128	1.640	0.156	37	1.3	387.616	
Q10	0.01450	0.8306	-0.3691	0.7655	1.622	0.157	37	1.8	452.031	
Q25	0.02522	0.8292	-0.3697	0.7165	1.588	0.161	38	2.4	533.158	
Q50	0.03711	0.8286	-0.3693	0.6847	1.559	0.166	40	2.8	594.569	
Q100	0.05364	0.8281	-0.3683	0.6556	1.527	0.171	41	3.1	653.662	
Q200	0.07658	0.8276	-0.3669	0.6284	1.495	0.178	43	3.4	717.346	
Q500	0.1209	0.8272	-0.3646	0.5948	1.449	0.188	45	3.6	799.020	

Table 3. Regression equations for estimating 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year peak streamflows for unregulated streams in Regions 1-7, Alaska and conterminous basins in Canada

[Q_T, T-year peak streamflow, in cubic feet per second; A, drainage area, in square miles; ST, area of lakes and ponds (storage), in percent; P, mean annual precipitation, in inches; J, mean minimum January temperature, in degrees Fahrenheit; E, elevation, in feet; F, area of forest, in percent]

Enter a site-description name:

Sher 2 - Cordova, AK

	Constant	Exponent for A	Exponent for ST	Exponent for P	Exponent for J	Average standard error of prediction (log units)	Average standard error of prediction (percent)	Average equivalent years of record	Estimate of recurrence interval Q_T using user-supplied characteristics	
									User: Enter values in shaded area for this region (9999 indicates a dummy value that must be replaced)	
	Region 1, Region 3 (93 gaging stations)								**A=**	0.03
	Applicable range of variables:								**ST=**	0
	A: 0.720-571; ST: 0-26; P: 70-300; J: 0-32								**P=**	180
									J=	16
Q2	0.004119	0.8361	-0.3590	0.9110	1.635	0.158	38	0.88	13.960	
Q5	0.009024	0.8322	-0.3670	0.8128	1.640	0.156	37	1.3	18.984	
Q10	0.01450	0.8306	-0.3691	0.7655	1.622	0.157	37	1.8	22.379	
Q25	0.02522	0.8292	-0.3697	0.7165	1.588	0.161	38	2.4	26.588	
Q50	0.03711	0.8286	-0.3693	0.6847	1.559	0.166	40	2.8	29.708	
Q100	0.05364	0.8281	-0.3683	0.6556	1.527	0.171	41	3.1	32.674	
Q200	0.07658	0.8276	-0.3669	0.6284	1.495	0.178	43	3.4	35.847	
Q500	0.1209	0.8272	-0.3646	0.5948	1.449	0.188	45	3.6	39.834	

APPENDIX D: HYDRAULIC ANALYSIS

Cordova 18 Mile Fish Passage
HY-8 Analysis Summary

COP 20		
	Proposed Culvert: 15'-6" x 7'-3" Aluminum Box Culvert w/ Overflow 4.75' x 3.167' Pipe Arch	Existing Culvert: 5' CPM
Culvert Inlet Invert Elevation	30.8	33.9
Culvert Inlet Thalweg Elevation	34.7	33.9
Culvert Diameter (ft)	7.3	5.0
Embedment (ft)	3.8	0.0
D (Depth to top of embedment, ft)	3.4	5.0
Q50 = 168		
Headwater Elevation	37.33	40.13
HW (to embedment, ft)	2.66	6.2
HW (to culvert invert, ft)	6.50	6.2
Freeboard (ft)	0.75	-1.2
HW/D	**0.78**	**1.25**
Q100 = 174		
Headwater Elevation	37.39	40.15
HW (to embedment, ft)	2.72	6.3
HW (to culvert invert, ft)	6.56	6.3
Freeboard (ft)	0.69	-1.3
HW/D	**0.80**	**1.25**

HY-8 Culvert Analysis Report

COP 20 – Existing 5' CMP

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Existing Culvert - COP 20

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	5' Round Existing Discharge (cfs)	Roadway Discharge (cfs)	Iterations
37.19	Q2D2	51.20	51.20	0.00	1
39.61	2	128.00	128.00	0.00	1
40.03	5	144.00	141.56	2.16	22
40.07	10	152.00	142.85	8.87	6
40.11	25	162.00	144.09	17.65	5
40.13	50	168.00	144.73	22.99	4
40.15	100	174.00	145.33	28.47	4
40.00	Overtopping	140.72	140.72	0.00	Overtopping

Table 2 - Culvert Summary Table: 5' Round Existing

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)
Q2D2	51.20	51.20	37.19	3.027	3.291	2-M2c	2.434	2.002	2.002	1.204	6.970	2.544
2	128.00	128.00	39.61	5.559	5.709	7-M2c	5.000	3.234	3.234	1.757	9.527	2.188
5	144.00	141.56	40.03	6.062	6.126	7-M2c	5.000	3.406	3.406	1.822	9.938	2.222
10	152.00	142.85	40.07	6.112	6.167	7-M2c	5.000	3.421	3.421	1.853	9.977	2.242
25	162.00	144.09	40.11	6.160	6.206	7-M2c	5.000	3.436	3.436	1.890	10.015	2.269
50	168.00	144.73	40.13	6.185	6.226	7-M2c	5.000	3.444	3.444	1.911	10.035	2.286
100	174.00	145.33	40.15	6.209	6.245	7-M2c	5.000	3.451	3.451	1.933	10.053	2.303

****

Straight Culvert

Inlet Elevation (invert): 33.90 ft,   Outlet Elevation (invert): 33.60 ft

Culvert Length: 57.00 ft,   Culvert Slope: 0.0053

****

Site Data - 5' Round Existing

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 33.90 ft

Outlet Station: 57.00 ft

Outlet Elevation: 33.60 ft

Number of Barrels: 1

Culvert Data Summary - 5' Round Existing

Barrel Shape: Circular

Barrel Diameter: 5.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Existing Culvert - COP 20)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
51.20	34.80	1.20	2.54	0.18	0.43
128.00	35.36	1.76	2.19	0.26	0.50
144.00	35.42	1.82	2.22	0.27	0.48
152.00	35.45	1.85	2.24	0.28	0.47
162.00	35.49	1.89	2.27	0.28	0.47
168.00	35.51	1.91	2.29	0.29	0.46
174.00	35.53	1.93	2.30	0.29	0.46

Tailwater Channel Data - Existing Culvert - COP 20

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0024

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	0.00	40.00	0.0350
2	2.00	35.00	0.0350
3	40.00	35.00	0.0350
4	42.00	33.60	0.0300
5	57.00	33.60	0.0300
6	59.00	35.00	0.0350
7	99.00	35.00	0.0350
8	101.00	40.00	0.0000

Roadway Data for Crossing: Existing Culvert - COP 20

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 40.00 ft

Roadway Surface: Gravel

Roadway Top Width: 40.00 ft

HY-8 Culvert Analysis Report

COP 20 – Proposed 15'-6" x 7'-3" Aluminum Box Culvert with 4.75' x 3.167' Pipe Arch Overflow

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Proposed Culvert #12 - COP 20

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	15'-6" x 7'-3" Alum. Box Discharge (cfs)	Overflow 4.75'x3.167' Pipe Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
36.00	Q2D2	51.20	40.42	10.73	0.00	5
36.94	2	128.00	98.33	29.66	0.00	3
37.10	5	144.00	110.56	33.41	0.00	3
37.18	10	152.00	116.67	35.29	0.00	3
37.27	25	162.00	124.36	37.63	0.00	3
37.33	50	168.00	128.96	39.04	0.00	3
37.39	100	174.00	133.52	40.43	0.00	2
40.00	Overtopping	397.90	303.40	94.50	0.00	Overtopping

Table 2 - Culvert Summary Table: 15'-6" x 7'-3" Alum. Box

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)
Q2D2	51.20	40.42	36.00	1.028	1.374	3-M2t	1.369	0.652	1.143	1.207	2.611	2.555
2	128.00	98.33	36.94	1.851	2.304	3-M2t	3.406	1.186	1.760	1.825	4.125	2.275
5	144.00	110.56	37.10	2.002	2.461	3-M2t	3.406	1.282	1.827	1.892	4.471	2.294
10	152.00	116.67	37.18	2.077	2.539	3-M2t	3.406	1.328	1.859	1.923	4.640	2.309
25	162.00	124.36	37.27	2.171	2.636	3-M2t	3.406	1.385	1.897	1.961	4.849	2.330
50	168.00	128.96	37.33	2.228	2.693	3-M2t	3.406	1.418	1.919	1.983	4.972	2.343
100	174.00	133.52	37.39	2.284	2.749	3-M2t	3.406	1.451	1.941	2.005	5.093	2.358

****

Straight Culvert

Inlet Elevation (invert): 34.67 ft, Outlet Elevation (invert): 34.55 ft

Culvert Length: 59.00 ft, Culvert Slope: 0.0020

****

Site Data - 15'-6" x 7'-3" Alum. Box

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 30.83 ft

Outlet Station: 59.00 ft

Outlet Elevation: 30.71 ft

Number of Barrels: 1

Culvert Data Summary - 15'-6" x 7'-3" Alum. Box

Barrel Shape: Metal Box

Barrel Span: 15.50 ft

Barrel Rise: 7.25 ft

Barrel Material: Corrugated Aluminum

Embedment: 46.13 in

Barrel Manning's n: 0.0350 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Culvert Summary Table: Overflow 4.75'x3.167' Pipe Arch

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)
Q2D2	51.20	10.73	36.00	1.055	1.192	3-M2t	1.032	0.696	1.007	1.207	2.696	2.555
2	128.00	29.66	36.94	1.932	2.143	3-M2t	2.049	1.237	1.625	1.825	4.336	2.275
5	144.00	33.41	37.10	2.080	2.298	3-M2t	2.293	1.324	1.692	1.892	4.680	2.294
10	152.00	35.29	37.18	2.153	2.375	3-M2t	2.440	1.366	1.723	1.923	4.850	2.309
25	162.00	37.63	37.27	2.241	2.470	3-M2t	3.167	1.417	1.761	1.961	5.056	2.330
50	168.00	39.04	37.33	2.294	2.527	3-M2t	3.167	1.447	1.783	1.983	5.179	2.343
100	174.00	40.43	37.39	2.345	2.583	3-M2t	3.167	1.475	1.805	2.005	5.298	2.358

****

Straight Culvert

Inlet Elevation (invert): 34.84 ft, Outlet Elevation (invert): 34.69 ft

Culvert Length: 59.00 ft, Culvert Slope: 0.0025

****

Site Data - Overflow 4.75'x3.167' Pipe Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 34.84 ft

Outlet Station: 59.00 ft

Outlet Elevation: 34.69 ft

Number of Barrels: 1

Culvert Data Summary - Overflow 4.75'x3.167' Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 57.00 in

Barrel Rise: 38.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Headwall

Inlet Depression: None

Table 4 - Downstream Channel Rating Curve (Crossing: Proposed Culvert #12 - COP 20)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
51.20	35.70	1.21	2.56	0.18	0.43
128.00	36.31	1.82	2.28	0.27	0.53
144.00	36.38	1.89	2.29	0.28	0.50
152.00	36.41	1.92	2.31	0.29	0.49
162.00	36.45	1.96	2.33	0.29	0.49
168.00	36.47	1.98	2.34	0.30	0.48
174.00	36.49	2.00	2.36	0.30	0.48

Tailwater Channel Data - Proposed Culvert #12 - COP 20

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0024

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	0.00	40.00	0.0350
2	2.00	36.00	0.0350
3	40.00	36.00	0.0350
4	42.00	34.49	0.0300
5	57.00	34.49	0.0300
6	59.00	36.00	0.0350
7	99.00	36.00	0.0350
8	101.00	40.00	0.0000

Roadway Data for Crossing: Proposed Culvert #12 - COP 20

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 40.00 ft

Roadway Surface: Gravel

Roadway Top Width: 40.00 ft

Cordova 18 Mile Fish Passage
HY-8 Analysis Summary

COP 22		
	Proposed Culvert: 19'-10" x 7'-8" Aluminum Box Culvert w/ Overflow 5.33' x 3.583' Pipe Arch	Existing Culvert: 6' CMP
Culvert Inlet Invert Elevation	31.4	32.7
Culvert Inlet Thalweg Elevation	34.1	32.7
Culvert Diameter (ft)	7.7	6.0
Embedment (ft)	2.7	0.0
D (Depth to top of embedment, ft)	5.0	6.0
Q50 = 413		
Headwater Elevation	38.25	41.42
HW (to embedment, ft)	4.15	8.7
HW (to culvert invert, ft)	6.83	8.7
Freeboard (ft)	0.84	-2.7
HW/D	**0.83**	**1.45**
Q100 = 427		
Headwater Elevation	38.34	41.44
HW (to embedment, ft)	4.24	8.7
HW (to culvert invert, ft)	6.92	8.7
Freeboard (ft)	0.75	-2.7
HW/D	**0.85**	**1.46**

HY-8 Culvert Analysis Report

COP 22 – Existing 6’ CMP

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Existing Culvert - COP 22

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	6' Round Existing Discharge (cfs)	Roadway Discharge (cfs)	Iterations
37.83	Q2D2	127.60	127.60	0.00	1
41.23	2	319.00	262.98	55.68	11
41.31	5	355.00	265.37	89.35	5
41.35	10	375.00	266.55	108.10	4
41.39	25	398.00	267.83	129.91	4
41.42	50	413.00	268.59	143.75	3
41.44	100	427.00	269.30	157.10	3
41.00	Overtopping	256.24	256.24	0.00	Overtopping

Table 2 - Culvert Summary Table: 6' Round Existing

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)
Q2D2	127.60	127.60	37.83	4.797	5.133	2-M2c	3.926	3.055	3.055	1.749	8.819	2.744
2	319.00	262.98	41.23	8.524	8.305	7-M2c	6.000	4.440	4.440	2.382	11.723	2.953
5	355.00	265.37	41.31	8.606	8.368	7-M2c	6.000	4.460	4.460	2.472	11.775	3.037
10	375.00	266.55	41.35	8.646	8.399	7-M2c	6.000	4.470	4.470	2.521	11.801	3.084
25	398.00	267.83	41.39	8.690	8.433	7-M2c	6.000	4.480	4.480	2.575	11.829	3.137
50	413.00	268.59	41.42	8.717	8.453	7-M2c	6.000	4.486	4.486	2.609	11.845	3.171
100	427.00	269.30	41.44	8.741	8.472	7-M2c	6.000	4.492	4.492	2.641	11.861	3.202

****

Straight Culvert

Inlet Elevation (invert): 32.70 ft, Outlet Elevation (invert): 32.40 ft

Culvert Length: 61.00 ft, Culvert Slope: 0.0049

****

Site Data - 6' Round Existing

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 32.70 ft

Outlet Station: 61.00 ft

Outlet Elevation: 32.40 ft

Number of Barrels: 1

Culvert Data Summary - 6' Round Existing

Barrel Shape: Circular

Barrel Diameter: 6.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Existing Culvert - COP 22)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
127.60	34.15	1.75	2.74	0.29	0.70
319.00	34.78	2.38	2.95	0.40	0.49
355.00	34.87	2.47	3.04	0.42	0.49
375.00	34.92	2.52	3.08	0.42	0.49
398.00	34.97	2.57	3.14	0.43	0.48
413.00	35.01	2.61	3.17	0.44	0.48
427.00	35.04	2.64	3.20	0.44	0.48

Tailwater Channel Data - Existing Culvert - COP 22

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0027

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	0.00	40.00	0.0350
2	2.00	34.00	0.0350
3	40.00	34.00	0.0350
4	42.00	32.40	0.0300
5	60.00	32.40	0.0300
6	62.00	34.00	0.0350
7	99.00	34.00	0.0350
8	101.00	40.00	0.0000

Roadway Data for Crossing: Existing Culvert - COP 22

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 41.00 ft

Roadway Surface: Gravel

Roadway Top Width: 40.00 ft

HY-8 Culvert Analysis Report

COP 22 – Proposed 19'-10" x 7'-8"Aluminum Box Culvert with 5.33' x 3.583' Pipe Arch Overflow

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Proposed Culvert #6 - COP 22

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	19'-10" x 7'-8" Alum. Box Discharge (cfs)	Overflow 5.33'x3.583' Pipe Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
36.14	Q2D2	127.60	110.12	17.46	0.00	5
37.62	2	319.00	265.46	53.53	0.00	4
37.87	5	355.00	294.74	60.24	0.00	3
38.00	10	375.00	311.06	63.94	0.00	3
38.15	25	398.00	329.84	68.16	0.00	3
38.25	50	413.00	342.10	70.90	0.00	2
38.34	100	427.00	353.57	73.45	0.00	2
41.00	Overtopping	778.21	649.81	128.40	0.00	Overtopping

Table 2 - Culvert Summary Table: 19'-10" x 7'-8" Alum. Box

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)
Q2D2	127.60	110.12	36.14	1.705	2.054	3-M1t	1.678	1.063	1.802	1.727	3.451	2.930
2	319.00	265.46	37.62	3.071	3.500	3-M2t	3.117	1.902	2.510	2.435	6.038	3.027
5	355.00	294.74	37.87	3.308	3.742	3-M2t	3.392	2.043	2.602	2.527	6.478	3.105
10	375.00	311.06	38.00	3.439	3.876	3-M2t	3.584	2.117	2.651	2.576	6.718	3.149
25	398.00	329.84	38.15	3.591	4.028	3-M2t	4.942	2.200	2.705	2.630	6.988	3.199
50	413.00	342.10	38.25	3.676	4.126	3-M2t	4.942	2.253	2.740	2.665	7.161	3.232
100	427.00	353.57	38.34	3.755	4.218	3-M2t	4.942	2.307	2.772	2.697	7.321	3.262

****

Straight Culvert

Inlet Elevation (invert): 34.15 ft,   Outlet Elevation (invert): 33.81 ft

Culvert Length: 74.00 ft,   Culvert Slope: 0.0045

****

Site Data - 19'-10" x 7'-8" Alum. Box

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 31.42 ft

Outlet Station: 74.00 ft

Outlet Elevation: 31.09 ft

Number of Barrels: 1

Culvert Data Summary - 19'-10" x 7'-8" Alum. Box

Barrel Shape: Metal Box

Barrel Span: 19.83 ft

Barrel Rise: 7.67 ft

Barrel Material: Corrugated Aluminum

Embedment: 32.70 in

Barrel Manning's n: 0.0350 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Culvert Summary Table: Overflow 5.33'x3.583' Pipe Arch

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)
Q2D2	127.60	17.46	36.14	1.382	1.504	3-M1t	1.101	0.873	1.317	1.727	2.907	2.930
2	319.00	53.53	37.62	2.754	2.976	3-M2t	2.317	1.650	2.025	2.435	5.556	3.027
5	355.00	60.24	37.87	2.976	3.220	3-M2t	2.590	1.761	2.117	2.527	5.977	3.105
10	375.00	63.94	38.00	3.098	3.353	3-M2t	3.583	1.819	2.166	2.576	6.200	3.149
25	398.00	68.16	38.15	3.239	3.505	3-M2t	3.583	1.883	2.220	2.630	6.449	3.199
50	413.00	70.90	38.25	3.332	3.604	3-M2t	3.583	1.929	2.255	2.665	6.607	3.232
100	427.00	73.45	38.34	3.420	3.697	3-M2t	3.583	1.967	2.287	2.697	6.752	3.262

****

Straight Culvert

Inlet Elevation (invert): 34.66 ft,   Outlet Elevation (invert): 34.30 ft

Culvert Length: 83.00 ft,   Culvert Slope: 0.0043

****

Site Data - Overflow 5.33'x3.583' Pipe Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 34.66 ft

Outlet Station: 83.00 ft

Outlet Elevation: 34.30 ft

Number of Barrels: 1

Culvert Data Summary - Overflow 5.33'x3.583' Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 64.00 in

Barrel Rise: 43.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Projecting

Inlet Depression: None

Table 4 - Downstream Channel Rating Curve (Crossing: Proposed Culvert #6 - COP 22)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
127.60	35.62	1.73	2.93	0.29	0.61
319.00	36.33	2.44	3.03	0.41	0.51
355.00	36.42	2.53	3.11	0.43	0.51
375.00	36.47	2.58	3.15	0.43	0.50
398.00	36.52	2.63	3.20	0.44	0.50
413.00	36.56	2.67	3.23	0.45	0.50
427.00	36.59	2.70	3.26	0.45	0.50

Tailwater Channel Data - Proposed Culvert #6 - COP 22

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0027

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	0.00	40.00	0.0350
2	2.00	36.00	0.0350
3	40.00	35.20	0.0350
4	42.00	33.89	0.0300
5	60.00	33.89	0.0300
6	62.00	35.20	0.0350
7	99.00	36.00	0.0350
8	101.00	40.00	0.0000

Roadway Data for Crossing: Proposed Culvert #6 - COP 22

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 41.00 ft

Roadway Surface: Gravel

Roadway Top Width: 40.00 ft

Cordova 18 Mile Fish Passage
HY-8 Analysis Summary

COP 25			
	Proposed Culvert: 29'-0" x 8'-3" Aluminum Box Culvert w/ Overflow 5.916' x 3.916' Pipe Arch	Existing Culvert: (2) 6' CMPS	
Culvert Inlet Invert Elevation	21.8	24.5	24.1
Culvert Inlet Thalweg Elevation	24.8	24.5	24.1
Culvert Diameter (ft)	8.3	6.0	6.0
Embedment (ft)	3.0	0.0	0.0
D (Depth to top of embedment, ft)	5.3	6.0	6.0
Q50 = 962			
Headwater Elevation	30.29	34.92	34.92
HW (to embedment, ft)	5.45	10.4	10.8
HW (to culvert invert, ft)	8.45	10.4	10.8
Freeboard (ft)	-0.20	-4.4	-4.8
HW/D	**1.04**	**1.74**	**1.80**
Q100 = 1002			
Headwater Elevation	30.41	34.97	34.97
HW (to embedment, ft)	5.57	10.5	10.9
HW (to culvert invert, ft)	8.57	10.5	10.9
Freeboard (ft)	-0.32	-4.5	-4.9
HW/D	**1.06**	**1.75**	**1.81**

HY-8 Culvert Analysis Report

COP 25 – Existing (2) 6’ CMP

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Existing Culvert - COP 25

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	6' Existing Round West Discharge (cfs)	6' Existing Round East Discharge (cfs)	Roadway Discharge (cfs)	Iterations
29.84	Q2D2	282.00	129.86	152.12	0.00	6
34.52	2	705.00	304.14	313.92	86.59	10
34.69	5	801.00	308.41	318.05	173.76	5
34.78	10	857.00	310.56	320.12	225.99	5
34.87	25	919.00	312.69	322.18	283.31	4
34.92	50	962.00	314.10	323.54	323.95	4
34.97	100	1002.00	315.34	324.73	361.67	4
34.22	Overtopping	602.98	296.46	306.53	0.00	Overtopping

Table 2 - Culvert Summary Table: 6' Existing Round West

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)
Q2D2	282.00	129.86	29.84	4.837	5.344	2-M2c	3.161	3.083	3.083	2.457	8.874	2.113
2	705.00	304.14	34.52	10.020	9.265	7-M2c	6.000	4.762	4.762	3.626	12.639	2.850
5	801.00	308.41	34.69	10.191	9.389	7-M2c	6.000	4.793	4.793	3.844	12.738	2.982
10	857.00	310.56	34.78	10.277	9.453	7-M2c	6.000	4.808	4.808	3.966	12.787	3.054
25	919.00	312.69	34.87	10.365	9.518	7-M2c	6.000	4.823	4.823	4.098	12.837	3.132
50	962.00	314.10	34.92	10.422	9.561	7-M2c	6.000	4.833	4.833	4.187	12.870	3.184
100	1002.00	315.34	34.97	10.473	9.600	7-M2c	6.000	4.842	4.842	4.269	12.899	3.231

****

Straight Culvert

Inlet Elevation (invert): 24.50 ft, Outlet Elevation (invert): 23.90 ft

Culvert Length: 61.00 ft, Culvert Slope: 0.0098

****

Site Data - 6' Existing Round West

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 24.50 ft

Outlet Station: 61.00 ft

Outlet Elevation: 23.90 ft

Number of Barrels: 1

Culvert Data Summary - 6' Existing Round West

Barrel Shape: Circular

Barrel Diameter: 6.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

Table 3 - Culvert Summary Table: 6' Existing Round East

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)
Q2D2	282.00	152.12	29.84	5.383	5.744	2-M2c	3.690	3.346	3.346	2.457	9.384	2.113
2	705.00	313.92	34.52	10.420	9.645	7-M2c	6.000	4.832	4.832	3.626	12.866	2.850
5	801.00	318.05	34.69	10.591	9.776	7-M2c	6.000	4.860	4.860	3.844	12.963	2.982
10	857.00	320.12	34.78	10.677	9.851	7-M2c	6.000	4.875	4.875	3.966	13.011	3.054
25	919.00	322.18	34.87	10.765	9.936	7-M2c	6.000	4.889	4.889	4.098	13.060	3.132
50	962.00	323.54	34.92	10.822	9.977	7-M2c	6.000	4.898	4.898	4.187	13.093	3.184
100	1002.00	324.73	34.97	10.873	10.018	7-M2c	6.000	4.906	4.906	4.269	13.121	3.231

****

Straight Culvert

Inlet Elevation (invert): 24.10 ft, Outlet Elevation (invert): 23.60 ft

Culvert Length: 60.00 ft, Culvert Slope: 0.0083

****

Site Data - 6' Existing Round East

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 24.10 ft

Outlet Station: 60.00 ft

Outlet Elevation: 23.60 ft

Number of Barrels: 1

Culvert Data Summary - 6' Existing Round East

Barrel Shape: Circular

Barrel Diameter: 6.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

Table 4 - Downstream Channel Rating Curve (Crossing: Existing Culvert - COP 25)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
282.00	26.36	2.46	2.11	0.17	0.32
705.00	27.53	3.63	2.85	0.25	0.32
801.00	27.74	3.84	2.98	0.26	0.32
857.00	27.87	3.97	3.05	0.27	0.32
919.00	28.00	4.10	3.13	0.28	0.32
962.00	28.09	4.19	3.18	0.29	0.32
1002.00	28.17	4.27	3.23	0.29	0.32

Tailwater Channel Data - Existing Culvert - COP 25

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0011

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	0.00	40.00	0.0350
2	2.00	25.40	0.0350
3	40.00	25.40	0.0350
4	42.00	23.90	0.0300
5	67.00	23.90	0.0300
6	69.00	25.40	0.0350
7	99.00	25.40	0.0350
8	101.00	40.00	0.0000

Roadway Data for Crossing: Existing Culvert - COP 25

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 34.22 ft

Roadway Surface: Gravel

Roadway Top Width: 40.00 ft

HY-8 Culvert Analysis Report

COP 25 – Proposed 29'-0" x 8'-3" Aluminum Box Culvert with 5.916' x 3.916' Pipe Arch Overflow

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Proposed Culvert #9 - COP 25

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	29'-0" x 8'-3" Alum. Box Discharge (cfs)	Overflow 5.916'x3.916' Pipe Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
27.70	Q2D2	282.00	242.28	39.68	0.00	5
29.41	2	705.00	613.53	92.03	0.00	3
29.74	5	801.00	698.30	102.63	0.00	3
29.93	10	857.00	748.24	108.45	0.00	4
30.14	25	919.00	812.40	114.58	0.00	7
30.29	50	962.00	842.71	119.03	0.00	3
30.41	100	1002.00	879.83	122.43	0.00	4
34.23	Overtopping	1811.54	1611.64	199.91	0.00	Overtopping

Table 2 - Culvert Summary Table: 29'-0" x 8'-3" Alum. Box

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)
Q2D2	282.00	242.28	27.70	1.875	2.962	3-M1t	2.746	1.301	2.758	2.728	3.029	2.261
2	705.00	613.53	29.41	3.487	4.688	3-M2t	5.250	2.410	3.964	3.934	5.338	2.912
5	801.00	698.30	29.74	3.831	5.024	3-M2t	5.250	2.622	4.185	4.155	5.754	3.037
10	857.00	748.24	29.93	4.004	5.216	3-M2t	5.250	2.736	4.309	4.279	5.988	3.107
25	919.00	812.40	30.14	4.226	5.447	3-M2t	5.250	2.894	4.442	4.412	6.307	3.182
50	962.00	842.71	30.29	4.331	5.569	3-M2t	5.250	2.964	4.532	4.502	6.412	3.232
100	1002.00	879.83	30.41	4.459	5.703	3-M2t	5.250	3.049	4.615	4.585	6.574	3.277

****

Straight Culvert

Inlet Elevation (invert): 24.84 ft, Outlet Elevation (invert): 24.77 ft

Culvert Length: 52.00 ft, Culvert Slope: 0.0013

****

Site Data - 29'-0" x 8'-3" Alum. Box

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 21.84 ft

Outlet Station: 52.00 ft

Outlet Elevation: 21.77 ft

Number of Barrels: 1

Culvert Data Summary - 29'-0" x 8'-3" Alum. Box

Barrel Shape: Concrete Box

Barrel Span: 29.00 ft

Barrel Rise: 8.25 ft

Barrel Material: Concrete

Embedment: 36.00 in

Barrel Manning's n: 0.0350 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: 1:1 Bevel Headwall

Inlet Depression: None

Table 3 - Culvert Summary Table: Overflow 5.916'x3.916' Pipe Arch

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)
Q2D2	282.00	39.68	27.70	2.151	2.641	3-M2t	2.669	1.323	2.278	2.728	3.310	2.261
2	705.00	92.03	29.41	3.712	4.530	3-M2t	3.917	2.140	3.484	3.934	5.317	2.912
5	801.00	102.63	29.74	4.036	5.022	7-M2t	3.917	2.280	3.705	4.155	5.732	3.037
10	857.00	108.45	29.93	4.223	5.312	7-M2t	3.917	2.352	3.829	4.279	5.981	3.107
25	919.00	114.58	30.14	4.429	5.631	4-FFf	3.917	2.431	3.917	4.412	6.289	3.182
50	962.00	119.03	30.29	4.584	5.861	4-FFf	3.917	2.484	3.917	4.502	6.534	3.232
100	1002.00	122.43	30.41	4.706	6.053	4-FFf	3.917	2.524	3.917	4.585	6.720	3.277

****

Straight Culvert

Inlet Elevation (invert): 25.34 ft, Outlet Elevation (invert): 25.25 ft

Culvert Length: 70.00 ft, Culvert Slope: 0.0013

****

Site Data - Overflow 5.916'x3.916' Pipe Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 25.34 ft

Outlet Station: 70.00 ft

Outlet Elevation: 25.25 ft

Number of Barrels: 1

Culvert Data Summary - Overflow 5.916'x3.916' Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 71.00 in

Barrel Rise: 47.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Projecting

Inlet Depression: None

Table 4 - Downstream Channel Rating Curve (Crossing: Proposed Culvert #9 - COP 25)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
282.00	27.53	2.73	2.26	0.19	0.35
705.00	28.73	3.93	2.91	0.27	0.33
801.00	28.95	4.15	3.04	0.29	0.33
857.00	29.08	4.28	3.11	0.29	0.33
919.00	29.21	4.41	3.18	0.30	0.33
962.00	29.30	4.50	3.23	0.31	0.33
1002.00	29.38	4.58	3.28	0.31	0.33

Tailwater Channel Data - Proposed Culvert #9 - COP 25

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0011

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	0.00	40.00	0.0350
2	2.00	26.80	0.0350
3	40.00	26.80	0.0350
4	42.00	24.80	0.0300
5	67.00	24.80	0.0300
6	69.00	26.80	0.0350
7	99.00	26.80	0.0350
8	101.00	40.00	0.0000

Roadway Data for Crossing: Proposed Culvert #9 - COP 25

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 34.23 ft

Roadway Surface: Gravel

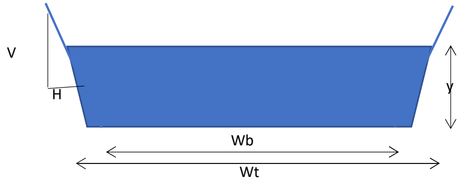
Roadway Top Width: 36.00 ft

Synthetic Width

COP 20

Slope	0.20%
Measured BFW (feet)	10.5-12
Measured BFD (feet)	1.5
Measured WSE (feet)	0.75
ADF&G Average OHW (feet)	30

Recurrance interval	Flows (cfs)
Q2D2	51.2
2	128
5	144
10	152
25	162
50	168
100	174



TRAPEZOIDAL CHANNEL

Long. Slope So:	0.002	ft/ft	
Channel Material:			
n:	0.035		
Channel Bottom Wb	12.00	ft	
Water Depth y (in):	30.9	in	
Water Depth y (ft):	2.58	ft	=D(in)/12
H:V Side Slope Ss:	2	:1	
Top Width Wt:	22.32	ft	=Wb+2*(Ss*y)
Flow Area Af:	44.25	ft^2	=y*(Wt+Wb)/2
Wet Perimeter Pw:	23.53	ft	=Wb+2*sqrt(y^2+(y*Ss)^2)
Hydraulic Radius Rh:	1.88	ft	=Af/Pw
Velocity:	2.89	ft/s	=(1.486/n)*(Rh^(2/3))*(slope^(1/2))
Design Flow:	128.00	ft^3/s	=Af*Velocity

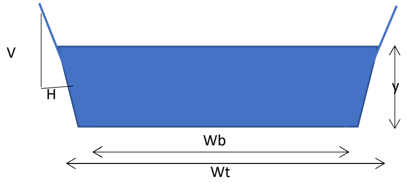
Proposed Structure 15% 12'-11" X 6'-0"
Proposed Structure 65% 15'-6" X 7'-3"
57" X 38" Aluminum Pipe Arch

Q=v*a (cfs)	v (ft/s)	a (sf)	h (ft)	w=4h (ft)
128	4	32	2.8	11.3
W/D ratio			4.0	

COP 22

Slope	0.40%
Measured BFW (feet)	15-23
Measured BFD (feet)	2
Measured WSE (feet)	1.08
ADF&G Average OHW (feet)	25

Recurrance interval	Flows (cfs)
Q2D2	127.6
2	319
5	355
10	375
25	398
50	413
100	427



TRAPEZOIDAL CHANNEL

Long. Slope So:	0.004	ft/ft	
Channel Material:			
n:	0.035		
Channel Bottom Wb	16.50	ft	
Water Depth y (in):	36.5	in	
Water Depth y (ft):	3.04	ft	=D(in)/12
H:V Side Slope Ss:	2	:1	
Top Width Wt:	28.65	ft	=Wb+2*(Ss*y)
Flow Area Af:	68.59	ft^2	=y*(Wt+Wb)/2
Wet Perimeter Pw:	30.09	ft	=Wb+2*sqrt(y^2+(y*Ss)^2)
Hydraulic Radius Rh:	2.28	ft	=Af/Pw
Velocity:	4.65	ft/s	=(1.486/n)*(Rh^(2/3))*(slope^(1/2
Design Flow:	319.00	ft^3/s	=Af*Velocity

Proposed Structure 15% 15'-4" X 6'-5"
Proposed Structure 65% 19'-10" X 7'-8"
64" X 43" Aluminum Pipe Arch

Q=v*a (cfs)	v (ft/s)	a (sf)	h (ft)	w=4h (ft)
319	4	80	4.5	17.9
W/D ratio			4.0	

QBKF(Design)	319 cfs
QBKF(Reference)	128 cfs
ABKF(Reference)	32 sf
ABKF(Design)	79.75 sf
WBKF(Reference)	11.3 ft
dBKF(Reference)	2.8 ft
WBKF(Design)	17.86 ft

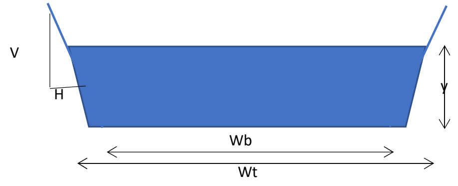
ABKF(Design)	79.75 sf
WBKF(Design)	17.86 ft
dBKF(Design)	4.47 ft

dMAX(Reference)	3 ft
dBKF(Design)	4.47 ft
dBKF(Reference)	2.8 ft
dMAX(Design)	4.74 ft

COP 25

Slope	0.13%
Measured BFW (feet)	23-34
Measured BFD (feet)	2.5
Measured WSE (feet)	1.00
ADF&G Average OHW (feet)	26

Recurrance interval	Flows (cfs)
Q2D2	282
2	705
5	801
10	857
25	919
50	962
100	1002



TRAPEZOIDAL CHANNEL

Long. Slope So:	0.0013	ft/ft	
Channel Material:			
n:	0.035		
Channel Bottom Wb	26.00	ft	
Water Depth y (in):	62.1	in	
Water Depth y (ft):	5.18	ft	=D(in)/12
H:V Side Slope Ss:	2	:1	
Top Width Wt:	46.71	ft	=Wb+2*(Ss*y)
Flow Area Af:	188.18	ft^2	=y*(Wt+Wb)/2
Wet Perimeter Pw:	49.15	ft	=Wb+2*sqrt(y^2+(y*Ss)^2)
Hydraulic Radius Rh:	3.83	ft	=Af/Pw
Velocity:	3.75	ft/s	=(1.486/n)*(Rh^(2/3))*(slope^(1/2))
Design Flow:	705.00	ft^3/s	=Af*Velocity

Proposed Structure 15% 19'-10" X 7'-8"
Proposed Structure 65% 29'-0" X 8'-3"
71" X 47" Aluminum Pipe Arch

Q=v*a (cfs)	v (ft/s)	a (sf)	h (ft)	w=4h (ft)
705	4	176	6.6	26.6
W/D ratio			4.0	

QBKF(Design)	705 cfs
QBKF(Reference)	128 cfs
ABKF(Reference)	32 sf
ABKF(Design)	176.25 sf
WBKF(Reference)	11.3 ft
dBKF(Reference)	2.8 ft
WBKF(Design)	26.55 ft

ABKF(Design)	176.25 sf
WBKF(Design)	26.55 ft
dBKF(Design)	6.64 ft

dMAX(Reference)	3 ft
dBKF(Design)	6.64 ft
dBKF(Reference)	2.8 ft
dMAX(Design)	7.04 ft

SHER02 Hydraulic Summary										
	Q (CFS)	**Shape**	**Bottom Width (ft)**	**Side Slope**	**A (ft^2)**	**R (ft)**	**S**	**n**	**h (ft)**	**V (fps)**
Q_{fish}	2.36	Trapezoid	5	10:1	1.123532	0.134344	0.026	0.03	0.168154	2.100519
Q_2	5.9	Trapezoid	5	10:1	2.13269	0.20306	0.026	0.03	0.275137	2.766459
Q_{100}	30.7	Trapezoid	5	10:1	7.037892	0.401991	0.026	0.03	0.625379	4.362101