Colville River Delta

Spring Breakup Monitoring & Hydrological Assessment

2021

Michael Baker

INTERNATIONAL

3900 C Street, Suite 900, Anchorage, AK 99503

Prepared for:

ConocoPhillips

Alaska

EXECUTIVE SUMMARY

This report presents the observations and results from the 2021 Colville River Delta Spring Breakup Monitoring and Hydrological Assessment for the Alpine Facilities conducted by Michael Baker International for ConocoPhillips Alaska. In the Colville River Delta, the breakup and downstream movement of river ice typically occurs during a three-week period in May and June. The spring breakup event historically produces flooding resulting from the rapid rise and fall of stage often attributed to ice jam formations and releases. Annual study and reporting of spring breakup is required by U.S. Army Corps of Engineers Permits 2-960874 Special Condition #6, POA-2004-253 Special Condition #17, and POA-2005-1576 Special Conditions #1 and #17 and Alaska Department of Fish and Game Permits FH04-III-0238, FG97-III-0260, FG99-III-0051, and FG97-III-0190. The analyses provide data to support design, permitting, and operation of oilfield development.

The 2021 monitoring and hydrological assessment is the 30th consecutive year of spring breakup investigations and the 35th year of historical breakup monitoring in the Colville River Delta. Water surface elevations were monitored throughout the delta at locations of hydrologic importance, including near infrastructure. Discharge was measured, and peak discharge was calculated at key locations. The entire breakup event was documented with visual observations and photography from a helicopter and from roadways. Following breakup, roads, pads, and drainage structures were assessed for erosion and damage.

This year's spring breakup flood was characterized as a protracted, long duration, historically low magnitude event. Initial floodwater arrived in the delta on May 22 and peak conditions throughout the delta occurred between June 6 and June 7. Peak stage at MON1C occurred on June 6 and was 12.3-ft British Petroleum Mean Sea Level (BPMSL) having an estimated recurrence interval of less than 2-years. Peak discharge at MON1C occurred on June 6 and was estimated at 220,000 cubic ft per second having an estimated 1.3-year recurrence interval. Recurrence intervals are relative to design basis values.

During peak conditions, overbank flooding and floodplain inundation were not observed around Alpine. Many typical hydraulic connections between lakes and channels were delayed or did not fully develop, including the recharge of one of the Alpine Drinking Water Lakes, Lake L9312 (which recharged via precipitation after breakup). Overall, ice jamming effects in the CRD were minimal, as was the associated backwater and flooding.

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ACRONYMS & ABBREVIATIONS

2D	Two-dimensional
ABR	Alaska Biological Research
ADF&G	Alaska Department of Fish and Game
Baro PT	barometric pressure transducer
BPMSL	British Petroleum Mean Sea Level
CD	Colville Delta
CFDD	cumulative freezing degree days
cfs	cubic feet per second
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
FEMA	Federal Emergency Management Agency
fps	feet per second
ft	feet
gage	hydrologic staff gage
GPS	Global positioning system
HDD	Horizontal directional drill
HWM	High water mark
Michael Baker	Michael Baker International
MON	Monument
MP-AMS	Monitoring Plan with an Adaptive Management Strategy
NOAA	National Atmospheric and Oceanic Administration
NRCS	Natural Resources Conservation Service
NPR-A	National Petroleum Reserve of Alaska
PT	pressure transducer
RM	river mile
RTFM	Real-Time Flood Monitoring
SAK	Sakoonang
TAM	Tamayayak
ULAM	Ulamnigiaq
UMIAQ	Umiaq, LLC (UMIAQ)
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VSM	Vertical support member
WSE	Water surface elevation

1. INTRODUCTION

The Colville River is the largest river on the North Slope, originating in the DeLong Mountains on the north side of the Brooks Range, running north and east through the Arctic Coastal Plain, and forms the Colville River Delta (CRD) where the river empties into the Beaufort Sea. The Colville River drainage basin is approximately 23,455 square miles and includes a large portion of the western and central areas north of the Brooks Range (Figure 1.1). Spring breakup starts with the arrival of meltwater in the delta and progresses with a rapid rise in stage which facilitates the breakup and downstream movement of river ice. The CRD spring breakup is generally considered to be the largest annual flooding event in the region and typically occurs during a three-week period in May and June. Spring breakup monitoring is integral to understanding regional hydrology and ice effects, establishing appropriate design criteria for proposed facilities, and maintaining the continued safety of the environment, oilfield personnel, and existing facilities during the flooding event.

The CRD Spring Breakup Monitoring and Hydrological Assessment supports the ConocoPhillips Alaska, Inc. (CPAI) Alpine Development Project and the Alpine Satellite Development Plan. The Alpine facilities are owned and operated by CPAI. Alpine facilities include the Colville Delta (CD) 1 processing facility (Alpine) and the CD2, CD3, CD4, CD5, and Greater Moose's Tooth (GMT)-1/MT6 and GMT-2/MT7 pads, access roads, and pipelines.

Colville River breakup monitoring has been ongoing since 1962. The timing and magnitude of breakup flooding has been determined annually since 1992 by measuring stage and discharge at established locations throughout the delta. The program was expanded to include additional Alpine facilities in 2004 and the CD5 development area in 2009. The 2021 monitoring and hydrological assessment is the 30th consecutive year of CRD spring breakup investigations.

The 2021 field program took place from April 20 to June 14. Spring breakup setup began on April 22 and concluded on May 22. Spring breakup monitoring began on May 22 and concluded on June 14. Primary field tasks included documenting the distribution of floodwater and measuring water levels and discharge at select locations. Observations of lake recharge, ice jams, ice road crossing degradation, and floodwater effects on infrastructure were also recorded. Hydrologic observations were documented at all Alpine facilities, roads, and drainage structures, and relevant waterbodies within the CRD.

Umiaq, LLC (UMIAQ), CPAI Alpine Field Environmental Coordinators, Alpine Helicopter Coordinators, and Pathfinder Aviation, LLC provided support during the field program and contributed to a safe and productive field season.

ConocoPhillips Alaska	Miles 0 25 50
Date: 10/20/2021	Scale: 1 Inch = 25 Miles
Drawn: JEM	Project: 183660
Checked: GCY	File: 2021_ColvilleDrainageBasin.mxd

★ Place Name
Stream
Colville River Basin Stream
Waterbody
Colville River Basin
NPRA Boundary

Michael Baker INTERNATIONAL

Michael Baker International, Inc.
3900 C Street, Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 COLVILLE RIVER DELTA SPRING BREAKUP

Colville River Drainage Basin

FIGURE 1.1

1.1 Monitoring Objectives

The primary objective of CRD spring breakup monitoring and hydrological assessment is to monitor and estimate the magnitude of breakup flooding within the CRD in relation to Alpine facilities. Water surface elevations (WSE, or stage, used interchangeably in this report), discharge, and observations are used to validate design parameters of existing infrastructure, for planning and design of proposed infrastructure, and to satisfy permit requirements. Data collection supports refinement of the CRD flood frequency, two-dimensional (2D) surface water model, and stage frequency analyses.

The CRD spring breakup monitoring satisfies permit stipulations by the U.S. Army Corps of Engineers (USACE) and the Alaska Department of Fish and Game (ADF&G).

Permit stipulations for USACE Permits 2-960874 Special Condition #6, POA-2004-253-2 Special Condition #17, ADF&G Fish Habitat Permit FH04-III-0238, and USACE Permit POA-2005-1576 Special Conditions #1 and #17 require monitoring Alpine facilities during spring breakup. Permit stipulations include documentation of annual hydrologic conditions, direct measurements and indirect calculations of discharge through drainage structures, and documentation of pad and road erosion caused by spring breakup flooding. USACE Permit POA-2005-1576 Special Condition #1 requires the *Monitoring Plan with an Adaptive Management Strategy* (MP-AMS) (Michael Baker and Alaska Biological Research [ABR] 2013) which includes monitoring channel sedimentation and erosion specific to the CD5 development. Observations of functionality and flooding effects to the CD2 road bridges are recorded to satisfy ADF&G permit FG97-III-0260-Amendment #3. The ADF&G permits FG99-III-0051-Amendment #8 and FG97-III-0190-Amendment #1 require monitoring of recharge to lakes L9312 and L9313, respectively. Alpine facilities rely on water withdrawal from these lakes for daily operations; the volume of which is dictated in part by annual spring recharge. The information presented in this report encompasses the data required by the permits.

1.2 Monitoring Locations

The 2021 monitoring locations and gage stations are the same as those studied in 2020 (Michael Baker 2020). In addition, MBI monitored three new locations in the East Channel: EC1.3, EC7.2, and EC12.9. Most gage stations are adjacent to major hydrologic features and were selected based on topography, importance to the historical record, and proximity and hydraulic significance to existing or proposed facilities or temporary infrastructure. Figure 1.2 shows the CRD monitoring locations and gage stations denoted with a MON or EC prefix. Monitoring locations and gage stations specific to Alpine facilities are shown in Figure 1.3. The location descriptions for each gage station are listed in Table 1.1. Gage and culvert geographic coordinates and associated vertical control are provided in Appendix A.

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Miles
0 2.5 5

Date:	11/12/2021	Scale:	1 Inch = 2.5 Miles
Drawn:	RC	Project:	183660
Checked:	GCY	File:	2020_CRD_Monitoring.mxd

Place Name	Pipeline	Facility
Gage Location	Gravel Road	Ice Pad
Ice Road Crossing	Ice Road	

Imagery from CPAI 2019 and Maxar 2019

Michael Baker INTERNATIONAL

Michael Baker International, Inc.
3900 C Street, Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP COLVILLE RIVER DELTA

Monitoring Locations

FIGURE 1.2

ConocoPhillips Alaska

0 1.5 3 Miles

Date:	10/20/2021	Scale:	1 Inch = 1.5 Miles
Drawn:	JEM	Project:	183660
Checked:	GCY	File:	2020_CRD_Monitoring.mxd

Gage Location
Pipeline
Gravel Road
Ice Road
Facility
Ice Pad

Imagery from CPAI 2019 and Maxar 2019

Michael Baker INTERNATIONAL

Michael Baker International, Inc.
3900 C Street, Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP COLVILLE RIVER DELTA

Monitoring Locations

FIGURE 1.3

Table 1.1: Monitoring & Gage Station Locations

Monitoring Location	Monitoring Location Description	Gage Station	Gage Station Description
CRD Monitoring Locations			
Colville River	Head of the CRD	MON1U	West bank, farthest downstream confined reach of the Colville River, conveying approximately 23,455 square miles of runoff in a single channel. Stations are located upstream (U), center (C), and downstream (D) and are offset be a distance of approximately 1 mile.
		MON1C	
		MON1D	
Colville River East Channel	East Channel Bifurcation	MON9	West bank, adjacent to horizontal directional drill (HDD) West, downstream of Nigliq Channel bifurcation
		MON9D	West bank, downstream (north) of HDD West, upstream of Sakoonang Channel bifurcation
		MON35	East side of Helmericks Homestead, Kupigruak Channel just upstream of the coastline, farthest downstream gage station
		EC12.9	West bank, RM 12.9, upstream of the Elaktoveach Channel anabranch
		EC7.2	East bank, RM7.2, downstream of the mouth of the Miluveach Channel
		EC1.3	East bank, RM 1.3, in the vicinity of the Nuna Pad, farthest downstream gage station
Nigliq Channel	Nigliq Channel Bifurcations	MON20	East bank, upstream (south) of CD4 pad, upstream of Toolbox Creek
		MON22	West bank, upstream of Nigliagvik Channel tributary
		MON23	East bank, downstream of Nigliagvik Channel tributary, downstream (northwest) of CD2 pad
		MON28	Eastern tributary channel at Harrison Bay, farthest downstream gage station
Alpine Facilities Monitoring Locations			
CD1 Pad & Drinking Water Lakes	Lake L9312	G9	Northwest side of lake, southwest of CD1 pad
	Lake L9313	G10	East side of lake, adjacent to CD1 pad
	CD1 Pad	G1	West bank of Sakoonang Channel, east side of CD1 pad
CD2 Pad & Road	Long Swale Bridge	G3	South side of road, downstream of Lake M9524
		G4	North side of road, downstream of Lake M9524
	Short Swale Bridge	G3	South side of road, downstream of Lake M9524
		G4	North side of road, downstream of Lake M9524
	Culverts	G3	South side of road, downstream of Lake M9524
		G4	North side of road, downstream of Lake M9524
		G6	South side of road, between Lake L9322 and Lake L9321
		G7	North side of road, between Lake L9322 and Lake L9321
		G12	South side of road, downstream of Nanuq Lake
		G13	North side of road, downstream of Nanuq Lake
	CD2 Pad	G8	Northwest side of CD2 pad, adjacent to Nigliq Channel
CD3 Pad & Pipeline	Pipeline Crossings	SAK	South side of Sakoonang Channel, downstream of pipeline bridge #2
		TAM	South side of Tamayayak Channel, downstream of pipeline bridge #4, downstream of Ulamnigiaq Channel bifurcation
		ULAM	North side of Ulamnigiaq Channel, downstream of pipeline bridge #5, upstream of East and West Ulamnigiaq Channel bifurcation
	CD3 Pad	G11	South side of CD3 pad, adjacent to north side of East Ulamnigiaq Channel
CD4 Pad & Road	Culverts	G15	East side of road, between Lake L9323 and Lake M9525
		G16	West side of road, between Lake L9323 and Lake M9525
		G17	North side of road, between Sakoonang Channel and Lake L9323
		G18	South side of road, between Sakoonang Channel and Lake L9323
		G40	West side of road, between Lake M9525 and Nanuq Lake
		G41	East side of road, between Lake M9525 and Nanuq Lake
		G42	West side of road, between Lake M9525 and Nanuq Lake
		G43	East side of road, between Lake M9525 and Nanuq Lake
	CD4 Pad	G19	South side of CD4 pad, north side of Lake L9324
		G20	West side of CD4 pad, east side of Tapped Lake
CD5 Road	Culverts	G30	South side of road, east of Lake L9341
		G31	North side of road, east of Lake L9341
		G34	South side of road, west of Lake L9341
		G35	North side of road, west of Lake L9341
		G36	South side of road, east of Nigliagvik Channel
		G37	North side of road, east of Nigliagvik Channel
		S1	South side of road, between Oil Lake and Lake MB0301, outside of the CRD
		S1D	North side of road, between Oil Lake and Lake MB0301, outside of the CRD
	Lake L9323 Bridge/ CD5 Bridge #1	G24	Northeast side of Lake L9323, 200-ft upstream of bridge centerline
		G25	Northeast side of Lake L9323, 310-ft downstream of bridge centerline
	Nigliq Bridge/ CD5 Bridge #2	G28	West side of Nigliq Channel, 2,600-ft upstream of bridge centerline
		G26	East side of Nigliq Channel, 200-ft upstream of bridge centerline
		G27	East side of Nigliq Channel, 160-ft downstream of bridge centerline
		G29	West side of Nigliq Channel, 2,300-ft downstream of bridge centerline
	Lake L9341 Bridge/ CD5 Bridge #3	G32	West side of Lake L9341, 180-ft upstream of bridge centerline
		G33	West side of Lake L9341, 300-ft downstream of bridge centerline
	Nigliagvik Bridge/ CD5 Bridge #4	G38	East side of Nigliagvik Channel, 350-ft upstream of bridge centerline
		G39	East side of Nigliagvik Channel, 300-ft downstream of bridge centerline
GMT1/MT6 Road	Tinmiaqsiugvik Bridge	UB6.7	West side of the Tinmiqsiugvik channel 500-ft downstream of bridge centerline
		UB6.9	West side of the Tinmiaqsiugvik channel 600-ft upstream of bridge centerline

2. METHODS

2.1 Observations

The U.S. Geological Survey (USGS) operates a hydrologic gage station on the Colville River at Umiat, approximately 90 river miles (RM) upstream of the head of the CRD at MON1. Real-time stage data and photos from this site were used during spring breakup monitoring to help forecast the arrival of floodwater and timing of peak conditions in the CRD study area. Reconnaissance flights to Ocean Point and the confluences of the Anaktuvuk River and the Chandler River assisted in tracking the progression of floodwater as breakup progressed.

Field data and observations of breakup progression, floodwater distribution, bank erosion, ice events, scour, lake recharge, and interactions between floodwaters and infrastructure were recorded in field notebooks (Photo 2.1). Photographic documentation of breakup conditions were collected using field phone cameras with integrated global positioning systems (GPS). Each photo was geotagged with the latitude and longitude, date, and time. The photo location is referenced to the World Geodetic System of 1984 horizontal datum. Additional photos were collected in 15-minute intervals via game cameras installed on the west bank of the Nigliq Bridge, which provided time-lapse observations of the Nigliq Channel.

UMIAQ provided Hägglund track vehicle support to access gage stations during setup and before a helicopter was onsite at Alpine (Photo 2.2). Pathfinder Aviation, LLC provided helicopter support to access CRD gage stations, and Alpine Environmental Coordinators provided a pickup truck to access Alpine facilities monitoring locations.

Photo 2.1: Field crew recording observations during site visit; April 20, 2021

Photo 2.2: Hägglund track vehicle transporting crew to Nigliq Channel; April 20, 2021

2.2 Water Surface Elevations

HYDROLOGIC STAFF GAGES

Water surface elevation (WSE) data was collected using hydrologic staff gages (gages) and pressure transducers (PTs) installed at monitoring locations. Gages are read during site visits and are used to verify the data collected on fixed intervals by the PTs. Site visits were performed as needed and as conditions allowed. The field methodologies used to collect hydrologic data on the North Slope of Alaska during spring breakup are proven safe, efficient, and accurate for the conditions encountered.

Gages were installed or rehabilitated as needed in the preceding fall and re-surveyed prior to spring breakup using standard differential leveling techniques.

Two types of gages were used:

1) **Direct-read gages** directly correspond to a British Petroleum Mean Sea Level (BPMSL) elevation and were surveyed by UMIAQ. The survey is used to determine if correction factors must be applied to adjust water surface elevations during spring breakup flooding. Physical adjustments to the gages are made annually by UMIAQ during ice-free conditions to correct for jacking or settlement induced by the freeze-thaw cycle. The gages consist of metal gage faceplates attached to drill stems permanently driven into the ground (Photo 2.3) or attached to pipeline vertical support members (VSMs).
2) **Indirect-read gages** do not directly correspond to a BPMSL elevation. The gage elevations were surveyed relative to a known benchmark elevation to determine a correction. The correction is applied to the gage reading to obtain the elevation in feet (ft) BPMSL.

Indirect-read gage stations consist of one or more gage assemblies positioned perpendicular to the waterbody or road. Each indirect-read gage assembly includes a standard USGS metal faceplate mounted on a wooden two-by-four. The two-by-four is attached with U-bolts to a 1.5-inch-wide angle iron post driven into the ground. The faceplate is graduated and indicates water levels every 0.01 feet between 0.00 to 3.33-ft (Photo 2.4).

Photo 2.3: Direct Read gage at G4; May 30, 2021

Photo 2.4: Indirect-read gages at MON1C; May 27, 2021

Alpine facilities gage stations were established at pads, along roads, and at drinking water source Lakes L9313 and L9312. Paired gages along the access roads captured water levels on the upstream and downstream side of drainage structures to determine stage differential.

The CRD gage stations were established throughout the delta at locations of hydrologic importance. The number of gage assemblies per station is dependent upon site specific conditions, primarily slope of the channel bank and overbank. In locations where terrain elevation varied by more than 3 feet, multiple gages were installed linearly from the edge of the low water channel up to the overbank. The gages were installed at elevations overlapping by approximately 1 foot. Individual gage assemblies were identified with alphabetical designations beginning with "A" representing the location nearest to the stream. High water marks (HWMs) were measured by applying chalk on the angle iron gage supports or VSMs and measuring the wash line (Photo 2.5).

Photo 2.5: Observing and recording a high-water mark on gage S12-A; May 25, 2021

PRESSURE TRANSDUCERS

Pressure transducers were used at select gage stations to supplement gage measurements and provide a continuous record of WSE when the water column is above the PT sensor (Photo 2.6). The PTs are designed to collect and store pressure and temperature data at discrete pre-set intervals. The PTs were programmed to collect data at 15-minute intervals beginning mid-May. Each PT was housed in a small perforated galvanized steel pipe and secured to the base of the gage assembly nearest to the channel via hose clamps. The PTs record the absolute pressure of the atmosphere and water column above the PT. Atmospheric pressure was accounted for using barometric (Baro) PTs, installed at two locations in the CRD (Photo 2.7). The depth of water above the PT sensor was calculated by subtracting the atmospheric pressure from the measured absolute pressure. During data processing, the PT measurements were adjusted to WSE readings recorded at the staff gages.

Secondary PTs were installed to validate and backup the primary PT data at locations where discharge is calculated. The PT setup and testing methods are detailed in Appendix B.

Photo 2.6: Installation of PT on staff gage SAK-A May 23, 2021

Photo 2.7: Baro at MON9/East Channel HDD

2.3 Discharge

MEASURED DISCHARGE

Discharge was measured as close to observed peak stage at the following drainage structures conveying flow:

- Colville River at MON1
- Nigliq Bridge/CD5 Bridge #2
- Nigliagvik Bridge/CD5 Bridge #4
- CD2 Road Long Swale Bridge
- CD2 Road Culverts

Discharge was not measured at the Lake L9323 Bridge/CD5 Bridge #1 or the Lake L9341 Bridge/CD5 Bridge #3 because either ice was present at the crossing, or the channel was not hydraulically connected.

Discharge at MON1 was measured using a boat mounted Acoustic Doppler Current Profiler (ADCP). Flow depth and velocity were measured at the Nigliq, Nigliagvik, and CD2 Road Long Swale bridges using a Price AA current meter suspended by cable with a sounding weight following USGS midsection procedures for measuring discharge (USGS 1982 [Photo 2.8]). Culvert flow depth and velocity were measured using a Hach flow meter attached to a wading rod following USGS velocity/area procedures for measuring discharge (USGS 1968 [Photo 2.9]). Measured discharge methods are further detailed in Appendix C.

Photo 2.8: Measuring discharge at the Nigliagvik Bridge; June 8, 2021

Photo 2.9: Field crews measuring discharge at a culvert; May 26, 2021

PEAK DISCHARGE

Discharge was calculated using indirect methods and observed WSEs to determine the timing and magnitude of peak discharge. When possible, these results were calibrated with a direct discharge measurement by adjusting the channel roughness factor (manning's n). Under open channel conditions, peak discharge typically occurs at the same time as peak stage; however, discharge in the CRD is typically affected by ice and snow during peak conditions. This often yields a lower discharge than an equivalent stage under open water conditions.

Discharge was calculated and peak discharge was determined at the following locations:

- Colville River (MON1)
- Colville River East Channel (MON9)
- Nigliq Bridge/CD5 Bridge #2
- Nigliagvik Bridge/CD5 Bridge #4
- CD2 Road Long Swale Bridge
- CD2 road culverts associated with gages G3/G4

Discharge conditions often include ice and snow effects, which are highly dynamic and challenging to quantify. Ice and snow conditions can affect channel geometry, roughness, energy gradient, and stage, all of which are used to calculate discharge indirectly. In consideration of these conditions, calculations of discharge are evaluated on a qualitative rating scale of good, fair, or poor, as described in Table 2.1. Detailed discharge calculation methods are presented in Appendix C.

Table 2.1: Discharge Quality Ratings

Quality Rating	Description
Good	Open channel/drainage structure free of ice and snow, no backwater effects from downstream ice jamming, uniform channel/drainage structure through reach
Fair	Some ice floes and/or snow in the channel/drainage structure, some backwater effects, fairly uniform conditions through reach
Poor	Significant quantities of ice and snow in the channel/drainage structure, significant backwater effects from downstream ice jamming, non-uniform conditions through channel/drainage structure reach

2.4 Post-Breakup Conditions Assessment

Alpine facilities roads, pads, and drainage structures were assessed immediately following breakup flooding. A systematic inventory was completed to document the effects of flooding on infrastructure with a focus on erosion. Both sides of the roads were photographed from the ground and the condition of the fill material was described.

2.5 CD5 Pier Scour, Bank Erosion, & Bathymetry

Monitoring described in this section supports additional requirements specific to the CD5 development per USACE Permit POA-2005-1576 Special Condition #1 which requires the MP-AMS (Michael Baker and ABR 2013).

PIER SCOUR

The objective of measuring pier scour is to monitor the progression of pier scour at bridge piers during and after breakup flooding. Pier scour measurements satisfy the requirement for annual pier scour measurements during spring breakup and other large flood events at the Nigliq Bridge and Nigliagvik Bridge (Michael Baker and ABR 2013). Maximum scour occurring under the influence of peak velocities is often greater than the final scour measured after flood recession due to sediment deposition in the scour hole associated with lower flow velocities. For this reason, real-time soundings are collected during peak flood conditions.

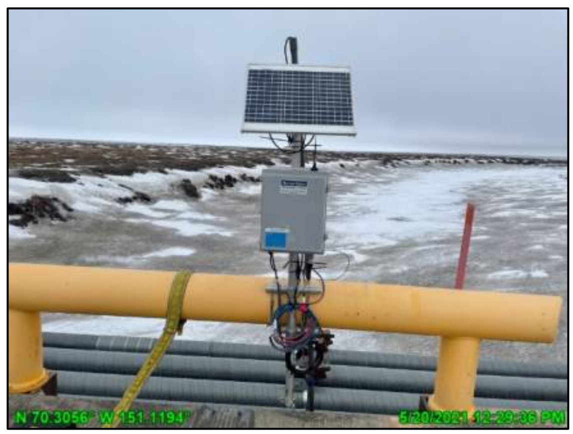

Photo 2.10: Installation of real-time pier scour equipment on the Nigliagvik Bridge; May 20, 2021

The Nigliq Bridge is supported by two bridge abutments (abutments 1 and 9) and seven bridge piers (piers 2 through 8) with numbers increasing west to east. Each bridge pier contains five piles labeled A through E, with pile A being the most upstream pile. Piles A and B support the ice breaker, while piles C, D, and E support the bridge superstructure. Nigliq Bridge piers 2 through 5 are located within the main portion of the Nigliq Channel.

The Nigliagvik Bridge is supported by two bridge abutments (abutments 1 and 5) and three bridge piers (piers 2 through 4) with numbers increasing west to east. Each bridge pier contains two piles labeled A and B, with pile A being the upstream pile. Bridge piers 3 and 4 are located within the main portion of the Nigliagvik Channel. Appendix E presents a plan view of each bridge (UMIAQ 2021a).

A real-time pier scour monitoring system was installed on the bridge piers most susceptible to scour (Photo 2.10). The systems were installed on piers 2 through 5 of the Nigliq Bridge in spring of 2016, and pier 3 of the Nigliagvik bridge in spring of 2015. Scour depths were measured using a single beam sonar installed inside a steel pipe casing welded to the downstream pile of the selected piers. Sonar measurements were recorded with an on-site datalogger. The sonar system was programmed to measure depths and record data at 30-minute intervals. A cellular based telemetry system provided remote access to the sonar measurements. A comprehensive post-breakup survey of the scour holes around the bridge piers within the main channel of the Nigliq Bridge and Nigliagvik Bridge was also conducted. Contour plots around the piers are provided in Appendix E.

BANK EROSION

The objective of the bank erosion study is to monitor bank migration upstream and downstream of the Nigliq Bridge and Nigliagvik Bridge. This work supports the requirements for visual inspection and documentation of tundra as well as bank erosion monitoring. A detailed edge-of-bank delineation was surveyed in 2013 to establish pre-construction baseline data. Bank surveys were performed annually between 2016 and 2019 (UMIAQ 2016, 2017b, 2018, and 2019b). After 2019, the bank surveys are performed every five years or following large flood events having a recurrence interval of 10-years of more (Michael Baker and ABR 2013). The 2021 flood had a stage recurrence interval that was less than 2 years around the CD5 infrastructure, however the bank erosion surveys were still completed (UMIAQ 2021b). Maximum and average rates of erosion between 2013 and 2021 were determined for each bank.

BATHYMETRY

A. Bathymetry at Bridges

Topographic and bathymetric baseline surveys upstream and downstream of the Nigliq Bridge, Nigliagvik Bridge, and Lake L9341 Bridge were performed by UMIAQ in August 2013, prior to construction of the bridges. The pre-construction survey included two transects surveyed upstream and two transects surveyed downstream of the Nigliq Bridge (Transects 8-11), the Nigliagvik Bridge (Transects 25-28), and the Lake L9341 Bridge (Transects 36-39). These transects have been surveyed annually since 2013 (Michael Baker and ABR 2013).

B. Channel Bathymetry

Topographic and bathymetric baseline post-breakup surveys of the Nigliq Channel and Nigliagvik Channel were performed by UMIAQ in August 2013, prior to construction of the bridges. The pre-construction survey included 15 transects surveyed along the Nigliq Channel upstream and downstream of the Nigliq Bridge (Transects 1-15) and 20 transects surveyed at the Nigliagvik Channel upstream and downstream of the Nigliagvik Bridge (Transects 16-35). These transects were surveyed post-construction in 2016 and annually through 2019. After 2019, the transects will be surveyed every five years (Michael Baker and ABR 2013). The next channel bathymetry survey is scheduled for 2024.

2.6 Ice Road Crossings Breakup

Aerial observations of the hydraulic effects of winter ice road crossings during breakup were documented at locations presented in Figure 2.1.

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Miles 0 4

Date:	10/20/2021	Scale:	1 Inch = 2 Miles
Drawn:	JEM	Project:	183660
Checked:	GCY	File:	2021_Ice_Monitoring.mxd

Monitoring Location
Gravel Road
Existing Gravel Structure
Ice Road
Stream
Ice Pad

Imagery from CPAI & Maxar 2019

Michael Baker INTERNATIONAL

Michael Baker International, Inc.
3900 C Street, Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP COLVILLE RIVER DELTA

Ice Structure Monitoring Locations

FIGURE 2.1

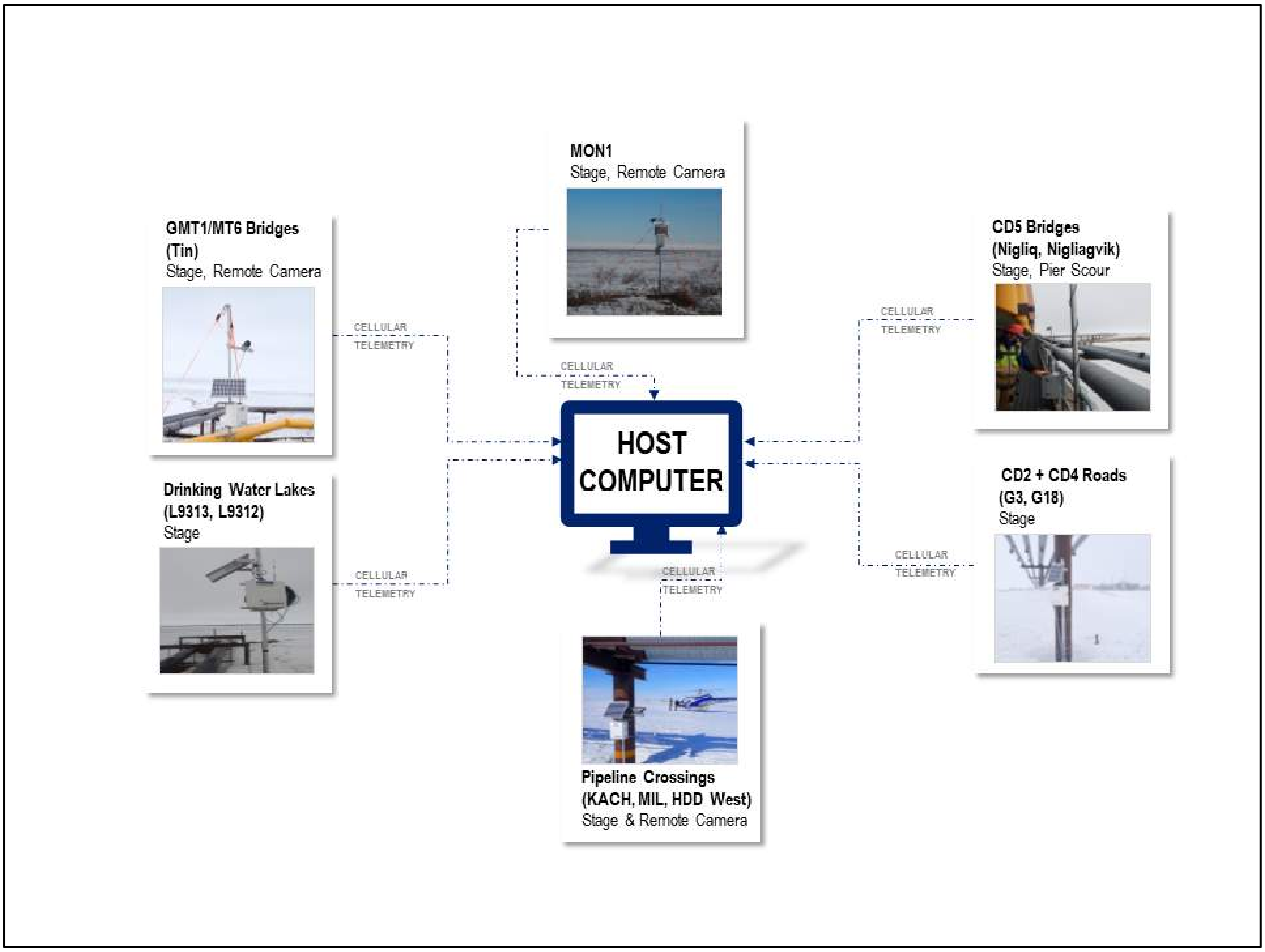
2.7 Real-Time Flood Monitoring Network

The objective of the Real-Time Flood Monitoring (RTFM) Network is to remotely monitor stage and pier scour at select monitoring locations during spring breakup flooding (Table 2.2). The RTFM Network has the following components: remote cameras to monitor stage and river conditions, sensors to monitor stage, barometric pressure and real-time bridge pier scour (discussed in Section 2.5), dataloggers and telemetry systems to collect and transmit data, and a host computer to receive the transmitted data (Figure 2.2). The ability to remotely monitor stage and scour helps reduce helicopter traffic, allows for round-the-clock monitoring of conditions, and provides an interactive tool for collecting hydrologic data when helicopter travel is restricted because of weather, maintenance, or subsistence hunting activities. In addition, a network of real-time monitoring stations at critical locations around Alpine infrastructure helps guide facilities operations preparedness, and helps hydrologists deploy resources during peak conditions when critical measurements are required.

Table 2.2: RTFM Network Stations

Monitoring Location	Gage Station	Real-Time Data
Colville River	• MON1U • MON1C • MON1D	Stage River conditions and staff gage measurements via remote camera images
Alpine Drinking Water Lakes	• L9312 (G9) • L9313 (G10)	Stage
CD2 Road Swale Bridges	• G3	Stage
CD4 Road/CD4 Pad	• G18	Stage Barometric pressure
CD5 Road	• Nigliq Bridge • Nigliagvik Bridge	Stage Pier scour
GMT1/MT6 Road	• Tinmiaqsiugvik Bridge	Stage River conditions via remote camera images
Alpine Pipeline Crossings	• Miluveach River • Kachemach River • HDD West Bank	Stage River conditions via remote camera images

Figure 2.2: RTFM Network Schematic



REMOTE CAMERAS

Remote camera systems were installed at the MON1 monitoring locations. A high-resolution digital camera was programmed to take pictures at 1-hour intervals. The camera collected wide-angle photographs of the Colville River to document conditions and monitor ice jam formation and releases in the MON1 reach. Additionally, camera zoom capabilities allowed hydrologists to remotely read staff gages for validating PT data. This has proved extremely valuable during peak stage when hydrologists are unable to land a helicopter at the MON1 monitoring locations due to weather conditions. Remote cameras were also installed to observed conditions at the Tinmiaqsiugvik Bridge and MON9 (Photo 2.11).

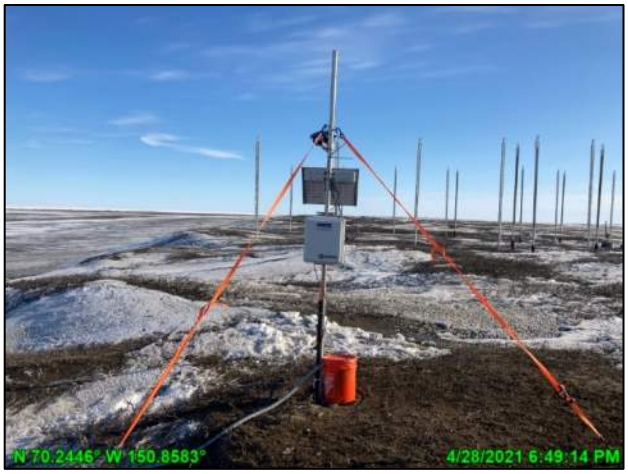


Photo 2.11: Remote camera setup at HDD West bank; April 28, 2021

SENSORS

Pressure transducers were programmed to read and record water levels and barometric pressure at 15-minute intervals. The RTFM PTs were installed at the head of the CRD (MON1), along the CD2 and CD4 road (G3 and G18), at the Nigliq and Nigliagvik Bridges (G45 and G46), at the Alpine drinking water lakes (G9 and G10 [Photo 2.12]), and at the Tinmiaqsiugvik Bridge. Real-time pier scour sensors were also installed on the Nigliq and Nigliagvik Bridges. Pier scour was measured using single beam sonars (Photo 2.13) at 30-minute intervals.

Photo 2.12: Remote stage monitoring equipment at Lake L9313 (G10); May 10, 2021

Photo 2.13: Pier scour sonar equipment on the Nigliagvik; May 20, 2021

DATALOGGERS & TELEMETRY

Onsite dataloggers were programmed to interface with the PTs and sonars. Data was uploaded to the datalogger via a data cable and stored internally. Dataloggers were programmed to interact with telemetry equipment to transmit data. Data was transmitted using an onsite cellular modem and TCP/IP communication where each cellular modem has a unique static IP address. Systems were powered with 12v DC batteries and charged with solar panels (Photo 2.14).

Photo 2.14: Installation of telemetry and solar/battery RTFM equipment at the Tinmiaqsiugvik Bridge; May 11, 2021

HOST COMPUTER, DATA ACCESS, & NOTIFICATIONS

A host computer monitored the cellular modem IP addresses offsite and received data from the dataloggers once the connection was established. Real-time stage was processed using downloaded stage and barometric pressure data. Real-time stage was periodically compared with field-observed stage data for quality assurance. Real-time stage and pier scour were plotted on graphs and updated in tables as data was received. Alarms were set to notify Alpine operations personnel if stage or pier scour reached the 50- or 200-year predicted values at any of the monitoring locations. If alarms were triggered, notifications would automatically be sent by email and text message to the Michael Baker project manager and Alpine Operations personnel for immediate assessment.

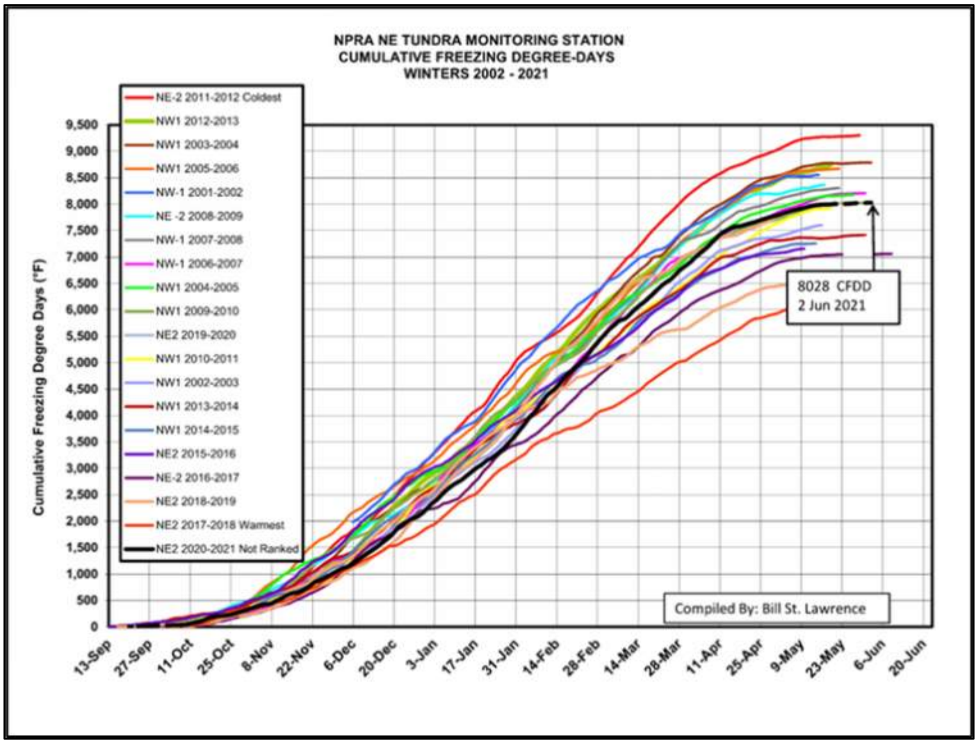
2.8 Flood & Stage Frequency Analyses

Peak discharge at MON1 is assigned a flood recurrence interval annually based on current design criteria. The flood recurrence interval provides an estimate of the magnitude of annual breakup flooding entering the CRD. A flood recurrence interval was assigned to the peak discharge at MON1 using the basis of design flood frequency analysis (Michael Baker 2021). Peak stage at select monitoring locations was compared to historical stage data and results from the 2D model. A stage recurrence interval was assigned to this year's peak stage.

3. OBSERVATIONS

3.1 General Climatic Summary

According to cumulative freezing degree-days (CFDD) measured at the National Petroleum Reserve Alaska (NPR-A) tundra monitoring station, the 2020-2021 (September – May) winter temperatures were within the normal range of the historical record for the past 20 years (Graph 3.1, ICE 2021).



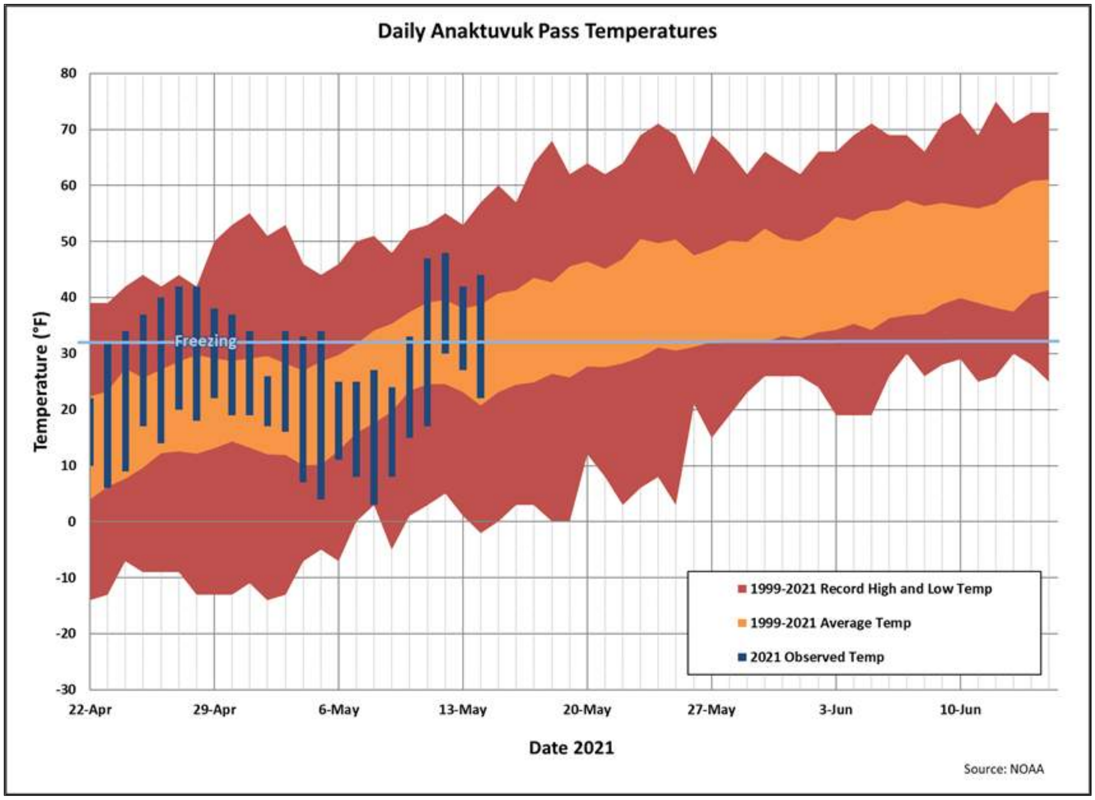
Graph 3.1: NPR-A N. Tundra Monitoring Station, CFDD, Winters 2002-2021 (ICE 2021)

North Slope snowpack data is limited, but according to NWS 2021 National Hydrologic Assessment, the 2020-2021 winter season snowpack was well below normal levels in the CRD (NWS, 2021).

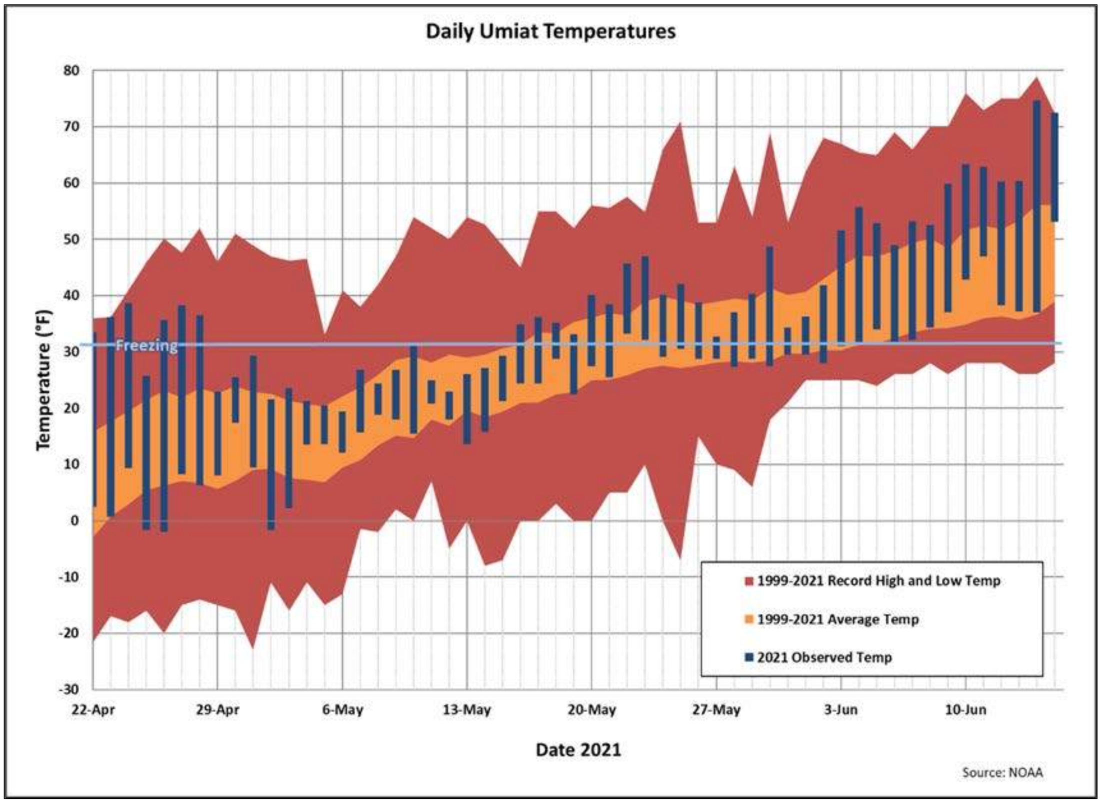
A slow, gradual warming trend in the Upper Colville River watershed (the Brooks Range foothills) was recorded at Umiat, beginning on May 5. Daily maximum temperatures began to exceed freezing on May 16 (USGS 2021a). After May 23, daily mean temperatures remained around freezing until June 2. Temperatures then started rapidly climbing, with daily minimum temperatures consistently exceeding freezing after June 7.

Temperatures at Nuiqsut followed a similar trend to temperatures upriver but were slightly cooler, experiencing a brief period above freezing in mid-May. Daily high temperatures consistently exceeded freezing after June 2 which lasted throughout the monitoring period. Daily minimum temperatures consistently exceeded freezing on June 9 and lasted throughout the monitoring period.

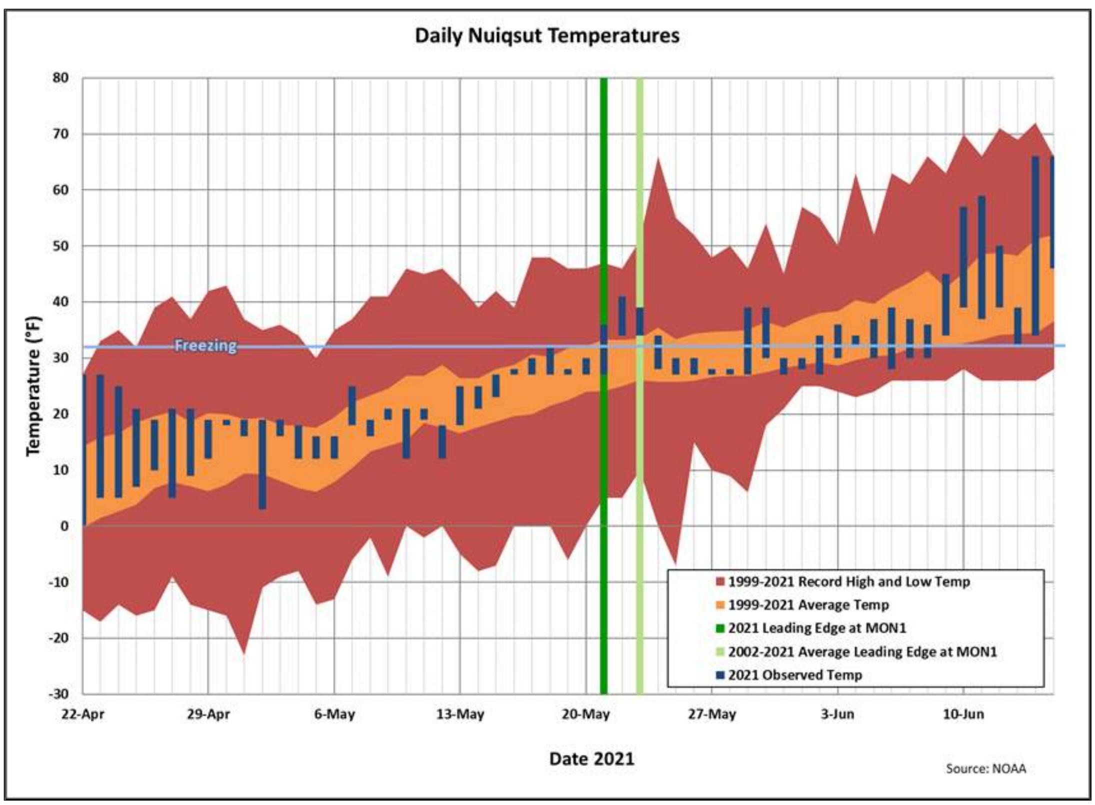
Graph 3.2, Graph 3.3, and Graph 3.4 illustrate daily high and low ambient air temperatures recorded in Anaktuvuk Pass, Umiat, and Nuiqsut, respectively, superimposed on the average and record daily highs and lows during the breakup monitoring period (National Oceanic and Atmospheric Administration [NOAA] 2021). Data not reported was missing from NOAA.



Graph 3.2: Anaktuvuk Pass Daily High and Low Ambient Air Temperatures



Graph 3.3: Umiat Daily High and Low Ambient Air Temperatures



Graph 3.4: Nuiqsut Daily High and Low Ambient Air Temperatures and MON1 Leading Edge

3.2 General Breakup Summary

On May 22, meltwater was first observed in the CRD which appeared as clear, non-flowing water overtop of channel ice. A reconnaissance flight on May 24 showed the leading edge of turbid flood water immediately upstream of the Horseshoe Bend (Photo 3.1). Intact channel ice was observed at MON1, along with local melt and overflow, which was forced above the bankfast ice by the pressure of the progressing upstream floodwater. (Photo 3.2). Downstream of MON1, hinge cracks, indicating rising water levels, were observed along the channel ice until the HDD crossing. Only local melt was observed in the distributary channels downstream of HDD. By May 25, the channel ice at Ocean Point had lifted, indicating increasing stage. Most sand bars were still exposed and stage was well below bankfull. The leading edge of turbid floodwater had not progressed past the Horseshoe Bend.

Photo 3.1: Approximate leading edge of floodwater upstream of the Horseshoe Bend, looking south (upstream); May 24, 2021

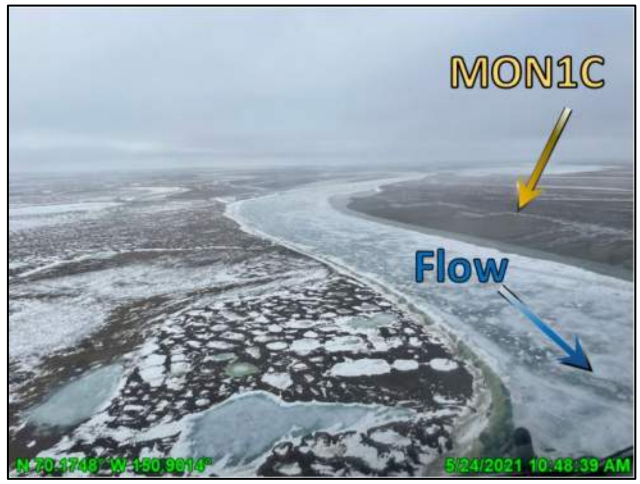


Photo 3.2: Intact channel ice through MON1 reach with overflow and local melt along the banks, looking south (upstream); May 24, 2021

On May 26, an ice jam approximately 4 river miles (RM) long had formed downstream of Ocean Point (Photo 3.3). Adjacent sandbars were submerged but stage remined below bankfull. Downstream of the Ocean Point ice jam, the channel was free of ice until the Horseshoe Bend, where a second small ice jam had formed, approximately 2 RM long (Photo 3.4). This ice jam was held by intact channel ice which continued downstream. Another small ice jam was observed at the Nigliq Channel bifurcation, just upstream of Nuiqsut. The hydraulic connection between the Nigliq and Sakoonang Channels had formed through Lake L9324, south of CD4. By May 27, the initial rise in stage in the CRD and around Alpine facilities crested and began to decrease as temperatures cooled.

On a May 28 reconnaissance flight approximately 15 RM upstream of Ocean Point, a considerable amount of stranded ice was observed, indicating stage had receded. Water levels in the CRD were also still receding. On May 29, field crews observed the Ocean Point ice jam had not progressed and was now approximately 6 RM long (Photo 3.5). The Horseshoe Bend ice jam remained unchanged from previous days. By May 31, receding stage around Alpine facilities leveled off as floodwater continued to slowly move through the delta. These conditions remained consistent until June 4, when stage began to rise at Umiat. On June 5, both the Ocean Point and Horseshoe Bend ice jams cleared as a result of the rising water levels (Photo 3.6). Periodic ice floes were observed moving through the Horseshoe Bend with intact channel ice generally starting just downstream. By June 6, channel ice had cleared the MON1 reach and stage began to rise around Alpine facilities. Peak stage at MON1 occurred the afternoon of June 6. Intact channel ice was observed at the HDD crossing (Photo 3.7). The gage at Umiat crested in the evening of June 6. Despite rising stage, sandbars were still exposed and water remained below bankfull with no overbank flooding observed (Photo 3.8).

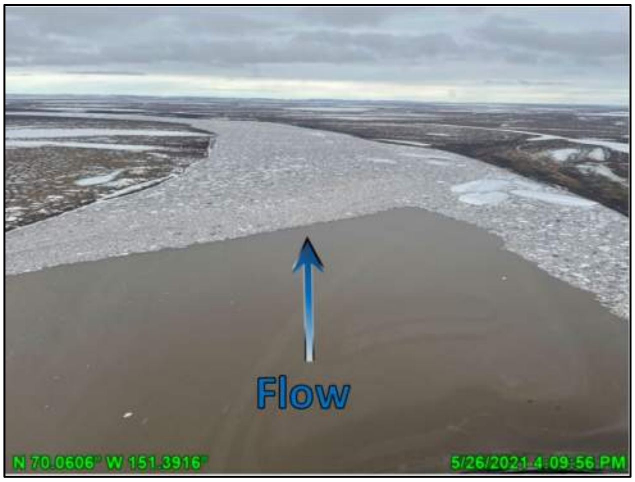


Photo 3.3: Colville River ice jam immediately downstream of Ocean Point, looking southeast (downstream); May 26, 2021

Photo 3.4: Colville River ice jam at the Horseshoe Bend, looking east (downstream); May 26, 2021

Photo 3.5: Extent of Colville River ice jam immediately downstream of Ocean Point, looking southwest (upstream); May 29, 2021

Photo 3.6: Open water conditions with periodic ice floes on the Colville River at Horseshoe Bend after both ice jams cleared, looking northwest (downstream); June 5, 2021

Photo 3.7: Fragmented channel ice just upstream of HDD, looking north (downstream); June 6, 2021

Photo 3.8: Intact channel ice on the east side of the Colville River near the Sakoonang Channel bifurcation, with no overbank flooding, looking north (downstream); June 6, 2021

On the morning of June 7, channel ice and ice floes in the East Channel had cleared downstream to the Tamayayak Channel bifurcation. Stage around Alpine facilities crested early that afternoon (Photo 3.9). Channel ice in the Nigliq Channel started moving downstream around midday and open water conditions were observed later that evening at the Nigliq Bridge. Water remained below all roads and pads during peak conditions around Alpine facilities (Photo 3.10).

Discharge was measured at all bridge and culvert crossings conveying flow around Alpine facilities on June 7 and June 8. Discharge was measured on the Colville River at MON1 on June 8. Stage continued to decrease throughout the CRD through the remainder of the monitoring period (Photo 3.11). Open water, extending to the coast in all distributary channels, was confirmed on June 9 (Photo 3.12).

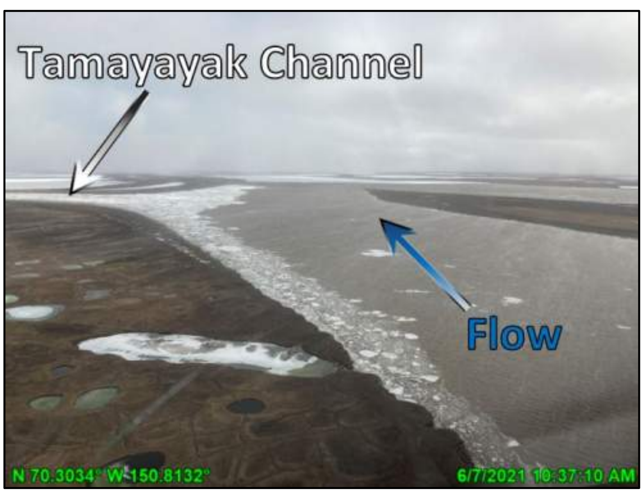


Photo 3.9: Ice in the East Channel accumulating near the Tamayayak Channel bifurcation, looking north (downstream); June 7, 2021

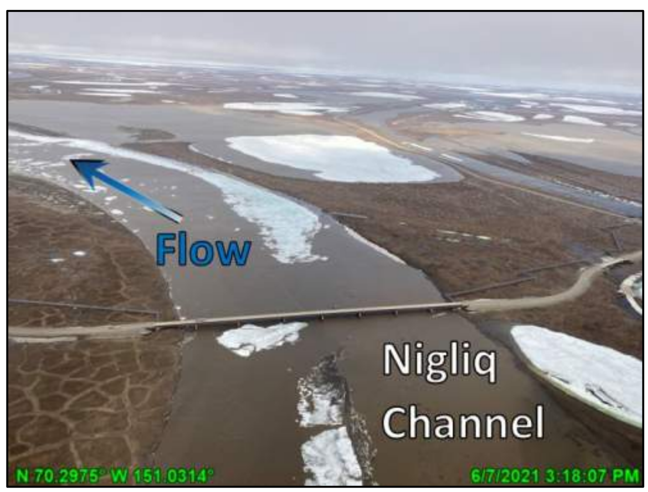


Photo 3.10: CD5 Bridge across the Nigliq Channel near peak conditions showing no floodplain inundation or overbank flooding, looking north (downstream); June 7, 2021

Photo 3.11: Open water conditions with decreasing stage at the MON1 reach, looking south (upstream); June 8, 2021

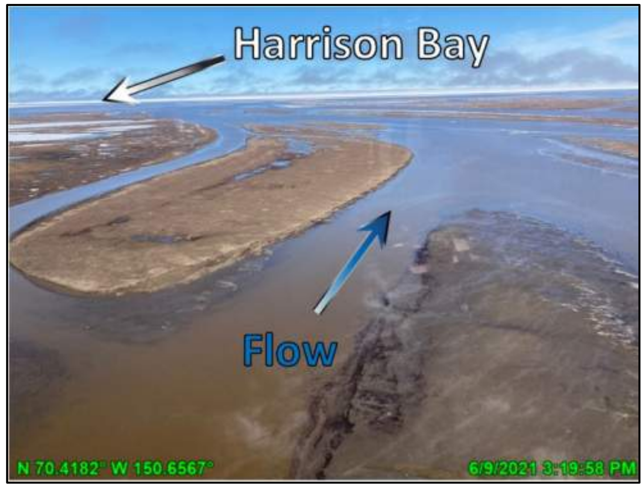
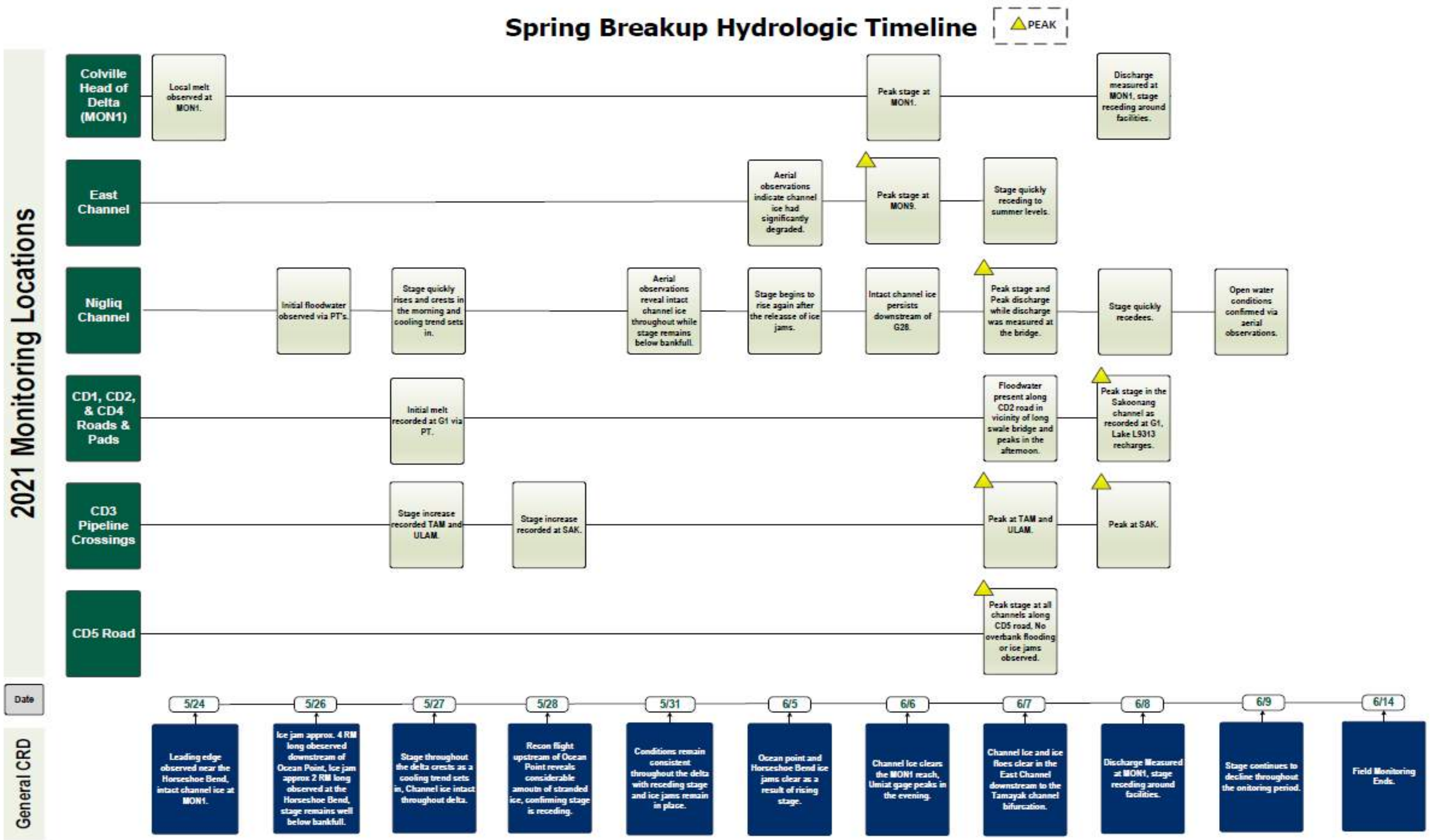


Photo 3.12: Ice-free channel extending to the coast in the Colville River Delta distributary channels, looking north (downstream); June 9, 2021

In general, peak stage was observed around the CRD and Alpine facilities between June 6 to June 7. During peak conditions, floodwater was confined to channels and connecting swales. No overbank flooding was observed around Alpine facilities. Due to the low water, some hydraulic connections typically observed during spring breakup were either delayed or did not fully develop. Lake L9313 was connected to floodwater and recharged above the bankfull elevation, however, floodwater did not reach Lake L9312. Figure 3.1 provides a visual timeline summarizing major breakup events.

Figure 3.1: Spring Breakup Hydrologic Timeline



4. STAGE & DISCHARGE

Table 4.1 contains a summary of peak stage, measured discharge (in cubic ft per second [cfs]), and peak discharge at each gage station.

Table 4.1: Peak Stage, Measured Discharge, and Peak Discharge Summary

Monitoring Location	Monitoring Location Description	Gage Station	Peak Stage		Measured Discharge			Peak Discharge		
			Stage ft BPMSL	Date & Time	Discharge cfs	Stage ft BPMSL	Date & Time	Discharge cfs	Stage ft BPMSL	Date & Time
Colville River	Upstream of Anaktuvuk & Chandler River Confluences	Umiat[1]	55.26	6/06, 5:45pm	18,700	49.55	6/2, 2:00pm	103,000	56.73	6/07, 7:00pm
CRD Monitoring Locations										
Colville River	Head of the CRD	MON1U	12.60	6/06, 3:45pm	141,000	10.57	6/08, 5:00pm	220,000	12.47	6/06, 5:15pm
		MON1C	12.34	6/06, 3:00pm		10.40			12.08	
		MON1D[2]	12.13	6/06		10.35			-	
Colville River East Channel	East Channel Distributary	MON9	10.77	6/06, 7:00pm	103,000[6]	8.16	6/08, 12:00pm	213,000	10.77	6/06, 7:00pm
		MON9D	10.49	6/06, 6:30pm		7.98			10.32	
		MON35[4]	3.90	6/07, 11:15am						
		EC12.9	8.27	6/07, 1:15pm						
		EC7.2[5]	96.13	6/07, 8:00pm						
		EC1.3[2]	4.14	6/07, 10:00pm						
Nigliq Channel	Nigliq Channel Distributary	MON20	9.01	6/07, 8:45am	28,200	6.93	6/08, 10:45am	32,000	8.58	6/07, 3:00pm
		MON22	7.33	6/07, 1:15pm		5.98			7.32	
		MON23	6.28	6/07, 5:45pm		5.25			6.26	
		MON28	2.32	6/07, 3:45pm		-			-	
Alpine Facilities Monitoring Locations										
CD1 Pad & Drinking Water Lakes	Lake L9312	G9[3]	--	--						
	Lake L9313	G10	6.53	6/08, 12:45pm						
	CD1 Pad	G1	5.87	6/08, 3:00am						
CD2 Pad & Road	Swale Bridges and Culverts	G3	6.08	6/07, 5:15pm	1,920	6.08	6/07, 5:00pm	1,920	6.08	6/07, 5:00pm
		G4	5.96	6/07, 5:45pm		5.96			5.96	
	Culverts	G6	Dry	--						
		G7	Dry	--						
		G12	Dry	--						
		G13	Dry	--						
	CD2 Pad	G8	Dry	--						
CD3 Pad & Pipeline	Pipeline Crossings	SAK	5.73	6/08, 4:00pm						
		TAM	6.02	6/07, 10:45pm						
		ULAM	5.34	6/07, 7:15pm						
	CD3 Pad	G11	Dry	--						
CD4 Pad & Road	Culverts	G15[2]	7.52	6/08, 1:30am						
		G16	7.32	6/08, 1:00am						
		G17	Dry	--						
		G18	Dry	--						
		G40	Dry	--						
		G41	Dry	--						
		G42	Dry	--						
		G43	Dry	--						
	CD4 Pad	G19	Dry	--						
		G20[4]	8.09	6/07, 10:45am						
CD5 Road	Culverts	G30	Dry	--						
		G31	Dry	--						
		G34	Dry	--						
		G35	Dry	--						
		G36	Dry	--						
		G37	Dry	--						
	Lake L9323 Bridge (CD5 Bridge #1)	G24	Dry	--						
		G25	Dry	--						
	Nigliq Bridge (CD5 Bridge #2)	G28	7.93	6/07, 12:15pm	28,200	6.23	6/08, 10:45am	32,000	7.75	6/07, 3:00pm
		G26	7.49	6/07, 12:15pm		5.88			7.43	
		G27	7.47	6/07, 12:30pm		5.84			7.38	
		G29	7.31	6/07, 12:45pm		5.75			7.19	
	Lake L9341 Bridge (CD5 Bridge #3)	G32	7.40	6/07, 11:30am						
		G33	7.34	6/07, 1:15pm						
	Nigliagvik Bridge (CD5 Bridge #4)	G38	7.07	6/07, 2:15pm	1,140	5.51	6/08, 4:00pm	3,150	7.06	6/07, 3:15pm
		G39	6.82	6/07, 7:45pm		5.48			6.35	
GMT-1 Road	Tinmiaqsiugvik Bridge	UB6.7	6.56	5/27, 8:00am						
		UB6.9	6.52	5/27, 8:00am						

Notes:
1. Data obtained from USGS Umiat gage station 15875000 and referenced to NAVD88 vertical datum
2. Peak stage timing estimated. Peak stage based on HWM reading
3. Peak Stage did not exceed bankfull recharge elevation
4. Highest recorded stage. Peak stage magnitude and timing unknown
5. Peak stage referenced to arbitrary elevation datum
6. Reported value is estimated from near-simultaneous discharge measurements at MON1 and in the Nigliq Channel and was not measured directly

Gray cells indicate that discharge was not measured or calculated. Reasons for this vary but include that discharge data was not included in program scope, ice influence at discharge cross section during and after peak, site remained dry, or PT malfunction

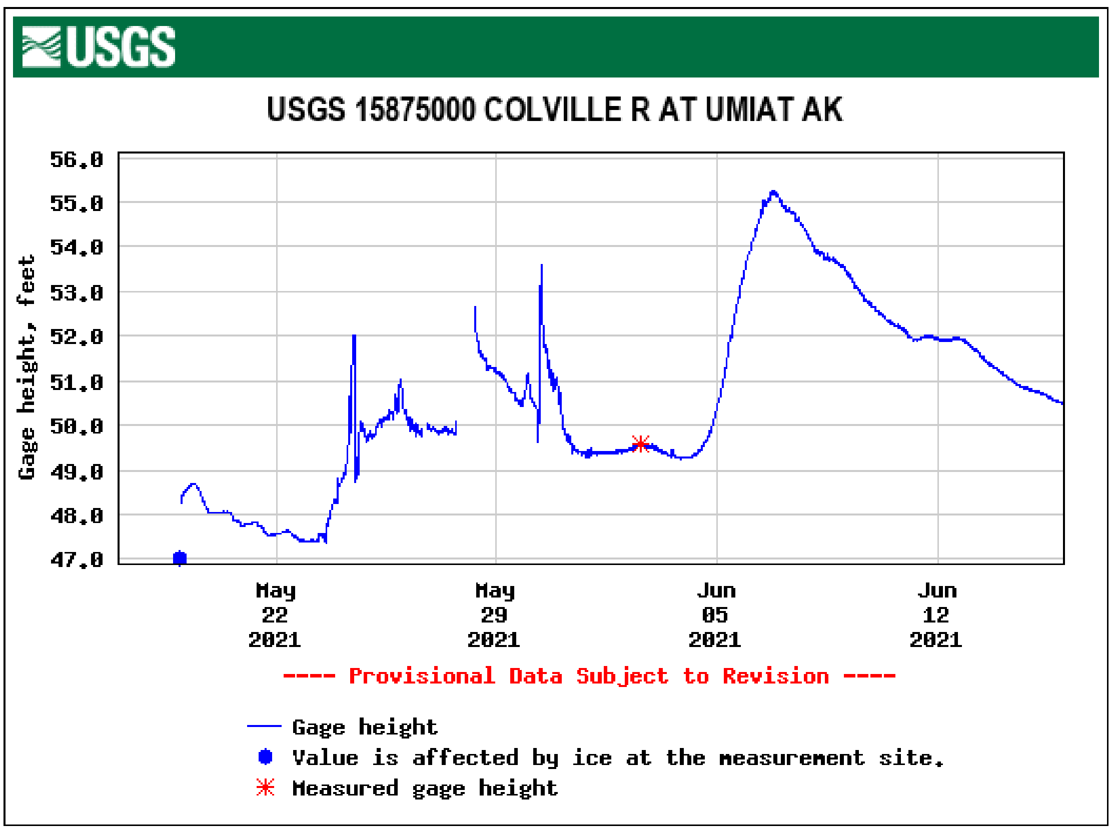
4.1 Colville River

UMIAT

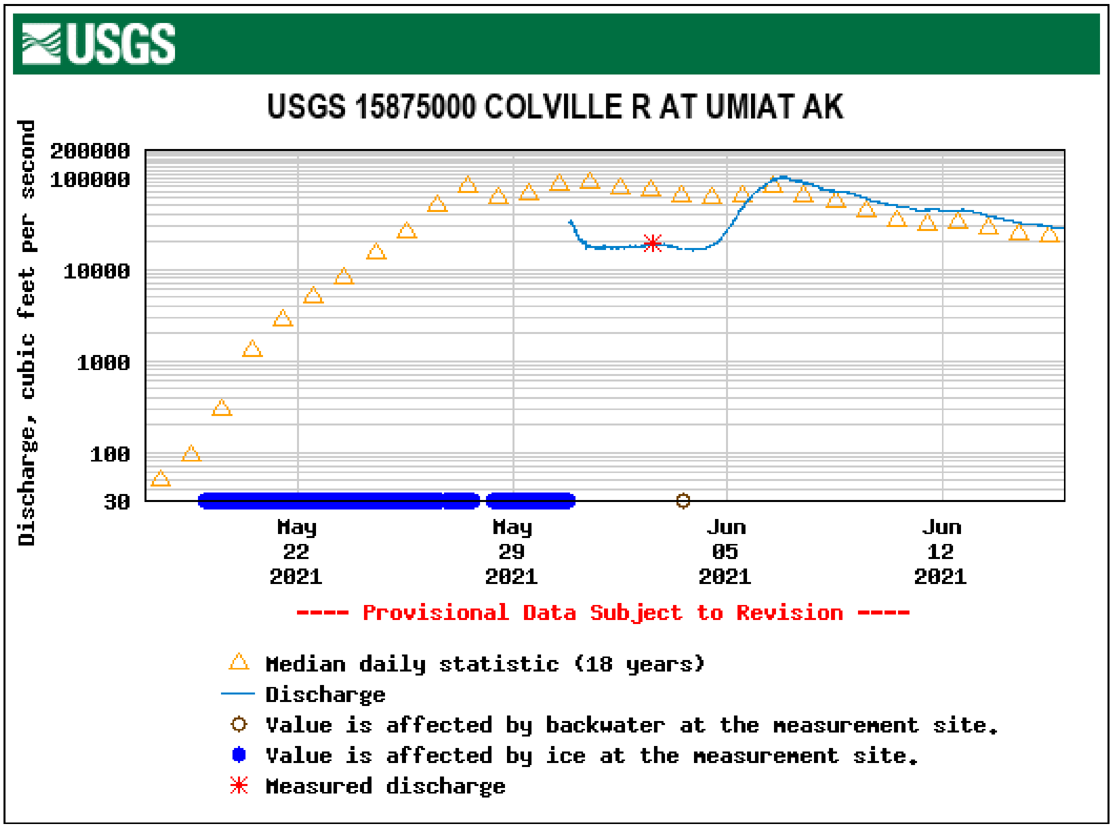
The USGS Umiat gage station 15875000 is located approximately 90 RM upstream of the CRD and is monitored throughout breakup. This real time data helps predict the timing of floodwater in the CRD. Umiat is upstream of the Chandler and Anaktuvuk River confluences, therefore the Umiat gage data does not account for the contribution from these two major tributaries. Due to local ice effects, distance, and tributaries between Umiat and the CRD, the magnitude of flooding at Umiat and in the CRD do not necessarily correlate.

The Umiat gage began measuring water levels on May 18. Stage remained low through May as cooler air persisted over the Brooks Range foothills. Observations from an overflight to Umiat on May 28 showed stage well below bankfull, with stranded ice on the banks and substantial snowpack remaining in the local foothills. Stage peaked on June 6 at 55.3 ft NAVD88. This is below the National Weather Service established flood stage of 59.0 ft NAVD88. Stage steadily receded to base summer conditions after peak stage was recorded.

The peak discharge of 103,000 cfs occurred near peak stage on June 6. Peak annual discharges from 2002 to 2021 at this location occur during spring breakup, with the exception of the lowest year of the reporting period 2017. Peak annual discharge values range from 82,000 cfs, recorded in August 2017, to 268,000 cfs, recorded in May 2015. USGS stage and discharge data are presented in Graph 4.1 and Graph 4.2, respectively.



Graph 4.1: Colville River at Umiat Stage (USGS 2021b)



Graph 4.2: Colville River at Umiat Discharge (USGS 2021b)

HEAD OF THE DELTA

MON1 is located at the head of the Colville River Delta, where all flow is confined to a single channel, upstream of the Nigliq Channel bifurcation. Stage and discharge have been monitored at MON1 annually since 1992 and periodically since 1962. This location has the longest historical record of all CRD monitoring locations.

Initial spring breakup meltwater was first observed at MON1 through aerial observations on May 24 which appeared as clear, non-turbid water forced overtop of intact channel ice by progressing floodwater upstream (Photo 4.1). On May 25 the leading edge of floodwater had progressed through the MON1 reach causing intact channel ice to lift (Photo 4.2). A reconnaissance flight on May 26 showed intact channel ice persisting along the east bank through the MON1 reach. Surrounding snow cover on the tundra was approximately 10% (Photo 4.3). Two ice jams were observed upstream of MON1 at the Horseshoe Bend and Ocean Point. Backwater did not appear to be developing behind the ice jams (Photo 4.4). Stage at MON1 remained well below bankfull.

These conditions persisted through June 5 as a prolonged cold period stalled breakup progress. An overflight on June 1 revealed conditions remained relatively unchanged at MON1. Stage was below bankfull and channel ice was still intact (Photo 4.5). On June 5, the Horseshoe Bend and Ocean point ice jams released, and water levels downstream started to rise. Degrading channel ice at MON1 was flushed out by the progression of floodwater on June 6 prior to peak stage. Peak conditions at MON1 occurred in the afternoon on June 6 and stage started to recede by that evening (Photo 4.6). During peak, stage remained below bankfull and periodic ice floes were present in the channel. Peak discharge was estimated to have occurred about 2 hours after peak stage. Open water conditions were observed on June 7 (Photo 4.9). Stage continued to recede through the spring breakup monitoring period. No overbank flooding or backwater effects were observed.

Discharge was measured at MON1 on June 8 with minimal ice and snow interference (Photo 4.8). Stage and discharge results at MON1 are presented in Graph 4.3.

Photo 4.1: MON1 reach with intact channel ice and melt along its banks, looking south (upstream); May 24, 2021

Photo 4.2: MON1 reach with channel ice remaining intact, looking south; May 25, 2021

Photo 4.3: Intact channel ice through the MON1 reach, looking east; May 26, 2021

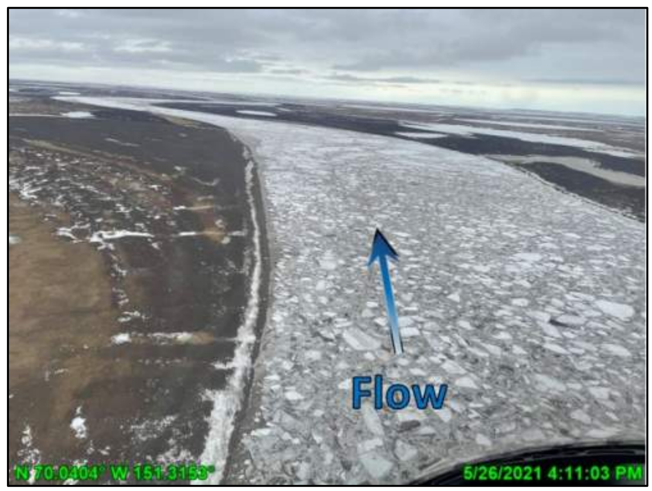


Photo 4.4: Ice jam at the Horseshoe Bend, looking south (downstream); May 26, 2021

Photo 4.5: Intact channel ice persisting at MON1, looking northwest (downstream); June 1, 2021

Photo 4.6: Peak conditions with periodic ice floes moving through the MON1 reach, looking southwest (upstream); June 6, 2021

Photo 4.7: MON1 reach with open water conditions, looking south (upstream); June 7, 2021

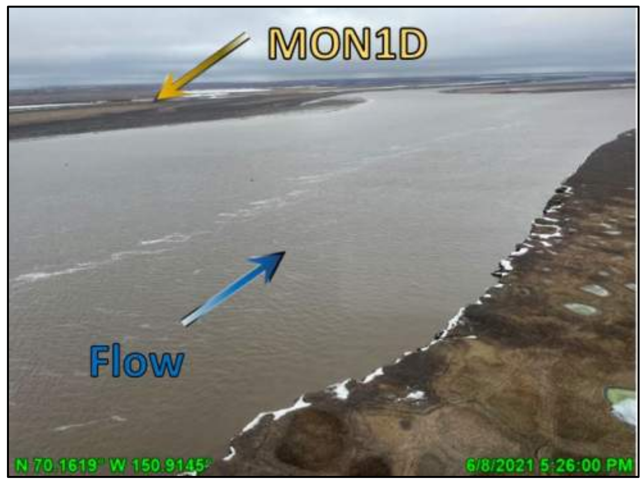
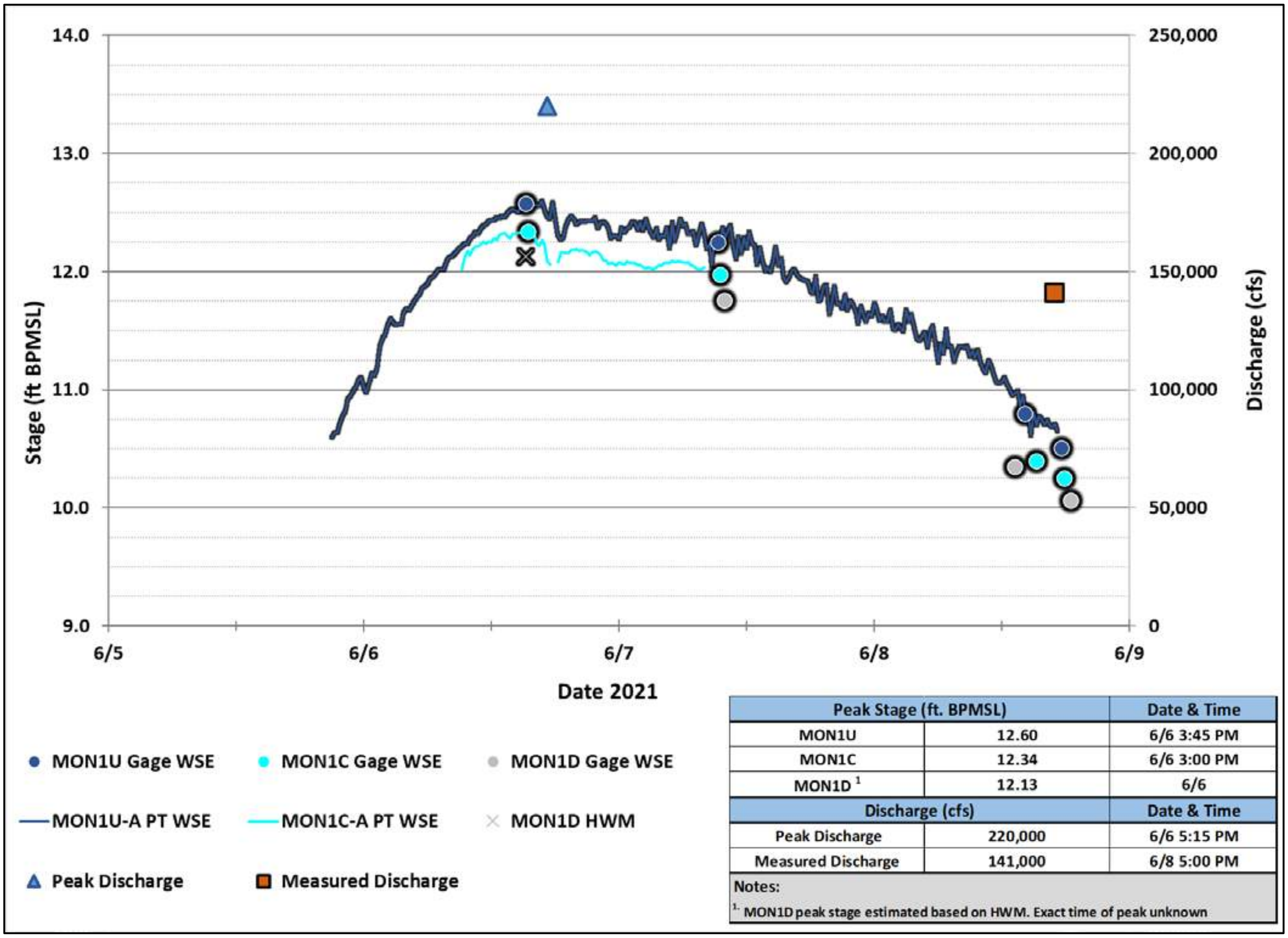


Photo 4.8: Open channel conditions during discharge measurement at MON1, looking northwest (downstream); June 8, 2021



Peak Stage (ft. BPMSL)		Date & Time
MON1U	12.60	6/6 3:45 PM
MON1C	12.34	6/6 3:00 PM
MON1D [1]	12.13	6/6
Discharge (cfs)		**Date & Time**
Peak Discharge	220,000	6/6 5:15 PM
Measured Discharge	141,000	6/8 5:00 PM

Notes:
[1] MON1D peak stage estimated based on HWM. Exact time of peak unknown

Graph 4.3: Colville River at the Head of the Delta Stage & Discharge

4.2 Colville River East Channel

MON9 is located at the Colville HDD pipeline crossing. It has been monitored annually since 2005. Data is collected to estimate the distribution of discharge between the East Channel and Nigliq Channel and to monitor stage and ice effects at the HDD pipeline crossing. MON35 is located at the Helmericks Homestead and has been monitored for stage at the outer extents of the CRD since 1999.

EC1.3, EC7.2, and EC12.9 are located in the East Channel between the coast and the Tamayayak Channel bifurcation.

Local melt was first recorded on the MON9 PTs on May 22. Aerial observations from May 25 show floodwater beginning to lift the channel ice (Photo 4.9). No hinge cracks were observed in the channel ice along the banks. Stage rose and crested on May 27 before a prolonged cold period stalled breakup progress (Photo 4.10). During the stage crest, channel ice was intact, and no further ice degradation was observed. Stage gradually receded and conditions remained relatively unchanged through June 5.

On June 5, stage rose sharply as the main surge of floodwater reached MON9. Aerial observations revealed the channel ice had considerably degraded, and full-length hinge cracks were observed in the ice along the east bank (Photo 4.11). Stage peaked on June 6 at about 6:30 PM. Peak stage corresponded with the approximate timing of channel ice breaking up and pushing through the reach. Peak discharge was estimated to have occurred directly after the channel ice broke apart. Observations near peak stage reveal stage levels below bankfull and no exposed sandbars in the channel (Photo 4.12). After peaking, stage remained elevated until gradually receding to low-flow levels beginning the morning of June 7.

Peak stage at MON35 and the other East Channel monitoring sites occurred on June 7, one day after peak stage at MON9. Observations from MON35 and the other East Channel monitoring sites at peak stage show intact channel ice and stage below bankfull (Photo 4.13 through Photo 4.16).

Stage and discharge at MON9 and MON9D and stage at MON35 are presented in Graph 4.4. Stage at EC12.9 and EC1.3 are presented in Graph 4.5. Stage at EC7.2 is presented in Graph 4.6. Plan and profile drawings are provided in Appendix C.

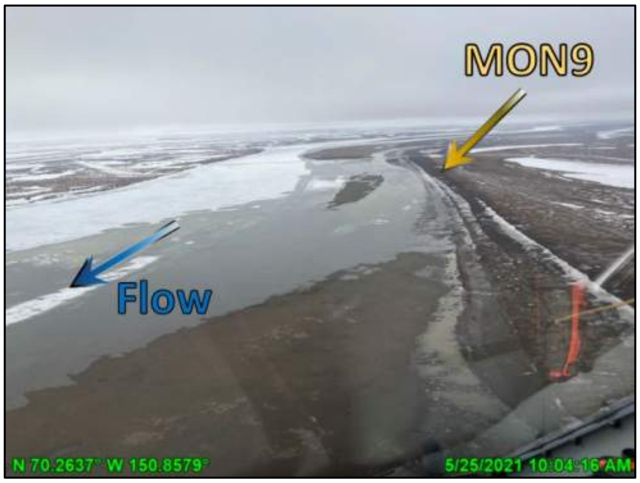


Photo 4.9: Lifting of channel ice at MON9, looking south (upstream); May 25, 2021

Photo 4.10: MON9 reach during initial stage crest, looking north (downstream); May 27, 2021

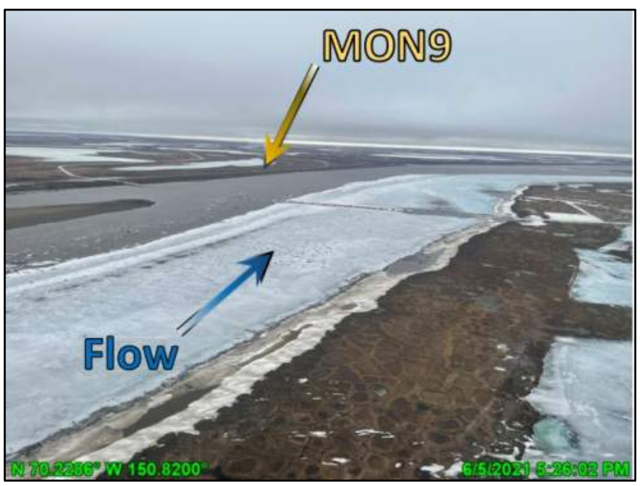


Photo 4.11: Rising stage and degrading channel ice at MON9, looking north (downstream); June 5, 2021

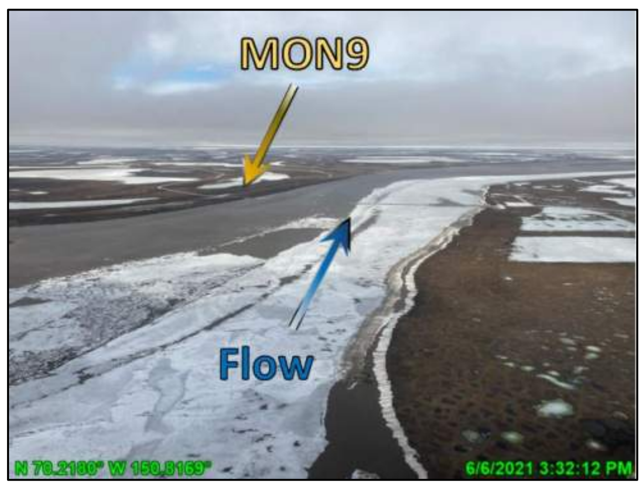


Photo 4.12: MON9 reach just prior to peak stage, looking north (downstream); June 6, 2021

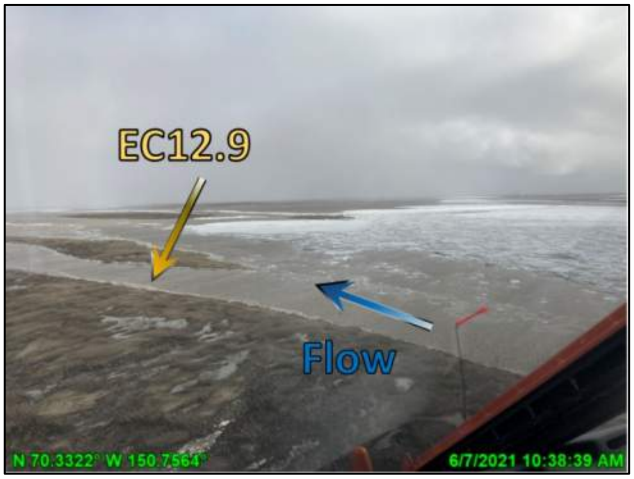


Photo 4.13: EC12.9 prior to peak stage, looking south (upstream); June 7, 2021

Photo 4.14: EC7.2 prior to peak stage, looking north (downstream); June 7, 2021

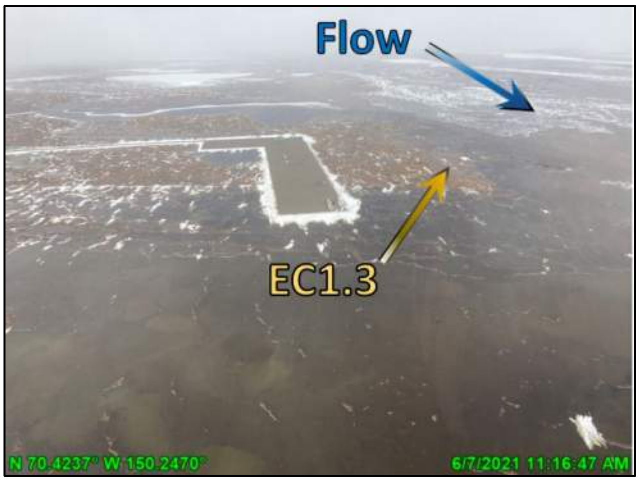


Photo 4.15: EC1.3 near peak stage, looking southwest (upstream); June 7, 2021

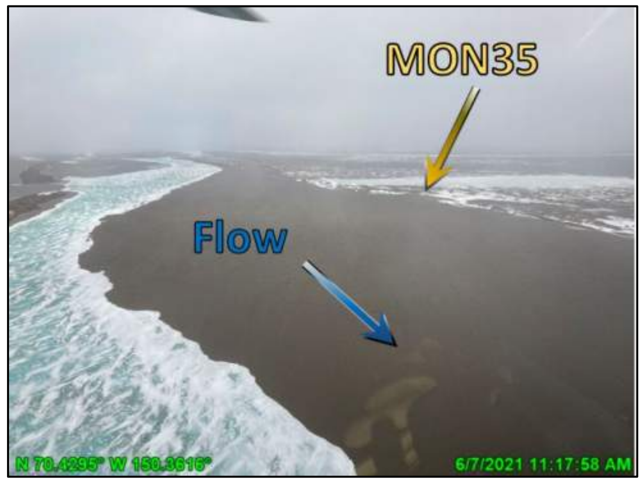
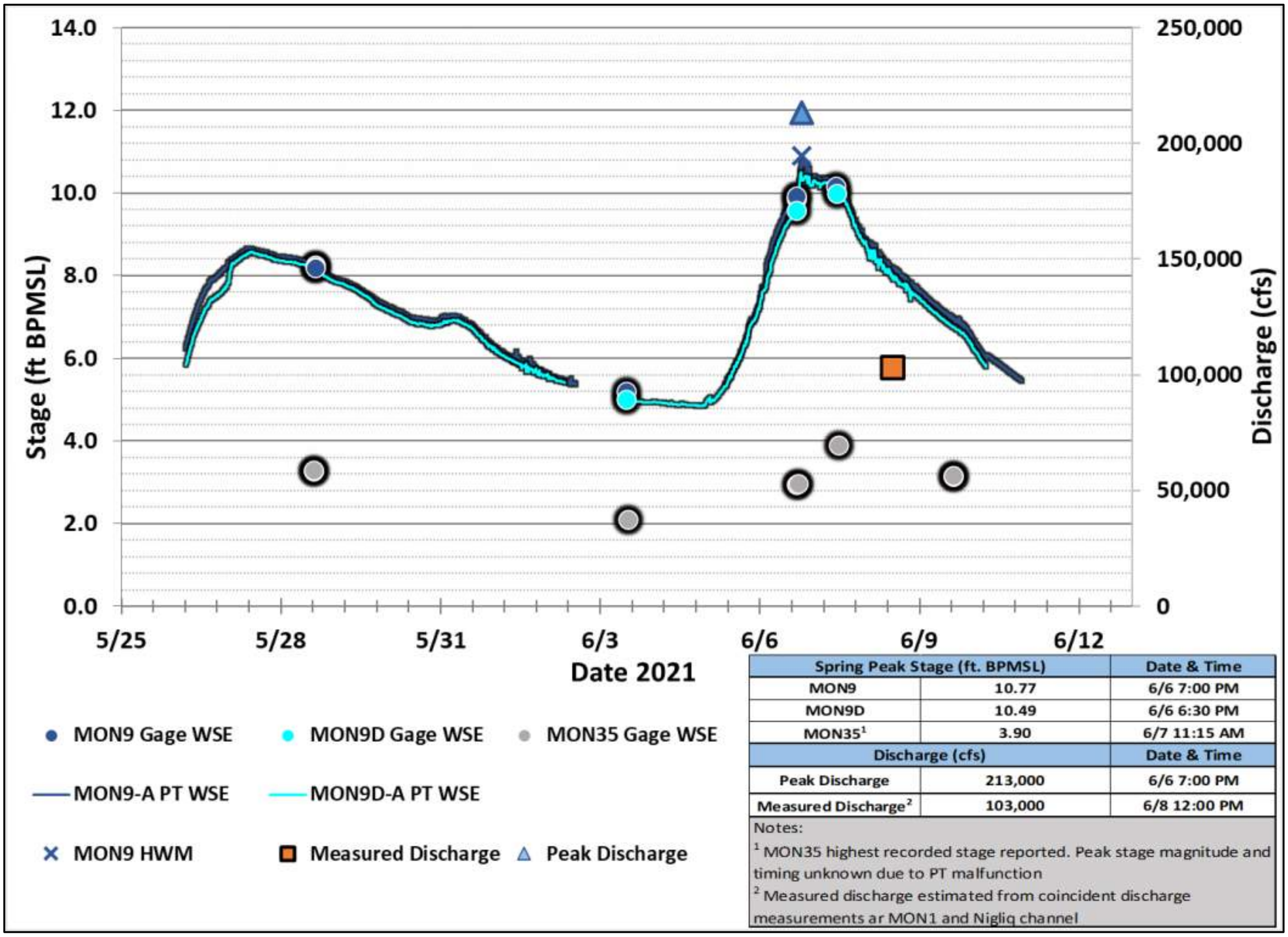


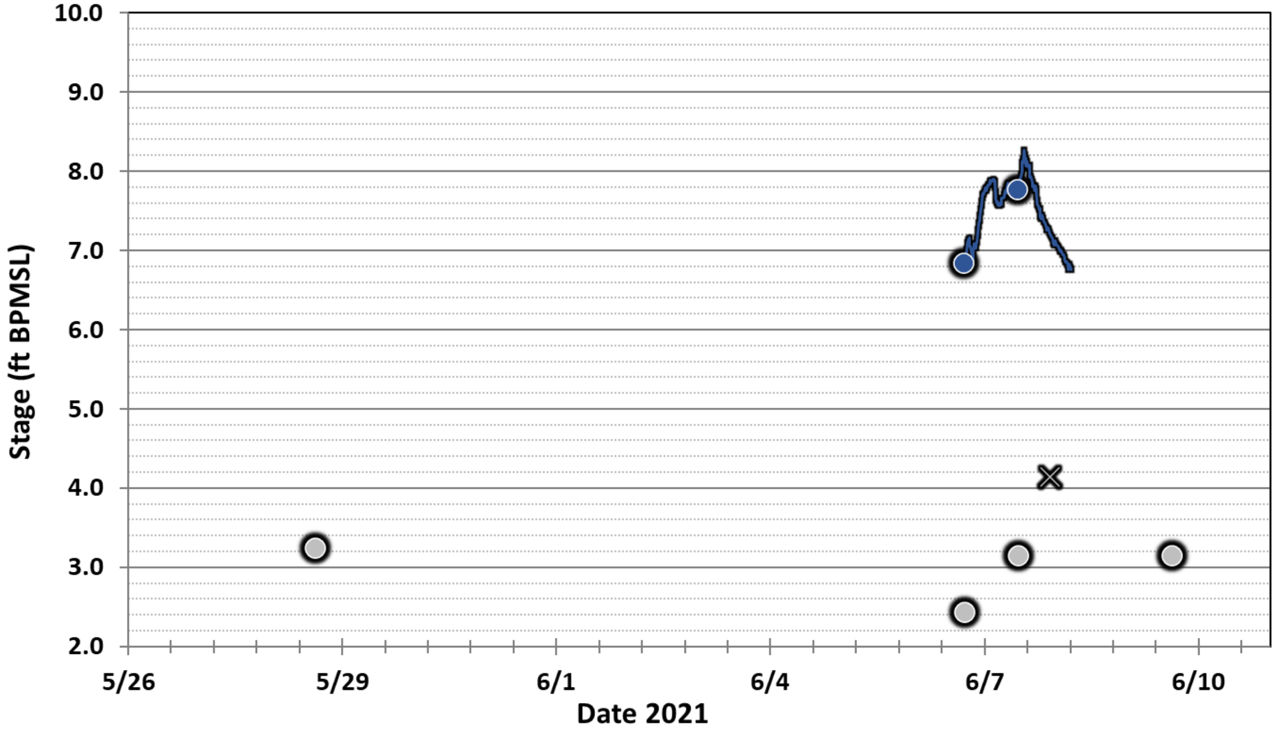
Photo 4.16: MON35 near peak stage, looking south (upstream); June 7, 2021



Spring Peak Stage (ft. BPMSL)		Date & Time
MON9	10.77	6/6 7:00 PM
MON9D	10.49	6/6 6:30 PM
MON35[1]	3.90	6/7 11:15 AM
Discharge (cfs)		**Date & Time**
Peak Discharge	213,000	6/6 7:00 PM
Measured Discharge[2]	103,000	6/8 12:00 PM

Notes:
[1] MON35 highest recorded stage reported. Peak stage magnitude and timing unknown due to PT malfunction
[2] Measured discharge estimated from coincident discharge measurements ar MON1 and Nigliq channel

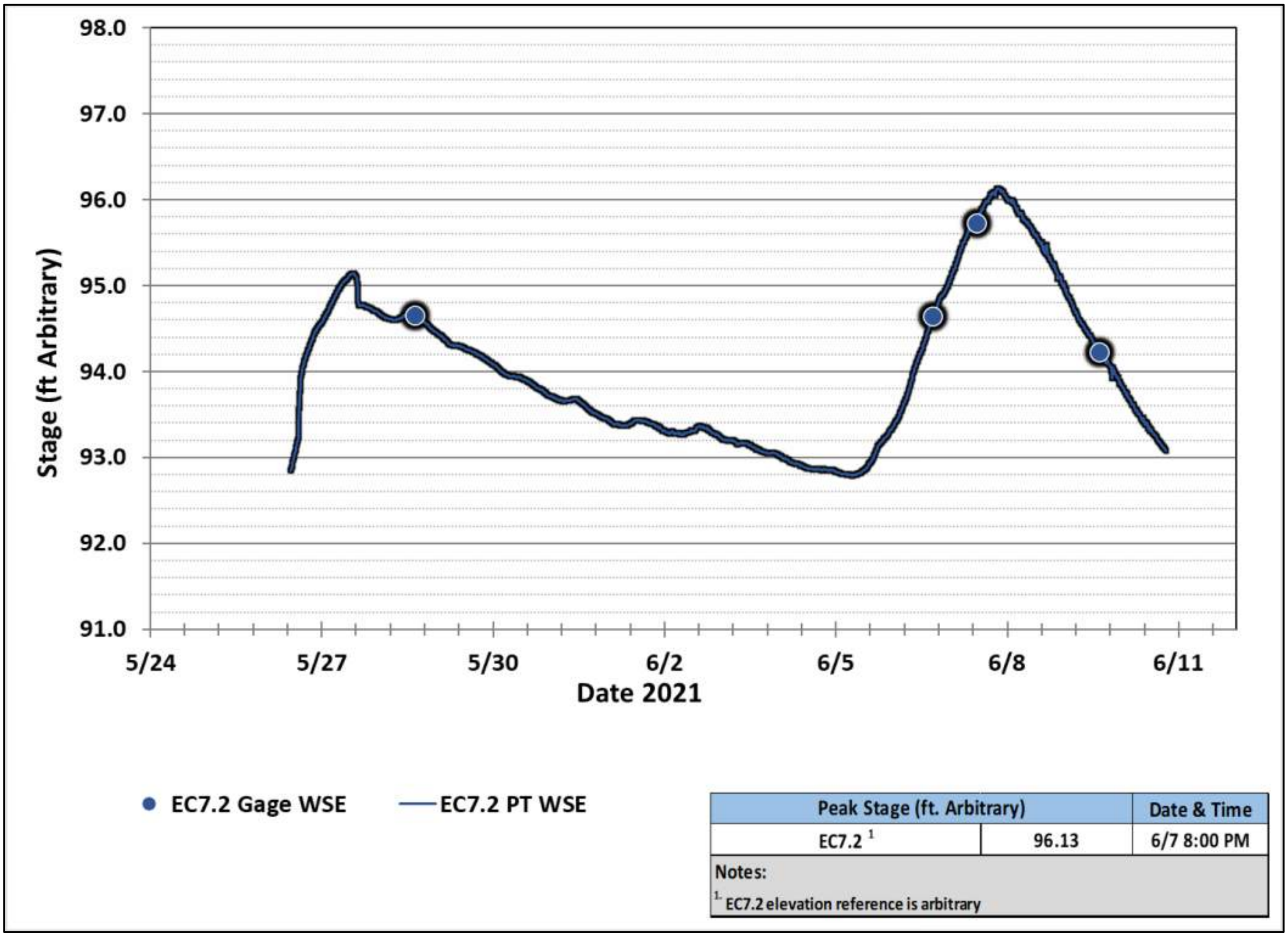
Graph 4.4: Colville River East Channel Stage & Discharge



Peak Stage (ft. BPMSL)		Date & Time
EC12.9	8.27	6/7 1:15 PM
EC1.3 [1]	4.14	6/7 10:00 PM

Notes:
[1] EC1.3 peak stage estimated based on HWM. Exact time of peak unknown

Graph 4.5: EC12.9 and EC1.3 Stage



Graph 4.6: EC7.2 Stage

4.3 Nigliq Channel

MON20, MON22, and MON23 have been monitored intermittently since 1998 and MON28 has been monitored since 1999. These monitoring sites are located on the Nigliq Channel between Toolbox Creek and the coast. Historically, the Nigliq Channel conveys approximately 20% of the flow of the Colville River.

Initial floodwater was first recorded at the MON20 PT on May 26. Stage quickly rose and crested on the morning of May 27. After this initial crest, stage in the Nigliq Channel began to recede due to the local cooling trend. A site visit to MON20 on May 28 revealed intact channel ice with saturated snow along the banks and stage well below bankfull (Photo 4.17). Stage on the Nigliq Channel continued to recede until June 5 when a surge of floodwater entered the delta. On the morning of June 6, stage was rising in the Nigliq Channel in response to this surge of floodwater (Photo 4.18 and Photo 4.19). Peak stage occurred in the Nigliq Channel on June 7. Aerial observations at peak showed channel ice had cleared through MON20 but was intact near MON22 and further downstream. Stage remained below bankfull and no backwater effects were observed. A small ice jam observed near lake L9324 did not appear to hold substantial backwater. (Photo 4.20 through Photo 4.22). After peaking, stage steadily receded and open water conditions were confirmed on June 9 (Photo 4.23 and Photo 4.24).

Discharge was measured at the Nigliq Bridge between MON20 and MON22 on June 8 with minimal snow or ice interference. Stage at MON20, MON22, MON23, and MON28 in the Nigliq Channel are presented in Graph 4.7.

Photo 4.17: Intact channel ice near MON20, looking northwest; May 28, 2021

Photo 4.18: Intact channel ice with stage rising at MON22, looking south (upstream); June 6, 2021

Photo 4.19: Stage rising near MON28, looking north (downstream); June 6, 2021

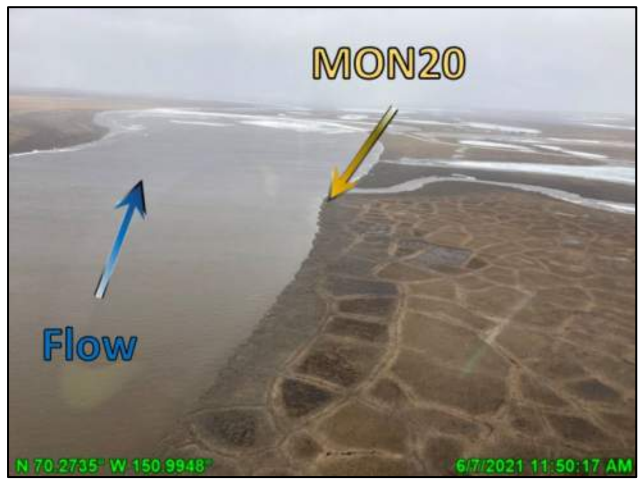


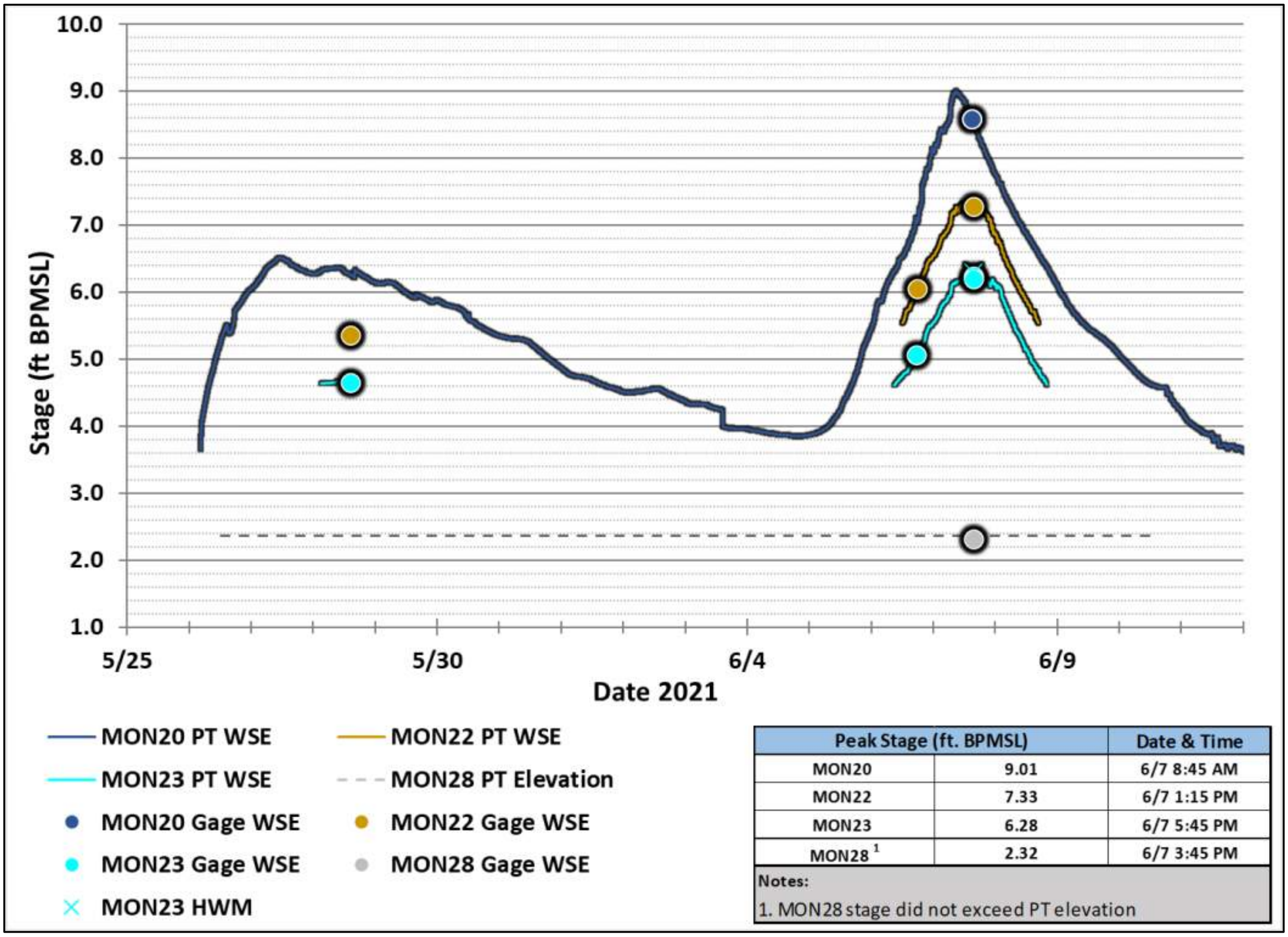
Photo 4.20: No overbank flooding in the Nigliq Channel near MON20, looking north (downstream); June 7, 2021

Photo 4.21: Persisting channel ice during peak conditions near MON22, looking north (downstream); June 7, 2021

Photo 4.22: Peak stage at MON23, looking north (downstream); June 7, 2021

Photo 4.23: Open water conditions near MON22, looking south (upstream); June 9, 2021

Photo 4.24: Open water conditions extending to the coast near MON28, looking north (downstream); June 9, 2021



Peak Stage (ft. BPMSL)		Date & Time
MON20	9.01	6/7 8:45 AM
MON22	7.33	6/7 1:15 PM
MON23	6.28	6/7 5:45 PM
MON28 [1]	2.32	6/7 3:45 PM

Notes:
1. MON28 stage did not exceed PT elevation

Graph 4.7: Nigliq Channel Stage

4.4 Alpine Facilities

Conditions in active channels surrounding Alpine facilities, including the Sakoonang, Tamayayak, and Ulamnigiaq channels to the east/northeast and the Nigliq Channel to the west, dictate the progression of the floodwater around facilities. Floodwaters in the Nigliq and Sakoonang Channels typically overtop the banks and facilitate the annual recharge of many lakes and paleochannels through overbank inundation. The extent of inundation is dependent on topography, vegetation, WSE, and local ice and ice jam influences.

Drainage structures are kept free of ice, snow accumulation, and blockages through regular maintenance by CPAI. Plywood covers are installed at the culvert inlets and outlets during the winter and removed prior to breakup. Snow is also mechanically removed from the immediate upstream and downstream areas of all culverts. Snow was cleared from the entrances and exits of CD2 swale bridges in the spring, though some drifted snow did accumulate prior to the arrival of floodwater, particularly under the short swale bridge.

Culverts were monitored to assess flow conditions and culvert performance. Almost all culvert covers and inflateable bags were removed prior to the arrival of floodwater with the exception of a few that were frozen in (Photo 4.25). Snow and ice were cleared at all culvert inlets prior to breakup. Limited flow restrictions were observed related to piles of removed snow and ice in and around culvert ends. Culvert locations and proximity to gages are shown in

Appendix A. Detailed culvert discharge measurements, calculations, and performance summary field notes are provided in Appendix C.

Photo 4.25: Snow cleared from the south side of the culvert battery between G6 & G7.

CD1 PAD & LAKES L9312 & L9313

Gage station G1 is situated along the east end of the CD1 pad to monitor stage in the adjacent Sakoonang Channel. Spring breakup stage data and observations have been collected at gage G1 since 2000. Peak stage at G1 occurred on June 8 after the intact channel ice in the East Channel flushed through the delta. Aerial observations from May 28 showed local melt over saturated snow with stage well below bankfull (Photo 4.26). Stage at gage G1 is presented in Graph 4.8.

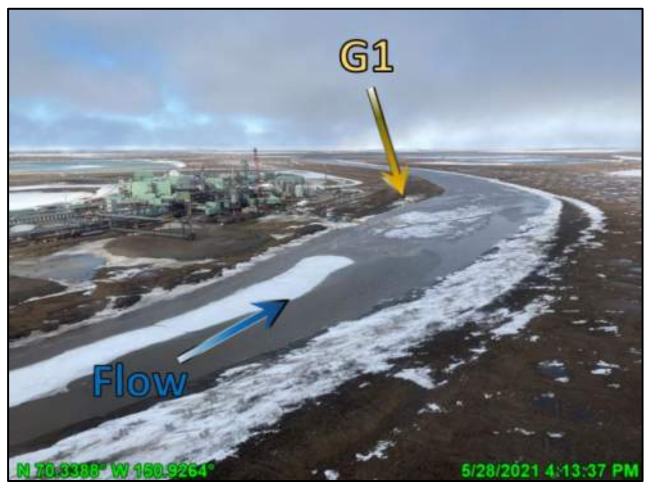
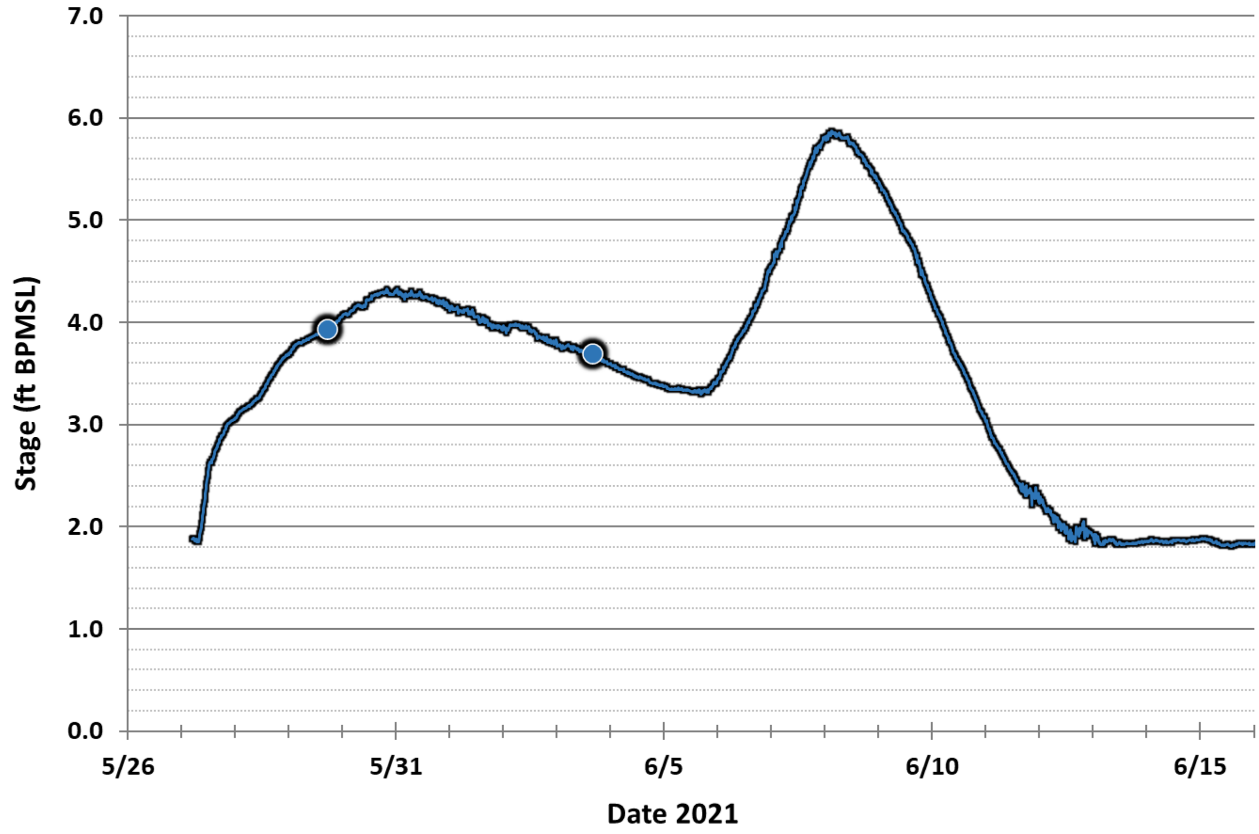


Photo 4.26: Local melt over saturated snow in the Sakoonang Channel at G1, looking north; May 28, 2021

Recharge at drinking water source Lake L9312 (gage G9) and Lake L9313 (gage G10) has been monitored annually since 1998. Overbank flooding from the Sakoonang Channel is the primary recharge mechanism for both lakes. Snowmelt from within each drainage basin, however, also contributes to recharge. Spring breakup overbank flow did not reach Lake L9312 and as a result did not recharge during spring breakup. After breakup, Lake L9312 recharged from precipitation, but not to the bankfull elevation of 7.8 feet. Lake L9313 became hydraulically connected to Lake M9525, observed on June 7, and recharged on June 8 (Photo 4.27 and Photo 4.28). Peak stage occurred on June 8 and correlated to peak stage in the Sakoonang Channel. Stage at gage G9 (L9312) and gage G10 (L9313) is presented in Graph 4.9.



Peak Stage (ft. BPMSL)		Date & Time
G1	5.87	6/8 3:00 AM

Graph 4.8: CD1 Pad (Gage G1) Stage

Photo 4.27: Lake L9312 after peak conditions with persisting ice, looking west; June 10, 2021

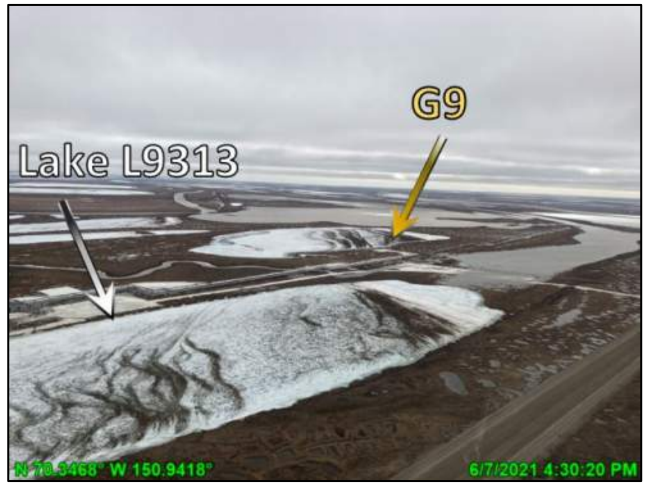
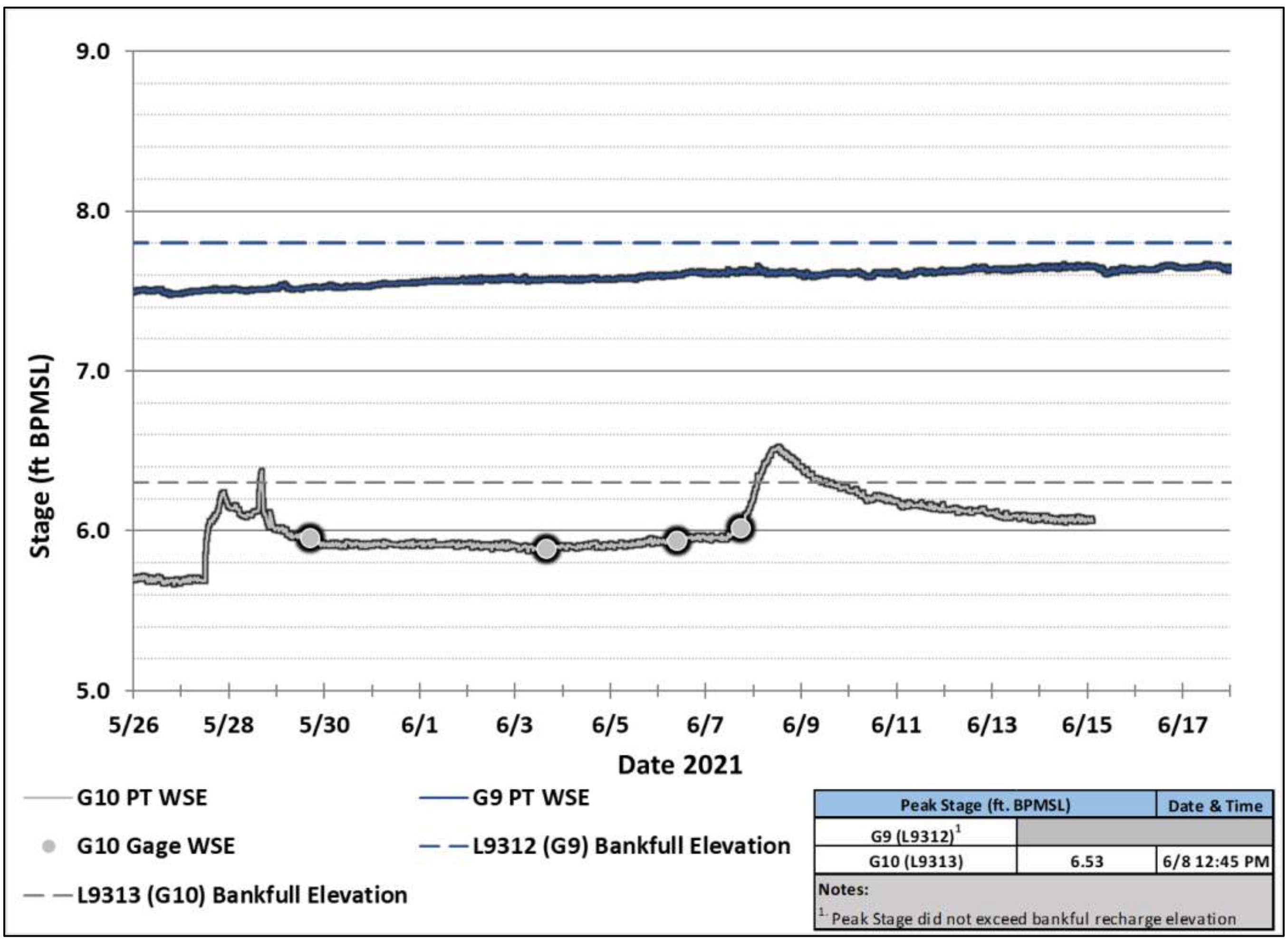


Photo 4.28: Lake L9313 hydraulically connected to Lake M9525, looking southwest; June 7, 2021



Graph 4.9: Lakes L9312 (Gage G9) and L9313 (Gage G10) Spring Stage

CD2 ROAD & PAD

Stage data and observations of breakup processes have been collected along the CD2 road and pad intermittently since 1998.

Floodwater along the CD2 road was present around the long and short swale bridges by June 7 (Photo 4.29). As stage rose quickly that afternoon, the long swale bridge and a few surrounding culverts conveyed flow from the Nigliq Channel (via Nanuq Lake then Lake M9524) across the CD2 road northeast towards Lake L9316 and M9933 (Photo 4.30). The short swale bridge remained partially blocked with drifted snow and was not observed to be conveying flow (Photo 4.31). Peak stage along the CD2 road occurred in the evening of June 7 (Photo 4.32). During peak conditions saturated snow remained drifted along the embankments of the road and stage remained well below all roads and pads. Discharge was measured at culverts conveying flow along the CD2 road on June 7. Discharge was measured at the long swale bridge on the afternoon of June 7.

The average velocity measured at the long swale bridge on June 7 was 1.07 ft per second (fps) and the highest depth averaged velocity within a single section was 2.4 fps. The bridge was clear of snow and ice and there were no snow berms impacting the bridge opening. Ice floes were minimal and flowing unobstructed under the bridge during the measurement. The measurement was classified as fair.

All bridges and culverts along the CD2 road performed as designed during this year's breakup event. Peak discharge through this area is estimated to have occurred on June 7, concurrent with measured discharge across the CD2 road measured at the long swale bridge.

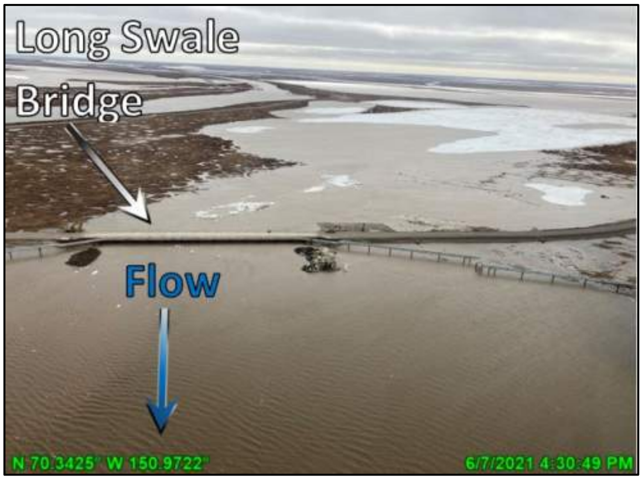


Photo 4.29: Floodwater near the CD2 pad, looking west; June 7, 2021

Photo 4.30: Floodwater passing through culverts near peak stage; looking northeast (downstream) June 7, 2021

Photo 4.31: Drifted snow and ice underneath the short swale bridge, looking north; June 7, 2021

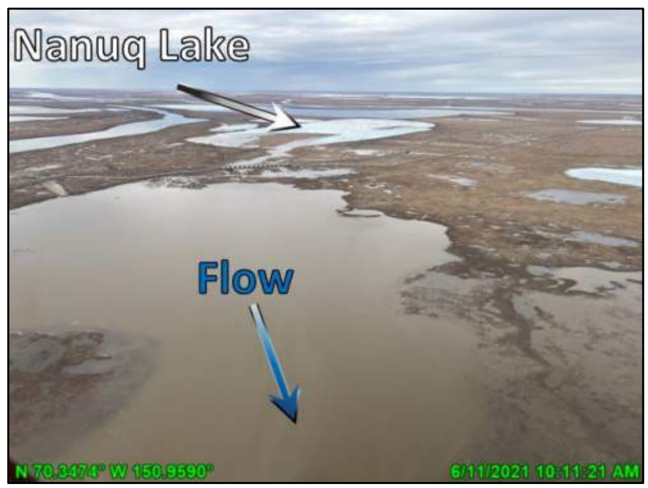
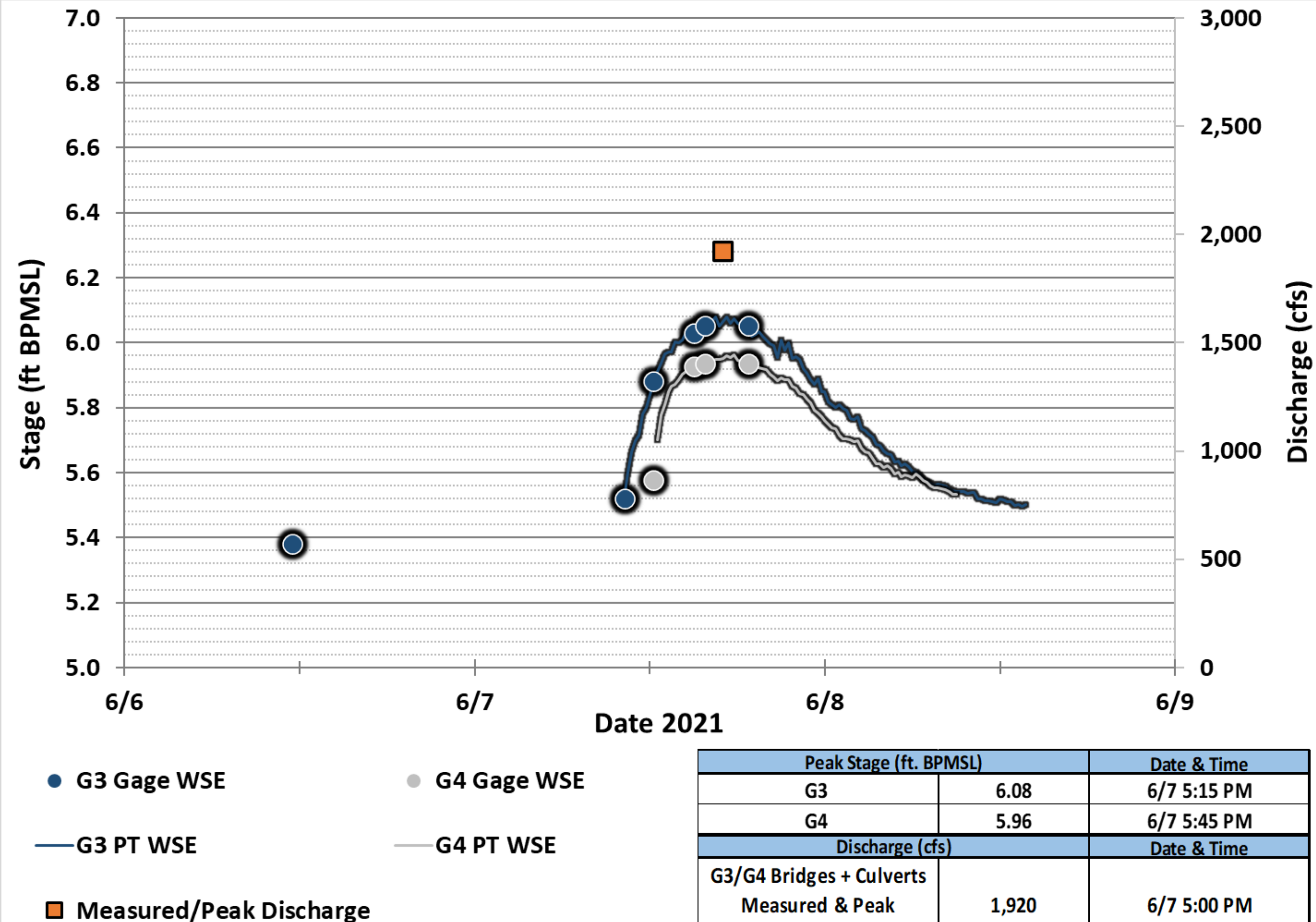


Photo 4.32: Nanuq lake and long swale bridge post peak conditions, looking southwest (upstream); June 11, 2021

Stage and total discharge at CD2 bridges and culverts are provided in Graph 4.10. Measured discharge and peak discharge at culverts conveying flow is summarized in Table 4.2. Historical discharge measurements and peak discharge at the long and short swale bridges are summarized in Section 8. A summary of discharge measurements for the CD2 road swale bridges and culverts are presented in Appendix C.



Peak Stage (ft. BPMSL)		Date & Time
G3	6.08	6/7 5:15 PM
G4	5.96	6/7 5:45 PM
Discharge (cfs)		**Date & Time**
G3/G4 Bridges + Culverts Measured & Peak Discharge	1,920	6/7 5:00 PM

Graph 4.10: CD2 Road Bridges and Culverts (Gages G3 & G4) Stage & Discharge

Table 4.2: CD2 Road Culverts Measured and Peak Discharge

Culvert	Measurement Date & Time	Total Depth of Flow (ft)	Measurement Depth [1] (ft)	Flow Direction	Measured Velocity (ft/s)	Calculated Discharge (cfs)	Total Discharge (cfs)
CD2-23	6/7 3:45 PM	0.95	0.38	South to North	5.55	13.5	26
CD2-24	6/7 2:55 PM	1.0	0.40	South to North	5.51	12.7	

Notes:
1. Measurement taken at 0.6 of total depth of flow.
2. Flow direction at time of measurement.

Table 4.3: CD2 Road Bridges Measured and Peak Discharge

Bridge	Measurement Date & Time	Measured Discharge (cfs)	Stage (ft. BPMSL)[1]	Peak Date & Time	Peak Discharge (cfs)	Stage (ft. BPMSL)[1]
Long Swale	6/7 4:00 PM	1,895	6.09	6/7 4:00 PM	1,895	6.12
Short Swale	-	-	-	-	-	-

Notes:
1. Stage as measured at G3

CD3 PAD & PIPELINE

Stage data and observations of breakup processes have been collected at the CD3 pad and along the pipeline intermittently since 2000. Gage stations SAK, TAM, and ULAM are situated at each respective pipeline crossing of each channel (Sakoonang, Tamayayak, and Ulamnigiaq), and G11 is situated on a VSM on the CD3 pipeline near the south end of the CD3 pad.

PTs at the Tamayayak and Ulamnigiaq Channels first recorded initial meltwater and subsequent rise in stage on May 27. Initial melt water was first recorded in the Sakoonang Channel on May 28. Site visits on May 28 revealed stage well below bankfull and saturated snow and ice in the channels (Photo 4.33 and Photo 4.34). Stage remained low as water slowly progressed through the delta until a sharp rise in stage was recorded at all pipeline crossing locations on June 6. Peak stage at the Tamayayak and Ulamnigiaq Channels occurred on June 7 while peak stage in the Sakoonang Channel occurred on June 8. During peak conditions no overbank flooding or backwater effects associated with ice jams were observed at the pipeline crossing locations, and stage remained below bankfull (Photo 4.35). Stage at the SAK, TAM, and ULAM is presented in Graph 4.11.

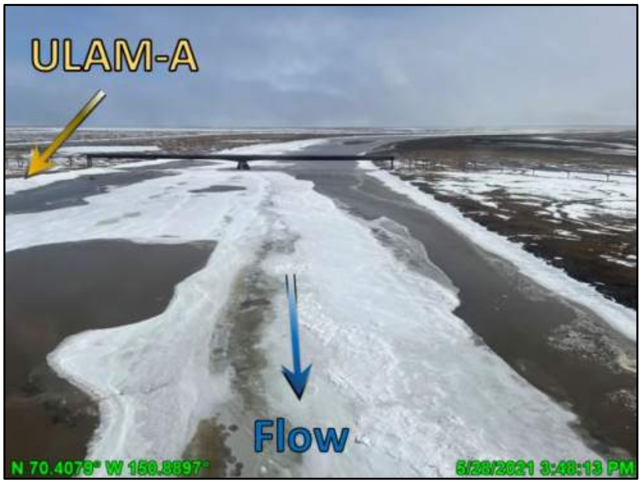


Photo 4.33: Saturated snow and channel ice in the Ulamnigiaq Channel prior to peak stage at ULAM, looking south; May 28, 2021

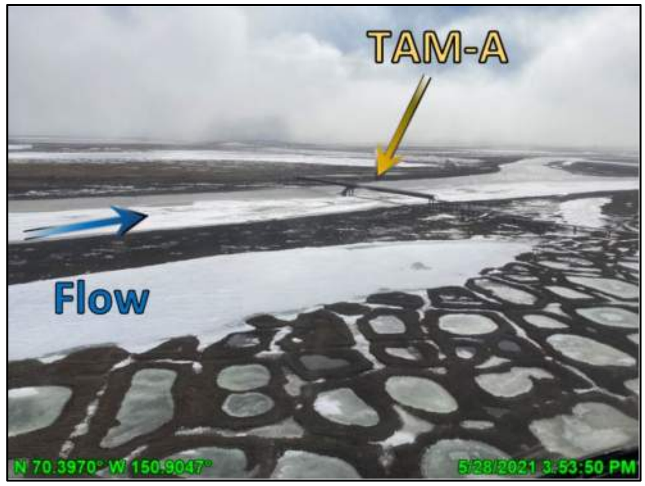
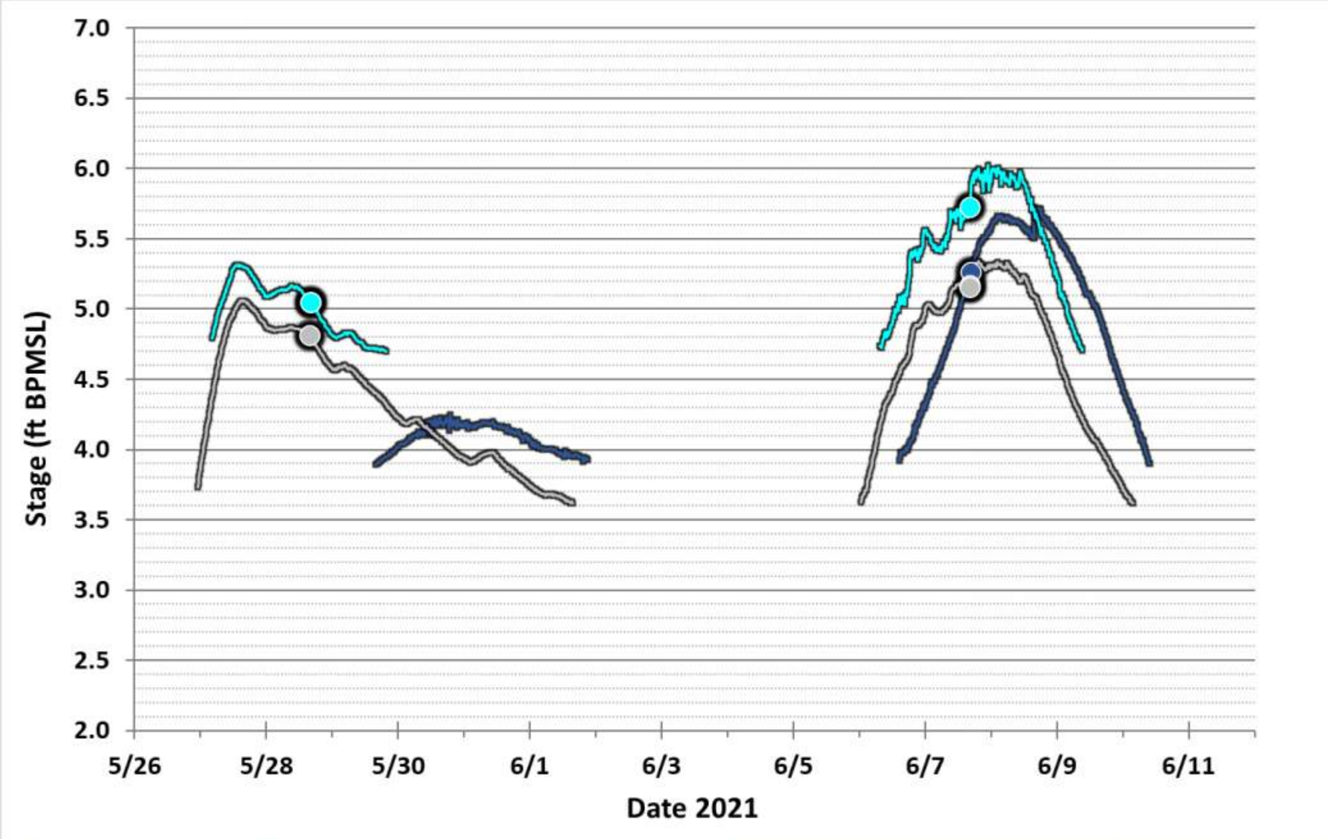


Photo 4.34: Saturated snow and channel ice in the Tamayayak Channel prior to peak stage at TAM, looking southeast; May 28, 2021

Photo 4.35: Fractured channel ice in the Tamayayak Channel during peak stage, looking northwest; June 7, 2021



Peak Stage (ft. BPMSL)		Date & Time
SAK	5.73	6/8 4:00 PM
TAM	6.02	6/7 10:45 PM
ULAM	5.34	6/7 7:15 PM

Graph 4.11: CD3 Pipelines Stage

CD4 ROAD & PAD

Stage data and observations of breakup processes have been collected at the CD4 road and pad intermittently since 2005. Gage stations G15/G16 are located at the north culvert battery near the CD5 road turnoff, G17/G18 at the south culvert battery before the CD4 pad, and G19 and G20 along the south and west side of the CD4 pad, respectively.

Initial localized melt was first observed along the CD4 road on June 1 (Photo 4.36). Stage remained stagnant over the next few days until PTs at G15/G16 recorded a rise in stage on June 7, attributed to flood water from Lake M9525 (Photo 4.37 through Photo 4.40). Stage hydrographs at G15/G16 culvert battery indicate stage gradually rose and fell over the evening of June 7 and morning of June 8. Peak conditions at G15/G16 culvert battery occurred in the early morning of June 8. During peak conditions, stage remained below bankfull and discharge was not measured due to timing of peak and minor flow through culverts.

G17 and G18 culvert battery experienced similar conditions as G15/G16 culvert battery. During 2021 breakup G17 and G18 experienced strictly local melt and discharge was not measured through the culvert battery. A flyover on June 9 after peak conditions revealed lake ice persisting on Lake L9324 and no signs of overbank flooding (Photo 4.41).

At the CD 4 pad, peak stage occurred on June 7 at G20 and coincided with peak stage in the Nigliq Channel. Floodwater did not reach G19.

Stage at CD4 road gages G15/G16 and CD4 pad gages G19/G20 are provided in Graph 4.12 and Graph 4.13, respectively.

Photo 4.36: Local melt at CD4 road south culvert battery near G17/G18, looking northeast; June 1, 2021

Photo 4.37: Conditions at CD4 pad near peak stage, looking north; June 7, 2021

Photo 4.38: Conditions prior to peak on CD4 road near Gage G17/G18, looking northeast; June 7, 2021

Photo 4.39: Conditions along the CD4 road prior to peak, looking north; June 1, 2021

Photo 4.40: Conditions prior to peak at the CD4 road near G15/G16 culvert battery, looking north; June 7, 2021

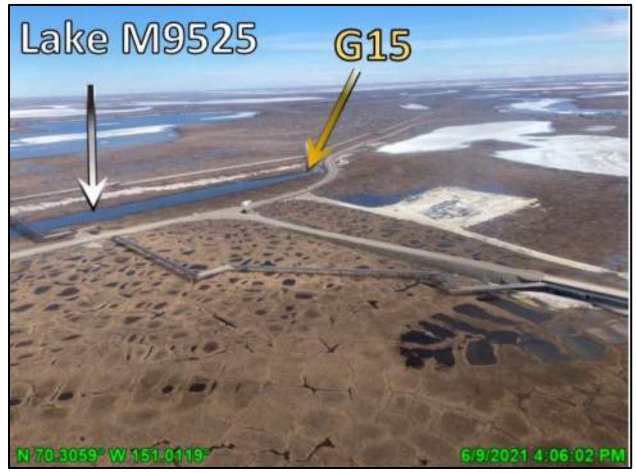
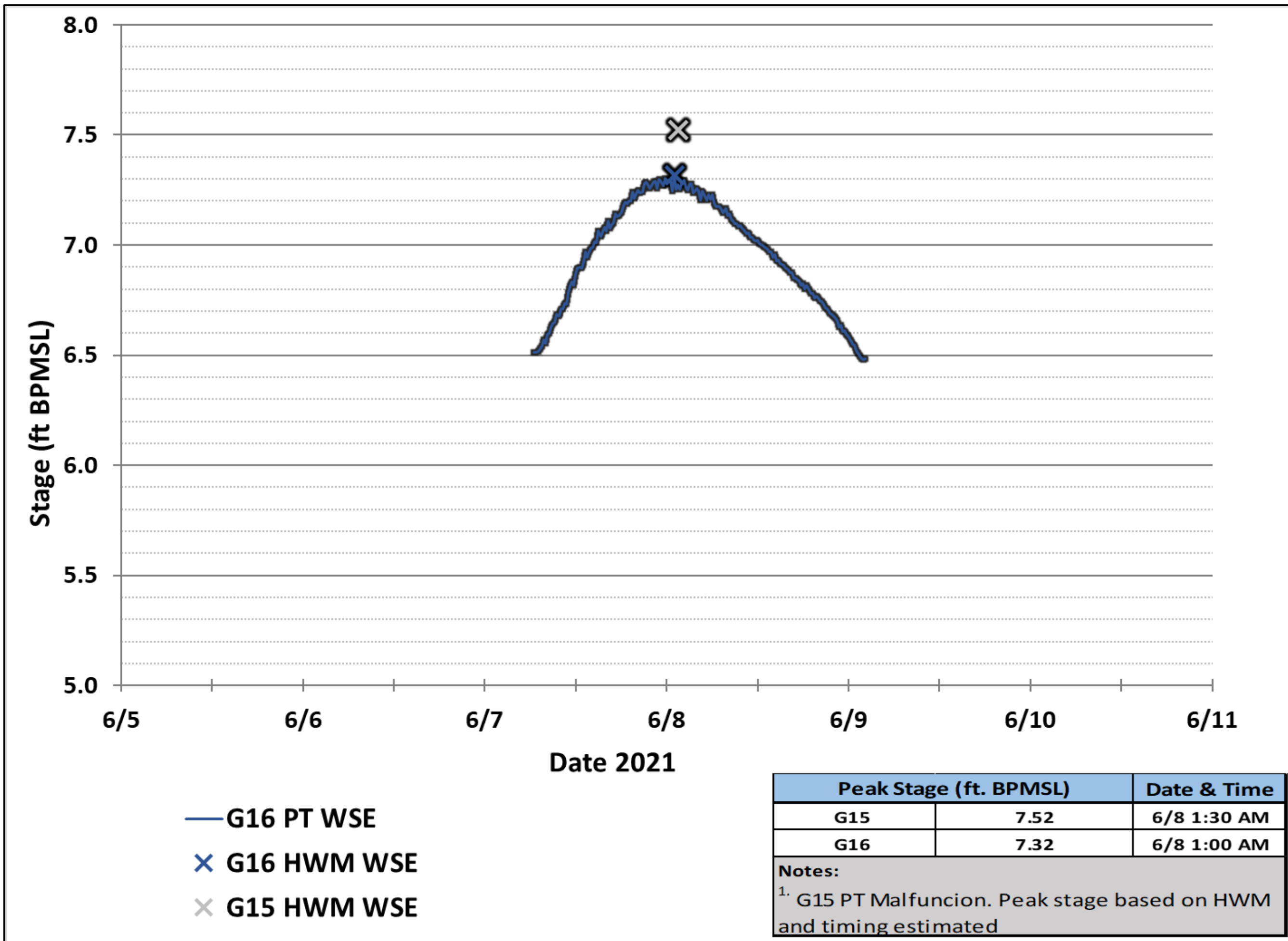


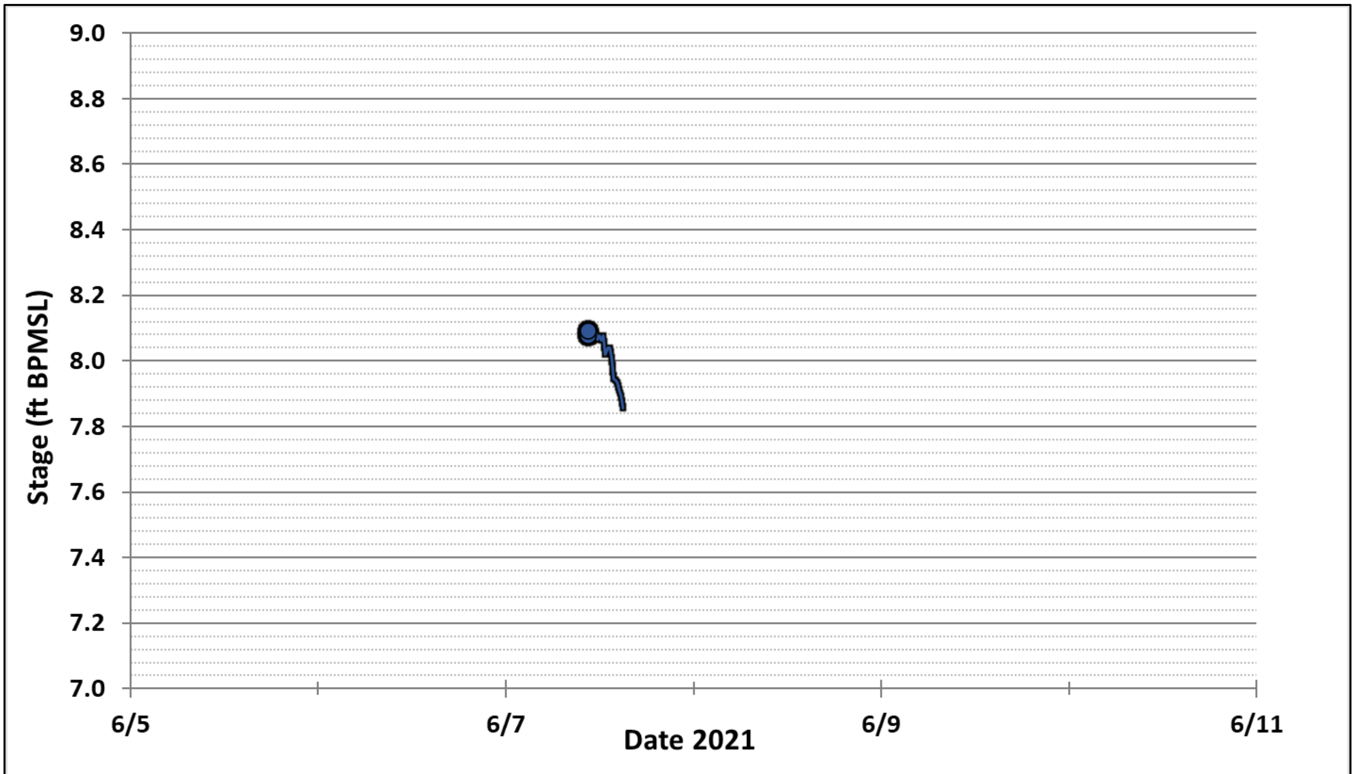
Photo 4.41: CD4 and CD5 intersection near G15/G16 culvert battery after peak stage, looking southeast; June 9, 2021



Peak Stage (ft. BPMSL)		Date & Time
G15	7.52	6/8 1:30 AM
G16	7.32	6/8 1:00 AM

Notes:
1. G15 PT Malfuncion. Peak stage based on HWM and timing estimated

Graph 4.12: CD4 Road Culverts (Gages G15 & G16) Stage & Discharge



Peak Stage (ft. BPMSL)		Date & Time
G19	Dry	-
G20 [1]	8.09	6/7 10:45 AM

Notes:
1. PT did not record WSE prior to 6/7 10:45. Highest recorded stage reported and exact peak timing unknown

Graph 4.13: CD4 Pad (Gages G19 & G20) Stage

CD5 ROAD

Stage data and observations of breakup processes have been collected along the CD5 road since 2009. Gage sets upstream and downstream of the road are used to evaluate stage at drainage structures, determine the flood extents and upstream/downstream WSE differential along the CD5 road as required per the MP-AMS. The 2021 flood event remained confined to main channels and flood waters did not reach the CD5 road.

Lake L9323 Bridge

The CD5 Road Bridge #1 crosses a swale at the north/downstream end of the western lobe of Lake L9323. Lake L9323 can become hydraulically connected to the Nigliq Channel (via Tapped Lake and north of the Lake L9323 Bridge) during periods of high water. Lake L9323 also becomes hydraulically connected to the Sakoonang Channel through the CD4 road culvert batteries at the northern/downstream and southern/upstream ends of the eastern lobe. Gage G24 is south/upstream and gage G25 is north/downstream of the bridge.

Local melt was first observed near Lake L9323 Bridge on May 30 via aerial observations (Photo 4.42). Lake L9323 did not become hydraulically connected from either the Sakoonang Channel or the Nigliq Channel (Photo 4.43 and Photo 4.44). Lake L9323 snow and ice melted throughout the monitoring period and did not reach PT elevations while drifted snow persisted underneath the bridge. A flyover on June 10 confirmed the ice remained in Lake L9323 (Photo 4.45).

Photo 4.42: Lake L9323 bridge and vicinity prior to peak stage, looking north; May 30, 2021

Photo 4.43: Nigliq Channel and Lake L9323 bridge near peak stage showing no overbank flooding, looking northeast; June 7, 2021

Photo 4.44: Lake L9323 hydraulically disconnected from Nigliq Channel, looking west; June 7, 2021

Photo 4.45: Lake L9323 bridge 3 days after peak stage showing no hydraulic connection, looking south; June 10, 2021

Nigliq Bridge

Initial floodwater was first recorded via PT at G28 on May 26. Stage quickly rose and crested on the morning of May 27. After this initial crest, stage in the Nigliq channel began to recede due to a local cooling trend. Aerial observations on May 28 and May 31 revealed channel ice still intact and stage well below bankfull (Photo 4.46 and Photo 4.47). Stage in the Nigliq Channel continued to recede until June 5 when a surge of floodwater entered the delta. On the morning of June 6, stage was rising as a result of this surge of floodwater (Photo 4.48). Intact channel ice persisted downstream of G28. Peak stage occurred in the Nigliq Channel on June 7 (Photo 4.49). Game camera pictures at peak revealed channel ice persisted upstream of the bridge but was quickly pushed through the reach of the bridge (Photo 4.50). Aerial observations a few hours later show intact channel ice near G27 and further downstream. Stage remained below bankfull and no backwater effects were observed during peak conditions. After peak, stage quickly receded and open water conditions were confirmed on June 9 (Photo 4.51).

Discharge was measured on June 8 on the upstream side of the Nigliq Bridge with minimal snow and ice interference. Conditions were considered steady and uniform. The quality of the measurement was classified as fair.

Nigliq Bridge stage and discharge data is provided in Graph 4.14. A summary of the discharge measurement, peak discharge calculation methods, and plan and profile drawings are presented in Appendix C.

Photo 4.46: Channel ice at the Nigliq Bridge, looking south (upstream); May 28, 2021

Photo 4.47: Channel ice persisting upstream of the bridge, looking southeast (upstream); May 31, 2021

Photo 4.48: Rising stage with channel ice persisting at the Nigliq bridge, looking southeast (upstream); June 6, 2021

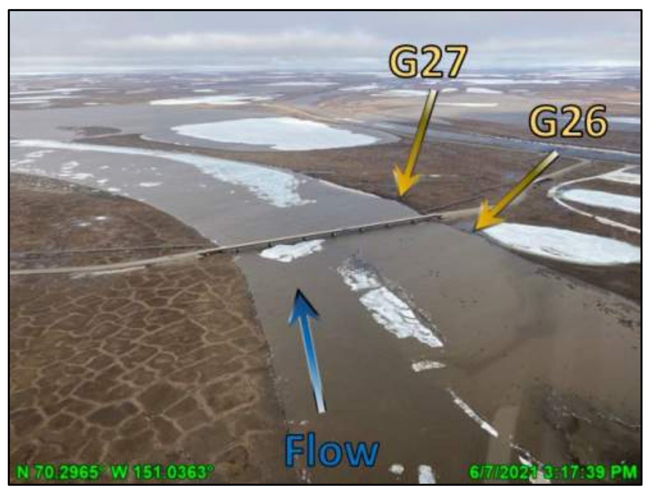


Photo 4.49: Peak conditions at the Nigliq bridge with no overbank flooding, looking northeast (downstream); June 7, 2021

Photo 4.50: Peak conditions from the game camera on the Nigliq Bridge, looking east; June 7, 2021

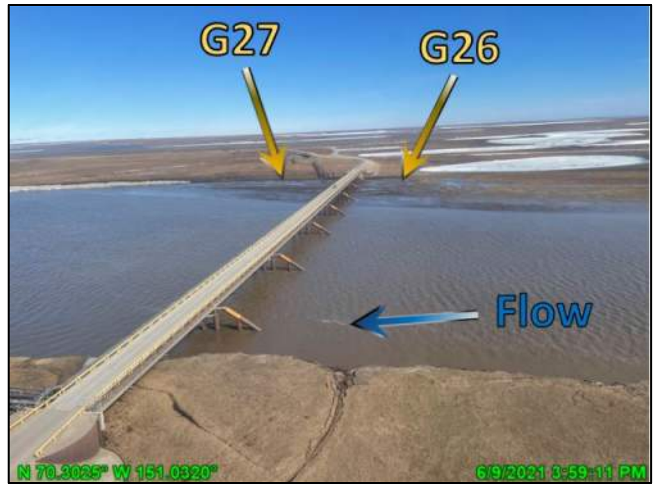
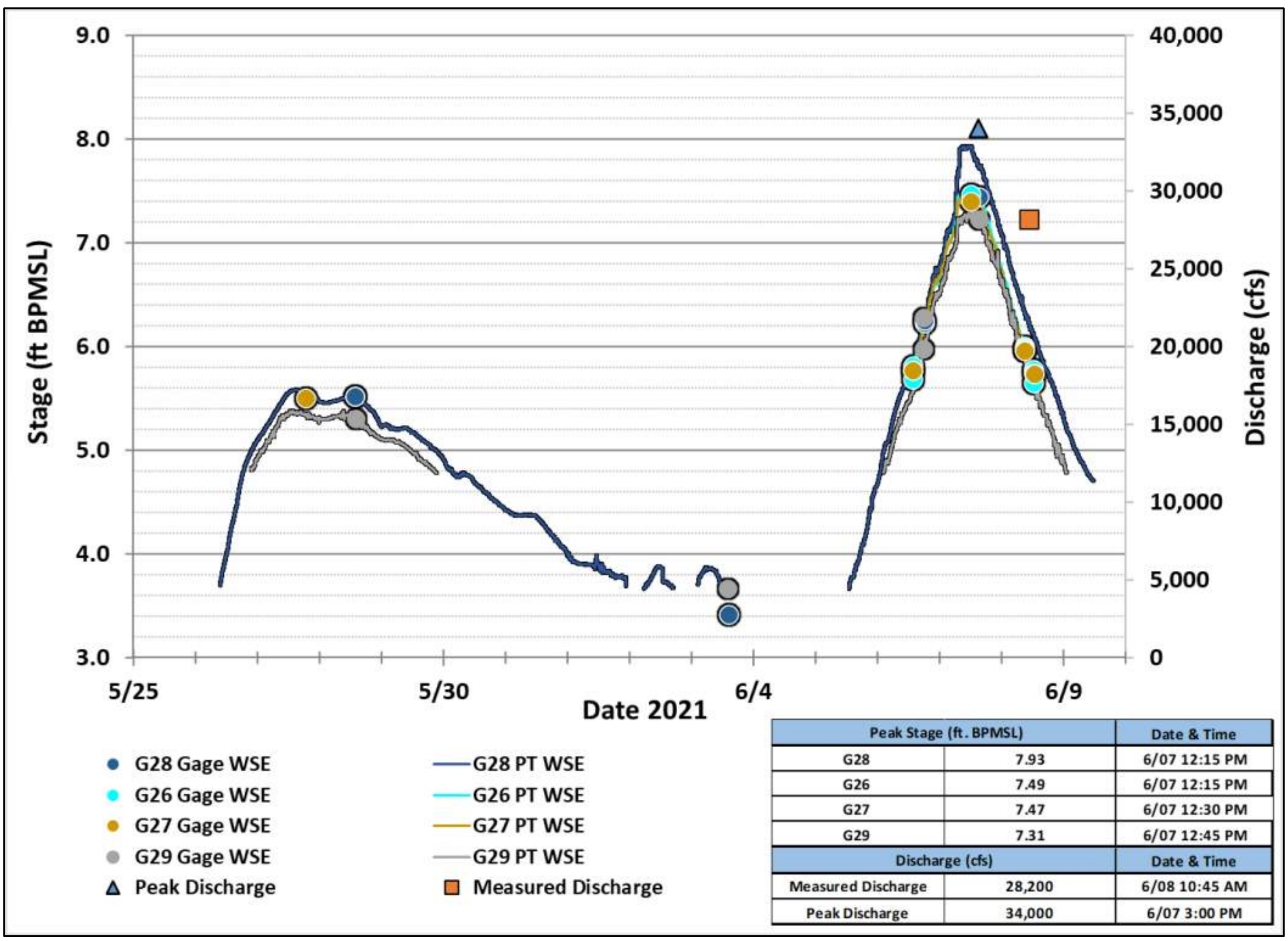


Photo 4.51: Open water conditions at the Nigliq bridge with receding stage, looking east; June 9, 2021



Peak Stage (ft. BPMSL)		Date & Time
G28	7.93	6/07 12:15 PM
G26	7.49	6/07 12:15 PM
G27	7.47	6/07 12:30 PM
G29	7.31	6/07 12:45 PM
Discharge (cfs)		Date & Time
Measured Discharge	28,200	6/08 10:45 AM
Peak Discharge	34,000	6/07 3:00 PM

Graph 4.14: Nigliq Bridge (Gages G26, G27, G28, and G29) Stage & Discharge

Lake L9341 Bridge

The Bridge #3 on the CD5 Road crosses Lake L9341, which is the downstream-most water body in a series of lakes formed through a paleochannel of the Nigliq Channel. This paleochannel can become an active channel during periods of high water. During lower stage breakup events, only backwater from the Nigliq Channel enters Lake L9341 from the northern end. Gage G32 is south (upstream) and gage G33 is north (downstream) of the bridge. G30 (south) and G31 (north) are situated on the overbank between Lake L9341 and the Nigliq Channel.

PT data shows stage at G32 and G33 began to rise on June 6, coinciding with stage rise at G29 in the Nigliq Channel suggesting backwater from the Nigliq Channel was infilling Lake L9341. Aerial observations on May 30 revealed channel ice still intact and local melt visible in the vicinity of the bridge (Photo 4.52). Stage continued to steadily rise in conjunction with the rise in the Nigliq Channel. Peak conditions at Lake L9341 occurred on June 7. Aerial observations a few hours after peak showed channel ice intact throughout the paleochannel (Photo 4.53). Stage began to steadily recede and was below the PT elevation by June 9 (Photo 4.54). A flyover on June 14 showed intact channel ice persisted in Lake L9341 throughout the monitoring period (Photo 4.55). Lake L9341 did not become hydraulically connected the Nigliq channel on the south end, therefore discharge was not measured. Discharge calculations were not performed due to the uncertainties in channel geometry associated with the intact ice.

Lake L9341 Bridge stage data is provided in Graph 4.15. Plan and profile drawings are presented in Appendix C.

Photo 4.52: Local melt observed overtop of channel ice at Lake L9341, looking east; May 30, 2021

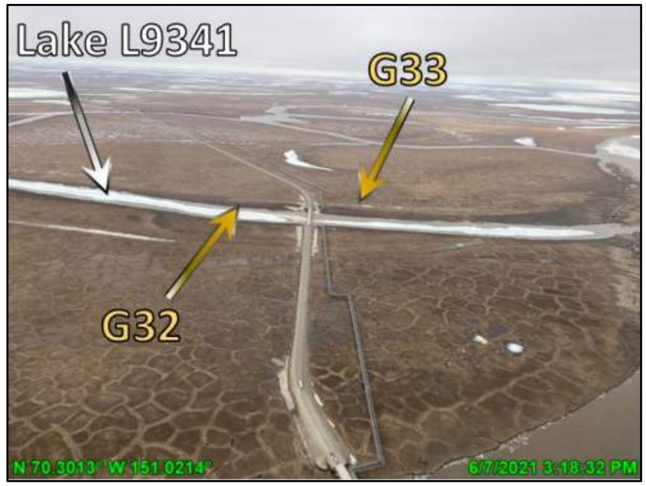
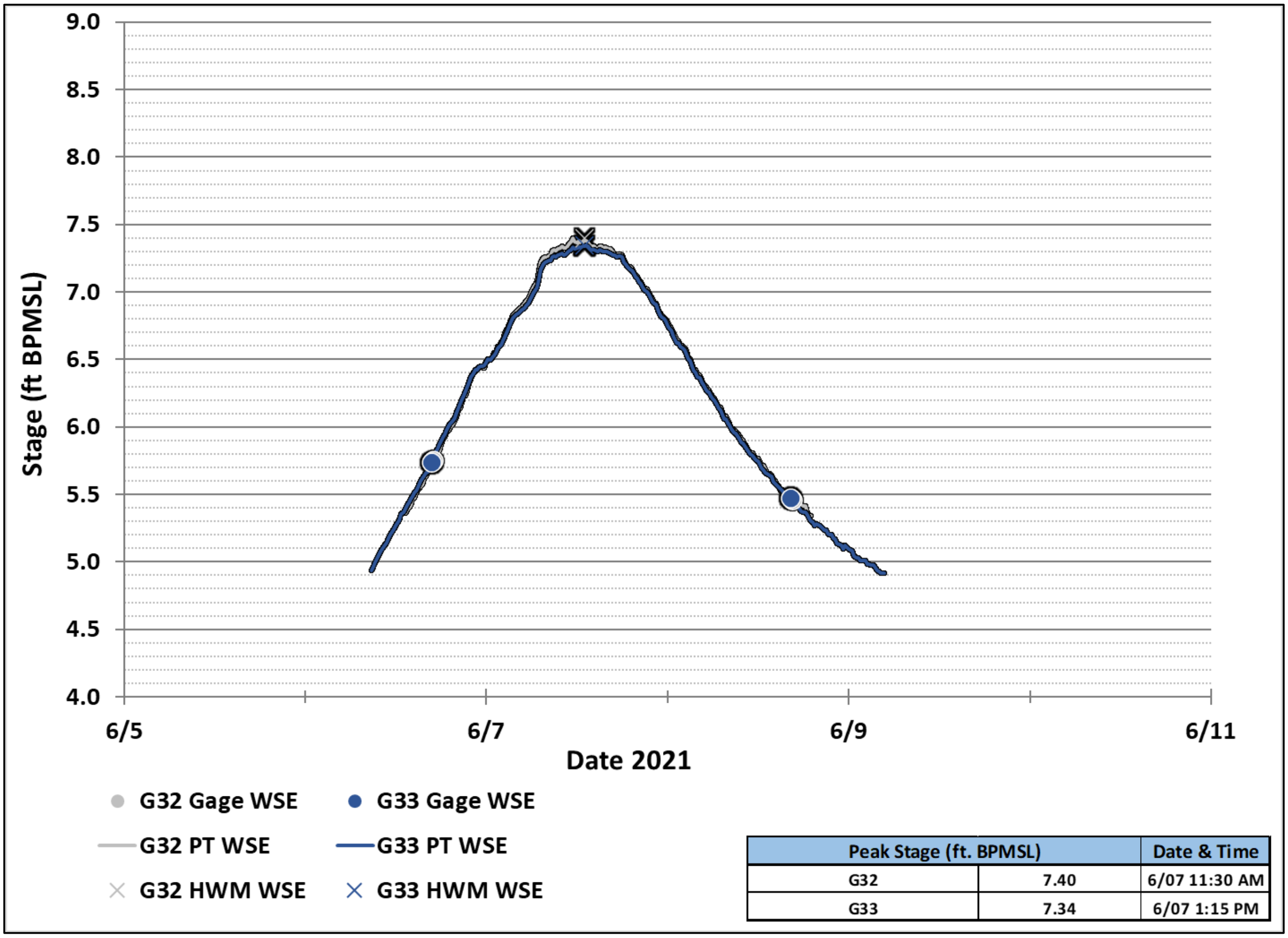


Photo 4.53: Intact channel ice in Lake L9341 briefly after peak conditions, looking west; June 7, 2021

Photo 4.54: Lake L9341 with intact channel ice persisting as stage is receding, looking south (downstream); June 9, 2021

Photo 4.55: Channel ice persisting in Lake L9341 throughout the monitoring period, looking south; June 14, 2021



Graph 4.15: Lake L9341 Bridge (Gages G32 and G33) Stage

Nigliagvik Bridge

The Bridge #4 on the CD5 Road crosses the Nigliagvik Channel, which is an anabranch of the Nigliq Channel on the western extent of the CRD. The Nigliagvik Channel diverges from the Nigliq Channel approximately 4 RM upstream of the Nigliq Bridge and 5.5 RM upstream of the Nigliagvik Bridge; it converges with the Nigliq Channel approximately 2 RM downstream of each bridge. The Nigliagvik Channel is typically hydraulically connected throughout its length with the Nigliq Channel during the open water season. Gage G38 is south (upstream) and gage G39 is north (downstream) of the bridge.

PT data shows an increase in stage at G38 and G39 starting on May 26. A site visit on May 26 revealed local melt over saturated snow and ice (Photo 4.56). This initial rise was attributed to backwater from the Nigliq Channel and crested by the next day corresponding to the initial crest in the Nigliq Channel. Stage began to decrease as a local cooling trend set in. A site visit on May 28 showed minor flow over saturated snow and ice immediately upstream of the bridge (Photo 4.57). Flow was cutting paths through the snow. Stage continued to recede until June 5 when a surge of floodwater entered the delta. Peak stage in the Nigliagvik Channel occurred on June 7. During peak stage no overbank flooding or ice jams were observed. Minor channel ice persisted in the channel (Photo 4.58). By June 11, stage had receded below the PT elevation and by June 14 open water conditions were confirmed (Photo 4.59).

Peak stage at the Nigliagvik Bridge lagged peak stage in the Nigliq Channel by a couple hours. Peak discharge occurred near peak stage. Calculated peak discharge was assigned a poor quality rating based on the high potential of ice and snow during peak conditions. Discharge was measured on the upstream side of the Nigliagvik Bridge on June 8. At the time of the measurement, the Nigliagvik Channel at the discharge location was clear of ice and snow. The quality of the measurement was classified as good due to the ice-free channel conditions.

Nigliagvik Bridge stage data is provided in Graph 4.16. A summary of the discharge measurement, peak discharge calculation methods, and plan and profile drawings are presented in Appendix C.

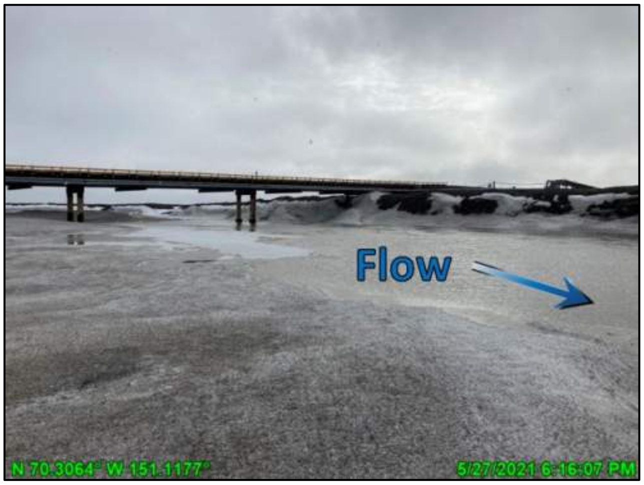


Photo 4.56: Local melt over saturated snow in the Nigliagvik Channel, looking south; May 27, 2021

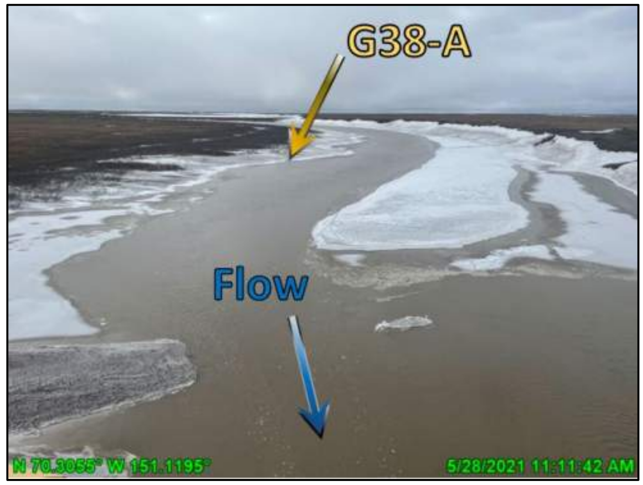
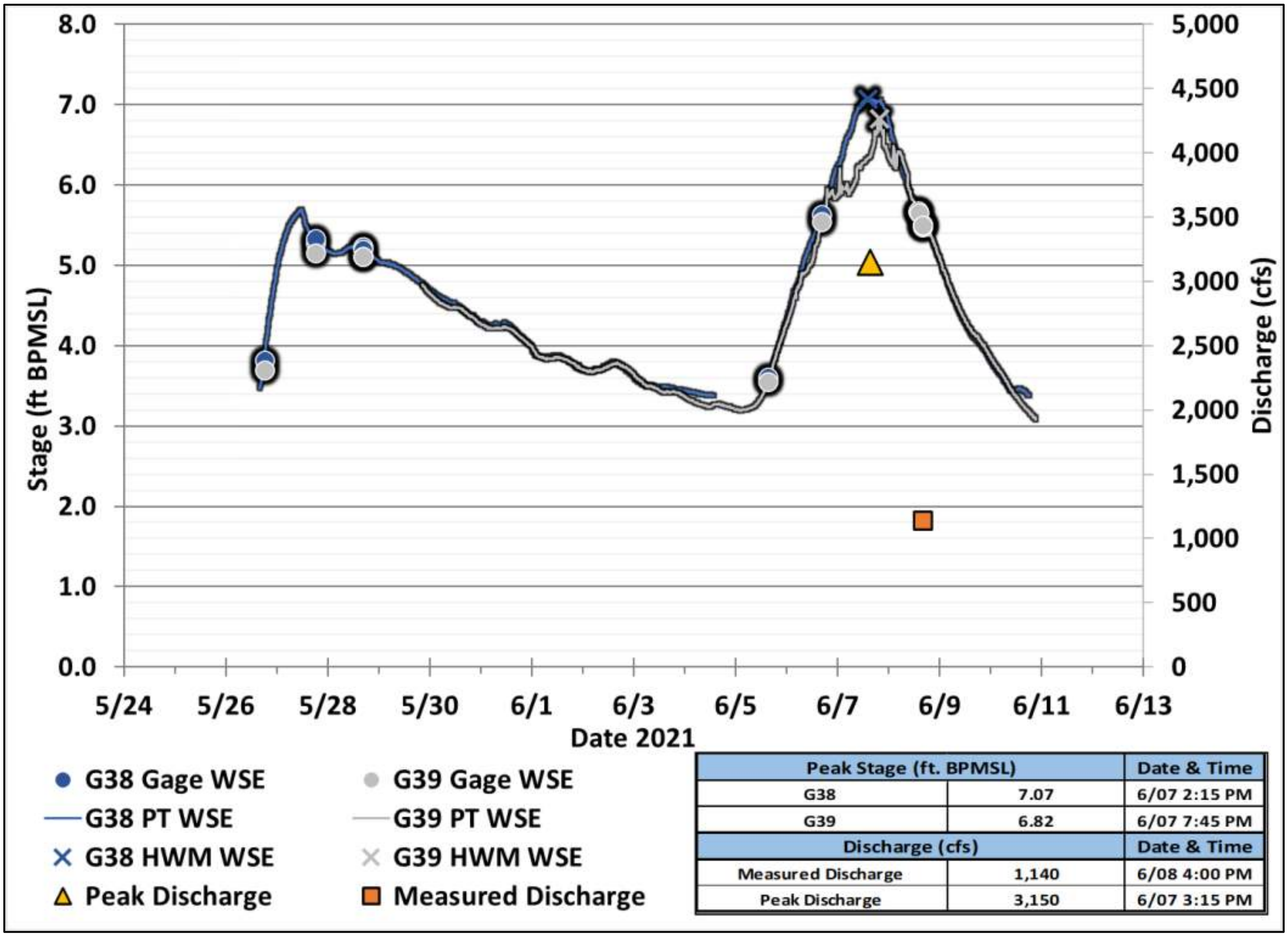


Photo 4.57: Minor flow over saturated snow and ice immediately upstream of the Nigliagvik Bridge, looking south (upstream); May 28, 2021

Photo 4.58: Conditions at the Nigliagvik Bridge during discharge measurement one day after peak stage, looking southwest (upstream); June 8, 2021

Photo 4.59: Stage below bankfull in the Nigliagvik Channel, looking south (upstream); June 14, 2021



Peak Stage (ft. BPMSL)		Date & Time
G38	7.07	6/07 2:15 PM
G39	6.82	6/07 7:45 PM
Discharge (cfs)		**Date & Time**
Measured Discharge	1,140	6/08 4:00 PM
Peak Discharge	3,150	6/07 3:15 PM

Graph 4.16: Nigliagvik Bridge (Gages G38 & G39) Stage

CD5 Culverts

The culverts along the CD5 road, east of the Nigliagvik Channel convey overbank floodwater from the Nigliq and Nigliagvik Channels during large flood events and equalize local meltwater across the CD5 road during low flood events. The CD5 culverts west of the Nigliagvik Channel are topographically isolated from CRD flooding. Lacking major channels in the vicinity, culverts in this region allow hydraulic equalization of meltwater between lakes, swales, and/or paleochannels.

A flyover near peak conditions on the CD5 road confirmed no overbank flooding of the Nigliq or Nigliagvik Channels and no flow was observed in culverts across the CD5 road (Photo 4.60 and Photo 4.61). Local melt was observed along the CD5 road west of the Nigliagvik Channel (Photo 4.62 and Photo 4.63). PTs deployed along the CD5 road remained dry throughout the monitoring period.

Photo 4.60: CD5 road near Lake L9341 with no overbank flooding, looking north; June 7, 2021

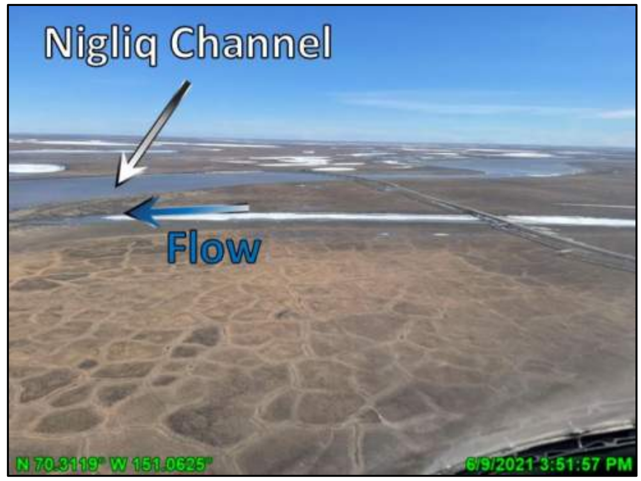


Photo 4.61: CD5 road near Nigliq Channel with no overbank flooding, looking east; June 9, 2021

Photo 4.62: CD5 road near CD5 pad turnoff, looking north; May 31, 2021

Photo 4.63: CD5 road near multi season ice pad, looking east; May 31, 2021

GMT1/MT6 ROAD

The UB6.7 and UB6.9 gage stations are located in the Tinmiaqsiugvik River at RM 6.7 (downstream of the Tinmiaqsiugvik Bridge) and at RM 6.9 (upstream of the Tinmiaqsiugvik Bridge), measured upstream from the confluence with Fish Creek. The drainage basin area is approximately 231 square miles upstream of the Tinmiaqsiugvik Bridge. The Tinmiaqsiugvik River drains northwest into Fish Creek 6.7 RM downstream of the bridge. The UB gage stations have been monitored intermittently since 2003.

PT data suggests meltwater became hydraulically connected through the bridge crossing on May 25. Stage quickly rose over the next two days as recorded on both the upstream and downstream gage locations. Peak stage occurred on May 27 (Photo 4.64). During peak conditions stage was confined to the channel and no overbank flooding was observed. Saturated snow and bottomfast ice were observed in the channel but floodwater was flowing over top. By June 5, stage had receded from peak levels but snow and ice persisted in the channel (Photo 4.65). Over the next few days stage fluctuated, cresting again on May 31 and June 7 below peak levels. After the June 7 crest, stage would gradually recede to summer levels and saturated snow persisted in the channel (Photo 4.66). A flyover on June 10 confirmed saturated snow persisted in the channel and beneath the bridge crossing throughout the monitoring period (Photo 4.67). Discharge was not measured in 2021 due ice and snow blockage directly at the bridge crossing.

Tinmiaqsiugvik Bridge stage data is provided in Graph 4.17.

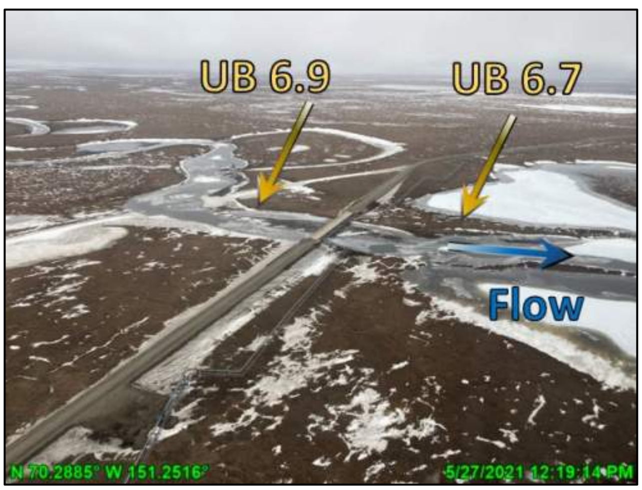


Photo 4.64: Tinmiaqsiugvik Bridge a few hours after peak stage with flow overtop saturated snow and ice, looking west; May 27, 2021

Photo 4.65: Receding stage with saturated snow and ice persisting, looking north (downstream); June 4, 2021

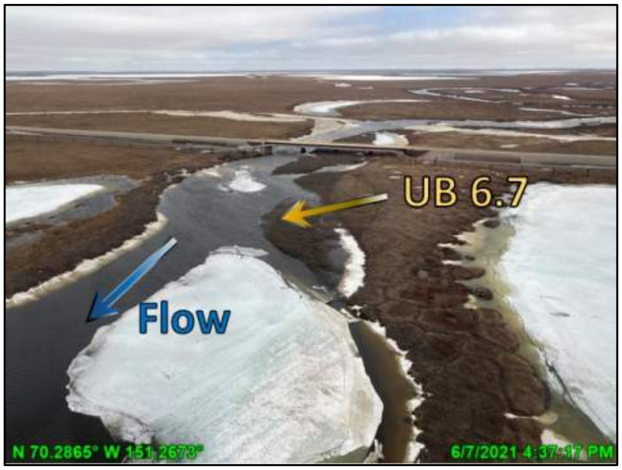
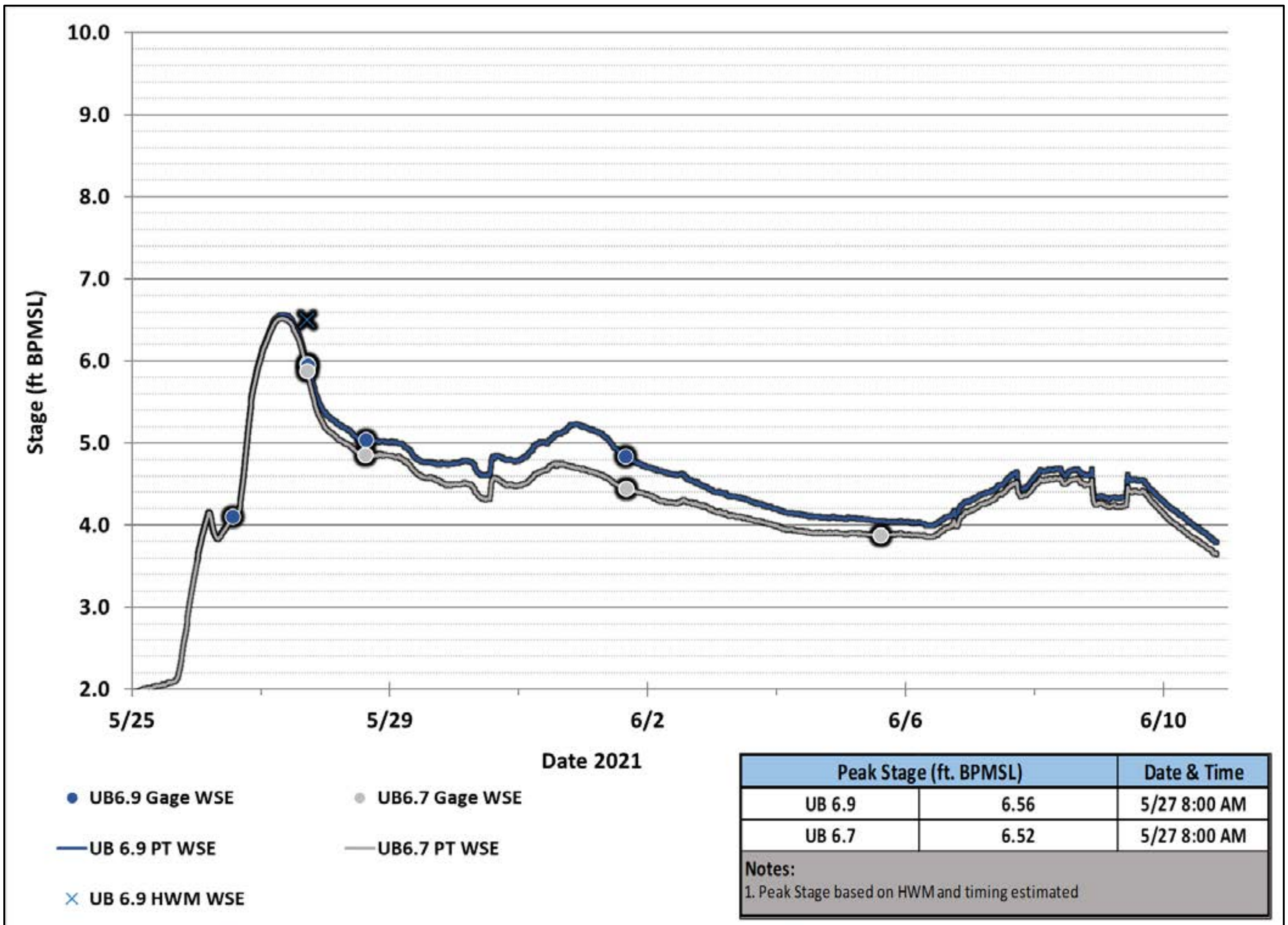


Photo 4.66: Tinmiaqsiugvik Bridge with persisting snow approximately 11 days after peak, looking south (upstream); June 7, 2021

Photo 4.67 Flyover of Tinmiaqsiugvik River showing persisting snow throughout the monitoring period, looking north (downstream); June 10, 2021



Peak Stage (ft. BPMSL)		Date & Time
UB 6.9	6.56	5/27 8:00 AM
UB 6.7	6.52	5/27 8:00 AM

Notes:
1. Peak Stage based on HWM and timing estimated

Graph 4.17: Tinmiaqsiugvik Bridge (UB6.7 & UB6.9) Stage

4.5 Peak Discharge Distribution

In general, flow distribution between the East Channel and Nigliq Channel bifurcations is about 80/20% respectively. Historically, this value is determined at the general time of peak discharge common to both channels. However, during years with dynamic ice jamming effects in the Colville River Delta, the timing of peak discharge between the two channels can vary greatly due to the storage and release of floodwater behind the jams. The 2021 spring flood event produced peak discharge in each channel nearly one day apart. Peak discharge at MON1 and in the East Channel was the result of an upstream ice jam release on June 6. Peak discharge in the Nigliq Channel was the result of the main surge of floodwater, in addition to the localized effects of smaller ice jams accumulating at various spots in the Nigliq Channel. Although peak discharge in each channel occurred on different days, the measured discharge at both MON1 and in the Nigliq Channel on June 8 provides nearly simultaneous data points to compare discharge distribution. The results from this comparison show an approximate 80/20% distribution between the East Channel and Nigliq Channel, respectively.

5. POST-BREAKUP CONDITIONS ASSESSMENT

Alpine roads and pads were inspected for erosion on June 9 and June 10. Washlines were noted on the north side of the CD2 road between the long and short swale bridge; however, vegetation under the washlines suggest this was from flood events prior to 2021, likely from 2015. Photo 5.1 through Photo 5.4 shows the CD2 and CD4 road, after stage had receded. No discernable erosion directly attributable to 2021 breakup flooding was observed during aerial and ground reconnaissance of the CD2, CD4, and CD5 roads. Floodwaters did not reach any of the CD5 bridge abutments, and no discernable erosion was observed along the abutments. Washlines from 2015 spring breakup, which was the largest historical flood event to impact Alpine facilities, remain evident along portions of the CD2, CD4, and CD5 roads. There were no signs of sloughing or undermining at drainage structures.

During the winter of 2020-2021, the scour hole on the long swale bridge between piers E9 and E10 was filled with gravel material.

Additional photo documentation of erosion surveys and breakup conditions along the Alpine facilities roads and pads are shown in Appendix D.

Photo 5.1: CD2 road post-breakup, looking northwest; June 10, 2021

Photo 5.2: CD2 road post-breakup, looking southeast; June 10, 2021

Photo 5.3: CD2 road post-breakup, looking southeast; June 10, 2021

Photo 5.4: CD4 road post breakup near Gage G16, looking northwest; June 10, 2021

6. CD5 PIER SCOUR, BANK EROSION, & BATHYMETRY

6.1 Pier Scour

Real-time pier scour was measured during spring breakup at the downstream pile at each scour-susceptible pier group. Post-breakup pier scour elevations that encompass all piles in each pier group were measured by UMIAQ in August 2021. Photo 6.1 and Photo 6.2 show pier numbers for the Nigliq and Nigliagvik bridges, respectfully. Post-breakup contour plots around the piers and within the main channel of the Nigliq Bridge and Nigliagvik Bridge are provided in Appendix E (UMIAQ 2021a).

Photo 6.1: Pier numbers on the Nigliq Bridge, looking northeast (downstream); June 7, 2021

Photo 6.2: Pier numbers on the Nigliagvik Bridge, looking south (upstream); June 14, 2021

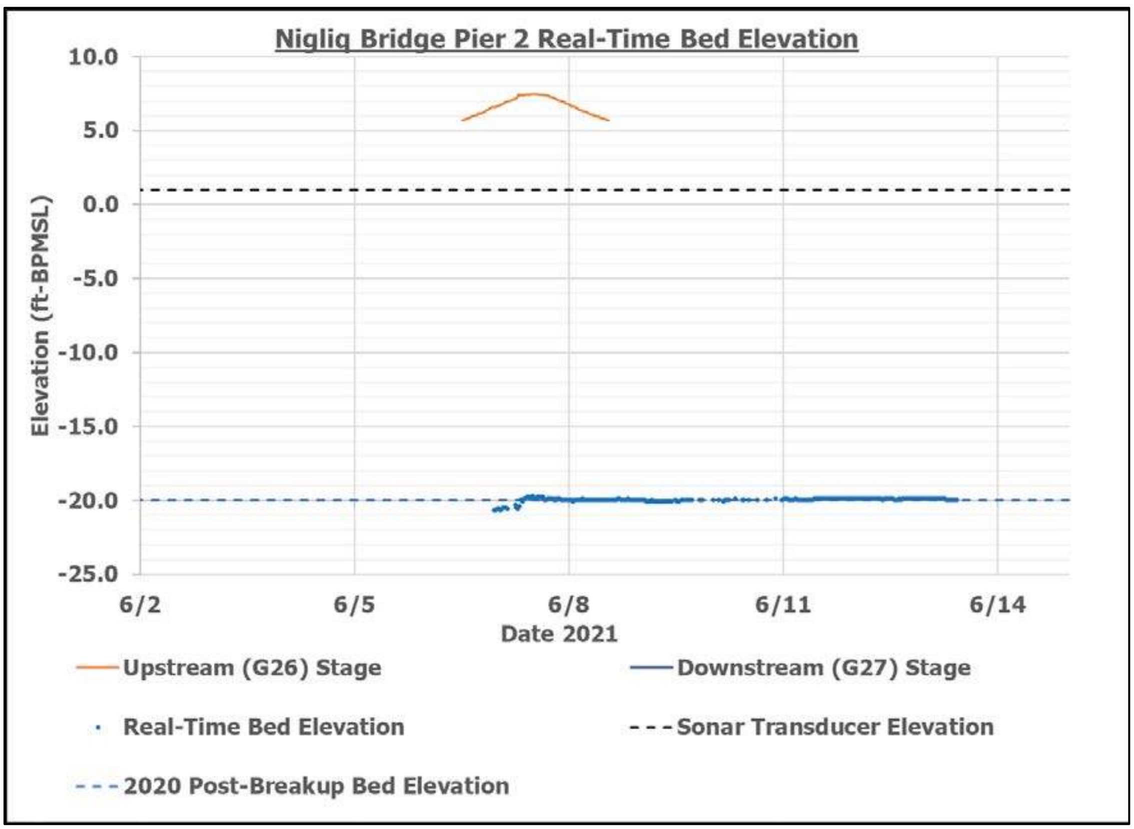
NIGLIQ BRIDGE

A comparison of design and observed scour elevations are presented in Table 6.1. The minimum post-breakup scour elevation (-33.5 ft BPMSL at pier 4, pile D) is 4.6 ft below the 50-year design scour elevation and 0.5 ft below the 200-year scour elevation. Real-time pier scour at piers 2 through 5 and corresponding WSEs during spring breakup monitoring are presented in Graph 6.1 through Graph 6.4. At piers 2, 3, 4, and 5, real-time scour measurements recorded approximately 0 ft of scour from the 2020 post breakup survey elevation.

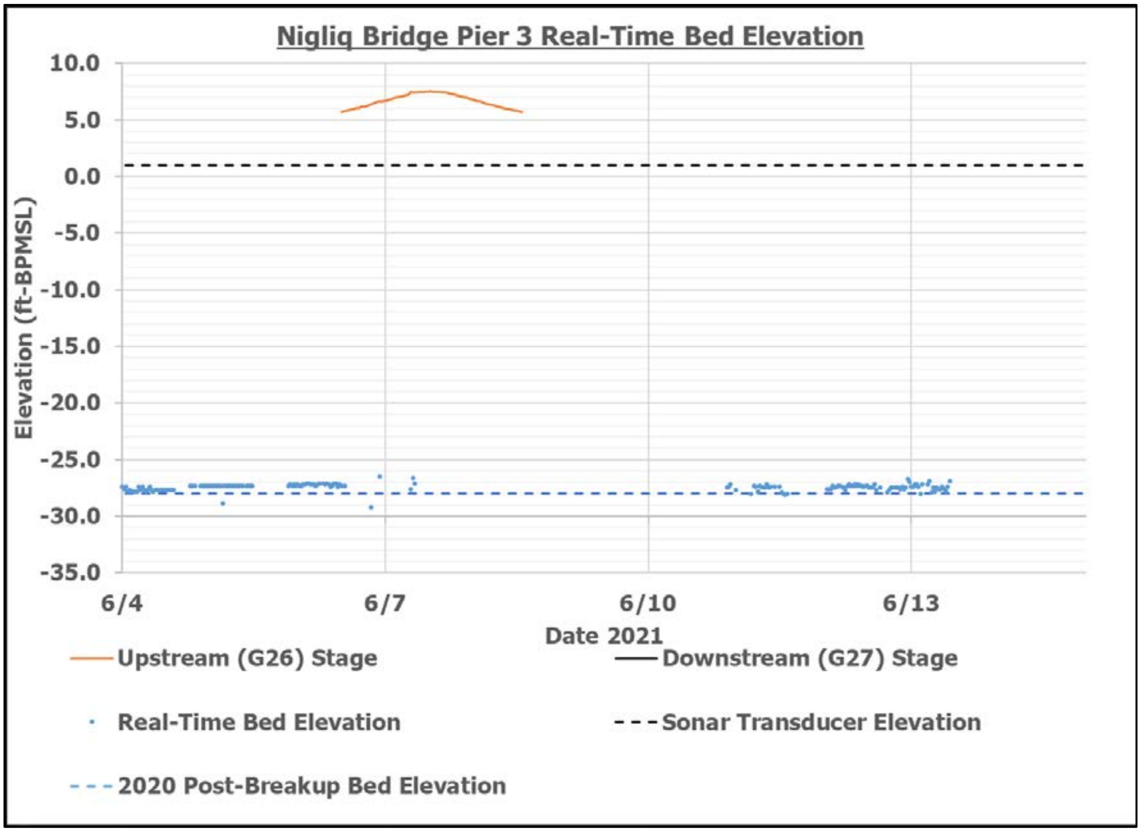
Table 6.1: Nigliq Bridge Comparison of Design and Observed Pier Scour Elevations

Nigliq Bridge Pier Scour		
During Breakup 2021		Elevation (ft-BPMSL)[1,2]
Pier 2	Pile E	-20.7
Pier 3	Pile E	-29.2
Pier 4	Pile E	-30.6
Pier 5	Pile E	-20.3
Post-Breakup 2021		Elevation (ft-BPMSL)[3]
Pier 2	Pile B on southeast side	-24.3
Pier 3	Pile E on southwest side	-28.1
Pier 4	Pile D on west side	-33.5
Pier 5	Pile E on east side	-17.2
Design 2013		Elevation (ft-BPMSL)[4,5]
50-year	Pier 2-6	-28.9
	Pier 7-8	-7.1
200-year	Pier 2-6	-33.0
	Pier 7-8	-16.4

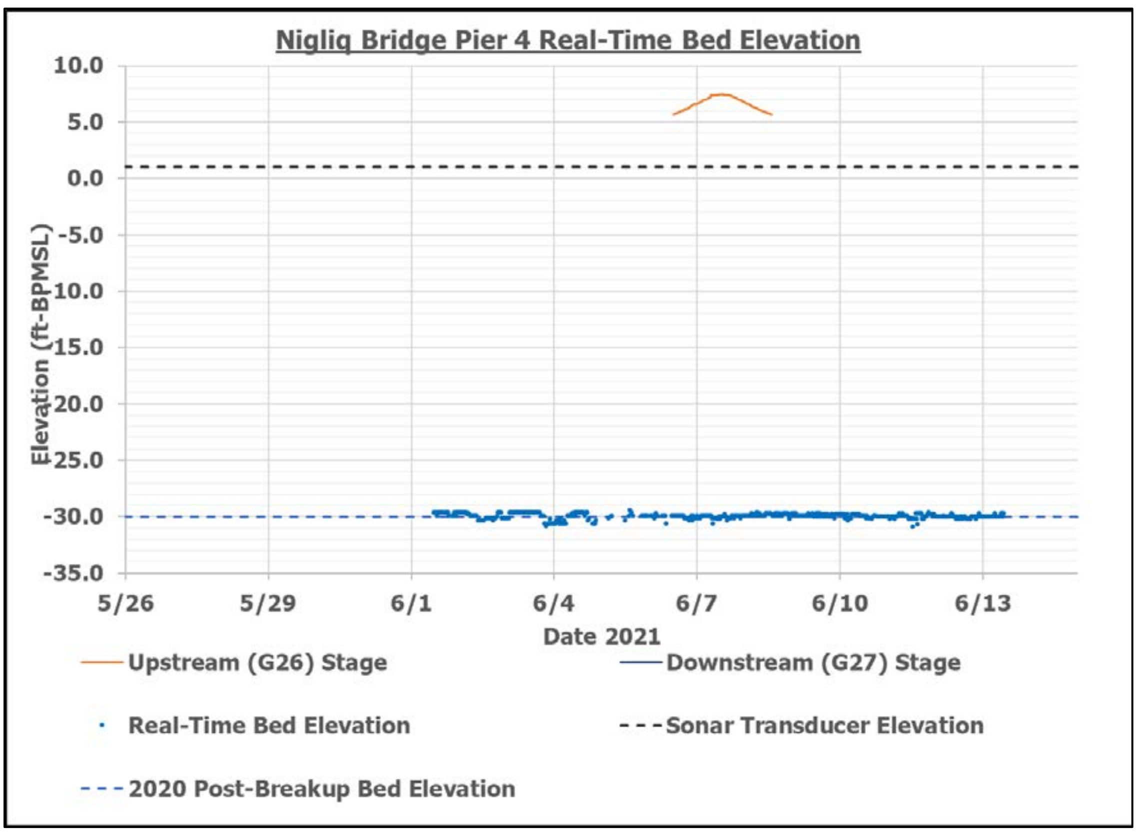
Notes:
[1]Minimum channel bed elevations recorded by real-time scour system in May and June 2021.
[2]Real-time scour measurements at downstream side of downstream pile.
[3]Minimum channel bed elevations recorded by LCMF in August 2021.
[4]Design values presented in PND 2013.
[5]Elevations based on LCMF 2008 survey.



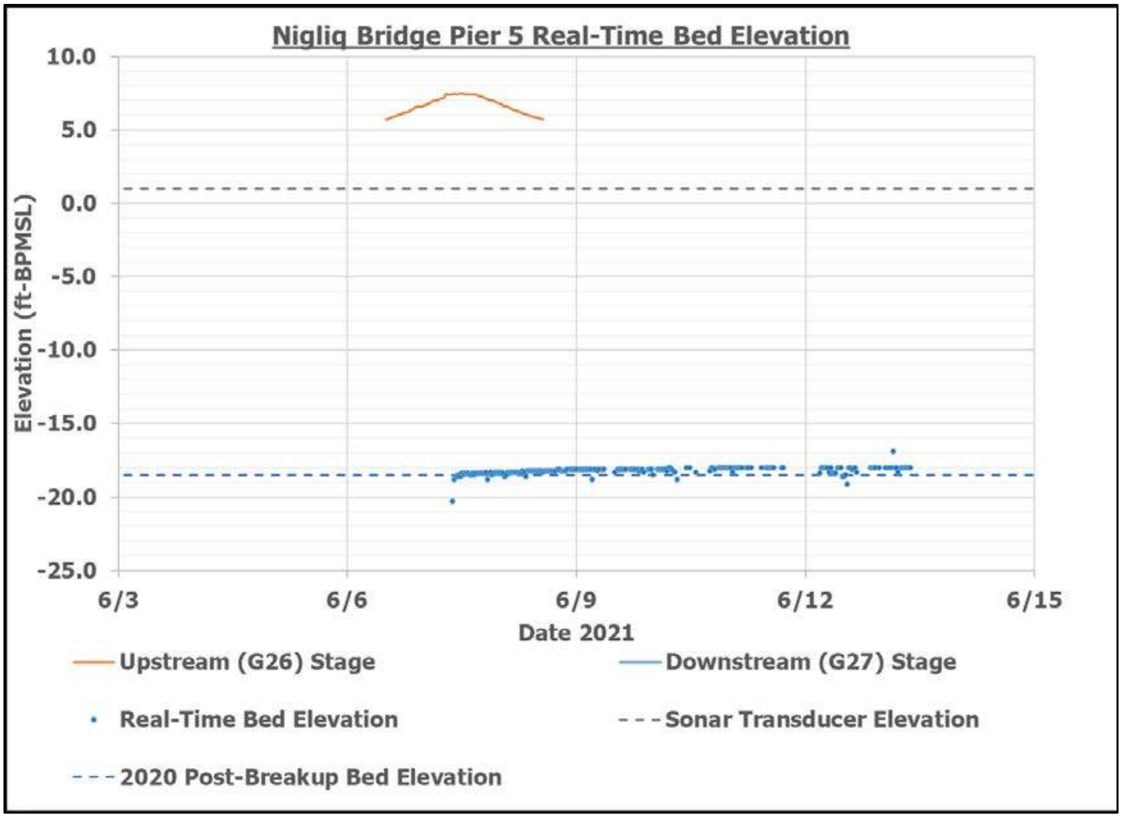
Graph 6.1: Nigliq Bridge Pier 2 (Pile E) Real-Time Scour Elevations



Graph 6.2: Nigliq Bridge Pier 3 (Pile E) Real-Time Scour Elevations



Graph 6.3: Nigliq Bridge Pier 4 (Pile E) Real-Time Scour Elevations



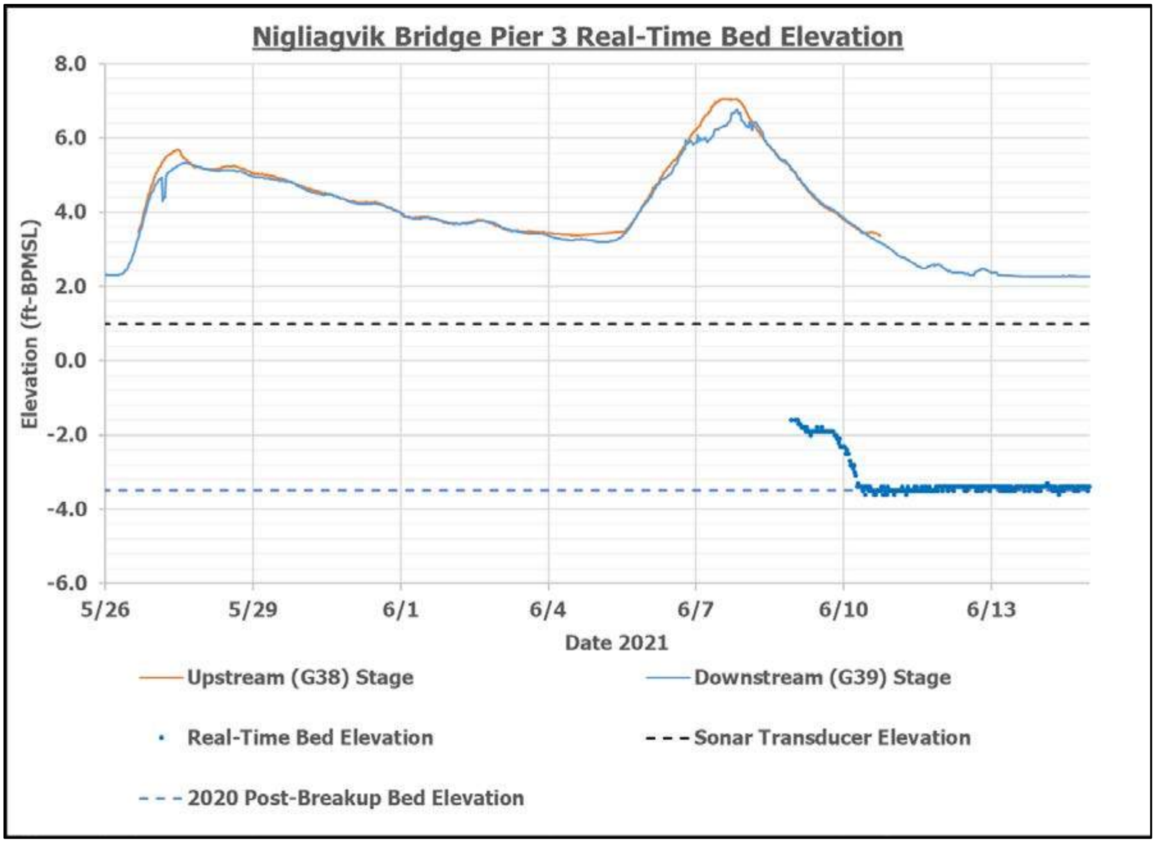
Graph 6.4: Nigliq Bridge Pier 5 (Pile E) Real-Time Scour Elevations

NIGLIAGVIK BRIDGE

The minimum post-breakup scour elevation (-5.0 ft BPMSL at pier 4, pile B) is 9.2 ft above the 50-year design scour elevation and 16.8 ft above the 200-year scour elevation. A comparison of design and observed scour elevations are presented in Table 6.2. Real-time pier scour at pier 3 and corresponding WSEs during spring breakup monitoring is presented in Graph 6.5. Real-time pier scour measurements indicated approximately 0 ft of active scour during peak conditions compared to the 2020 post breakup survey.

Table 6.2: Nigliagvik Bridge Comparison of Design and Observed Pier Scour Elevations

Nigliagvik Bridge Pier Scour		
During Breakup 2021		**Elevation (ft-BPMSL)[1]**
Pier 3	Pile B on north side	-3.6
Post-Breakup 2021		**Elevation (ft-BPMSL)[1]**
Pier 3	Pile A on north side	-4.5
Pier 4	Pile B on North side	-5.0
Design 2013		**Elevation (ft-BPMSL)[2,3]**
50-year	Pier 3-4	-14.2
200-year	Pier 3-4	-21.8
Notes: [1]Minimum channel bed elevations recorded by LCMF in August 2021 [2]Design values presented in PND 2013 [3]Elevations based on LCMF 2008 survey		



Graph 6.5: Nigliagvik Bridge Pier 3 (Pile B) Real-Time Scour Elevations

6.2 Bank Erosion

Aerial photos taken post breakup showing no apparent channel migration of the Nigliq and Nigliagvik Channels and are presented in Photo 6.3 and Photo 6.4, respectively. A bank erosion survey upstream and downstream of the Nigliq and Nigliagvik Bridges was performed on August 12. Site conditions during the bank erosion survey at the Nigliq Bridge are presented in Photo 6.5 and Photo 6.6, respectively. Maximum incremental and cumulative erosion at the Nigliq Bridge and Nigliagvik Bridge and maximum incremental, maximum cumulative, and average erosion along the top of bank, upstream and downstream of the bridges, are presented in Table 6.3. Bank erosion tabulated data from the bank erosion survey is presented in Appendix E (UMIAQ 2021).

Photo 6.3: Nigliq Channel post breakup showing no channel migration, looking south; June 14, 2021

Photo 6.4: Nigliagvik Channel post breakup showing no channel migration, looking southwest; June 14, 2021

Photo 6.5: West bank of the Nigliq Channel near the Nigliq Bridge, looking north; August 12, 2021

Photo 6.6: West bank of the Nigliq Channel south of the Nigliq Bridge, looking north; August 12, 2021

Table 6.3: Nigliq Channel and Nigliagvik Channel Bank Erosion

		Nigliq Channel						Nigliagvik Channel					
		West Bank			East Bank			West Bank			East Bank		
		Station[1] (STA)	Distance (ft)	Rate (ft/yr)	Station[1] (STA)	Distance (ft)	Rate (ft/yr)	Station[1] (STA)	Distance (ft)	Rate (ft/yr)	Station[1] (STA)	Distance (ft)	Rate (ft/yr)
Bridge Stations[2]	Maximum Incremental Erosion (2020-2021)	12+00	2.7	--	None	None	--	None	None	--	5+00	3.1	--
Bridge Stations[2]	Maximum Cumulative Erosion (2013-2021)	12+00	14.7	1.8	14+00	4.2	0.5	5+00	20.6	2.6	5+00	0.4	0.1
All Stations	Maximum Incremental Erosion (2020-2021)	2+00	5.4	--	0+00	0.9	--	10+28	0.1	--	4+00	0.1	--
All Stations	Maximum Cumulative Erosion (2013-2021)	1+00	47.4	5.9	0+00	0.9	0.1	0+00	9.0	1.1	4+00	7.4	0.9
All Stations	Average Cumulative Erosion (2013-2021)	All	--	1.8	All	--	0.1	All	--	0.7	All	--	0.1

Notes:
1. Stationing begins upstream of bridge
2. Nigliq Bridge Stations 10+00 through 13+00 on West Bank and 13+00 through 15+00 on East Bank. Nigliagvik Bridge Stations 5+00 through 6+00 on both banks

6.3 Bathymetry

BATHYMETRY AT BRIDGES

The 2021 survey results at each CD5 bridge location were compared with the survey results from 2013-2020 to obtain maximum incremental scour and deposition between 2021 and 2020, and maximum cumulative scour and deposition between 2021 and 2013 (Table 6.4). Transect profiles, bathymetric cross-sections, and tabulated data are provided in Appendix E (UMIAQ 2021).

Table 6.4: Nigliq Bridge, Lake L9341 Bridge, and Nigliagvik Bridge Scour and Deposition

	Nigliq Bridge			Lake L9341 Bridge			Nigliagvik Bridge		
	Depth (ft)	Station (STA)	Transect	Depth (ft)	Station (STA)	Transect	Depth (ft)	Station (STA)	Transect
Maximum Incremental Scour (2020-2021)	6.5	2+62	9	1.0	3+90	36	1.6	1+30	27
Maximum Cumulative Scour (2013-2021)	13.1	2+67	10	0.9	Varies	36	2.5	1+00	25
Maximum Incremental Deposition (2020-2021)	4.7	8+15	10	1.2	1+89	36	1.0	2+32	26
Maximum Cumulative Deposition (2013-2021)	9.6	1+67	10	1.3	3+49	36	3.8	1+03	26

7. ICE ROAD CROSSINGS BREAKUP

Ice roads are constructed annually for ground transportation of supplies, equipment, and maintenance of Alpine facilities. Aerial surveys were conducted before, during, and after spring breakup at most locations to observe and document the ice deterioration at stream and dragline crossings. To expedite melt and facilitate flow through the crossings during breakup flooding, ice road crossings are mechanically slotted at the conclusion of the winter season.

In general, ice road crossings deteriorated at a similar rate as surrounding channel ice. Aerial surveys showed that slotting was completed, and floodwaters were passing through all ice road crossings. The majority of the crossings were submerged during the peak flood conditions. When flooding receded, the ice road crossings and channel ice had cleared at most locations. Photos of all monitored ice road crossings are presented in Appendix D.

8. HISTORICAL BREAKUP TIMING & MAGNITUDE

Colville River breakup monitoring has been ongoing, intermittently, since 1962. The timing and magnitude of breakup flooding has been determined annually since 1992 by measuring WSEs and discharge at established locations throughout the delta.

8.1 Colville River – Head of the Delta

The historical record of peak stage and peak discharge for the CRD is at MON1C, at the head of the delta. Annual peak stage and peak discharge at MON1C has been recorded intermittently from 1962 to 1992 and annually from 1992 to 2021 (Table 8.1 and Graph 8.1).

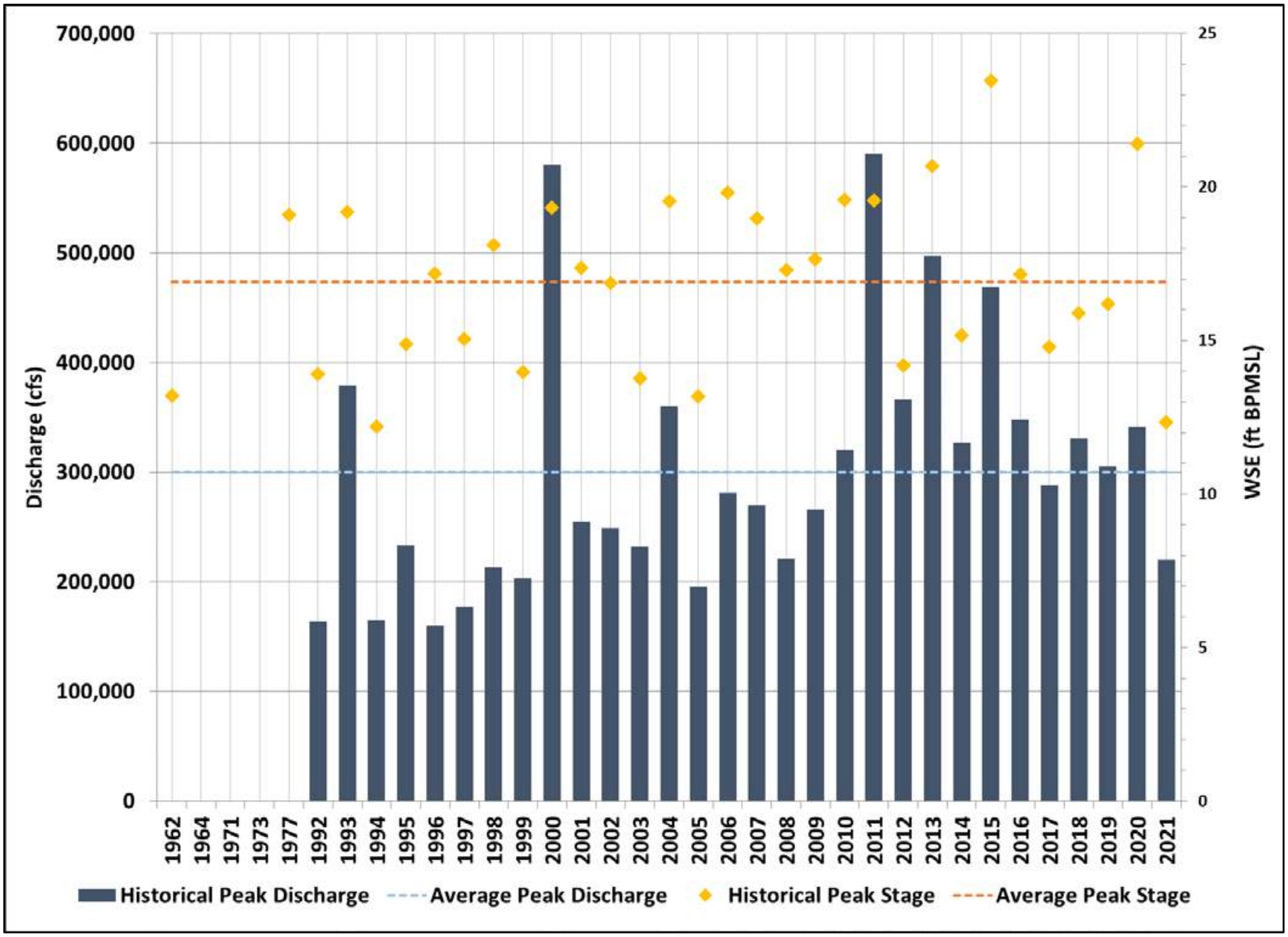
Peak stage at MON1C was 12.34 ft BPMSL and occurred on June 6. The average historical peak stage is 16.91 ft BPMSL and the average date is May 30. The maximum historical peak stage is 23.47 ft BPMSL occurring in 2015 on May 21.

Peak discharge at MON1C was 220,00 cfs and occurred on June 6. The average historical peak discharge is 300,000 cfs and the average date is May 31. The maximum historical peak discharge is 590,000 cfs occurring in 2011 May 28.

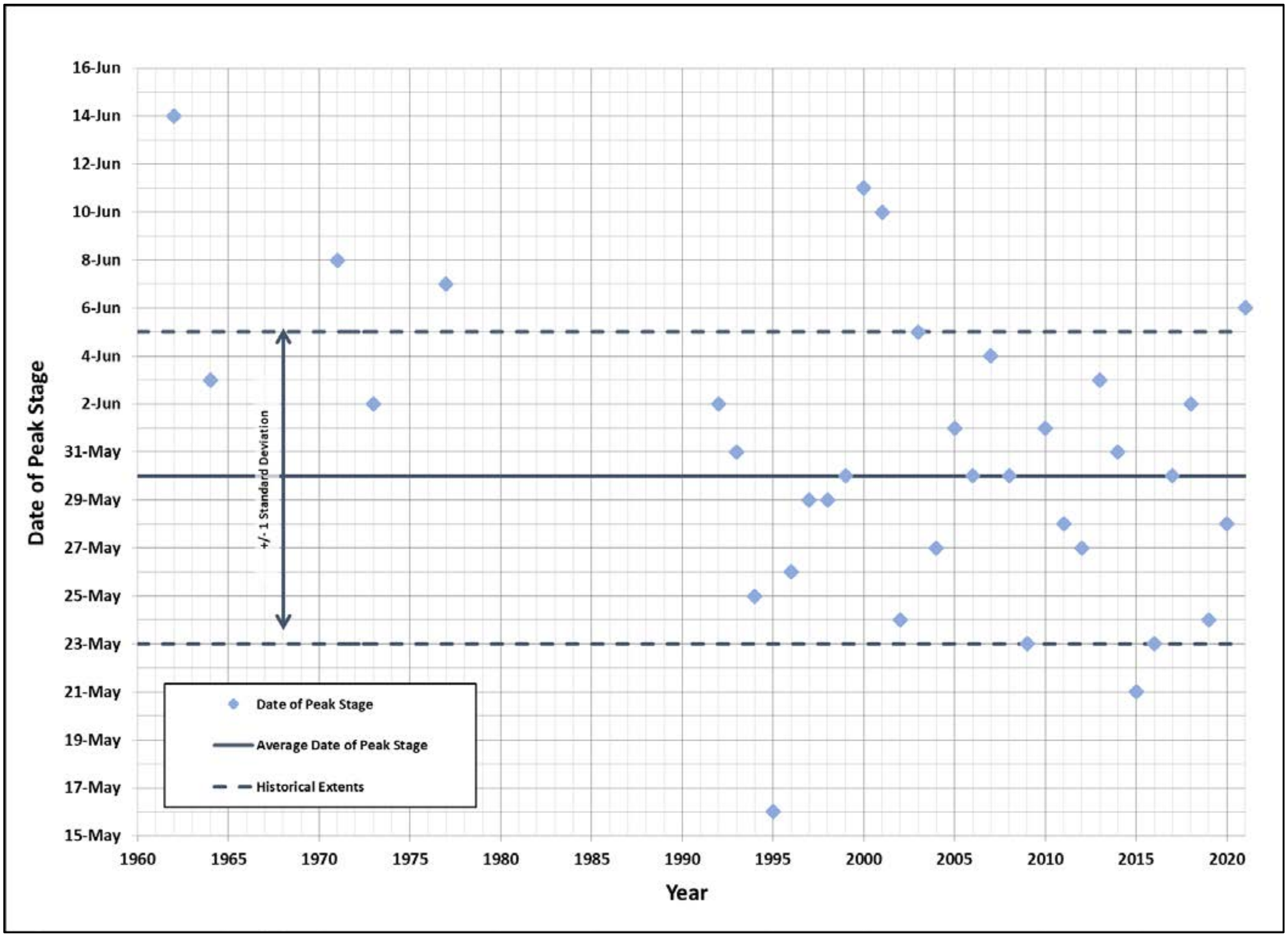
Statistical analysis of historical peak stage dates shows 79 percent of the peaks at MON1C occur during a 13-day period from May 23 to June 5. This represents one standard deviation of 6.2 days on either side of the average (mean) peak stage date of May 30, based on a normal distribution, as illustrated in Graph 8.2. Peak stage at MON1C this year was seven days later with respect to the historical average.

Table 8.1: Colville River at the Head of the Delta Peak Discharge and Peak Stage Historical Summary

Year	Discharge		Stage (WSE)		Reference
	Peak Discharge (cfs)	Date	Peak Stage (ft BPMSL)	Date	
2021	**220,000**	**6-Jun**	**12.34**	**6-Jun**	**This Report**
2020	341,000	27-May	21.41	28-May	Michael Baker 2020
2019	305,000	24-May	16.19	24-May	Michael Baker 2019
2018	331,000	1-Jun	15.90	2-Jun	Michael Baker 2018
2017	288,000	30-May	14.79	30-May	Michael Baker 2017
2016	348,000	23-May	17.16	23-May	Michael Baker 2016
2015	469,000	22-May	23.47	21-May	Michael Baker 2015
2014	327,000	1-Jun	15.18	31-May	Michael Baker 2014
2013	497,000	3-Jun	20.69	3-Jun	Michael Baker 2013
2012	366,000	1-Jun	14.18	27-May	Michael Baker 2012b
2011	590,000	28-May	19.56	28-May	Michael Baker 2012a
2010	320,000	31-May	19.59	1-Jun	Michael Baker 2010
2009	266,000	23-May	17.65	23-May	Michael Baker 2009b
2008	221,000	28-May	17.29	30-May	Michael Baker 2008
2007	270,000	3-Jun	18.97	4-Jun	Michael Baker 2007b
2006	281,000	30-May	19.83	30-May	Michael Baker 2007a
2005	195,000	9-Jun	13.18	1-Jun	Michael Baker 2005b
2004	360,000	26-May	19.54	27-May	Michael Baker 2005a
2003	232,000	11-Jun	13.76	5-Jun	Michael Baker 2006a
2002	249,000	27-May	16.87	24-May	Michael Baker 2006a
2001	255,000	11-Jun	17.37	10-Jun	Michael Baker 2006a
2000	580,000	11-Jun	19.33	11-Jun	Michael Baker 2000
1999	203,000	30-May	13.97	30-May	Michael Baker 1999
1998	213,000	3-Jun	18.11	29-May	Michael Baker 1998b
1997	177,000	-	15.05	29-May	Michael Baker 2002b
1996	160,000	26-May	17.19	26-May	Shannon & Wilson 1996a
1995	233,000	-	14.88	16-May	ABR 1996
1994	159,000	25-May	12.20	25-May	ABR 1996
1993	379,000	31-May	19.20	31-May	ABR 1996
1992	188,000	-	13.90	2-Jun	ABR 1996
1977	407,000	-	19.10	7-Jun	ABR 1996
1973	478,000	-	-	2-Jun	ABR 1996
1971	447,000	8-Jun	-	8-Jun	ABR 1996
1964	-	-	-	3-Jun	ABR 1996
1962	215,000	-	13.20	14-Jun	ABR 1996

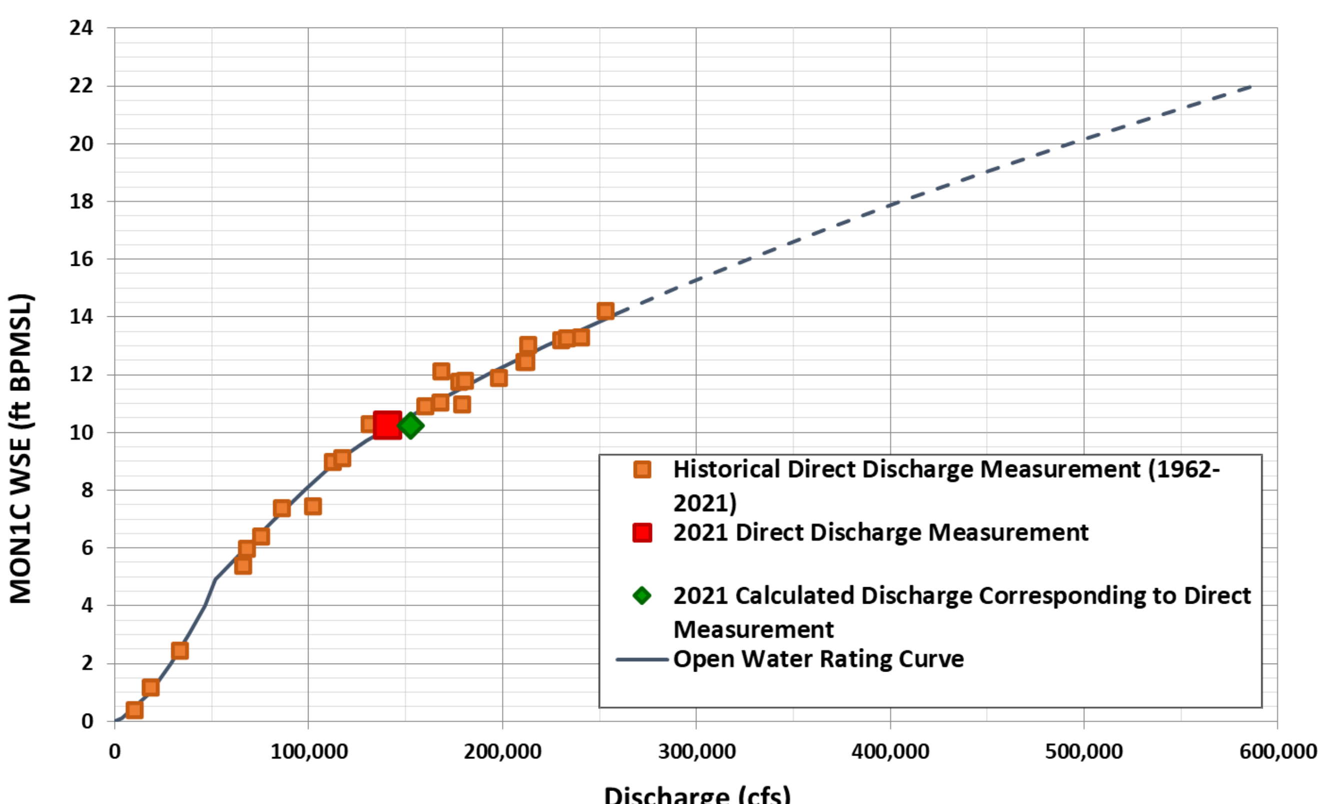


Graph 8.1: Colville River at the Head of the Delta Historical Peak Stage and Peak Discharge



Graph 8.2: Colville River at the Head of the Delta Historical Timing of Peak Stage

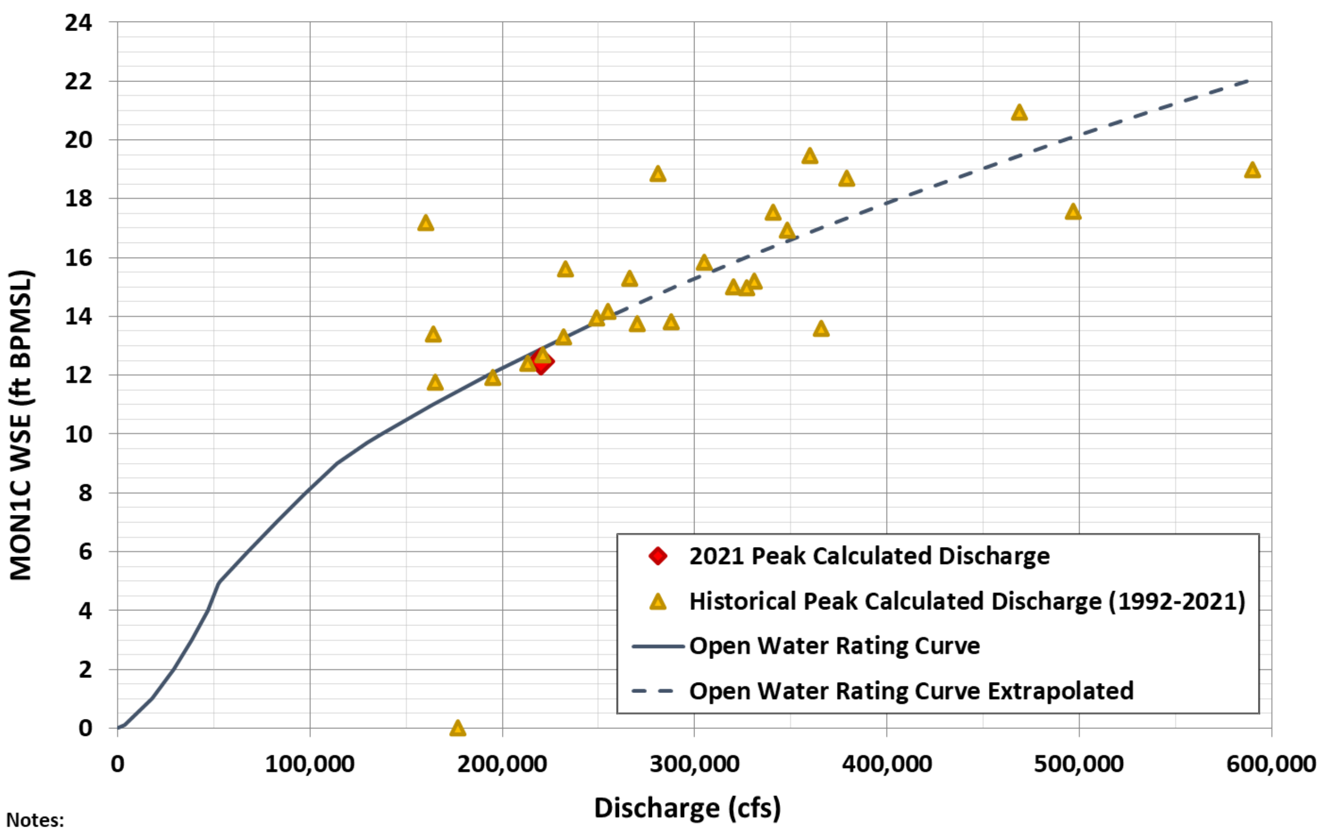
The MON1C stage-discharge rating curve, shown in Graph 8.3, represents a relationship between stage and discharge. The rating curve was calculated from direct discharge measurements taken during ice-free conditions between 1992 and 2005. Colville River discharge can be greatly influenced by channel ice; the rating curve more accurately represents the relationship between stage and discharge at lower stage values when ice-free discharge measurements are possible.



Notes:
1. Rating curve calculated from direct discharge measurements made during open water (ice free) conditions between 1962 and 2005.
2. Extrapolated portion is extension of slope of curve between highest known stage/discharge value; physical geometery of the banks and floodplain would cause the curve to asymptote at an unknown stage - to be used for reference only.

Graph 8.3: Colville River at the Head of the Delta Stage-Discharge Rating Curve with Measured Discharge

Peak discharge between 1992 and 2021 are plotted against the open water rating curve in Graph 8.4. Open water conditions rarely occur (ice influences are typically present) at or near peak discharge during breakup. Differences between peak discharge and the open water rating curve are attributed to ice effects on stage and discharge. Values that fall to the right and below the rating curve tend to be the result of an upstream ice jam release. Conversely, values that fall to the left and above the rating curve tend to be the result of downstream ice jam backwater effects. Peak discharge in 2021 falls to the right of the rating curve.



Notes:
1. Rating curve calculated from direct discharge measurements made during open water (ice free) conditions between 1962 and 2005
2. Extrapolated portion is extension of slope of curve between highest known stage/discharge values; physical geometery of the banks and floodplain would cause the curve to asymptote at an unknown stage - to be used for reference only
3. Stage corresponds to direct measurement/indirect calculation

Graph 8.4: Colville River at the Head of the Delta Stage-Discharge Rating Curve with Peak Discharge

8.2 CD2 Road Bridges

Discharge has been measured at the CD2 road bridges since 2000, and overall, the measurements are estimated to be within 5-10% of the true discharge value based on the quality rating assigned to measurements. Discharge was not measured at the short swale bridge as no discernable flow was observed. Measured flow in 2021 through the Long Swale Bridge was 51.8% of the average annual measured flow through both bridges (3,662 cfs). A summary of historical discharge measurements at the CD2 road bridges is presented in Table 8.2.

Table 8.2: CD2 Road Bridges Measured Discharge Historical Summary

Date	Stage[1] (ft)	Stage Differential[2] (ft)	Width (ft)	Area (ft²)	Mean Velocity[3] (ft/s)	Discharge (cfs)	Measurement Rating[4]	Number of Sections	Measurement Type	Reference
Short Swale Bridge (62 ft)										
2021[5]	–	–	–	–	–	–	–	–	–	This Report
05/29/20	9.92	0.81	55	476	5.17	2,460	F	22	Cable	Michael Baker 2020
05/26/19	7.27	0.02	53	349	0.7	244	G	11	Cable	Michael Baker 2019
06/03/18	6.63	0.08	36	32	0.22	5.40	P	22	Cable	Michael Baker 2018
2017[5]	–	–	–	–	–	–	–	–	–	Michael Baker 2017
05/25/16	7.39	0.32	53	322	2.11	700	G	27	Cable	Michael Baker 2016
05/23/15	7.85	0.05	54	373	0.81	302	F	19	Cable	Michael Baker 2015
06/02/14	7.90	0.12	54	365	1.31	479	F	28	Cable	Michael Baker 2014
06/05/13	9.75	0.46	54	446	3.60	1,608	G	36	Cable	Michael Baker 2013
06/03/12	7.04	0.17	52	306	1.26	386	F	19	Cable	Michael Baker 2012b
05/28/11	8.15	0.43	52	336	2.51	840	F	27	Cable	Michael Baker 2012a
06/03/10	7.58	0.16	55	316	1.79	570	F	28	Cable	Michael Baker 2010
2009[5]	–	–	–	–	–	–	–	–	–	Michael Baker 2009b
05/29/08	6.35	0.18	55	211	0.58	120	P	14	Cable	Michael Baker 2008
06/05/07	7.83	0.09	55	292	1.18	350	F	20	Cable	Michael Baker 2007b
05/31/06	8.49	0.26	55	615	1.59	980	F	20	Cable	Michael Baker 2007a
2005[5]	–	–	–	–	–	–	–	–	–	Michael Baker 2005b
05/29/04	8.34	0.14	55	451	1.60	720	F	17	Cable	Michael Baker 2005a
2003[5]	–	–	–	–	–	–	–	–	–	Michael Baker 2003
05/25/02	6.74	0.22	56	283	1.52	430	G	17	Cable	Michael Baker 2002b
06/11/01	7.64	0.56	56	336	1.79	600	G	15	Cable	Michael Baker 2001
06/10/00	7.87	0.61	47	175	3.30	580	F	13	Cable	Michael Baker 2000
Long Swale Bridge (452 ft)										
06/07/21	**6.09**	**0.12**	**445**	**2,667**	**1.07**	**1,895**	**G**	**30**	**Cable**	**This report**
05/30/20	7.89	0.06	445	3,602	0.59	2,131	F	32	Cable	Michael Baker 2020
05/25/19	6.84	0.29	440	2,046	1.37	2,795	F	21	Cable	Michael Baker 2019
06/03/18	7.05	0.16	431	2,090	1.50	3,140	P	-	Cable	Michael Baker 2018
06/01/17	5.92	0.04	445	1,505	0.86	1,290	F	27	Cable	Michael Baker 2017
05/25/16	7.48	0.40	445	2,025	2.25	4,800	G/F	28	Cable	Michael Baker 2016
05/22/15	9.93	0.55	447	3,024	3.12	9,440	G	24	Cable	Michael Baker 2015
06/02/14	8.00	0.13	445	2,183	1.30	2,842	G	38	Cable	Michael Baker 2014
06/05/13	9.87	0.42	448	2,947	2.47	7,286	G	36	Cable	Michael Baker 2013
06/03/12	7.10	0.17	445	1,686	1.53	2,582	-	26	Cable	Michael Baker 2012b
05/29/11	8.16	0.38	447	2,027	2.22	4,500	F	26	Cable	Michael Baker 2012a
06/01/10	7.97	0.47	441	1,699	2.66	4,500	G	25	Cable	Michael Baker 2010
05/26/09	5.89	0.09	445	1,592	0.82	730	F	27	Wading	Michael Baker 2009b
05/29/08	6.35	0.18	445	949	2.03	1,930	F	21	Wading	Michael Baker 2008
06/05/07	7.76	0.08	447	1,670	0.74	1,240	F	20	Cable	Michael Baker 2007b
05/31/06	8.42	0.18	409	1,730	1.89	3,260	F	29	Cable	Michael Baker 2007a
06/02/05	6.13	0.08	445	841	1.37	1,100	G	20	Wading	Michael Baker 2005b
05/29/04	8.34	0.14	446	1,700	1.40	2,400	F	18	Cable	Michael Baker 2005a
06/08/03	5.48	-0.05	444	478	0.88	420	G	16	Wading	Michael Baker 2003
05/25/02	6.74	0.22	445	930	3.47	3,200	G	17	Cable	Michael Baker 2002b
06/11/01	7.64	0.56	460	1,538	2.40	3,700	G	16	Cable	Michael Baker 2001
06/09/00	7.34	0.78	437	1,220	3.27	4,000	F	15	Cable	Michael Baker 2000

Notes:
1. Source of stage is G3
2. Stage differential between G3/G4 at time of discharge measurement
3. Mean velocities adjusted with angle of flow coefficient
4. Measurement Rating -
   - E - Excellent: Within 2% of true value
   - G - Good: Within 5% of true value
   - F - Fair: Within 8% of true value
   - P - Poor: Velocity < 0.70 ft/s; shallow depth for measurement; greater than 8% error
5. Bridge obstructed with snow or ice and/or lack of flow; no measurement performed

Calculated peak flow through the long swale bridge was 43.2% of the average annual peak flow through both bridges (4,389 cfs). Table 8.3 summarizes peak stage and calculated peak discharge at the CD2 Long and Short Swale Bridges between 2000 and 2021.

Table 8.3: CD2 Road Bridges Peak Stage and Discharge Historical Summary

Date[1]	Peak Stage[2] (ft BPMSL)	Stage Differential[3] (ft)	Long Swale Bridge (452 ft)		Short Swale Bridge (62 ft)		References
			Peak Discharge (cfs)	Mean Velocity (ft/s)	Peak Discharge (cfs)	Mean Velocity (ft/s)	
06/07/21	**6.12**	**0.22**	**1,895**	**1.07**	– [4]	– [4]	**This report**
05/29/20	10.91	1.61	2,868	0.59	2,765	5.17	Michael Baker 2020
05/25/19	7.32	0.35	3,000	1.37	250	0.71	Michael Baker 2019
06/02/18	7.12	0.25	3,240	1.50	12	0.22	Michael Baker 2018
05/31/17	6.04	0.04	1,350	0.86	– [4]	– [4]	Michael Baker 2017
05/25/16	7.50	0.44	4,800	2.35	680	2.06	Michael Baker 2016
05/22/15	11.93	1.54	12,350	3.12	484	0.81	Michael Baker 2015
06/02/14	8.18	0.19	2,971	1.30	501	1.31	Michael Baker 2014
06/04/13	10.27	1.17	7,723	2.47	1,706	3.60	Michael Baker 2013
06/03/12	7.60	0.41	2,940	1.53	425	1.26	Michael Baker 2012b
05/29/11	8.89	0.30	5,200	2.22	940	2.51	Michael Baker 2012a
06/02/10	8.64	0.59	5,300	2.66	670	1.79	Michael Baker 2010
05/25/09	7.63	0.45	1,400	0.82	– [4]	– [4]	Michael Baker 2009b
05/30/08	6.49	0.26	2,100	0.49	130	0.58	Michael Baker 2008
06/05/07	8.60	0.43	1,500	1.35	400	1.18	Michael Baker 2007b
05/31/06	9.72	0.87	4,400	1.77	1,100	1.59	Michael Baker 2007a
05/31/05	6.48	0.20	1,400	1.37	– [4]	– [4]	Michael Baker 2005b
05/27/04	9.97	0.50	3,400	1.38	900	1.59	Michael Baker 2005a
06/07/03	6.31	0.12	700	0.88	– [4]	– [4]	Michael Baker 2003
05/26/02	7.59	0.69	4,000	3.47	500	1.52	Michael Baker 2002b
06/11/01	7.95	0.73	3,900	2.40	600	1.79	Michael Baker 2001
06/12/00	9.48	0.73	7,100	3.60	1,000	4.30	Michael Baker 2000

Notes:
[1]Based on gage HWM readings.
[2]Source of stage is Gage 3.
[3]Stage differential between G3/G4 at time of peak discharge.
[4]Bridge obstructed with snow or ice, no velocity measurements.

8.3 CD5 Road Bridges

Peak annual discharge has been calculated at the Nigliq Bridge since 2009 and at the Nigliagvik, Lake L9341, and Lake L9323 bridges since 2012. A summary of peak stage and peak discharge during breakup flood events for the CD5 road bridges is shown in Table 8.4.

Table 8.4: CD5 Road Bridges Peak Discharge and Peak Stage Historical Summary

Year	Lake L9323 Bridge		Nigliq Bridge		Lake L9341 Bridge		Nigliagvik Bridge	
	Peak Discharge (cfs)	Peak Stage [G24] (ft BPMSL)	Peak Discharge (cfs)	Peak Stage [G26] (ft BPMSL)	Peak Discharge (cfs)	Peak Stage [G32] (ft BPMSL)	Peak Discharge (cfs)	Peak Stage [G38] (ft BPMSL)
Post-Bridge Construction								
2021	**- [1]**	**- [3]**	**34,000**	**7.49**	**- [1]**	**7.40**	**3,150**	**7.07**
2020	1,620	12.43	100,500	12.23	- [1]	11.89	6,800	11.24
2019	- [1]	8.49	95,000	9.16	- [1]	8.63	- [3]	9.30
2018	- [1]	9.67	42,200	8.43	- [1]	8.77	10,400	7.43
2017	- [1]	9.54	47,400	8.60	- [1]	7.10	2,550	6.86
2016	- [1]	8.85	65,000	9.05	- [1]	8.65	2,800	8.35
2015[2]	9,100	15.39	112,000	14.50	22,500	14.51	17,300	13.57
2014	- [1]	8.58	66,000	9.38	- [3]	8.48	7,800	8.64
Pre-Bridge Construction								
2013	- [1]	12.40	110,000 [4]	12.42 [5]	5,000 [4]	11.07	7,800 [4]	11.41
2012	- [1]	8.55	94,000 [6]	8.82	6,000 [6]	8.58	11,000 [6]	8.51
2011	- [3]	- [3]	141,000 [6]	9.89 [7]	- [3]	9.5 [8]	- [3]	8.78 [9]
2010	- [3]	- [3]	134,000 [6]	9.65 [7]	- [3]	5.85 [8]	- [3]	8.69 [9]
2009	- [3]	- [3]	57,000 [6]	7.91 [7]	- [3]	7.98 [8]	- [3]	7.71 [9]

Notes:
[1]No discharge reported because of a lack of hydraulic connection through bridge, backwater flow, and/or ice conditions return unreasonable calculation results.
[2]Discharge influenced by flow contraction through bridges.
[3]Data not available.
[4]Indirect discharge computed with consideration of intact channel ice present at time of peak discharge.
[5]Inferred from G25 at Lake L9323 Crossing.
[6]Indirect discharge computed as open water conditions, even though channel ice was present at time of peak discharge.
[7]Stage data from decommissioned gage G21 at proposed bridge centerline.
[8]Stage data from decommissioned gage G22 at proposed bridge centerline.
[9]Stage data from decommissioned gage G23 at proposed bridge centerline.

8.4 Alpine Drinking Water Lakes Recharge

Recharge of Alpine drinking water lakes L9312 and L9313 has been documented annually since 1998. Primary recharge mechanisms for these lakes are overland flood flow and local melt. Lakes are determined to be fully recharged if bankfull conditions are met: either overland floodwater was observed flowing into the lake, or there was evidence of a stage rise and fall on the breakup hydrograph.

In most years, Lake L9313 is recharged by overland flow from the Sakoonang Channel via the North Paleo Lake and Lake M9525. The historical record of observed flooding and stage indicates bankfull elevation of Lake L9313 is approximately 6.5 ft BPMSL at gage G10 (Michael Baker 2006a, 2007b).

In 2018, the bankfull recharge elevation at Lake L9313 was revised from 6.5 ft BPMSL to 6.29 ft BPMSL, based on observations of hydraulic connectivity from Lake M9525. In 2021, Lake L9313 recharged via flooding from Lake M9525 to a peak WSE of 6.53 ft BPMSL.

Lake L9312 is surrounded by higher tundra than Lake L9313 and is less frequently recharged by floodwater from the Sakoonang Channel. During most years, recharge at this lake is limited to local melt of snow and ice and precipitation. Bankfull elevation of Lake L9312 is 7.8 ft BPMSL at gage G9 per the Fish Habitat Permit FG99-III-0051-Amendment #8. Lake L9312 did not recharge to the bankfull elevation from floodwater or snow and ice melt in 2021. The lake recharged post-breakup from precipitation, but not to the bankfull elevation of 7.8 ft.

Table 8.5 provides a historical summary of Alpine drinking water lakes stage and bankfull recharge record. Lake L9312 has recharged to bankfull during breakup 17 of the last 24 years, and Lake L9313 has recharged to bankfull 21 of the last 24 years.

Table 8.5: Alpine Drinking Water Lakes Historical Recharge Summary

Year	Lake L9312		Lake L9313	
	Peak Stage (ft BPMSL)	Bankfull Recharge to 7.8 ft BPMSL[1]	Peak Stage (ft BPMSL)	Bankfull Recharge to 6.29 ft BPMSL[2]
2021	**-**	**No[3]**	**6.53**	**Yes[3]**
2020	10.08	Yes	10.37	Yes
2019	8.09	Yes[3]	8.72	Yes
2018	8.10	Yes[3]	6.29	Yes[3]
2017	-	No[3]	7.40	Yes
2016	7.47	No[3]	8.15	Yes
2015	13.32	Yes	12.71	Yes
2014	7.94	Yes	8.59	Yes
2013	8.79	Yes	10.44	Yes
2012	8.23	Yes	8.20	Yes
2011	10.72	Yes	10.67	Yes
2010	7.63	No[3]	7.52	Yes
2009	7.65	No[3]	7.12	Yes
2008	7.45	No[3]	6.95	Yes
2007	9.35	Yes	9.47	Yes
2006	9.55	Yes	9.95	Yes
2005	8.00	Yes	6.12	No[3]
2004	8.37	Yes	9.40	Yes
2003	8.01	Yes	7.12	Yes
2002	8.05	Yes	7.98	Yes
2001	7.55	No[3]	8.31	Yes
2000	-	Yes	-	Yes
1999	7.93	Yes	6.14	No[3]
1998	8.35	Yes	7.35	Yes

Notes:
[1]Bankfull recharge is based on peak stage exceeding 7.8 ft BPMSL per Fish Habitat Permit FG99-III-0051, Amendment #8.
[2]Bankfull recharge elevation is based on visual observations of hydraulic connectivity of lake to breakup floodwater.
[3]Lake recharged from snow meltwater or post-breakup precipitation.

9. FLOOD & STAGE FREQUENCY ANALYSES

9.1 Flood Frequency

Continuous record and design-magnitude flood frequency analyses were performed for the Colville River at the head of the delta (MON1) in 2021. Previous flood frequency analysis was based on reported annual peak discharge data from 1992 through 2018 and extrapolated data extending back to 1971. As of 2021, the observed record of continuous peak annual discharges is 30 years. Rather than add the uncertainty and error associated with the extrapolated peak values, the 2021 analysis is based entirely on the observed period of record, 1992 through 2021, as presented in Table 9.1 (Michael Baker 1998-2020, Michael Baker and Hydroconsult 2002, Michael Baker and Shannon & Wilson 1998, Shannon & Wilson 1996b and 1996c). The data was ranked by Weibull distribution for the continuous record and fitted to a Log-Pearson Type III (17C) distribution, performed using HEC-SSP (USACE 2019), v2.2, following Bulletin 17C guidelines (USGS 2019).

Comparison of the 2021 Weibull and 17C distribution for the period of continuous record (1992 to 2021) are presented in Table 9.2, ranked in order (largest to smallest) of peak discharge. As noted, the Weibull analysis limits the return period (also known as recurrence interval) to the number of record years plus one. As a result, the return period for each year is based solely on the ranked position within the continuous record with a maximum return period of 31 years assigned to the event with the largest peak discharge.

Table 9.1: Colville River Peak Annual Discharge Values (1992-2021)

YEAR	DATE	PEAK ANNUAL DISCHARGE (CFS)
2021	June 6	220,000
2020	May 27	341,000
2019	May 24	305,000
2018	June 2	331,000
2017	May 30	288,000
2016	May 23	348,000
2015	May 22	469,000
2014	June 1	327,000
2013	May 31	497,000
2012	May 27	366,000
2011	May 28	590,000
2010	June 1	320,000
2009	May 23	266,000
2008	May 30	221,000
2007	June 4	270,000
2006	May 30	281,000
2005	June 1	195,000
2004	May 27	360,000
2003	Jun 5	232,000
2002	May 24	249,000
2001	June 10	255,000
2000	June 11	580,000
1999	May 30	203,000
1998	May 29	213,000
1997	May 29	177,000
1996	May 26	160,000
1995	May 16	233,000
1994	May 25	165,000
1993	May 31	379,000
1992	June 2	164,000

Notes:

Observed values reported annually from spring breakup monitoring programs.

Table 9.2: Colville River Flood Frequency Analysis Results

Year	Discharge (cfs)	Weibull Return Period (years)	17C Return Period (years)
2011	590,000	31.0	38.6
2000	580,000	15.5	35.4
2013	497,000	10.3	17.2
2015	469,000	7.8	12.9
1993	379,000	6.2	5.1
2012	366,000	5.2	4.6
2004	360,000	4.4	4.4
2016	348,000	3.9	4.1
2020	341,000	3.4	3.8
2018	331,000	3.1	3.5
2014	327,000	2.8	3.4
2010	320,000	2.6	3.2
2019	305,000	2.4	2.7
2017	288,000	2.2	2.2
2006	281,000	2.1	2.1
2007	270,000	1.9	1.9
2009	266,000	1.8	1.9
2001	255,000	1.7	1.7
2002	249,000	1.6	1.6
1995	233,000	1.6	1.5
2003	232,000	1.5	1.5
2008	221,000	1.3	1.4
2021	**220,000**	**1.3**	**1.4**
1998	213,000	1.3	1.3
1999	203,000	1.2	1.2
2005	195,000	1.2	1.2
1997	177,000	1.1	1.0
1994	165,000	1.1	1.0
1992	164,000	1.1	1.0
1996	160,000	1.0	<1.0

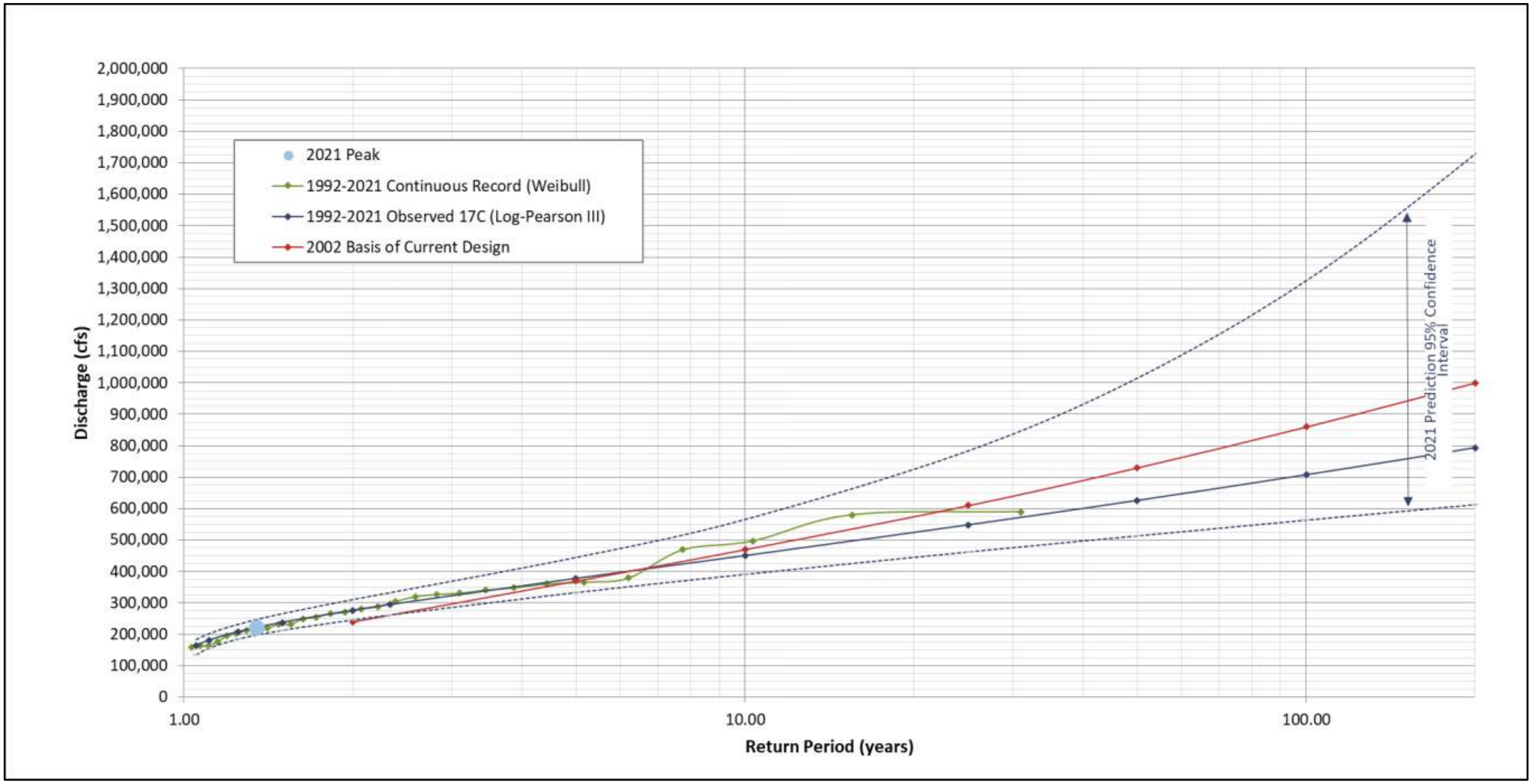
A flood frequency analysis is typically performed every three years for the head of the CRD at MON1 to estimate and update flood magnitudes for standard recurrence intervals. The basis of design flood magnitudes are compared with the flood frequency analysis results to ensure the basis of design values are relevant as the body of data grows. The basis of design was computed in 2002 using a mix of observed flooding and extrapolated data. The extrapolated data used the Kuparuk and Sagavanirktok Rivers to estimate flooding discharge on the Colville River. With 30 consecutive years of flood record on the Colville River, the Kuparuk and Sagavanirktok Rivers do not correlate as well to the Colville River as anticipated and were omitted from the latest flood frequency analysis in favor of using only the extended historical record.

Results of the Bulletin 17C analysis are tabulated in Table 9.3 and plotted in Graph 9.1. Both the table and graph present the computed mean discharge as well as the lower confidence limit (LCL) and upper confidence limit (UCL) of the statistical analysis. The LCL is the value at which 95% of all probable discharges will be exceeded for the given exceedance probability. The UCL is the value at which 5% of all probable discharges will be exceeded. The LCL and UCL give a range of uncertainty in the distribution of probable discharges based on the population used to calculate flow statistics. The mean value represents the discharge having the expected, or most likely, occurrence for a given exceedance probability. In Graph 9.1, the mean expected probability curve is represented by the '1992-2021 observed 17C' line. Relative to the 2002 basis of design values, the updated Bulletin 17C results yield lower high magnitude, low frequency discharges and higher low magnitude, high frequency discharges. While the mean 2-year discharge has increased from 240,000 to 276,000 cfs, the mean 200-year discharge has decreased from 1,000,000 to 793,000 cfs.

This year's peak discharge of 220,000 cfs has a recurrence interval of <2 years or a <50% chance of occurrence in any given year based on both 2002 and updated 2021 flood frequency analysis values. A comparison of the 2002 and 2021 flood frequency results for the period of continuous record (1992 to 2021) is shown in Table 9.4.

Table 9.3: Colville River Flood Frequency Analysis Comparison

ANNUAL EXCEEDANCE PROBABILITY (%)	PETURN PERIOD (YEARS)	2002 BASIS OF DESIGN (CFS)	2021 MEAN DISCHARGE (CFS)	2021 LCL [0.95] (CFS)	2021 UCL [0.05] (CFS)
50	2	240,000	***276,000***	245,000	311,000
20	5	370,000	***377,000***	332,000	445,000
10	10	470,000	***450,000***	390,000	566,000
4	25	610,000	***548,000***	462,000	784,000
2	50	730,000	***625,000***	513,000	1,015,000
1	100	860,000	***707,000***	563,000	1,325,000
0.5	200	1,000,000	***793,000***	612,000	1,728,000



Graph 9.1: CRD Flood Frequency Analysis Distribution

Table 9.4: Comparison of Colville River 2002 and 2021 Flood Frequency Analysis Results for the Period of Continuous Record (1992-2021)

Year	Peak Discharge (cfs)	2002 Return Period (Current Basis of Design Criteria) (years)	2021 Return Period (years)
2011	590,000	22.9	38.6
2000	580,000	21.8	35.4
2013	497,000	12.9	17.2
2015	469,000	10.0	12.9
1993	379,000	5.5	5.1
2012	366,000	4.9	4.6
2004	360,000	4.8	4.4
2016	348,000	4.5	4.1
2020	341,000	4.5	3.8
2018	331,000	4.0	3.5
2014	327,000	3.8	3.4
2010	320,000	3.8	3.2
2019	305,000	3.5	2.7
2017	288,000	3.1	2.2
2006	281,000	2.9	2.1
2007	270,000	2.7	<2
2009	266,000	2.6	<2
2001	255,000	2.3	<2
2002	249,000	2.2	<2
1995	233,000	<2	<2
2003	232,000	<2	<2
2008	221,000	<2	<2
2021	220,000	<2	<2
1998	213,000	<2	<2
1999	203,000	<2	<2
2005	195,000	<2	<2
1997	177,000	<2	<2
1994	165,000	<2	<2
1992	164,000	<2	<2
1996	160,000	<2	<2

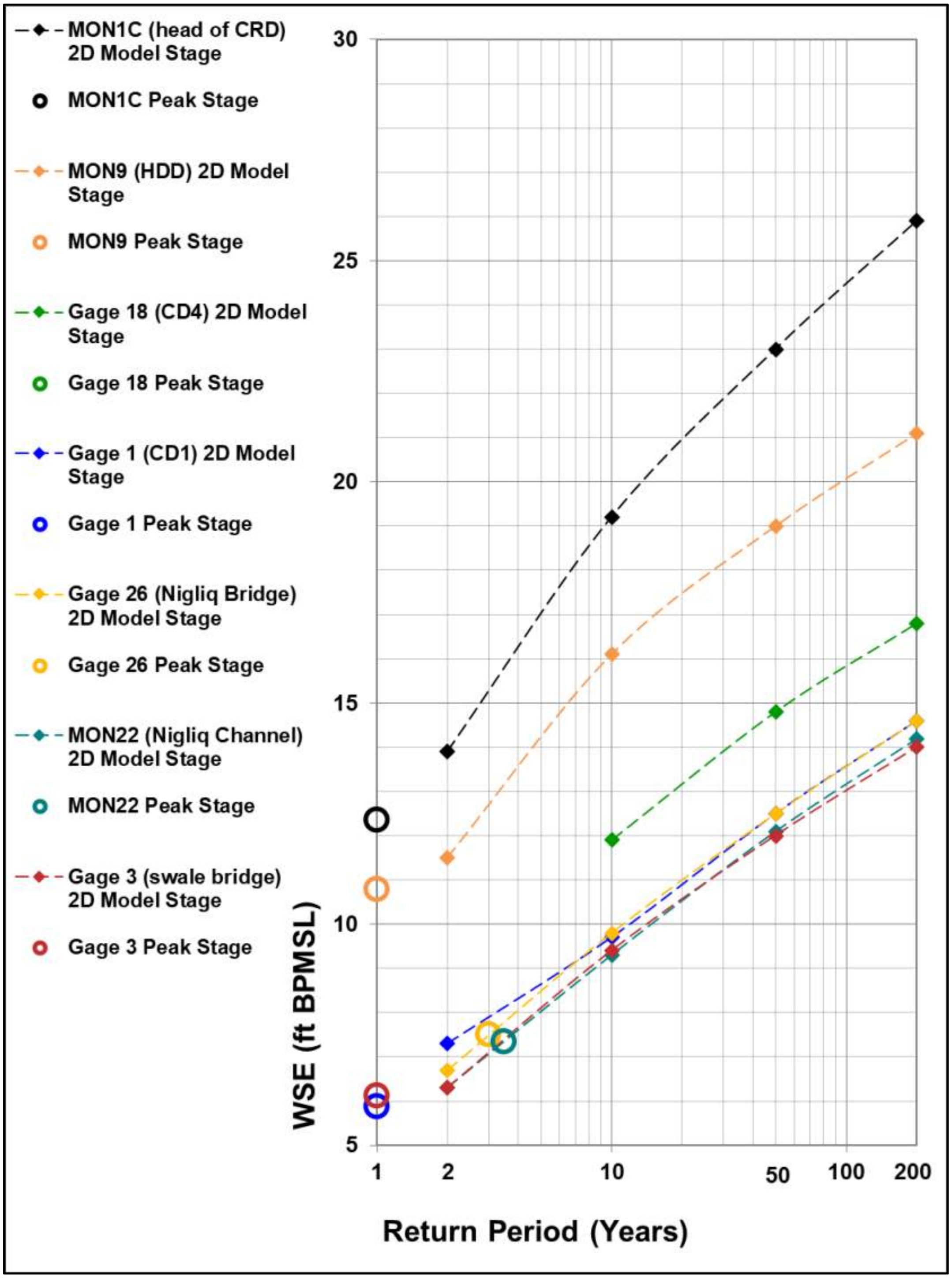
9.2 Stage Frequency

HIGH MAGNITUDE, LOW FREQUENCY

The CRD 2D surface water model was first developed in 1997 to estimate stage and velocities at the proposed Alpine facility locations (Michael Baker 1998a). The model has undergone numerous revisions to include improved topographic and bathymetric data and the addition of CD3, CD4, and CD5 facilities (Michael Baker 2002a, 2006b, 2009a, and 2012b).

The 2D model was developed to predict open water flood conditions during low-frequency, high-magnitude events, i.e., design events having 50- and 200-year recurrence intervals. To estimate the relationship between discharge and stage during more frequent, lower magnitude floods, 2- and 10-year recurrence intervals have also been modeled. The 2021 peak stage at select gage stations were assigned a recurrence interval relative to the 2D model predictions (Graph 9.2 and Table 9.3). The 2D model assumes open water steady-state conditions and does not account for snow, channel ice, or ice jams. Elevated stage resulting from snow and ice effects is typically localized and more pronounced during lower magnitude flood events. As a result, the 2D model generally under-predicts stage for lower recurrence intervals of approximately 10 years and less.

Based on the 2D model predictions, flood stage recurrence intervals throughout the CRD ranged from below model results of area inundation (i.e., site-specific areas can be dry during lower magnitude flood-recurrence events) to a maximum of 5.4 years. Peak stage during spring breakup flood is highly variable throughout the CRD. Local ice and snow processes influence specific sites, and the effect is more pronounced during lower-magnitude, higher-frequency spring breakup flood events.



Graph 9.2: 2D Model Stage and Peak Stage Recurrence Intervals

Table 9.5: Peak Stage Frequency Relative to 2D Model Stage Frequency Analysis

Gage Station	2D Model Stage Recurrence Intervals[1] (ft BPMSL)				Peak Stage (ft BPMSL)	Peak Stage Recurrence Interval (years)
	2-year	10-year	50-year	200-year		
Colville River						
MON1C (head of CRD)	13.9	19.2	23	25.9	12.34	<2
Colville River East Channel						
MON9 (HDD)	11.5	16.1	19	21.1	10.77	<2
MON35 (Helmericks)[2]	4.3	5.4	6.1	6.5	3.90	<2
Nigliq Channel						
MON20	7.8	11.4	14.6	16.8	9.01	3.4
MON22	6.3	9.3	12.1	14.2	7.33	3.5
MON23	5.1	7.4	10.2	12.0	6.28	4.6
MON28	3.1	3.4	3.9	4.3	2.32	<2
CD1 Pad & Drinking Water Lakes						
Gage G1 (Sakoonang)	7.3	9.7	12.5	14.6	5.87	<2
Gage G9 (Lake L9312)	8.3	10.8	13.4	15.7	[3]	<2
Gage G10 (Lake L9313)	8.3	10.8	13.4	15.7	6.53	<2
CD2 Pad & Road						
Gage G8 (CD2 pad)	\	8.7	10.6	12.3	[4]	[4]
Gage G3 (swale bridges)	6.3	9.4	12.0	14.0	6.12	<2
Gage G4 (swale bridges)	6.2	8.5	10.1	11.6	6.02	<2
Gage G6	\	9.5	12.2	14.2	DRY	<10
Gage G7	\	8.4	10.0	11.6	DRY	<10
Gage G12	\	9.5	12.1	14.1	DRY	<10
Gage G13	\	8.4	10.0	11.6	DRY	<10
CD3 Pad & Pipeline						
Gage G11 (CD3 pad)	5.2	6.4	6.9	8	[4]	[4]
SAK Gage (Pipeline Crossing #2)	6.4	8.9	11.2	12.9	5.73	<2
TAM Gage (Pipeline Crossing #4)	6.7	8.5	9	9.8	6.02	<2
ULAM Gage (Pipeline Crossing #5)	5.5	7.1	7.8	8.7	5.34	<2
CD4 Pad & Road						
Gage G15	8.4	10.8	13.5	15.9	7.83	<2
Gage G16	8.4	11.1	14.2	16.3	7.63	<2
Gage G17	\	11.1	14.2	16.3	DRY	<10
Gage G18	\	11.9	14.8	16.8	DRY	<10
Gage G19 (CD4 pad)	\	\	14.7	16.8	DRY	<50
Gage G20 (CD4 pad)	\	11.1	14.3	16.4	8.09	<10
CD5 Road						
Gage G24 (Lake L9323/CD5 Bridge #1)	\	11.1	14.1	16	DRY	<10
Gage G26 (Nigliq/CD5 Bridge #2)	6.7	9.8	12.5	14.6	7.49	3.0
Gage G27 (Nigliq/CD5 Bridge #2)	6.7	9.8	12.5	14.5	7.47	3.0
Gage G30	\	\	13.3	15.5	DRY	<50
Gage G32 (Lake L9341/CD5 Bridge #3)	\	\	13.3	15.1	7.4	<50
Gage G34	\	\	13.3	15.7	DRY	<50
Gage G36	\	\	13.3	15.7	DRY	<50
Gage G38 (Nigliagvik/CD5 Bridge #4)	6.9	10	12.8	14.9	7.07	2.2

Notes:
1. Sites having dry ground in 2D model during lower recurrence intervals are denoted with a backward slash "\"
2. 2021 highest recorded stage reported. Not representative of peak stage
3. Stage attributed to ponded local melt
4. Not monitored this year

LOW MAGNITUDE, HIGH FREQUENCY

A site-specific stage frequency analysis using the historical record can provide a better estimate of low magnitude stage recurrence intervals. Uncertainty increases when extrapolating stage data beyond the continuous record for a river impacted by ice and ice jamming (USACE 2002; FEMA 2003). This is because of the inherent unpredictability of ice jams, the greater impact ice effects have on lower magnitude events, and the upper limit of stage considering available floodplain storage for overbank flow (i.e., water height can only increase so much once it has crested the banks and spilled into the floodplain). Stage frequency was extrapolated to the 50-year recurrence interval, nearly twice the continuous record at MON1C, for comparison to the 2D model because this is where the 2D model results and stage frequency analysis results tend to converge. Unlike the 2D model, the observed data upon which the stage frequency analyses are based reflect ice-affected flooding conditions. Therefore, the stage frequency analysis results can be used to supplement the stage frequency curve for low-magnitude, ice impacted flood events.

Stage frequency was performed at MON1, MON22, and gages G1, G3, and G18, which have the longest periods of continuous record and are distributed throughout the project area. The maximum period of continuous record is 30 years at MON1C. Analyses have been performed every three years as the body of data grows (Michael Baker 2007a, 2009b, 2012b, 2015, and 2018), and were performed again this year to incorporate the 2019, 2020, and 2021 stage data. Similar to the flood frequency analysis, stage at the select locations was ranked by Weibull distribution for the continuous record and fitted to a Log-Pearson Type III distribution for comparison with the 2D model results. Measured peak annual stage data from 1992 through 2018 for locations used in the stage frequency analysis are presented in Table 9.6. For sites that lack an adequate historical record, Bulletin 17C allows the use of perception thresholds to supplement the datasets. These thresholds were determined based off historical data from the gage and other proximal gages.

Table 9.7 and Graph 9.3 presents the Log-Pearson Type III 2021 stage frequency analysis results and the assigned recurrence interval to the 2021 peak stage. Based on the stage frequency analysis, all gage stations fell below the 2-year recurrence interval. Graph 9.4 through Graph 9.8 visually compare the stage frequency analysis and 2D model results to the measured or extrapolated peak annual stage for each selected location.

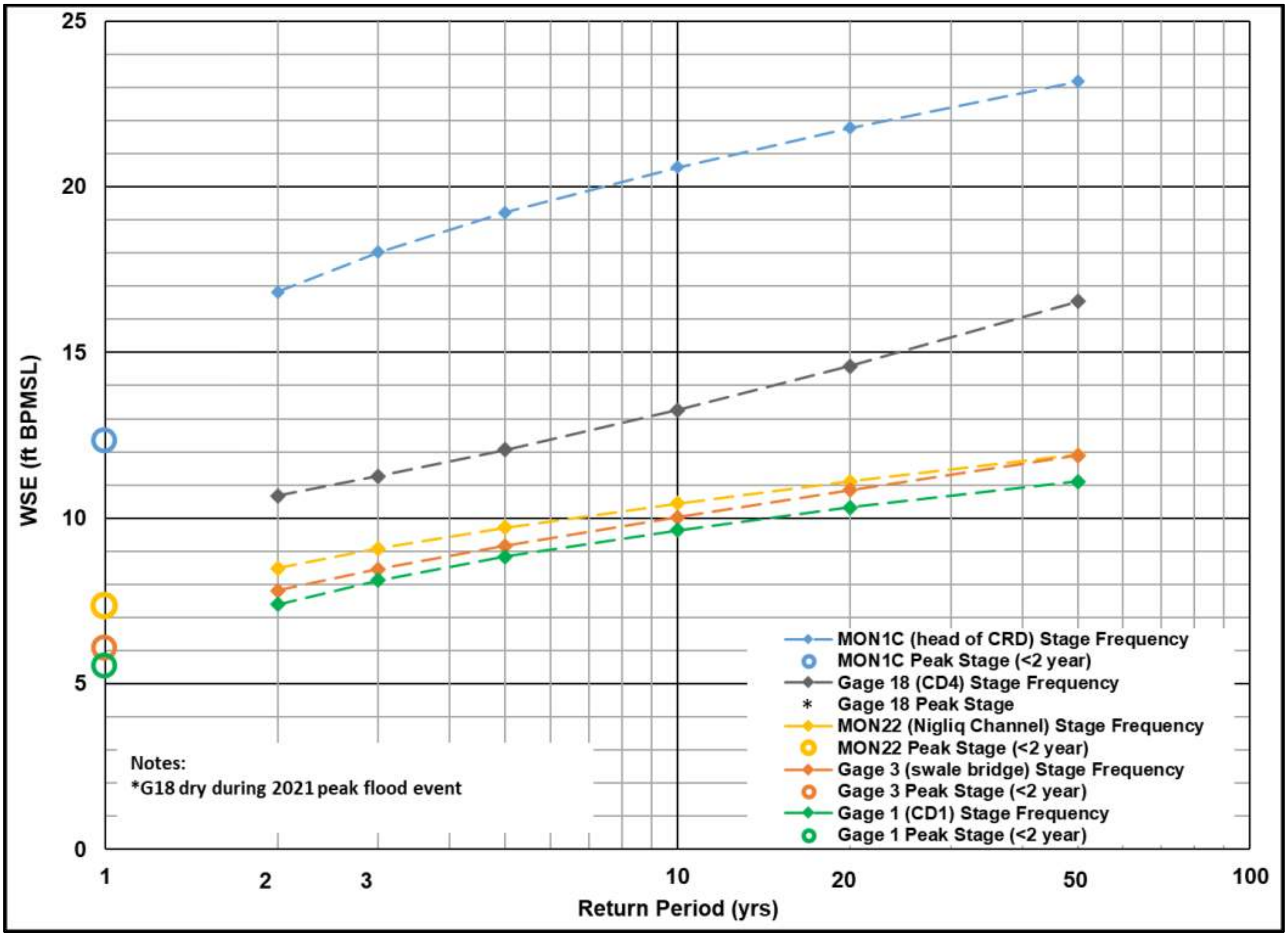
Table 9.6: Peak Annual Stage for Selected Locations (1992-2021)

Year	Monument 1 (Head of Delta)	Monument 22 (Nigliq/CD2)	Gage 1 (CD1)	Gage 3 (Swale Bridge)	Gage 18 (CD4)
2021	12.34	7.33	5.52	6.12	-
2020	21.41	11.61	8.88	10.91	14.00
2019	16.19	8.59	7.83	7.64	11.15
2018	15.90	7.85	5.50	7.30	-
2017	14.79	7.27	6.17	6.04	-
2016	17.16	8.52	7.17	7.49	10.84
2015	23.47	11.98	11.26	11.93	16.58
2014	15.18	8.67	8.29	8.18	-
2013	20.69	10.56	9.90	10.27	14.15
2012	14.18	8.17	7.97	7.60	-
2011	19.56	8.97	9.33	8.89	12.84
2010	19.59	8.69	7.15	8.64	11.72
2009	17.65	7.76	6.65	7.63	-
2008	17.29	6.78	5.61	8.60	-
2007	18.97	9.04	8.64	6.49	10.98
2006	19.83	9.95	9.29	9.72	14.67
2005	13.18	7.65	4.46	6.48	
2004	19.54	10.17	8.88	9.97	
2003	13.76	7.02	6.07	6.31	
2002	16.87	7.94	7.68	7.59	
2001	17.37	8.80	6.95	7.95	
2000	19.33	9.58	9.10		
1999	13.97	5.89			
1998	18.11	10.20			
1997	15.05				
1996	17.19				
1995	14.88				
1994	12.20				
1993	19.20				
1992	13.90				

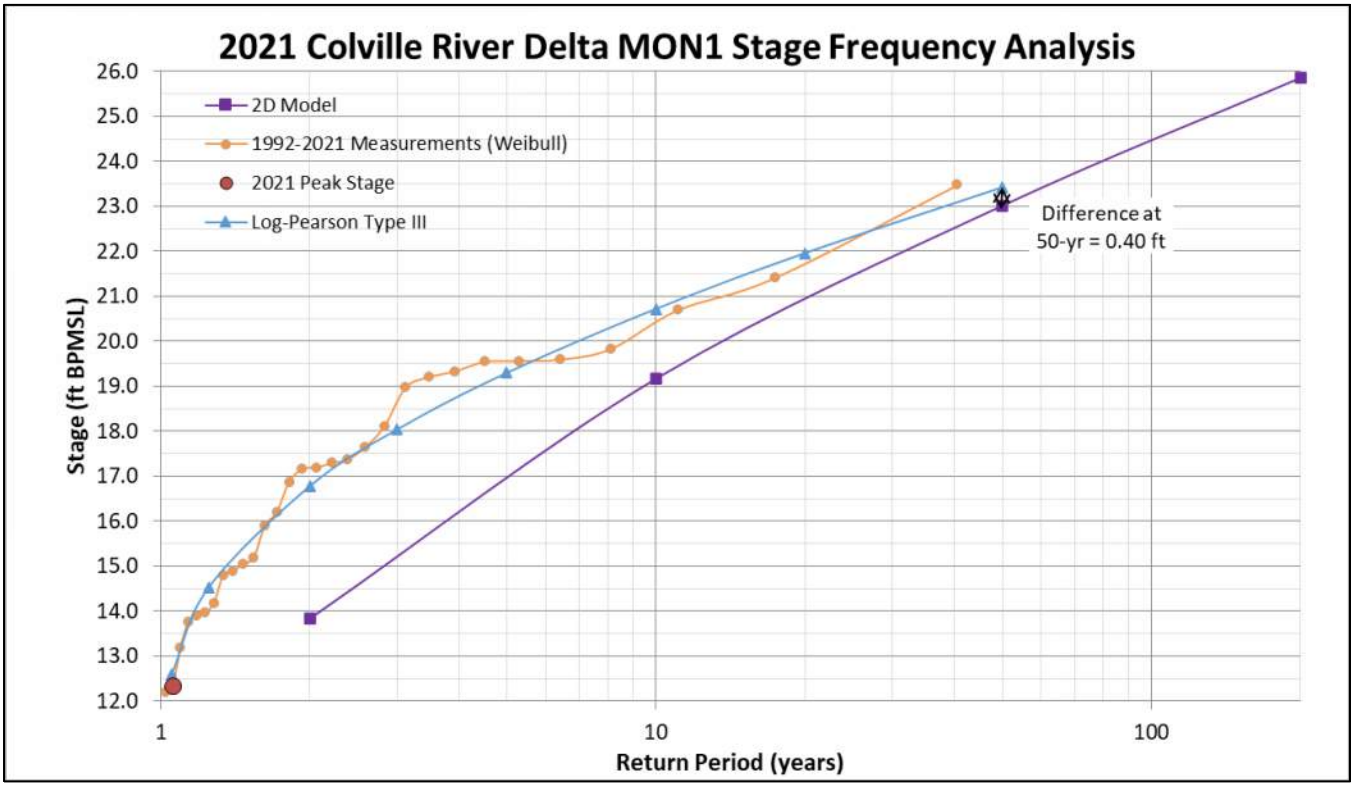
Notes:
1. Blank cells represent no data collected that year
2. Dash "- " indicates no observed WSE (i.e. gage remained dry)

Table 9.7: Peak Stage Frequency Relative to Stage Frequency Analysis

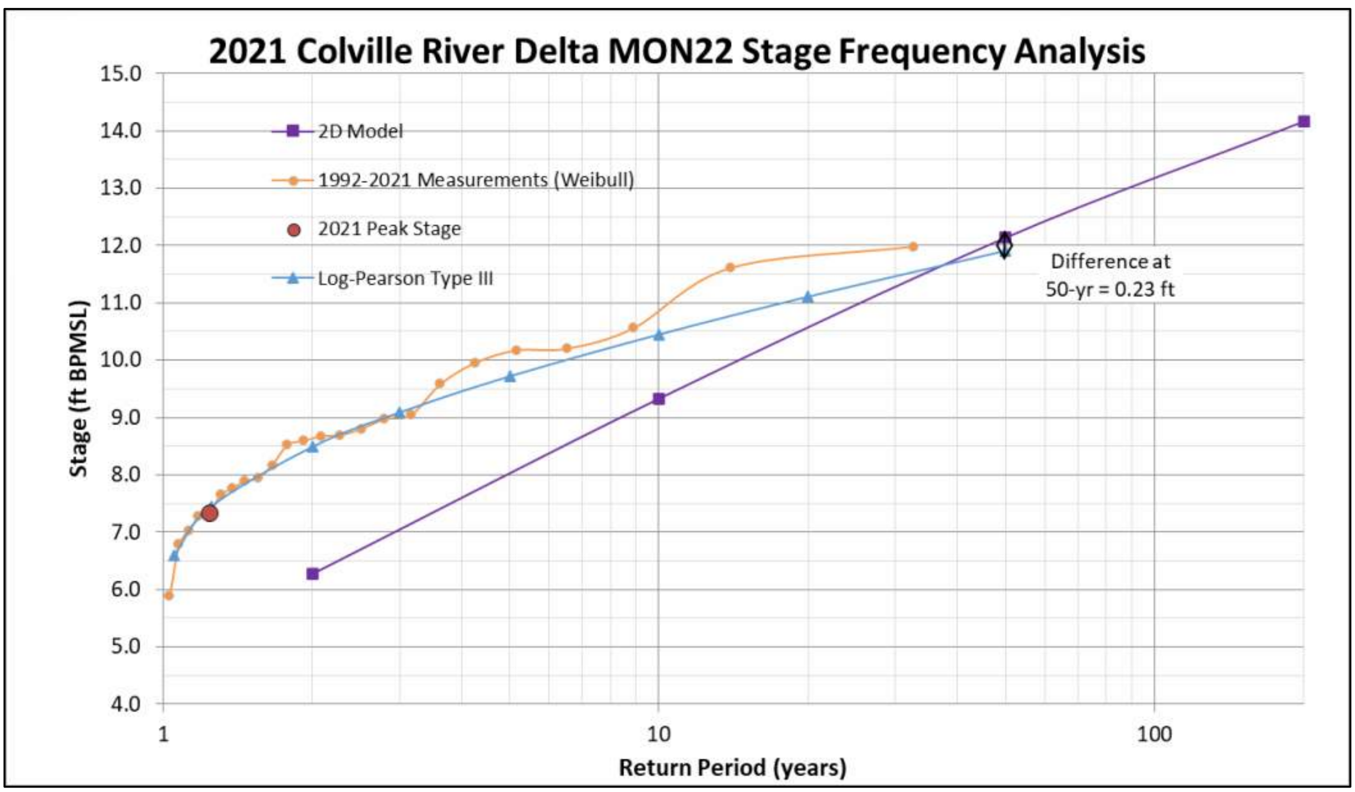
Monitoring Location	Stage Frequency Recurrence Intervals (ft BPMSL)						Peak Stage (ft BPMSL)	Peak Stage Recurrence Interval (years)
	2-year	3-year	5-year	10-year	20-year	50-year		
MON1C (head of CRD)	16.78	18.04	19.30	20.72	21.96	23.42	12.34	<2
MON22 (Nigliq Channel)	8.49	9.09	9.72	10.45	11.11	11.91	7.33	<2
Gage G1 (CD1 Pad)	7.40	8.12	8.84	9.64	10.32	11.11	5.52	<2
Gage G3 (CD2 Road)	7.81	8.46	9.17	10.03	10.85	11.89	6.08	<2
Gage G18 (CD4 Road)	10.68	11.27	12.07	13.26	14.58	16.54	DRY	-



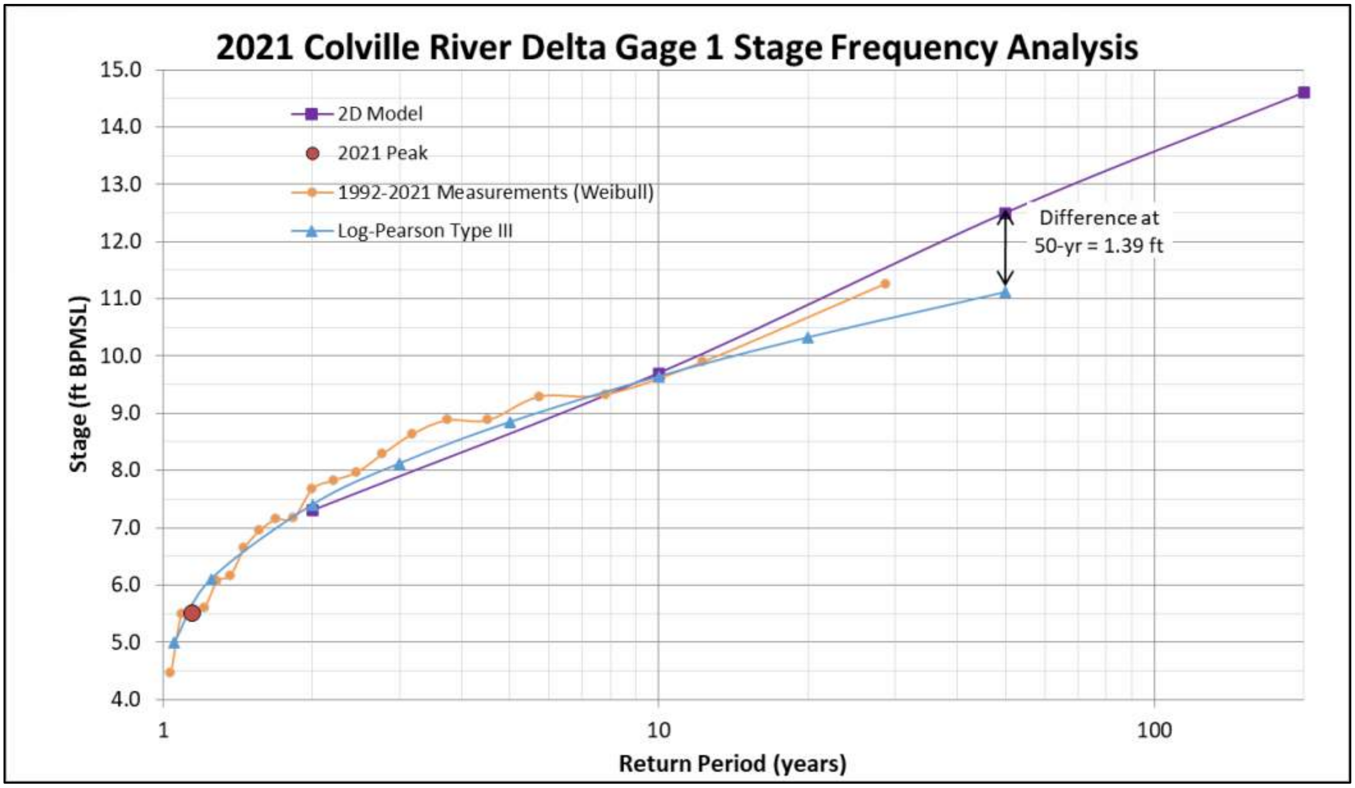
Graph 9.3: Stage Frequency and Peak Stage Recurrence Intervals



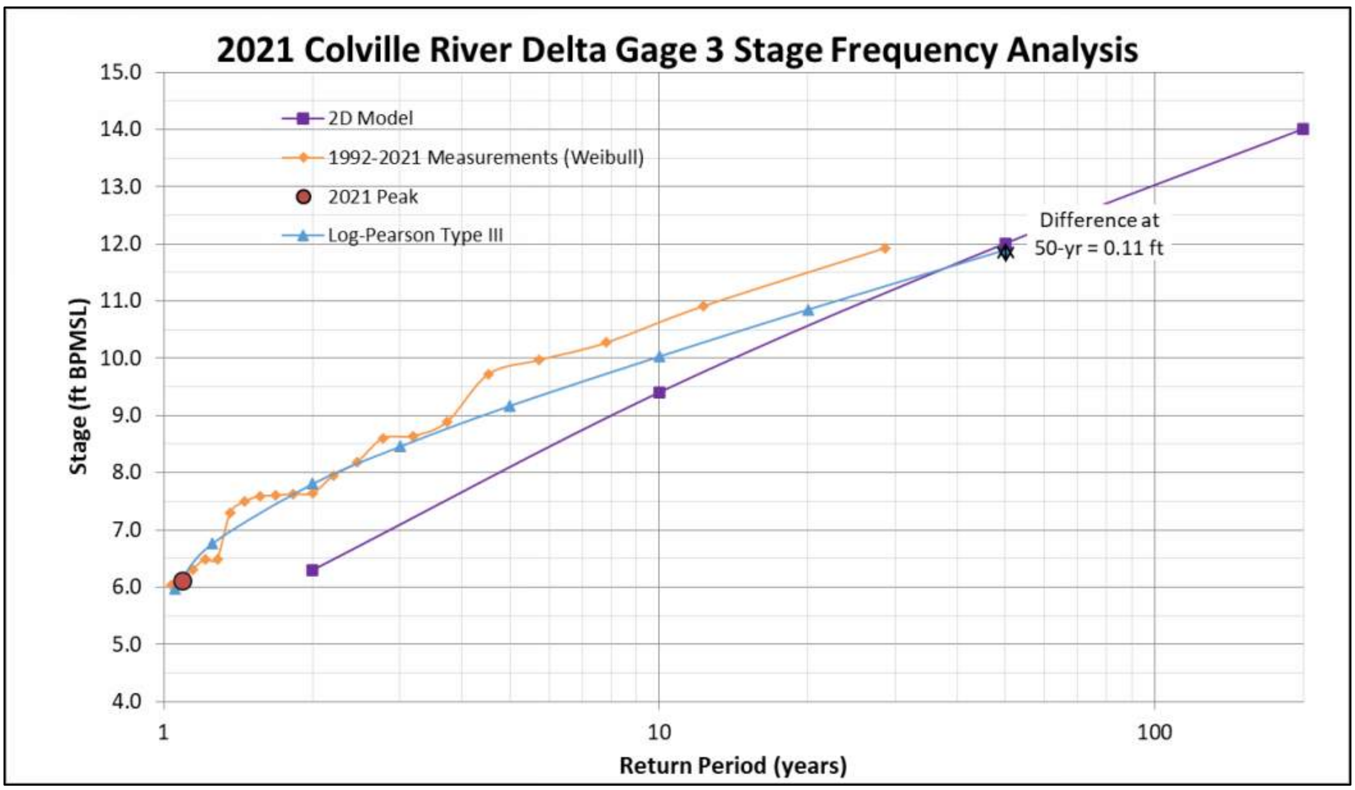
Graph 9.4: MON1 Stage Frequency Analysis, 2D Model Results and Peak Annual Stage Data



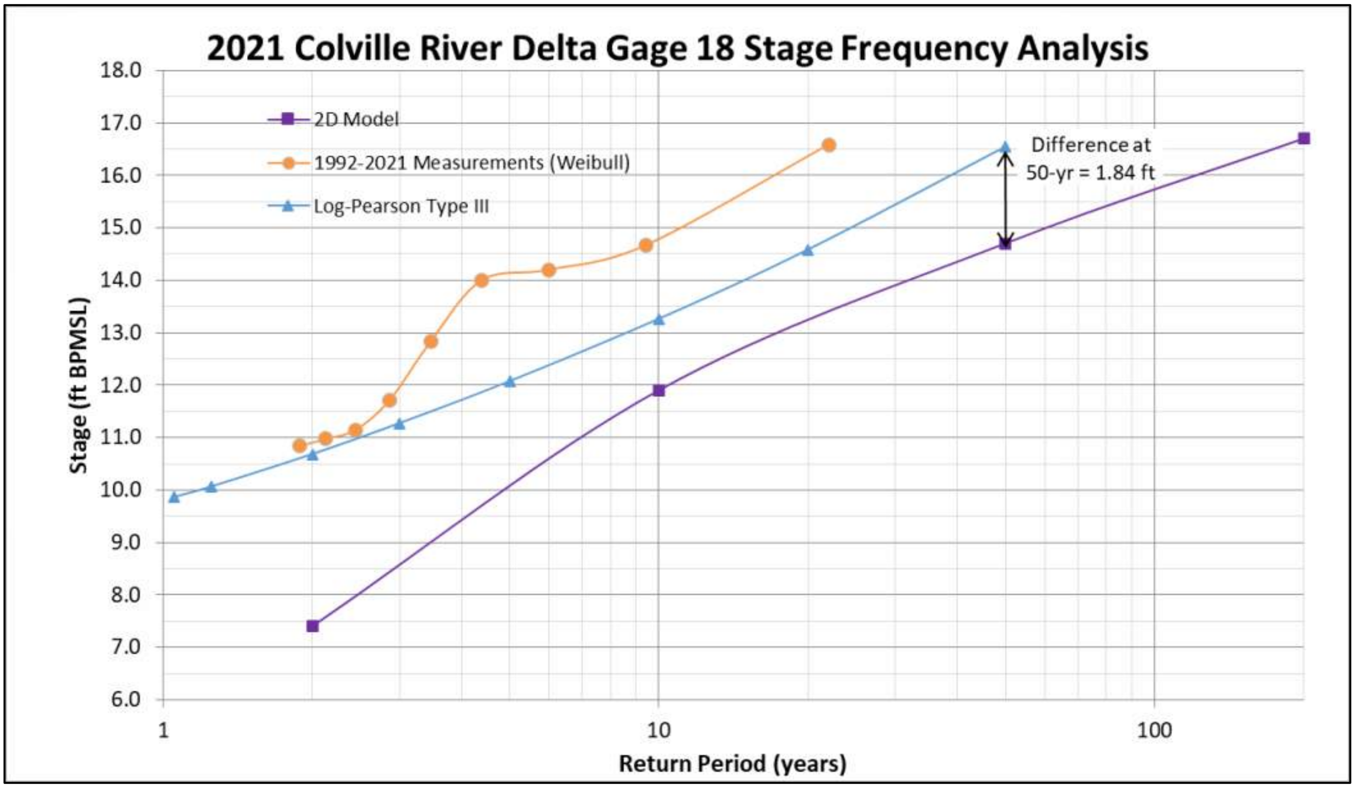
Graph 9.5: MON22 Stage Frequency Analysis, 2D Model Results and Peak Annual Stage Data



Graph 9.6: Gage 1 Stage Frequency Analysis, 2D Model Results and Peak Annual Stage Data



Graph 9.7: Gage 3 Stage Frequency Analysis, 2D Model Results and Peak Annual Stage Data



Graph 9.8: Gage 18 Stage Frequency Analysis, 2D Model Results and Peak Annual Stage Data

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APPENDIX A VERTICAL CONTROL, GAGE LOCATIONS, & CULVERT LOCATIONS

A.1 VERTICAL CONTROL

Control	Elevation (ft BPMSL)	Latitude (NAD83) [1]	Longitude (NAD83)	Control Type	Reference
CD2-6N	8.89	N 70.3399°	W 151.0292°	Culvert top	UMIAQ 2020
CD2-6S	8.68	N 70.3397°	W 151.0291°	Culvert top	UMIAQ 2020
CD2-14N	10.89	N 70.3371°	W 151.0110°	Culvert top	UMIAQ 2020
CD2-14S	10.85	N 70.3369°	W 151.0111°	Culvert top	UMIAQ 2020
CD2-22N	9.15	N 70.3404°	W 150.9829°	Culvert top	UMIAQ 2020
CD2-22S	9.10	N 70.3402°	W 150.9827°	Culvert top	UMIAQ 2020
CD4-10E	11.57	N 70.3274°	W 150.9929°	Culvert top	UMIAQ 2020
CD4-10W	11.98	N 70.3275°	W 150.9934°	Culvert top	UMIAQ 2020
CD4-12E	11.33	N 70.3235°	W 150.9954°	Culvert top	UMIAQ 2020
CD4-12W	12.12	N 70.3401°	W 150.9962°	Culvert top	UMIAQ 2020
CD4-22E	6.42	N 70.3021°	W 150.9932°	Culvert top	UMIAQ 2020
CD4-22W	7.32	N 70.3018°	W 150.9930°	Culvert top	UMIAQ 2020
CD5-29N	12.28	N 70.3060°	W 151.0951°	Culvert top	UMIAQ 2016
CD5-29S	12.38	N 70.3058°	W 151.0948°	Culvert top	UMIAQ 2016
CD5-35N	13.09	N 70.3065°	W 151.0683°	Culvert top	UMIAQ 2016
CD5-35S	13.26	N 70.3063°	W 151.0683°	Culvert top	UMIAQ 2016
CD5-40N	10.65	N 70.3050°	W 151.0439°	Culvert top	UMIAQ 2016
CD5-40S	10.93	N 70.3048°	W 151.0442°	Culvert top	UMIAQ 2016
CP01-13-09A	12.94	N 70.3401°	W 150.9843°	Top rail support	UMIAQ 2016
CP08-11-12	7.36	N 70.3639°	W 150.9204°	Alcap	BAKER 2012
CP08-11-23	8.52	N 70.3916°	W 150.9078°	Alcap	LCMF 2008
CP08-11-35	8.88	N 70.4066°	W 150.8822°	Alcap	BAKER 2015 (UMIAQ 2010)
CP08-12-61	11.95	N 70.2777°	W 150.9935°	Alcap	LCMF 2017
MONUMENT 1	27.93	N 70.1659°	W 150.9400°	Alcap	LCMF 2005
MONUMENT 9	25.06	N 70.2446°	W 150.8583°	Alcap	UMIAQ 2016
MONUMENT 20	18.97	N 70.2800°	W 151.0115°	Alcap	BAKER 2017
MONUMENT 21	13.28	N 70.3424°	W 150.9236°	Top of bolt	UMIAQ 2020
MONUMENT 22 (BAKER)	10.03	N 70.3181°	W 151.0560°	Alcap	UMIAQ 2020
MONUMENT 22	11.21	N 70.3422°	W 150.9321°	Alpine drill stem	UMIAQ 2020
MONUMENT 23	9.55	N 70.3444°	W 151.0613°	Alcap	BAKER 2009c
MONUMENT 25	17.89	N 70.3024°	W 151.0130°	Capped drill stem	UMIAQ 2016
MONUMENT 27	13.86	N 70.3060°	W 151.0533°	Capped drill stem	UMIAQ 2016
MONUMENT 28 (Colville @ Coast)	3.65	N 70.4256°	W 151.0670°	Alcap	UMIAQ 2002
MOUNMENT 29	28.63	N 70.3052°	W 151.1228°	Capped drill stem	UMIAQ 2016
NANUQ 4	12.64	N 70.2954°	W 150.9813°	Alcap	UMIAQ 2016

Control	Elevation (ft BPMSL)	Latitude (NAD83) [1]	Longitude (NAD83)	Control Type	Reference
NANUQ-5	17.39	N 70.2917°	W 150.9805°	Alcap	UMIAQ 2020
PBM-F	17.88	N 70.3393°	W 151.0467°	Top of rod	UMIAQ 2020
PBM-P	20.88	N 70.2915°	W 150.9889°	South side of CD4 pad	UMIAQ 2020
Pile 08	16.74	N 70.4175°	W 150.9105	SW Bolt	UMIAQ 2020
Pile 568	23.72	N 70.3639°	W 150.9206°	HSM cap SW bolt	LCMF 2010
TBM A	5.89	N 70.4264°	W 150.4053°	Corner of entryway	BAKER 2017
TBM B	8.46	N 70.4264°	W 150.4056°	East corner of structure	BAKER 2017
TBM C	8.15	N 70.3338°	W 150.4057°	West corner of structure	BAKER 2017
TBM 02-01-39 O	11.72	N 70.3338°	W 150.9522°	Top SW corner 2nd HSM	UMIAQ 2020
TBM 02-01-39 P	11.92	N 70.3337°	W 150.9521°	Top SW corner 1st HSM	UMIAQ 2020
TBM 05-05-06 B	21.01	N 70.3427°	W 150.9250°	NW corner F1 Product	UMIAQ 2016
TBM 99-32-60	15.86	N 70.3420°	W 150.9321°	Top lifting lug	LCMF 2015
TBM L99-32-59	14.60	N 70.3338°	W 150.9522°	Pile Cap SE VSM	UMIAQ 2015
TBM M9603-X	-	N 70.2213°	W 150.7896°	Angle iron	BAKER 2011
TBM M9605-X	-	N 70.2290°	W 150.5127°	Angle iron	BAKER 2011

1. North American Datum of 1983 (NAD83)

A.2 CRD GAGE LOCATIONS

Location	Gage Station	Gage Type	Gage Assembly	Latitude (NAD83)	Longitude (NAD83)	Control
Head of the Colville River Delta	MON1U	Indirect-Read	MON1U-A[1]	N 70.1585°	W 150.9450°	MONUMENT 1
			MON1U-B[2]	N 70.1585°	W 150.9451°	
			MON1U-C	N 70.1585°	W 150.9455°	
			MON1U-D	N 70.1585°	W 150.9461°	
			MON1U-E	N 70.1585°	W 150.9462°	
			MON1U-F	N 70.1585°	W 150.9464°	
			MON1U-G	N 70.1585°	W 150.9465°	
	MON1C		MON1C-A[1]	N 70.1657°	W 150.9383°	
			MON1C-B[2]	N 70.1656°	W 150.9385°	
			MON1C-C	N 70.1658°	W 150.9386°	
			MON1C-D	N 70.1658°	W 150.9392°	
			MON1C-E	N 70.1658°	W 150.9393°	
			MON1C-F	N 70.1658°	W 150.9395°	
			MON1C-G	N 70.1659°	W 150.9397°	
	MON1D		MON1D-A[1]	N 70.1738°	W 150.9359°	
			MON1D-B[2]	N 70.1738°	W 150.9371°	
			MON1D-C	N 70.1738°	W 150.9372°	
			MON1D-D	N 70.1738°	W 150.9373°	
Colville River East Channel	MON9	Indirect-Read	MON9-A[1]	N 70.2447°	W 150.8573°	MONUMENT 9
			MON9-B[1]	N 70.2447°	W 150.8575°	
			MON9-C	N 70.2447°	W 150.8578°	
			MON9-D	N 70.2446°	W 150.8580°	
			MON9-E	N 70.2446°	W 150.8580°	
			MON9-F	N 70.2446°	W 150.8580°	
			MON9-F1	N 70.2446°	W 150.8580°	
			MON9-F2	N 70.2446°	W 150.8580°	
			MON9-G	N 70.2446°	W 150.8581°	
			MON9-BARO[3]	N 70.2442°	W 150.8605°	
	MON9D		MON9D-A[1]	N 70.2586°	W 150.8593°	
			MON9D-B[1]	N 70.2586°	W 150.8597°	
			MON9D-C	N 70.2586°	W 150.8598°	
			MON9D-D	N 70.2586°	W 150.8600°	
			MON9-D1	N 70.2586°	W 150.8600°	
			MON9D-E	N 70.2586°	W 150.8600°	
	MON35		MON35-A[1]	N 70.4260°	W 150.4058°	TBM B
			MON35-B	N 70.4260°	W 150.4058°	
			MON35-C	N 70.4261°	W 150.4058°	
			MON35-D	N 70.4261°	W 150.4058°	
			MON35-E	N 70.4261°	W 150.4058°	
	EC12.9		EC12.9-A[1]	N 70.3406°	W 150.7529°	HALO
			EC12.9-B	N 70.3408°	W 150.7531°	
			EC12.9-C	N 70.3407°	W 150.7532°	
			EC12.9-D	N 70.3407°	W 150.7533°	
	EC7.2		EC7.2-A[1]	N 70.3816°	W 150.5148°	Arbitrary
			EC7.2-B	N 70.3816°	W 150.5146°	
	EC1.3		EC1.3-A[1]	N 70.4234°	W 150.2746	BYRON
			EC1.3-B	N 70.4231°	W 150.2741	
Nigliq Channel	MON20	Indirect-Read	MON20-A[1]	N 70.2786°	W 150.9986°	MONUMENT 20
			MON20-B	N 70.2786°	W 150.9985°	
			MON20-C	N 70.2786°	W 150.9983°	
			MON20-D	N 70.2785°	W150.9982°	
			MON20-E	N 70.2785°	W 150.9982°	
	MON22		MON22-A[1]	N 70.3186°	W 151.0546°	MONUMENT 22
			MON22-B	N 70.3185°	W 151.0549°	
			MON22-C	N 70.3185°	W 151.0550°	
			MON22-D	N 70.3183°	W 151.0555°	
	MON23		MON23-A[1]	N 70.3436°	W 151.0659°	MONUMENT 23
			MON23-B	N 70.3436°	W 151.0657°	
			MON23-C	N 70.3436°	W 151.0652°	
			MON23-D	N 70.3436°	W 151.0649°	
			MON23-E	N 70.3436°	W 151.0648°	
	MON28		MON28-A[1]	N 70.4258°	W 151.0697°	MONUMENT 28 (Colville @ Coast)
			MON28-B	N 70.4257°	W 151.0692°	
			MON28-C	N 70.4256°	W 151.0672°	

Notes:
1. PT, 2. RTFM PT, 3. Baro PT

A.3 ALPINE FACILITIES GAGE LOCATIONS

Location	Gage Station	Gage Type	Gage Assembly	Latitude (NAD83)	Longitude (NAD83)	Control
CD1 Pad & Lakes L9312 & L9313	G1	Direct-Read	G1[1]	N 70.3428°	W 150.9208°	TBM 05-05-06 B
	G9		G9[1]	N 70.3336°	W 150.9519°	TBM 02-01-39 O
	G10		G10[1]	N 70.3425°	W 150.9328°	MONUMENT 22
CD2 Road and Pad	G3	Direct-Read	G3[1,2]	N 70.3400°	W 150.9831°	CD2-22S
	G4		G4[1]	N 70.3403°	W 150.9833°	
	G6	Direct-Read	G6[1]	N 70.3396°	W 151.0293°	CD2-6N
	G7		G7[1]	N 70.3400°	W 151.0289°	
	G12	Indirect-Read	G12[1]	N 70.3367°	W 151.0117°	CD2-14S
	G13		G13[1]	N 70.3373°	W 151.0118°	CD2-14N
	G8	Indirect-Read	G8	N 70.3393°	W 151.0491°	PBM-F
CD3 Pad & Pipeline	SAK	Indirect-Read	SAK-A[1]	N 70.3646°	W 150.9217°	Pile 568 cap SW bolt
			SAK-B	N 70.3645°	W 150.9220°	
			SAK-C	N 70.3645°	W 150.9220°	
	TAM		TAM-A[1]	N 70.3917°	W 150.9115°	CP08-11-23
			TAM-B	N 70.3915°	W 150.9113°	
			TAM-C	N 70.3914°	W 150.9113°	
			TAM-Z	N 70.3912°	W 150.9109°	
	ULAM		ULAM-A[1]	N 70.4068°	W 150.8835°	CP08-11-35
			ULAM-B	N 70.4069°	W 150.8833°	
			ULAM-C	N 70.4070°	W 150.8831°	
			ULAM-Z	N 70.4070°	W 150.8831°	
	G11	Direct-Read	G11	N 70.4175°	W 150.9105°	Pile 08
CD4 Road & Pad	G15	Indirect-Read	G15-A[1]	N 70.3023°	W 150.9929°	CD4-22W
			G15-B	N 70.3023°	W 150.9929°	
	G16		G16-A[1]	N 70.3017°	W 150.9933°	CD4-22E
			G16-B	N 70.3017°	W 150.9933°	
	G17		G17-A[1]	N 70.2933°	W 150.9827°	NANUQ-5
	G18		G18-A	N 70.2930°	W 150.9818°	
		Direct-Read	G18-B[1,2,3,4]	N 70.2925°	W 150.9828°	
	G19	Direct-Read	G19	N 70.2915°	W 150.9882°	PBM-P
	G20	Indirect-Read	G20-A	N 70.2917°	W 150.9968°	
			G20-B	N 70.2917°	W 150.9968°	
	G40		G40	N 70.3234°	W 150.9968°	CD4-12E
	G41		G41	N 70.3235°	W 150.9949°	
	G42		G42	N 70.3276°	W 150.9939°	CD4-10E
	G43		G43	N 70.3274°	W 150.9924°	
CD5 Road	G24	Indirect-Read	G24-A[1]	N 70.3030°	W 151.0065°	MONUMENT 25
			G24-B	N 70.3034°	W 151.0041°	
	G25		G25-A[1]	N 70.3044°	W 151.0066°	
			G25-B	N 70.3046°	W 151.0049°	
	G26		G26-A[1]	N 70.3023°	W 151.0217°	MONUMENT 25
			G26-B[1]	N 70.3022°	W 151.0206°	
			G26-C	N 70.3022°	W 151.0190°	
			G26-D	N 70.3022°	W 151.0190°	
			G26-E	N 70.3023°	W 151.0185°	
	Notes: 1. PT, 2. RTFM PT, 3. Baro PT					

Location	Gage Station	Gage Type	Gage Assembly	Latitude (NAD83)	Longitude (NAD83)	Control
CD5 Road	G27	Indirect-Read	G27-A[1]	N 70.3033°	W 151.0216°	PBM-24
			G27-B[1]	N 70.3033°	W 151.0207°	
			G27-C	N 70.3033°	W 151.0194°	
			G27-D	N 70.3032°	W 151.0185°	
			G27-E	N 70.3032°	W 151.0179°	
	G28		G28-A[1]	N 70.2959°	W 151.0329°	
			G28-B	N 70.2959°	W 151.0331°	
			G28-C	N 70.2959°	W 151.0331°	
			G28-D	N 70.2959°	W 151.0332°	
			G28-E	N 70.2959°	W 151.0335°	
	G29		G29-A[1]	N 70.3095°	W 151.0332°	
			G29-B	N 70.3095°	W 151.0334°	
			G29-C	N 70.3095°	W 151.0337°	
			G29-D	N 70.3094°	W 151.0343°	
			G29-E	N 70.3093°	W 151.0350°	
	G32		G32-A[1]	N 70.3054°	W 151.0507°	MONUMENT 27
			G32-B	N 70.3055°	W 151.0513°	
	G33		G33-A[1]	N 70.3065°	W 151.0484°	
			G33-B	N 70.3065°	W 151.0487°	
			G33-C	N 70.3068°	W 151.0500°	
	G38		G38-A[1]	N 70.3046°	W 151.1187°	MONUMENT 29
			G38-B[1]	N 70.3046°	W 151.1185°	
			G38-C	N 70.3046°	W 151.1183°	
			G38-D	N 70.3047°	W 151.1172°	
	G39		G39-A[1]	N 70.3064°	W 151.1177°	
			G39-B[1]	N 70.3063°	W 151.1175°	
			G39-C	N 70.3063°	W 151.1172°	
			G39-D	N 70.3063°	W 151.1170°	
	G30		G30[1]	N 70.3046°	W 151.0443°	CD5-40S
	G31		G31[1]	N 70.3051°	W 151.0437°	CD5-40N
	G34		G34[1]	N 70.3060°	W 151.0710°	CD5-35S
	G35		G35[1]	N 70.3067°	W 151.0711°	CD5-35N
	G36		G36[1]	N 70.3056°	W 151.0968°	CD5-29S
	G37		G37[1]	N 70.3063°	W 151.0971°	CD5-29N
GMT1/MT6 Road	UB6.7	Indirect-Read	UB6.7-A	70.2856	-151.2626	PBM-35
			UB6.7-B	70.2855	-151.2627	
			UB6.7-C	70.2852	-151.2632	
	UB6.9		UB6.9-A	70.2834	-151.2578	
			UB6.9-B	70.2830	-151.2571	
	Notes: 1. PT, 2. RTFM PT, 3. Baro PT					

A.4 CULVERT LOCATIONS

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)
CD2-01N	18+71	N 70.3396°	W 151.0403°
CD2-01S		N 70.3395°	W 151.0396°
CD2-02N	26+12	N 70.3399°	W 151.0340°
CD2-02S		N 70.3397°	W 151.0340°
CD2-03N	30+24	N 70.3399°	W 151.0308°
CD2-03S		N 70.3397°	W 151.0306°
CD2-04N	32+01	N 70.3399°	W 151.0292°
CD2-04S		N 70.3397°	W 151.0292°
CD2-05N	32+10	N 70.3399°	W 151.0291°
CD2-05S		N 70.3397°	W 151.0292°
CD2-06N	32+21	N 70.3399°	W 151.0290°
CD2-06S		N 70.3397°	W 151.0291°
CD2-07N	32+30	N 70.3399°	W 151.0290°
CD2-07S		N 70.3397°	W 151.0291°
CD2-08N	35+29	N 70.3397°	W 151.0265°
CD2-08S		N 70.3394°	W 151.0268°
CD2-09N	41+30	N 70.3388°	W 151.0224°
CD2-09S		N 70.3386°	W 151.0227°
CD2-10N	45+25	N 70.3381°	W 151.0198°
CD2-10S		N 70.3379°	W 151.0206°
CD2-11N	48+85	N 70.3375°	W 151.0174°
CD2-11S		N 70.3374°	W 151.0180°
CD2-12N	53+08	N 70.3372°	W 151.0144°
CD2-12S		N 70.3370°	W 151.0145°
CD2-13N	54+84	N 70.3371°	W 151.0133°
CD2-13S		N 70.3369°	W 151.0129°
CD2-14N	57+38	N 70.3371°	W 151.0110°
CD2-14S		N 70.3369°	W 151.0111°
CD2-15N	63+01	N 70.3373°	W 151.0065°
CD2-15S		N 70.3372°	W 151.0066°
CD2-16N	67+69	N 70.3377°	W 151.0029°
CD2-16S		N 70.3375°	W 151.0029°
CD2-17N	71+51	N 70.3380°	W 150.9999°
CD2-17S		N 70.3378°	W 150.9999°
CD2-18N	76+29	N 70.3383°	W 150.9960°
CD2-18S		N 70.3381°	W 150.9963°
CD2-19N	81+56	N 70.3387°	W 150.9922°
CD2-19S		N 70.3386°	W 150.9921°
CD2-20N	84+06	N 70.3391°	W 150.9905°
CD2-20S		N 70.3389°	W 150.9901°
CD2-21N	88+50	N 70.3396°	W 150.9873°
CD2-21S		N 70.3394°	W 150.9869°
CD2-22N	94+42	N 70.3403°	W 150.9829°
CD2-22S		N 70.3401°	W 150.9827°
CD2-23N	98+66	N 70.3403°	W 150.9793°
CD2-23S		N 70.3402°	W 150.9795°
CD2-24N	101+43	N 70.3402°	W 150.9771°
CD2-24S		N 70.3400°	W 150.9772°
CD2-25N	113+94	N 70.3393°	W 150.9670°
CD2-25S		N 70.3391°	W 150.9679°
CD2-26N	119+33	N 70.3397°	W 150.9638°
CD2-26S		N 70.3396°	W 150.9632°
CD4-01E	10+50	N 70.3391°	W 150.9670°
CD4-01W		N 70.3392°	W 150.9678°
CD4-02E	13+51	N 70.3383°	W 150.9675°
CD4-02W		N 70.3383°	W 150.9680°
CD4-03E	16+02	N 70.3377°	W 150.9672°
CD4-03W		N 70.3376°	W 150.9677°
CD4-04E	18+95	N 70.3368°	W 150.9672°

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)
CD4-05E	23+08	N 70.3358°	W 150.9682°
CD4-05W		N 70.3358°	W 150.9686°
CD4-06E	28+03	N 70.3347°	W 150.9709°
CD4-06W		N 70.3349°	W 150.9712°
CD4-07E	34+16	N 70.3337°	W 150.9748°
CD4-07W		N 70.3338°	W 150.9751°
CD4-08E	44+28	N 70.3319°	W 150.9811°
CD4-08W		N 70.3320°	W 150.9814°
CD4-09E	59+20	N 70.3287°	W 150.9886°
CD4-09W		N 70.3289°	W 150.9890°
CD4-10E	66+48	N 70.3274°	W 150.9929°
CD4-10W		N 70.3275°	W 150.9933°
CD4-11E	81+24	N 70.3236°	W 150.9954°
CD4-11W		N 70.3236°	W 150.9961°
CD4-12E	81+66	N 70.3235°	W 150.9954°
CD4-12W		N 70.3235°	W 150.9961°
CD4-13E	82+09	N 70.3233°	W 150.9955°
CD4-13W		N 70.3233°	W 150.9961°
CD4-14E	82+51	N 70.3232°	W 150.9955°
CD4-14W		N 70.3232°	W 150.9961°
CD4-15E	102+00	N 70.3180°	W 150.9980°
CD4-15W		N 70.3180°	W 150.9985°
CD4-16E	129+97	N 70.3104°	W 151.0003°
CD4-16W		N 70.3104°	W 151.0009°
CD4-17E	143+00	N 70.3070°	W 150.9990°
CD4-17W		N 70.3069°	W 150.9994°
CD4-18E	146+55	N 70.3060°	W 150.9985°
CD4-18W		N 70.3059°	W 150.9989°
CD4-19E	154+57	N 70.3038°	W 150.9973°
CD4-19W		N 70.3038°	W 150.9978°
CD4-20A E	162+95	N 70.3022°	W 150.9937°
CD4-20A W		N 70.3019°	W 150.9936°
CD4-20B E	163+15	N 70.3021°	W 150.9934°
CD4-20B W		N 70.3018°	W 150.9933°
CD4-21E	163+35	N 70.3021°	W 150.9933°
CD4-21W		N 70.3018°	W 150.9932°
CD4-22E	163+55	N 70.3021°	W 150.9932°
CD4-22W		N 70.3018°	W 150.9930°
CD4-23E	164+40	N 70.3020°	W 150.9926°
CD4-23W		N 70.3017°	W 150.9925°
CD4-23A E	164+60	N 70.3080°	W 150.9924°
CD4-23A W		N 70.3017°	W 150.9923°
CD4-23B E	164+80	N 70.3019°	W 150.9923°
CD4-23B W		N 70.3016°	W 150.9922°
CD4-23C E	165+00	N 70.3019°	W 150.9921°
CD4-23C W		N 70.3016°	W 150.9920°
CD4-23D E	165+20	N 70.3019°	W 150.9920°
CD4-23D W		N 70.3016°	W 150.9919°
CD4-24E	197+02	N 70.2942°	W 150.9798°
CD4-24W		N 70.2944°	W 150.9803°
CD4-25E	200+89	N 70.2933°	W 150.9812°
CD4-25W		N 70.2934°	W 150.9818°
CD4-26E	201+05	N 70.2932°	W 150.9813°
CD4-26W		N 70.2934°	W 150.9818°
CD4-27E	201+05	N 70.2932°	W 150.9815°
CD4-27W		N 70.2934°	W 150.9820°
CD4-28E	201+21	N 70.2932°	W 150.9816°
CD4-28W		N 70.2933°	W 150.9821°
CD4-29E	201+21	N 70.2929°	W 150.9825°

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)
CD4-04W		N 70.3369°	W 150.9676°
CD4-30E	201+37	N 70.2929°	W 150.9826°
CD4-30W		N 70.2930°	W 150.9829°
CD4-31E	201+37	N 70.2928°	W 150.9827°
CD4-31W		N 70.2930°	W 150.9830°
CD4-32E	202+88	N 70.2928°	W 150.9828°
CD4-32W		N 70.2930°	W 150.9832°
CD4-33E	202+88	N 70.2926°	W 150.9838°
CD4-33W		N 70.2928°	W 150.9841°
CD5-01E	14+08	N 70.3122°	W 151.2186°
CD5-01W		N 70.3121°	W 151.2190°
CD5-02E	28+83	N 70.3083°	W 151.2161°
CD5-02W		N 70.3082°	W 151.2166°
CD5-03E	31+50	N 70.3076°	W 151.2153°
CD5-03W		N 70.3075°	W 151.2158°
CD5-04N	37+97	N 70.3060°	W 151.2134°
CD5-04S		N 70.3059°	W 151.2138°
CD5-05N	44+77	N 70.3047°	W 151.2103°
CD5-05S		N 70.3045°	W 151.2104°
CD5-06N	53+53	N 70.3051°	W 151.2036°
CD5-06S		N 70.3049°	W 151.2033°
CD5-07N	60+82	N 70.3059°	W 151.1984°
CD5-07S		N 70.3058°	W 151.1978°
CD5-08N	64+82	N 70.3064°	W 151.1953°
CD5-08S		N 70.3062°	W 151.1950°
CD5-09N	64+89	N 70.3064°	W 151.1952°
CD5-09S		N 70.3062°	W 151.1950°
CD5-10N	71+74	N 70.3072°	W 151.1900°
CD5-10S		N 70.3070°	W 151.1901°
CD5-11N	74+56	N 70.3074°	W 151.1881°
CD5-11S		N 70.3073°	W 151.1878°
CD5-12N	82+45	N 70.3082°	W 151.1821°
CD5-12S		N 70.3081°	W 151.1818°
CD5-13N	88+82	N 70.3089°	W 151.1774°
CD5-13S		N 70.3087°	W 151.1769°
CD5-14N	90+76	N 70.3090°	W 151.1757°
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CD5-16S		N 70.3088°	W 151.1725°
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CD5-17S		N 70.3081°	W 151.1686°
CD5-18N	101+99	N 70.3079°	W 151.1673°
CD5-18S		N 70.3079°	W 151.1679°
CD5-19N	111+86	N 70.3056°	W 151.1634°
CD5-19S		N 70.3055°	W 151.1639°
CD5-20N	122+31	N 70.3037°	W 151.1578°
CD5-20S		N 70.3035°	W 151.1578°
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CD4-29W		N 70.2931°	W 150.9828°
CD5-21S	126+42	N 70.3033°	W 151.1546°
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CD5-24N	153+63	N 70.3048°	W 151.1336°
CD5-24S		N 70.3046°	W 151.1331°
CD5-25N	160+11	N 70.3052°	W 151.1284°
CD5-25S		N 70.3050°	W 151.1280°
CD5-26N	179+13	N 70.3056°	W 151.1130°
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CD5-27N	188+59	N 70.3058°	W 151.1054°
CD5-27S		N 70.3056°	W 151.1052°
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CD5-28S		N 70.3057°	W 151.0987°
CD5-29N	201+40	N 70.3060°	W 151.0951°
CD5-29S		N 70.3058°	W 151.0948°
CD5-30N	205+72	N 70.3060°	W 151.0916°
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CD5-31N	209+46	N 70.3061°	W 151.0885°
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CD5-32N	216+78	N 70.3062°	W 151.0824°
CD5-32S		N 70.3060°	W 151.0826°
CD5-33N	216+86	N 70.3062°	W 151.0823°
CD5-33S		N 70.3060°	W 151.0825°
CD5-34N	225+38	N 70.3063°	W 151.0755°
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CD5-35N	234+35	N 70.3065°	W 151.0683°
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CD5-36N	239+00	N 70.3065°	W 151.0645°
CD5-36S		N 70.3064°	W 151.0645°
CD5-37N	245+56	N 70.3066°	W 151.0592°
CD5-37S		N 70.3065°	W 151.0592°
CD5-38N	249+12	N 70.3066°	W 151.0563°
CD5-38S		N 70.3064°	W 151.0564°
CD5-39N	254+23	N 70.3063°	W 151.0522°
CD5-39S		N 70.3060°	W 151.0525°
CD5-40N	265+63	N 70.3049°	W 151.0439°
CD5-40S		N 70.3047°	W 151.0441°
CD5-41N	272+56	N 70.3041°	W 151.0388°
CD5-41S		N 70.3039°	W 151.0391°
CD5-42N	276+40	N 70.3036°	W 151.0359°
CD5-42S		N 70.3035°	W 151.0365°
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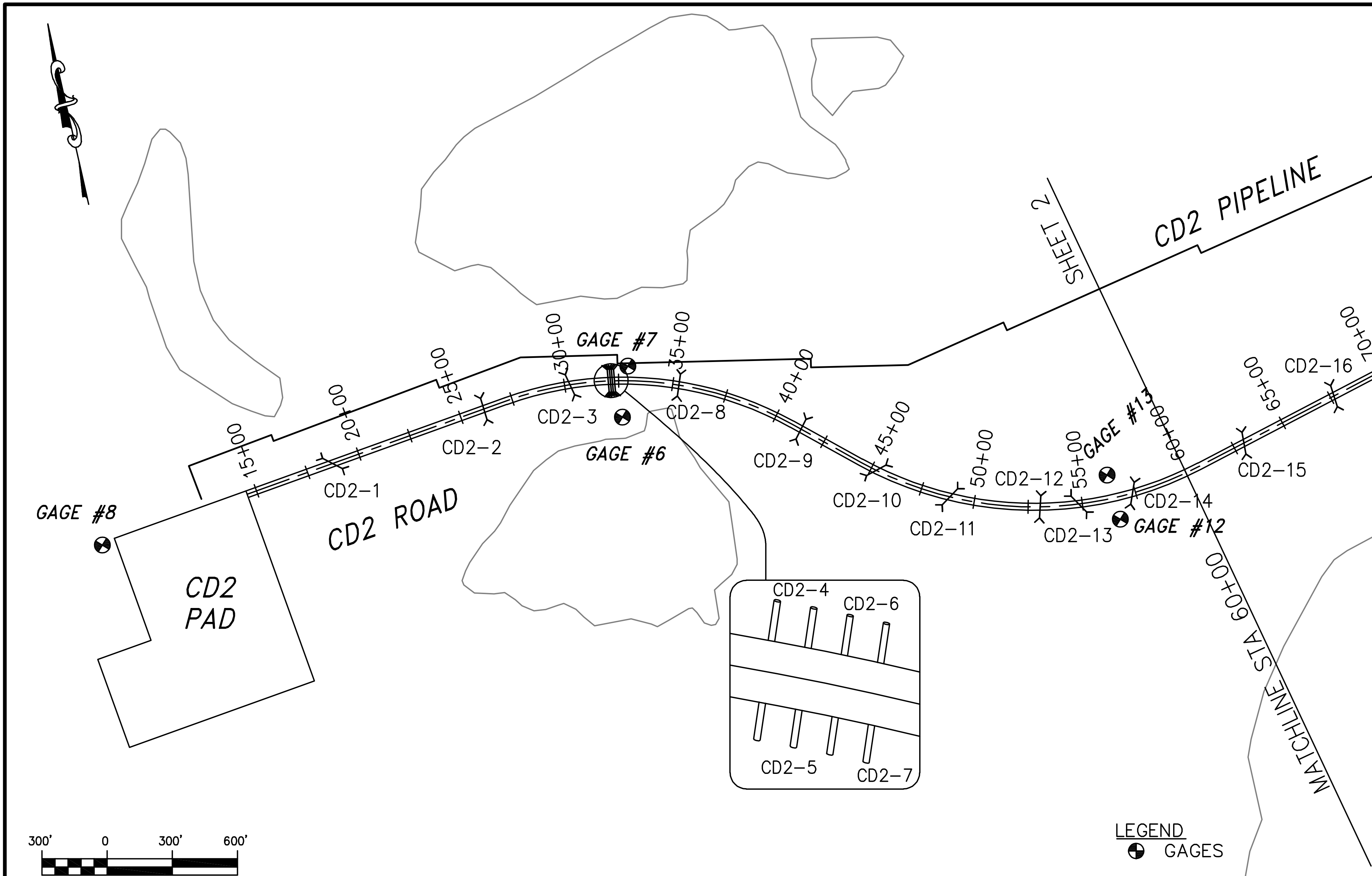


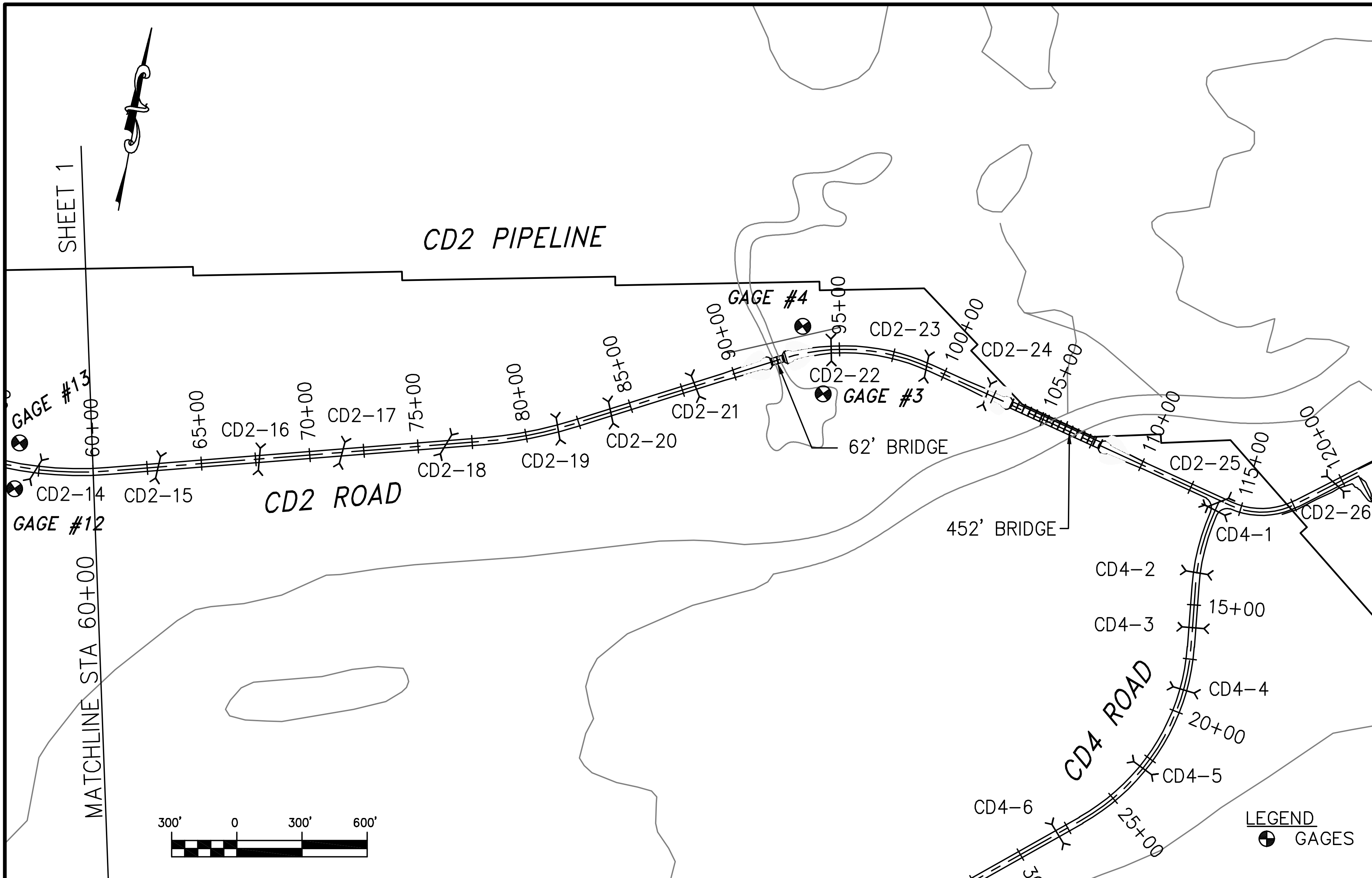
ConocoPhillips
Alaska, Inc.

DATE:	10/14/2021	PROJECT:	183660
DRAWN:	DTR	FILE:	ALPINE_FACILITES.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Michael Baker
INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET 1 OF 13)



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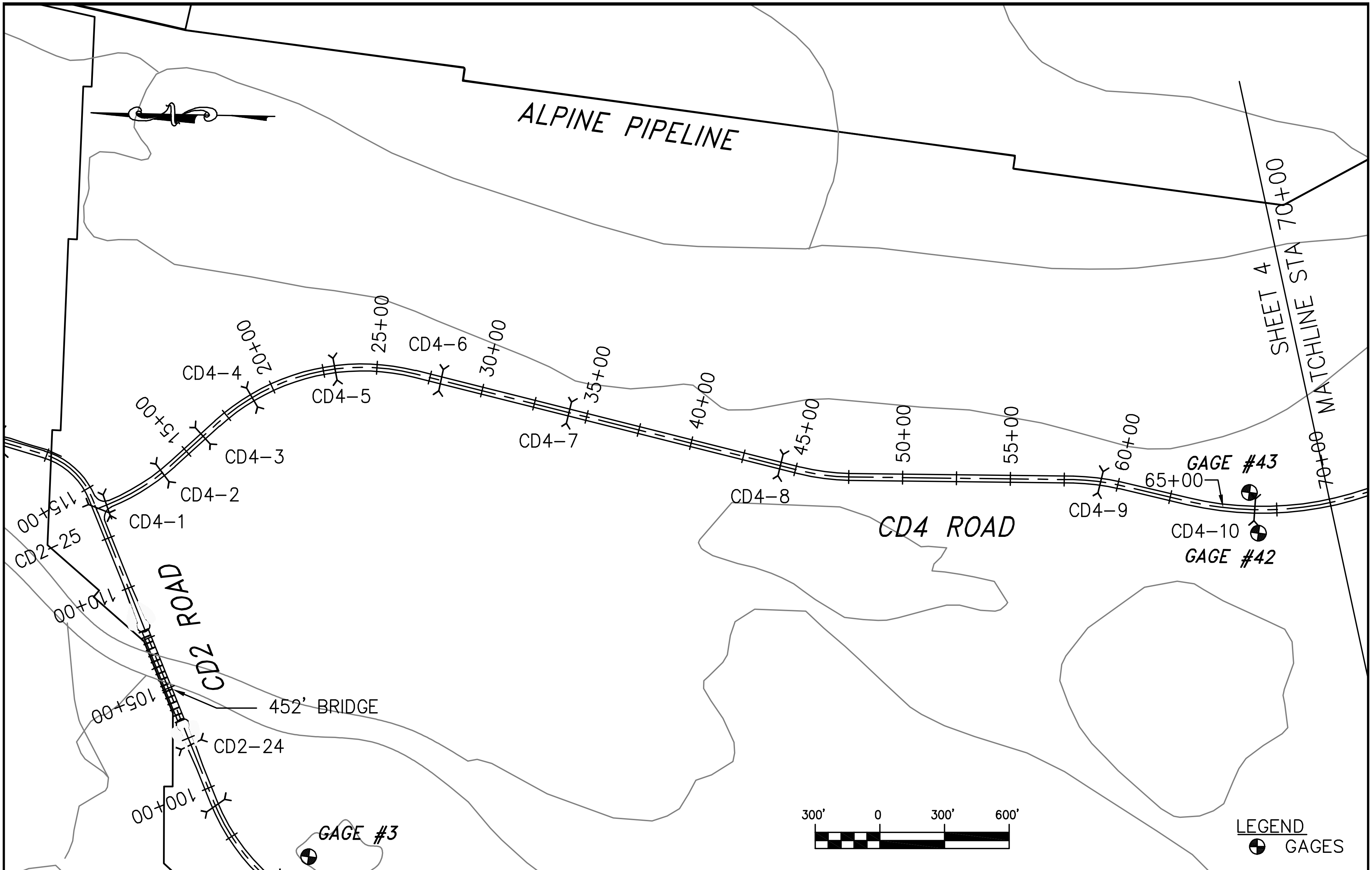
Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273–1600
Fax: (907) 273–1699

2021 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION



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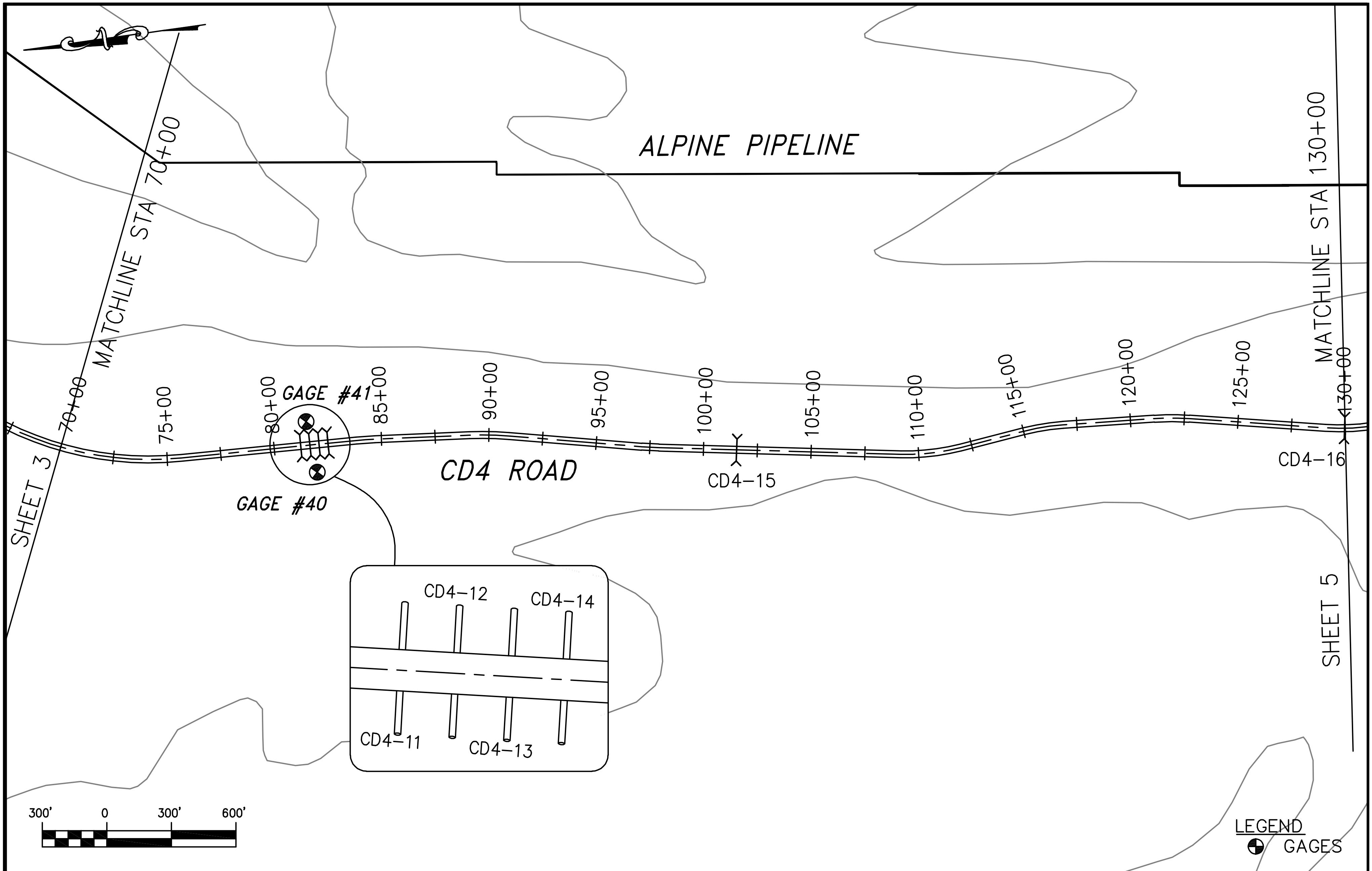
Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION



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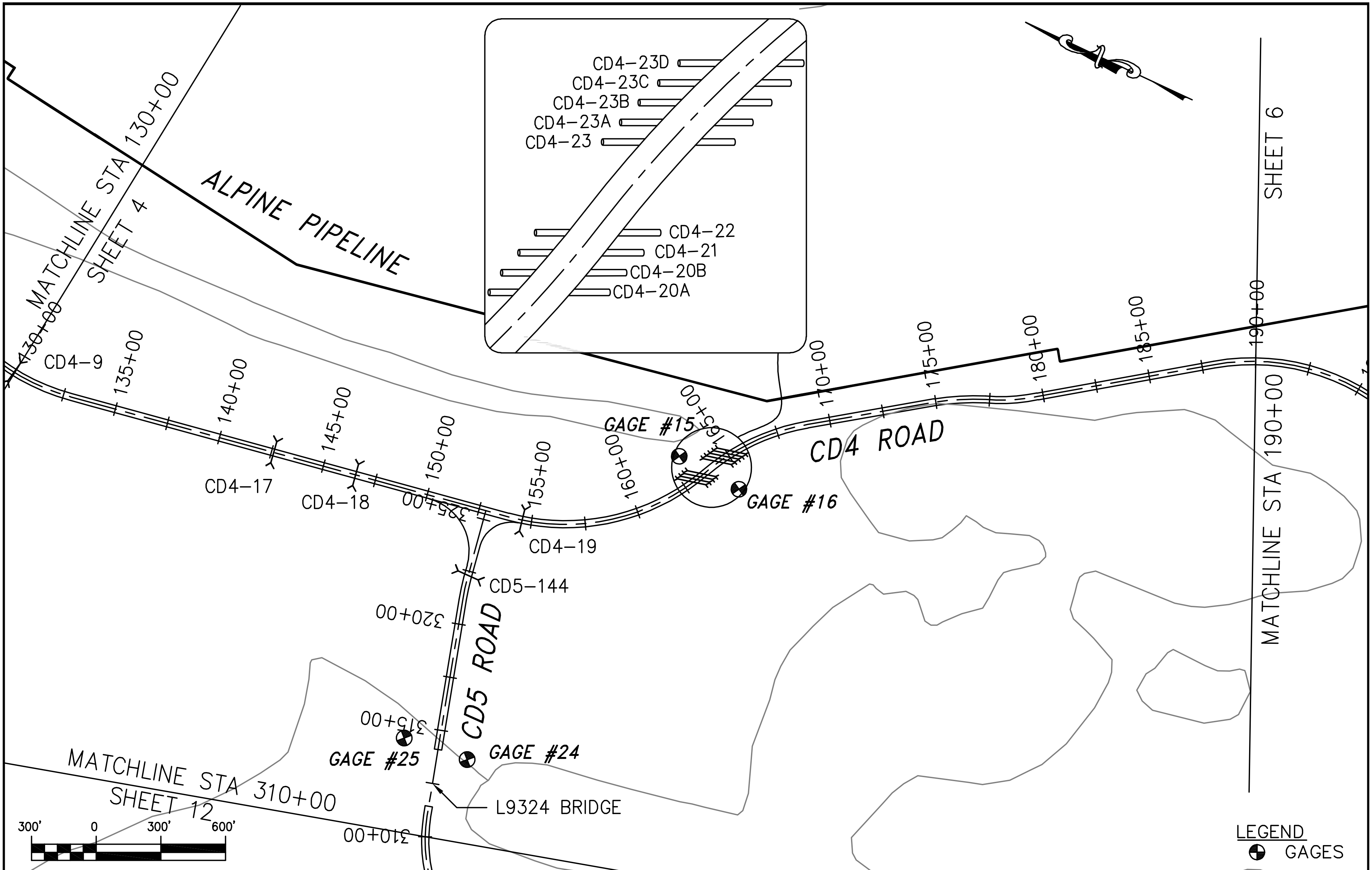
Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273–1600
Fax: (907) 273–1699

2021 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET 4 OF 13)



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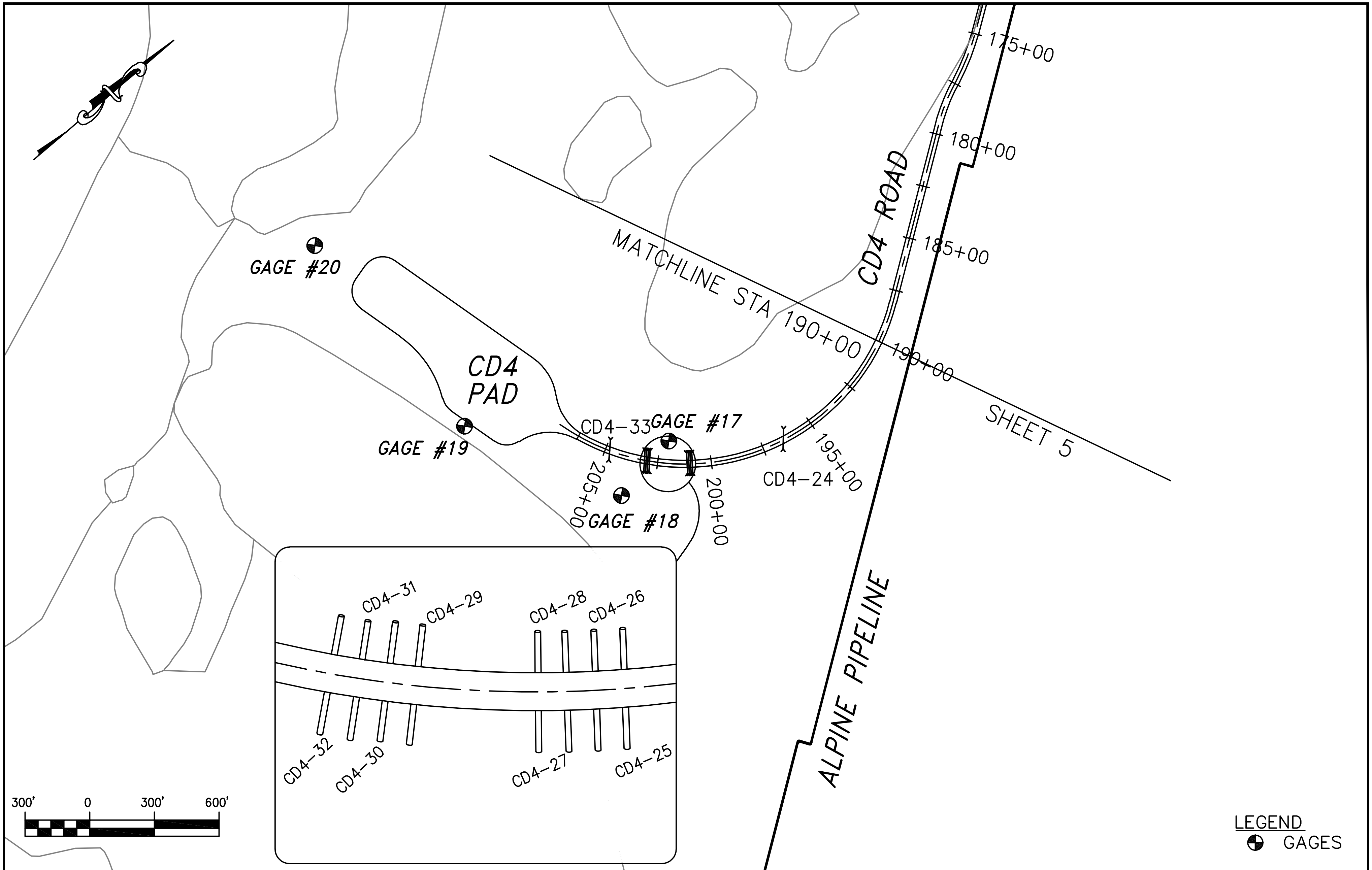
Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION



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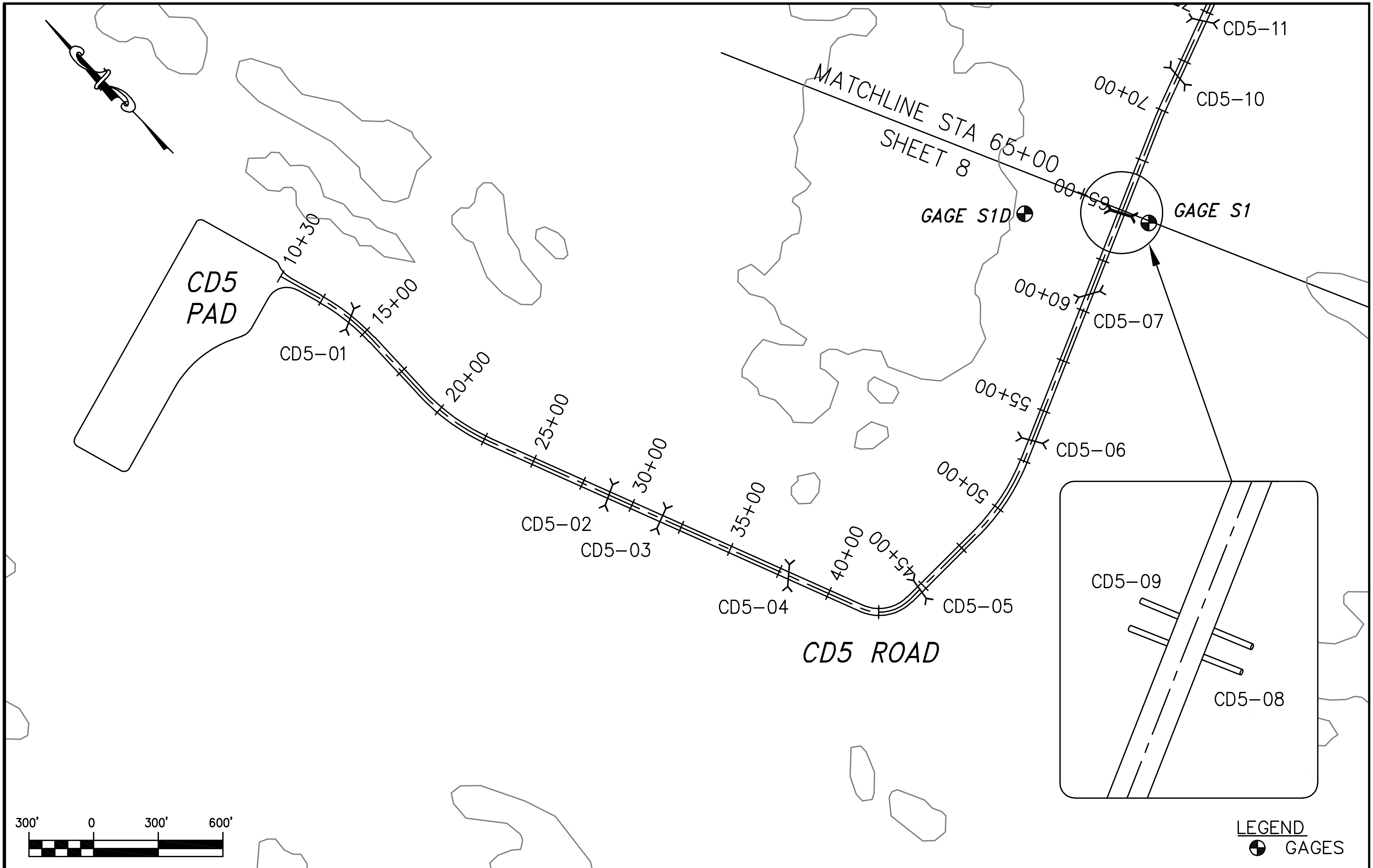
Michael Baker INTERNATIONAL

Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION



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Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP
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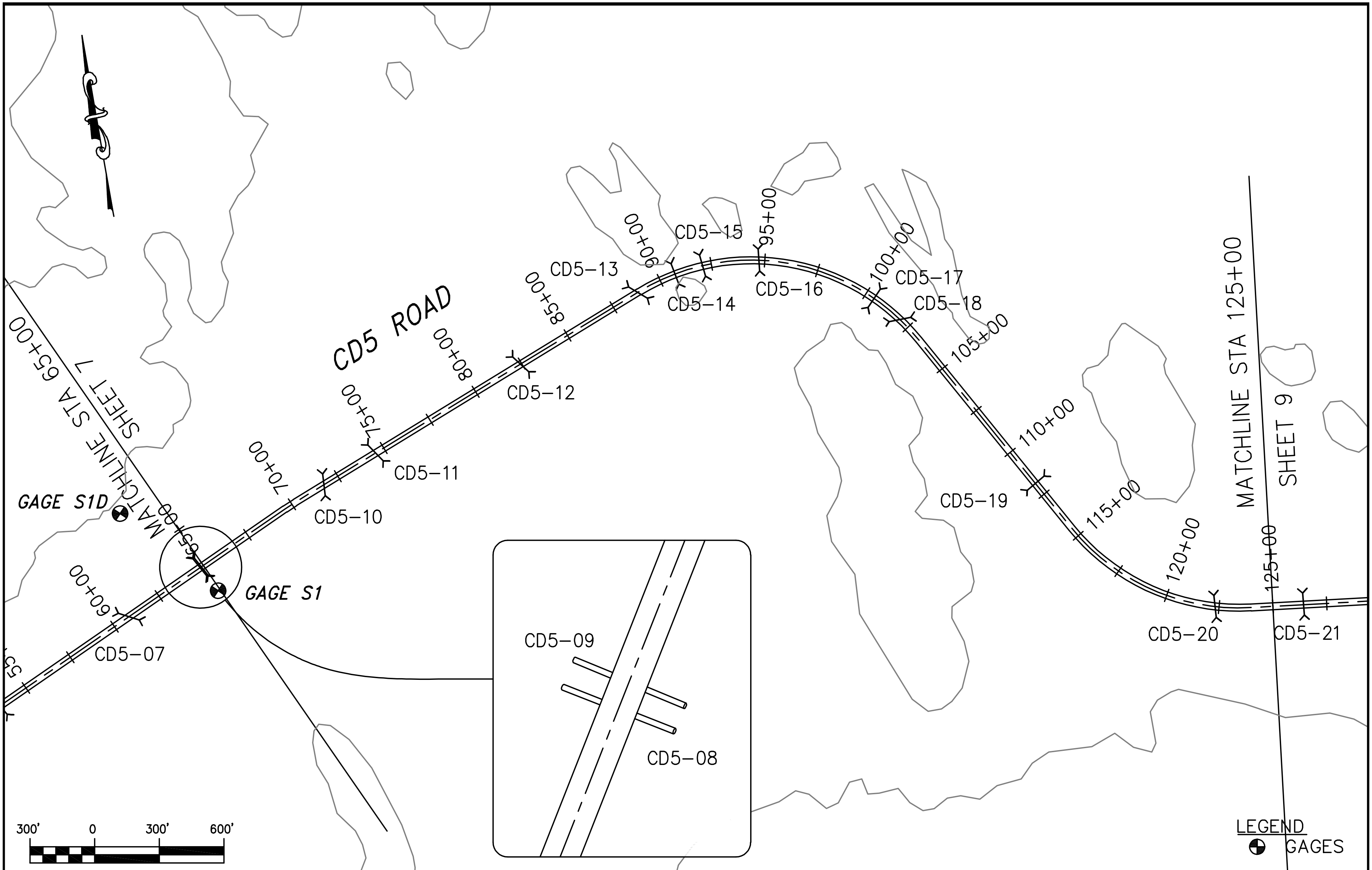

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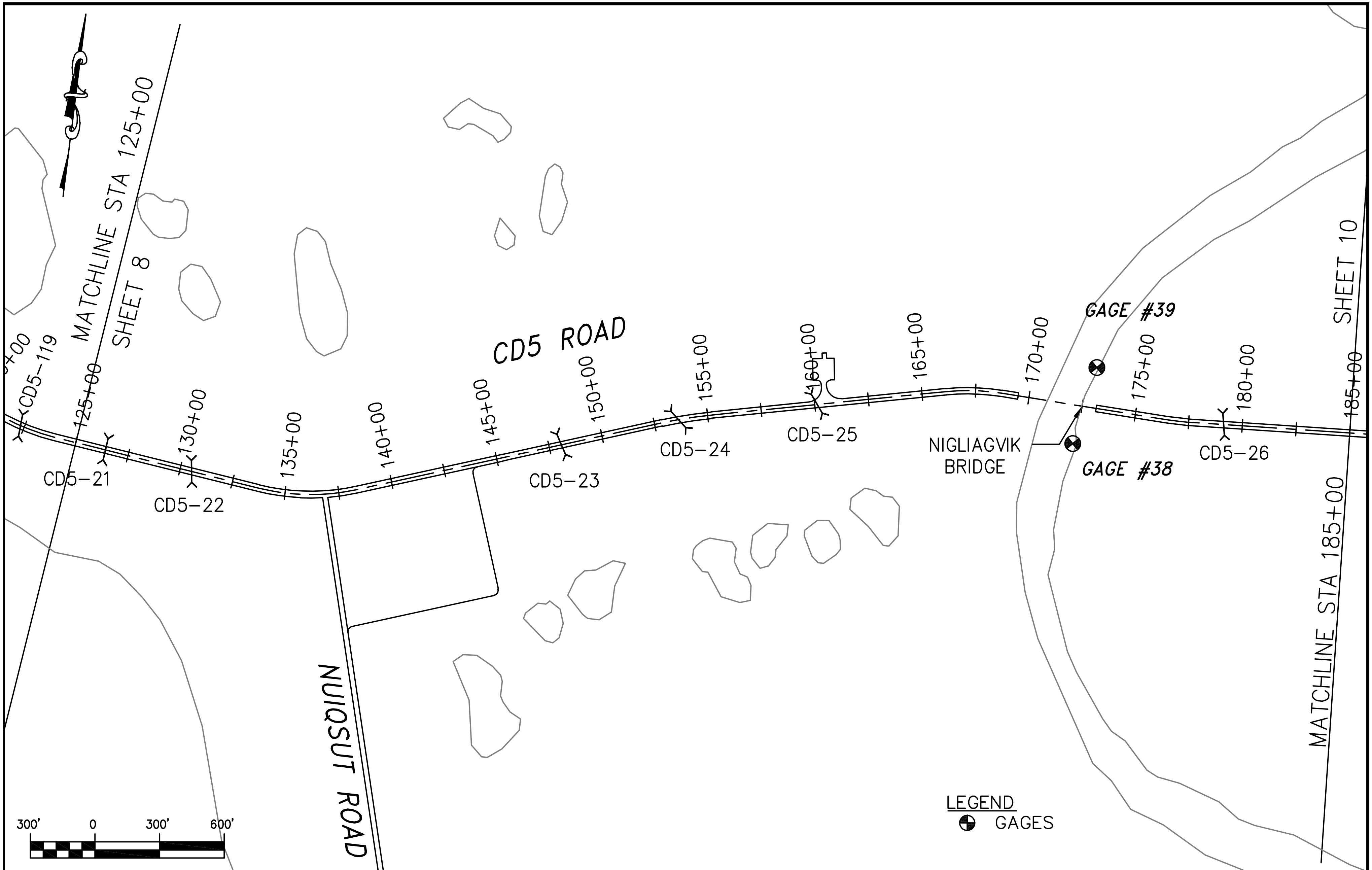
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273–1600
Fax: (907) 273–1699

2021 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET 8 OF 13)



ConocoPhillips
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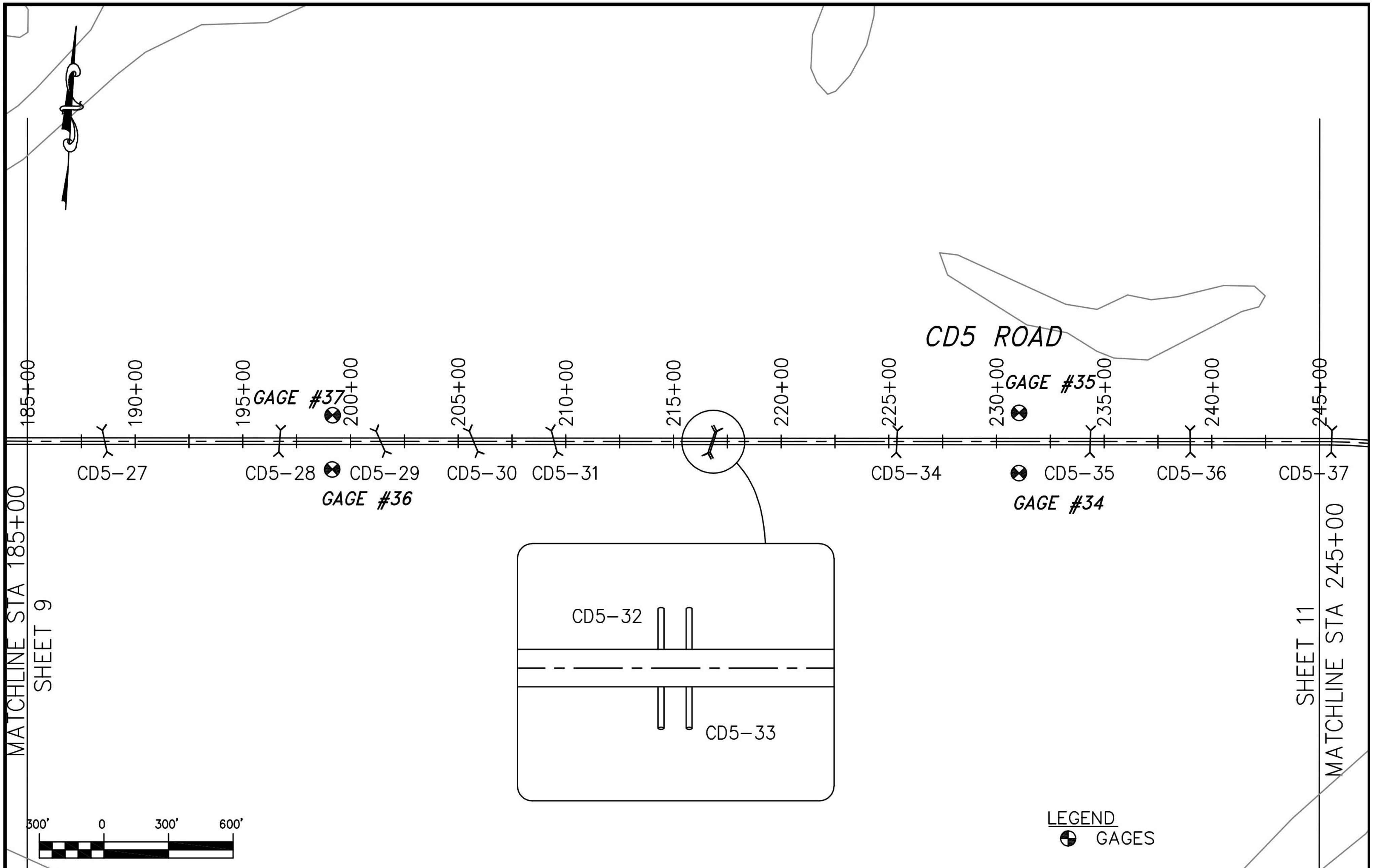
Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION



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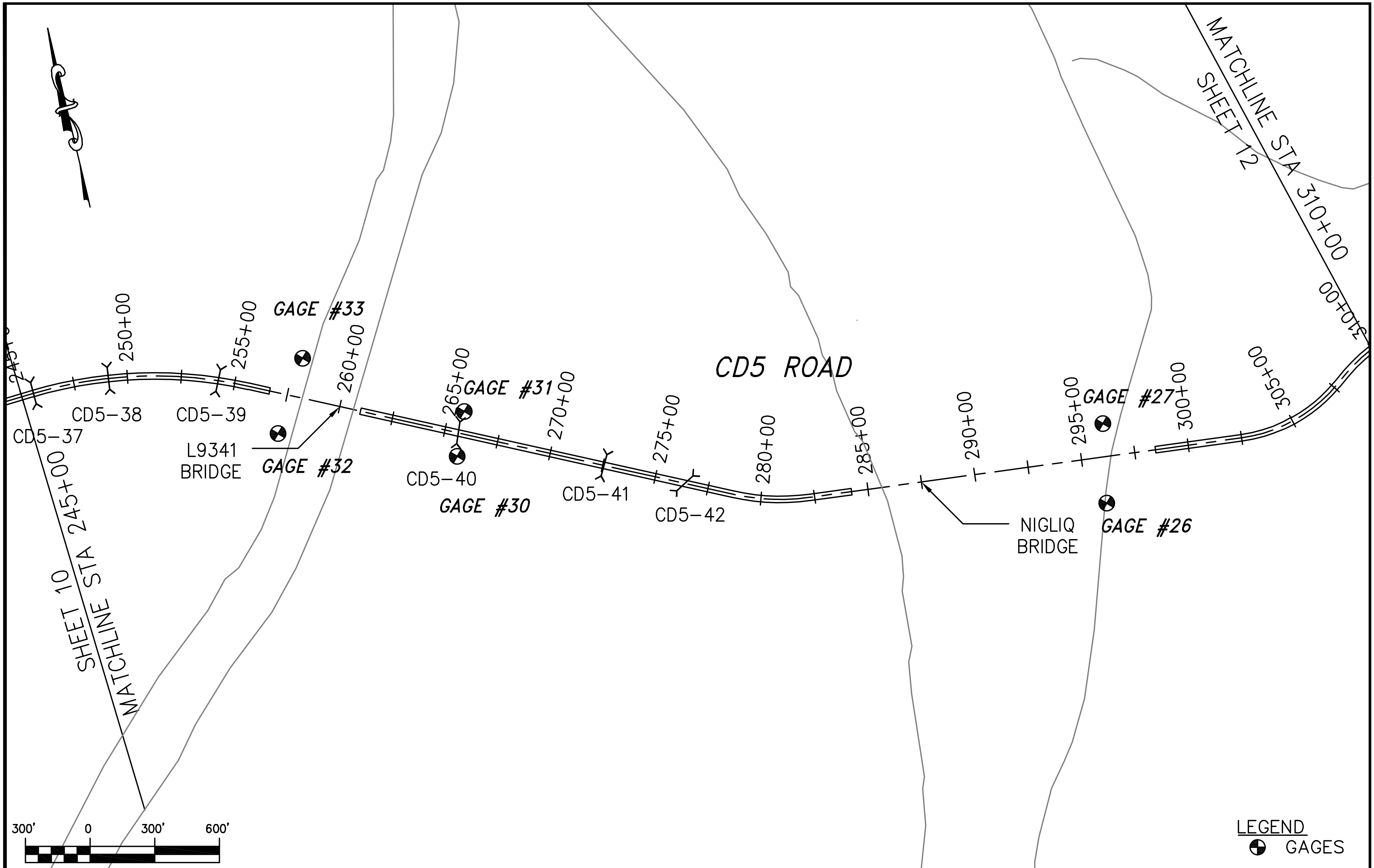
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273−1600
Fax: (907) 273−1699

2021 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION



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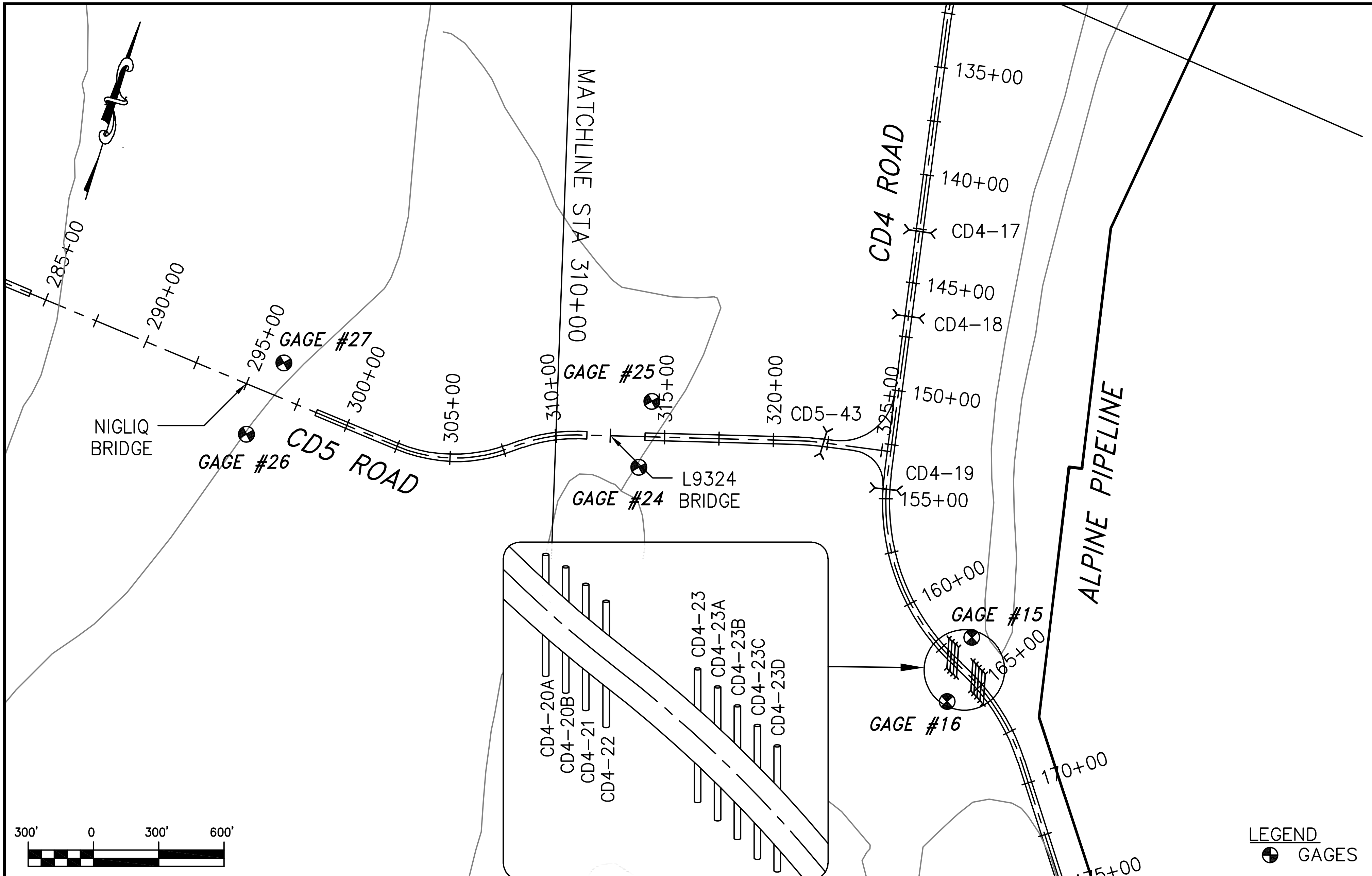
Michael Baker
INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273−1600
Fax: (907) 273−1699

2021 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET11 OF 13)



ConocoPhillips Alaska, Inc.

DATE:	10/15/2021	PROJECT:	183660
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CHECKED:	GCY	SCALE:	AS SHOWN

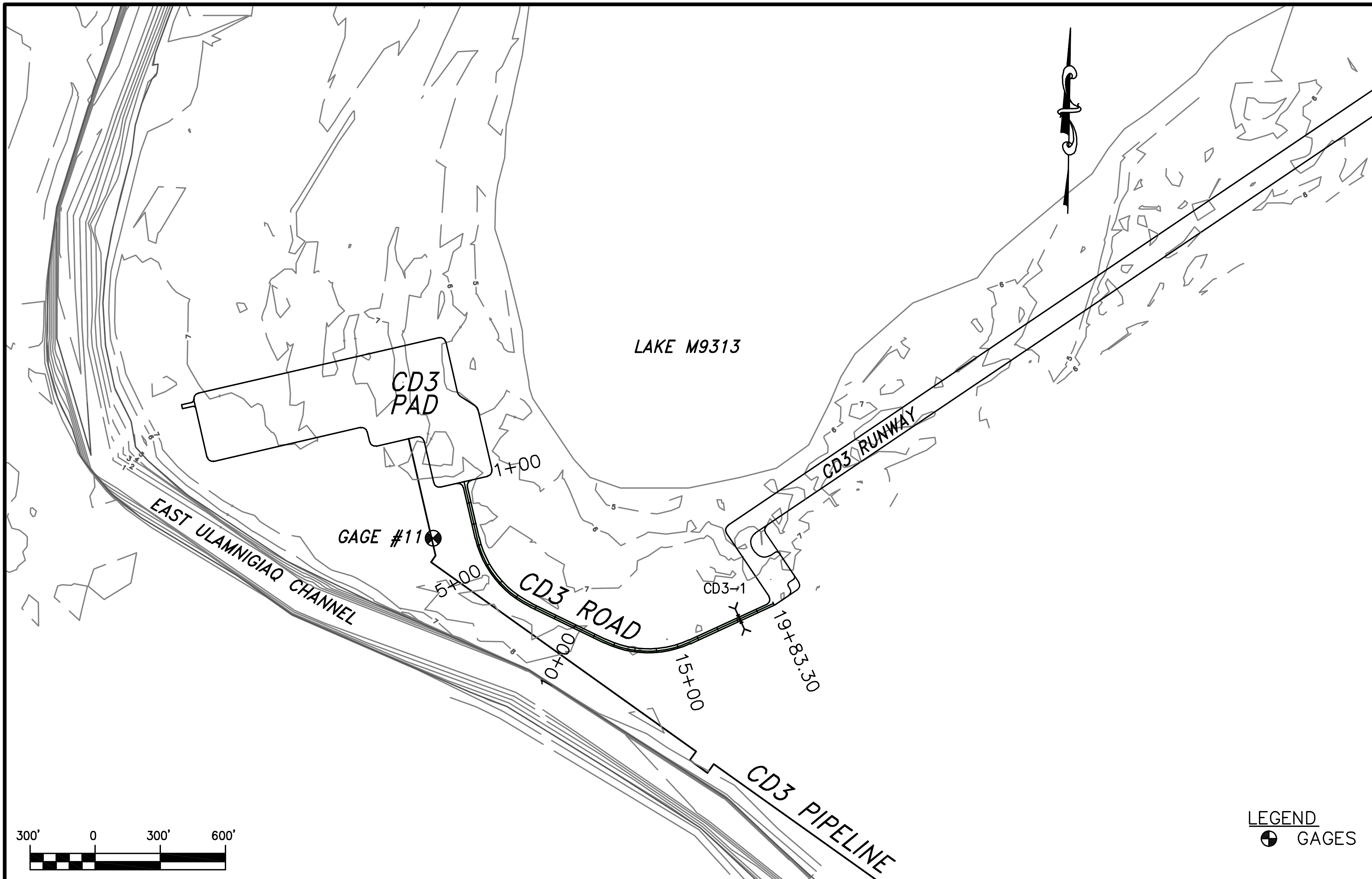
Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

(SHEET12 OF 13)



ConocoPhillips Alaska, Inc.

DATE:	10/15/2021	PROJECT:	183660
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Michael Baker International
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET13 OF 13)

APPENDIX B PT SETUP & TESTING METHODS

PTs measure the absolute pressure of the atmosphere and water, allowing the depth of water above the sensor to be calculated. Resulting data yield a comprehensive record of the fluctuations in stage. The reported pressure is the sum of the forces imparted by the water column and atmospheric conditions. Variations in local barometric pressure were taken into account using a Solinst Barologger® barometric pressure logger. A correction of barometric pressure was obtained from the Solinst Levelogger installed at MON9 and gage G18.

The PTs were tested before field mobilization. The PTs were configured using Solinst Levelogger® v4.0.3 (for both the Solinst Leveloggers and Barologgers) software prior to placement in the field. Absolute pressure was set to zero. The PT sensor was surveyed during setup to establish a vertical datum using local control.

PT-based stage values were determined by adding the calculated water depth and the surveyed sensor elevation. PTs have the potential to drift and can be affected by ice and sediment. Gage WSE readings were used to validate and adjust the data collected by the PTs. A standard conversion using the density of water at 0°C was used to calculate all water depths from adjusted gage pressures. Fluctuations in water temperature during the sampling period did not affect WSE calculations because of the limited range in temperature and observed water depths

APPENDIX C DISCHARGE METHODS, SITE SPECIFIC INFORMATION, & PLAN & PROFILE DRAWINGS

C.1 METHODS

C.1.1 MEASURED DISCHARGE

1) USGS Midsection Technique

Bridge flow depth and velocity measurements were taken from the upstream side of bridge decks using a sounding reel mounted on a USGS Type A crane with 4-wheel truck. A Price AA velocity meter was attached to the sounding reel and stabilized with a counterweight. A tag line was placed along the bridge rail to define the cross section and to delineate measurement subsections within the channel. The standard rating table No.2 for Price AA velocity meters, developed by the USGS Office of Surface Water (OSW) Hydraulic Laboratory as announced in the OSW Technical Memorandum No. 99.05 (OSW 1999a), was used to convert revolutions to stream velocity. The Price AA velocity meter was serviced prior to spring breakup monitoring in accordance with USGS precise standards. A spin test of the meter was completed prior to and after each measurement. Procedures outlined in OSW Technical Memorandum No. 99.06 (OSW 1999b) were followed to confirm accurate meter performance. Discharge was calculated based on velocity and flow depth.

2) USGS Velocity/Area Technique

Standard USGS velocity/area techniques (USGS 1968) were used to measure depth of flow and velocity to determine discharge at each culvert experiencing flow. Depth of flow and velocity were measured on the downstream end of the culvert using a HACH FH950 electromagnetic velocity meter attached to a wading rod. The accuracy of the HACH meter is ± 2% of the reading, ± 0.05 ft/s between 0 ft/s and 10 ft/s, and ± 4% of the reading from between 10 ft/s and 16 ft/s. Discharge was calculated based on velocity, flow depth, and culvert geometry.

3) ADCP METHODS

Direct discharge was measured using an Acoustic Doppler Current Profiler (ADCP). Information regarding ADCP discharge measurements are included in the following sections.

A. HARDWARE & SOFTWARE

A Teledyne RD Instruments 600-kilohertz Workhorse Sentinel broadband ADCP was used. The unit has a phased array, Janus four-beam transducer with a 20-degree beam angle. The ADCP unit and supporting laptop (Panasonic Toughbook CF-19) were self-powered via internal batteries.

BBTalk v3.06, a DOS-based communication program, was used to perform pre-deployment tests. WinRiverII v2.18 was used to configure, initiate, and communicate with the ADCP while on the river. WinRiverII was also used to review and evaluate collected discharge data after returning from the field.

B. PRE-DEPLOYMENT TESTING

Prior to deployment of the ADCP unit, a full suite of tests were run in accordance with the manufacturer's instructions using BBTalk. The tests confirmed the signal path and all major signal processing subsystems were functioning properly. Tests also confirmed accurate tilt and pitch readings. A beam continuity test was performed to verify the transducer beams were connected and operational. Additional diagnostic tests were performed using WinRiverII. Pre-deployment tasks also included compass calibration and verification and a moving bed test. The internal compass was calibrated to an error of 1.9°, which is within the specified 5° limit. A loop test was performed to detect and estimate compensation for a moving bed, which was identified at a velcoity of 0.073 ft/s.

C. ADCP DEPLOYMENT & DATA COLLECTION

The Workhorse Sentinel ADCP was mounted to an Achilles SGX-132 inflatable raft powered by a Tohatsu 9.8 horsepower outboard motor. A fabricated aluminum tube framework spanning the boat's gunwales provided a rigid and secure placement of the ADCP unit, and allowed necessary navigation adjustments as river conditions required.

The discharge measurements were performed at bridge crossings and areas of hydraulic importance in the CRD. Cross section end points were marked with handheld GPS units having wide area augmentation system enabled accuracy. The position of the boat was determined by tracking the bottom of the channel with the ADCP. Distances to the right and left edge of water from respective end points were estimated from GPS coordinates.

The four most agreeing of a total of six transects were used. The measured discharges varied by 0.00%, which is less than the standard 5% of their mean. Cross section end points were dependent on a depth associated with a minimum of two good bins to provide acceptable data.

D. ADCP BACKGROUND & DATA PROCESSING

An ADCP measures the velocity of particles in the water. Particles, on average, move at the same horizontal velocity of the water relative to the ADCP unit. The velocity of flow is then calculated relative to the earth, based on the simultaneous velocity and position of the boat. The velocity and position of the boat were recorded by tracking the bottom of the channel with the ADCP unit.

Some channels in the CRD are composed of fine-grained sediment, and water velocities are sufficient to entrain the materials resulting in a moving river bed condition. When using bottom tracking, a moving bed can affect the accuracy of the results by biasing the velocity and discharge lower than actual values. This phenomenon can be eliminated with the use of either a differential global positioning system (DGPS), the loop method (USGS 2006). To account for the bias introduced by a moving bed, the loop method was employed.

The loop method is a technique to determine whether a moving bed is present and, if present, to provide an approximate correction to the final discharge value. The USGS established guidance for the loop method by outlining procedures for mean correction and distributed correction (USGS 2006). Both procedures yield results within 2 percent of the actual discharge, as measured using DGPS. Since a moving bed was identified, the mean correction procedure was applied to the because of the simple geometry of the channel cross section. The results of the loop test, performed during discharge measurements, was used to estimate the mean velocity of the moving bed. The mean velocity was multiplied by the cross-sectional area perpendicular to the mean observed flow to yield a discharge correction. The resulting correction was applied to each transect, and the resulting direct discharge measurement was determined by averaging the corrected discharge measurements.

C.1.2 PEAK DISCHARGE

1) Culverts

Bentley CulvertMaster® software was used to calculate peak discharge through the CRD road culverts associated with gage stations that experienced flow. Timing and magnitude of peak discharge through the culverts was determined based on recorded stage on both sides of the road prism. Peak discharge results were evaluated against visual assessment of performance. Average velocity and discharge through the culverts assume ice-free open-water conditions and were estimated based on several variables, including:

- Headwater and tailwater elevations at each culvert (hydraulic gradient)
- Culvert diameter and length from UMIAQ as-built surveys (UMIAQ 2002, 2017)
- Culvert upstream and downstream invert elevations (UMIAQ 2017a, 2019d)
- Culvert Manning's roughness coefficients (0.013 for smooth steel and 0.024 for corrugated metal pipe)

2) Streams

Peak discharge in streams was calculated indirectly using either the Slope Area (Benson and Dalrymple 1967) or the Normal Depth method (Chow 1959). Both methods use channel roughness, cross sectional geometry, and stage differential between gage sites as an estimate for the energy grade line. The methods differ by the number of cross sections used in the calculations. The Slope Area method is considered the standard for indirect discharge calculations and is generally used if sufficient stage data is available for multiple cross-sections through a reach. The accuracy of each method, however, depends on conditions at the time of calculation, particularly the presence of channel ice and bottom-fast ice, ice jam activity, and backwater effects. Direct discharge measurements at or near the time of peak can support calibration and accuracy of indirect calculations.

Cross sectional geometry for MON1 is current as of 2004 (UMIAQ 2004), MON9 is current as of 2009 (UMIAQ 2009), Nigliq Bridge (CD5 Bridge #2) is current as of 2019 (UMIAQ 2019a). Cross-sectional geometry data was collected in the summer and does not account for bank-fast or bottom-fast ice or snow. Additionally, because of channel bed morphology, cross sectional geometry becomes less accurate with time, particularly for those CRD channels that are predominantly comprised of fine grained. Stage and energy gradient data were obtained from observations, gage data, and PT data.

3) CD5 Bridges

Peak discharge at the Nigliq and Nigliagvik bridges were calculated using the Normal Depth method (Chow, 1959). Lake L9323 bridge (CD5 bridge #1) and Lake L9341 bridge (CD5 bridge #3) were under the influence of competent lake ice. Peak discharge could not be estimated with a sufficient degree of confidence.

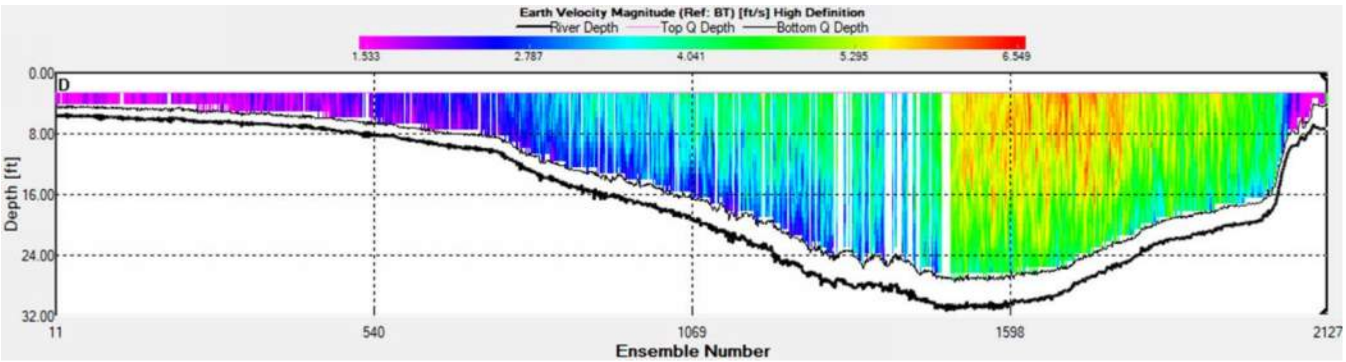
C.2 Site Specific Data & Plan & Profile Drawings

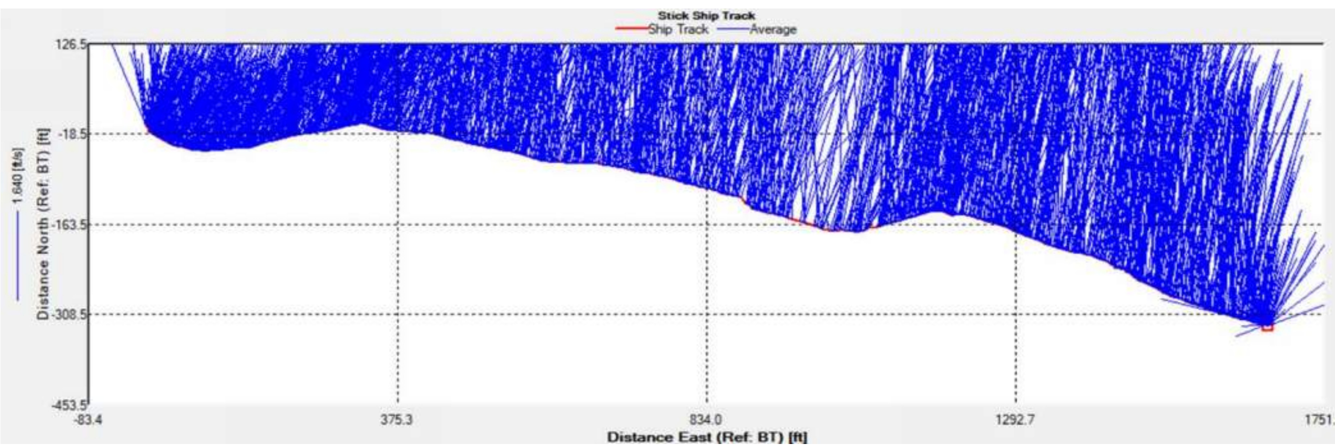
C.2.1 MON1

1) MEASURED DISCHARGE

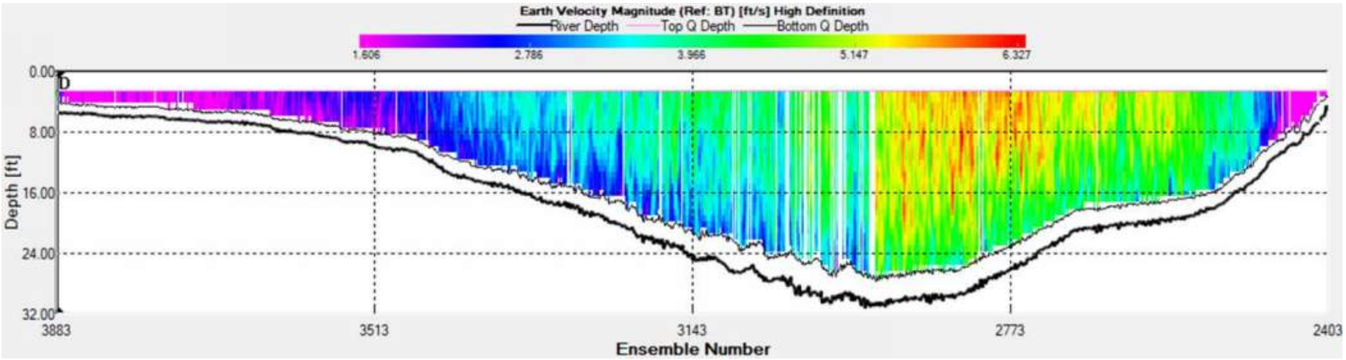
Transect	Area (ft^2)	Unadjusted Measured Discharge (cfs)	Discharge Correction Attributed to Moving Bed (cfs)	Adjusted Measured Discharge (cfs)	Error	Average Velocity (ft/s)
Transect000 at 16:44	35505	131,174	10,190	141,364	0.12%	3.98
Transect001 at 16:59	35203	131,628	10,103	141,731	0.36%	4.03
Transect002 at 17:09	35415	131,138	10,164	141,302	0.08%	3.99
Transect003 at 17:21	35181	130,287	10,097	140,384	-0.57%	3.99
Average	**35,326**	**131,057**	**10,139**	**141,195**	**0.00%**	**4.00**

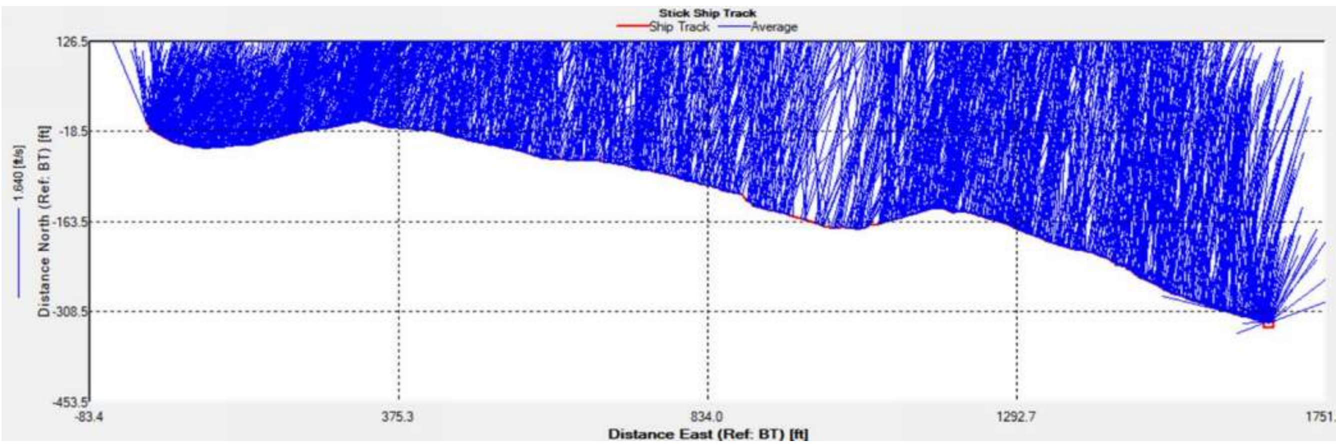
E. TRANSECT 000 RAW DATA OUTPUT



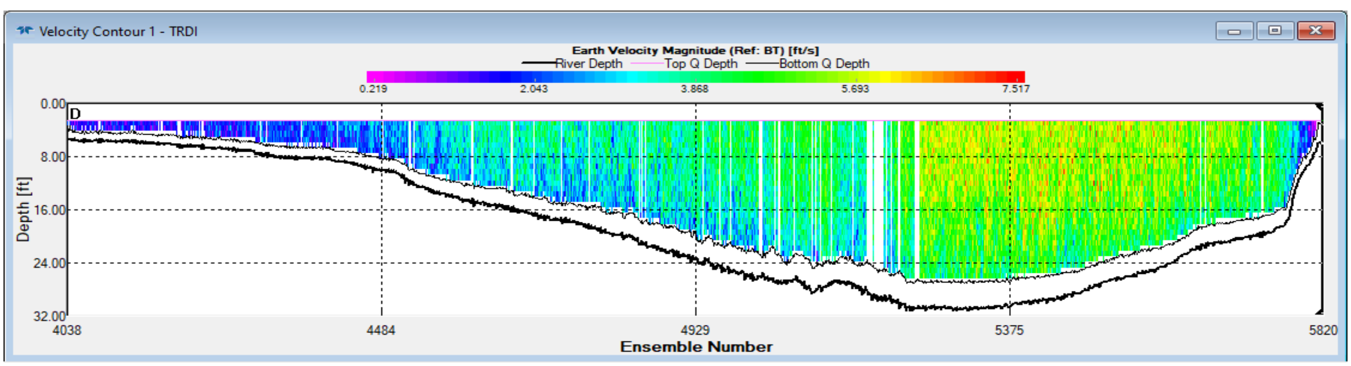


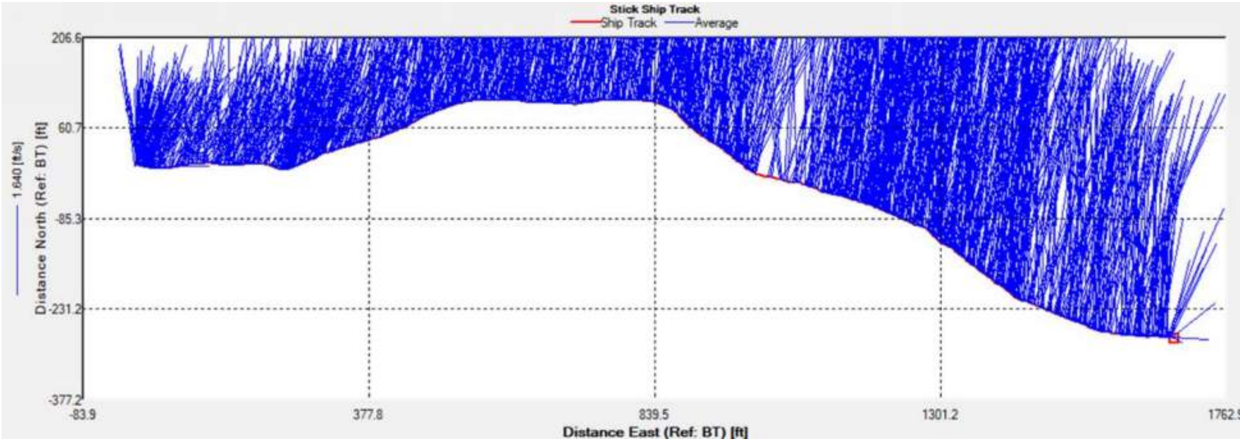
F. TRANSECT 001 RAW DATA OUTPUT



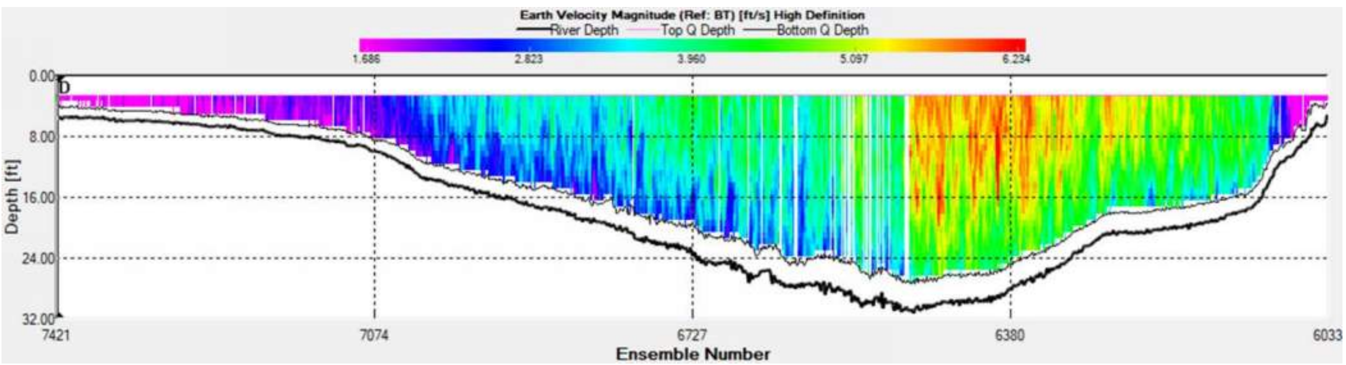


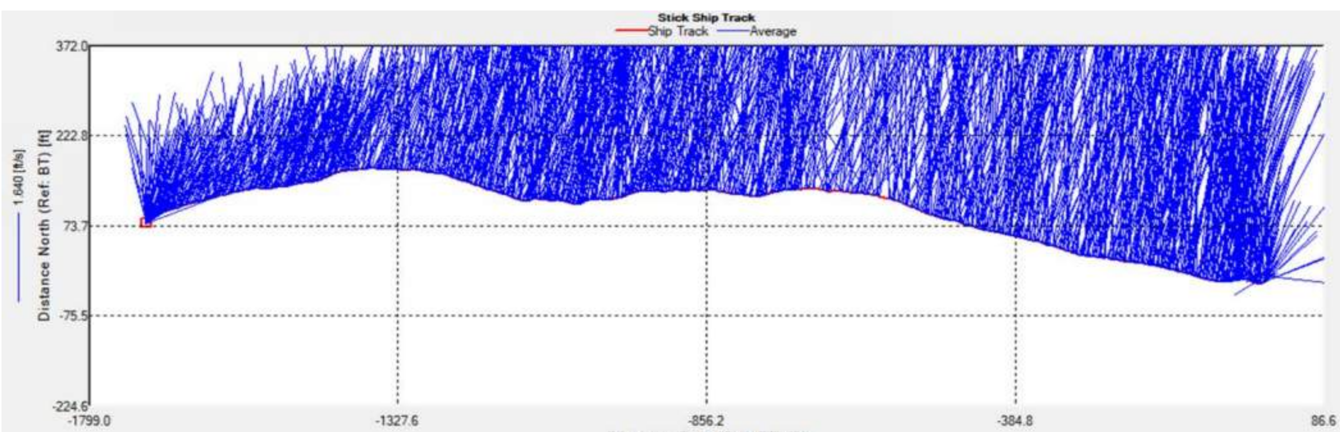
G. TRANSECT 002 RAW DATA OUTPUT





H. TRANSECT 003 RAW DATA OUTPUT

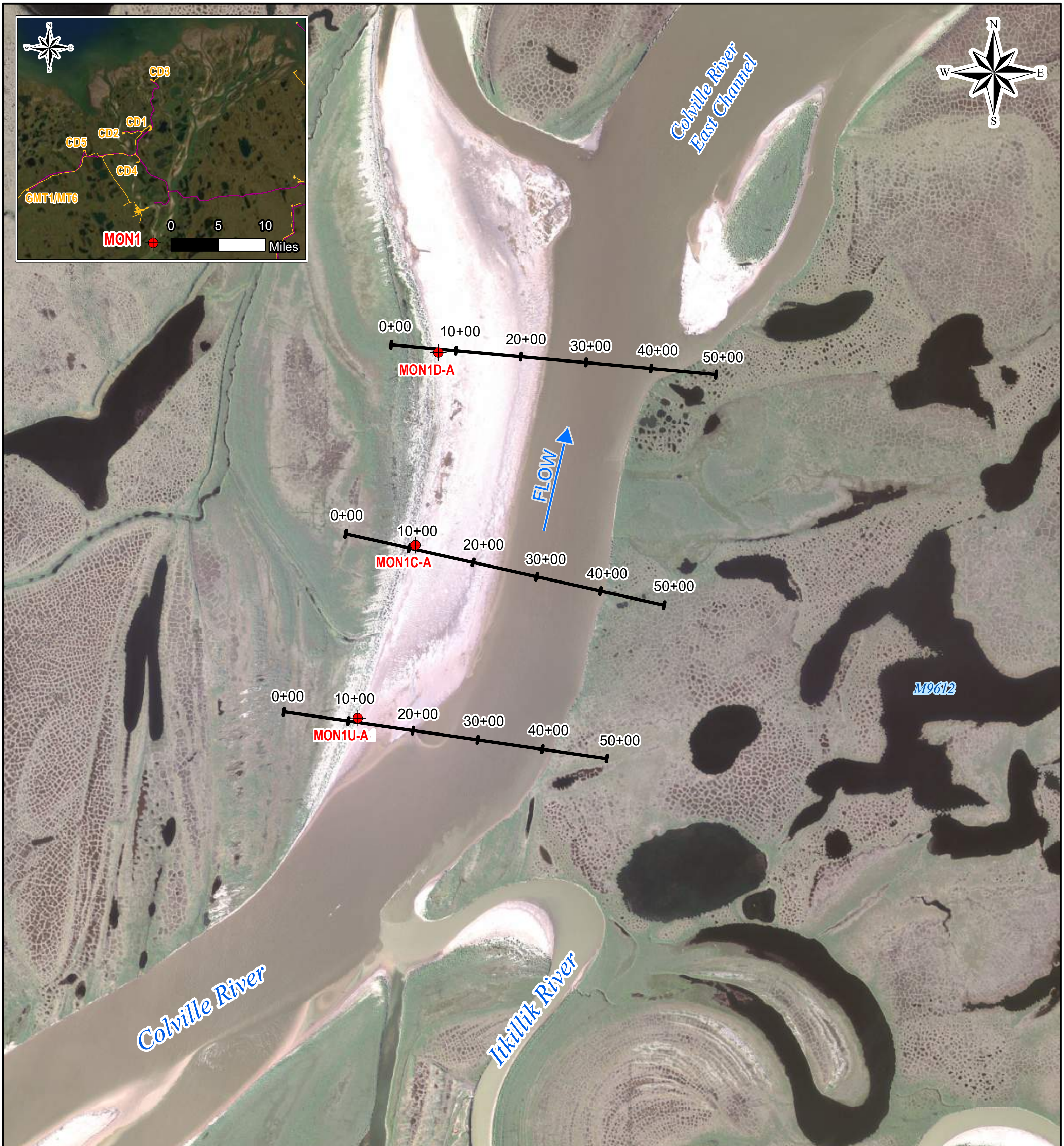




2) PEAK DISCHARGE DATA

Peak discharge at MON1 was calculated indirectly using the Normal Depth method. The energy grade-line was approximated by the average water surface slope between MON1U, MON1C, and MON1D. Manning's n roughness values used were 0.0256 for the main channel and 0.06 for the overbanks, based on historical calibration of measured discharge and corresponding stage.

3) PLAN & PROFILES



Michael Baker
INTERNATIONAL
Michael Baker International, Inc.
3900 C Street, Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

Date:	9/27/2021	Scale:	1 Inch = 2,000 feet
Drawn:	JEM	Project:	183660
Checked:	GCY	File:	Mon1.mxd

Feet
0 2,000 4,000

Gage Location
Flow Direction
Cross Section Alignment
Pipeline
Facility

Imagery from CPAI 2019

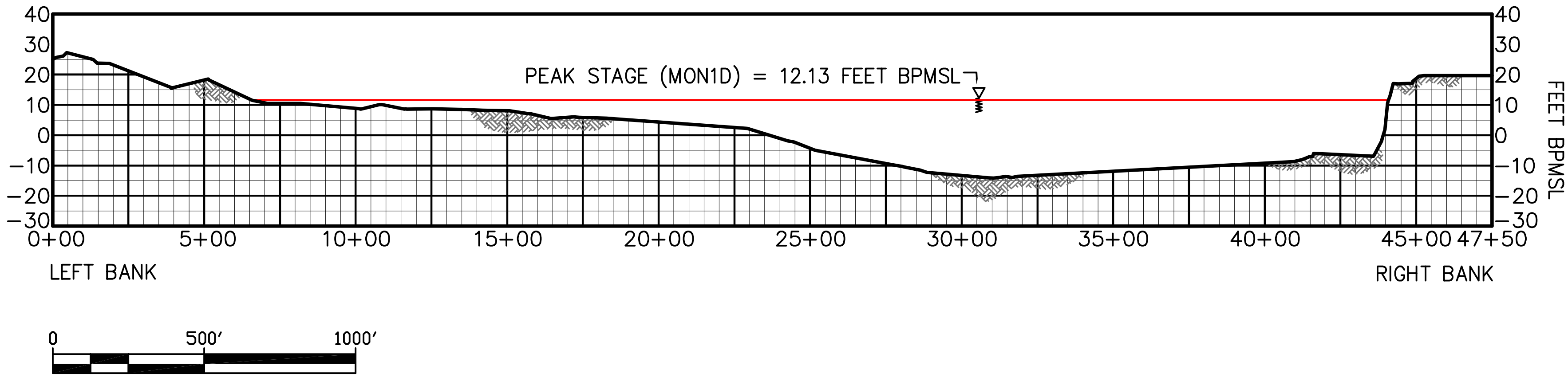
ConocoPhillips
Alaska

2021 SPRING BREAKUP
COLVILLE RIVER DELTA

Monitoring Locations

FIGURE C.1.2 | Sheet 1 of 4

NOTES
1. BASIS OF ELEVATION, MONUMENT 1.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY UMIAQ (KUUKPIK/LCMF INC.)



1D COLVILLE RIVER AT MON1 DOWNSTREAM CROSS-SECTION

ConocoPhillips Alaska, Inc.

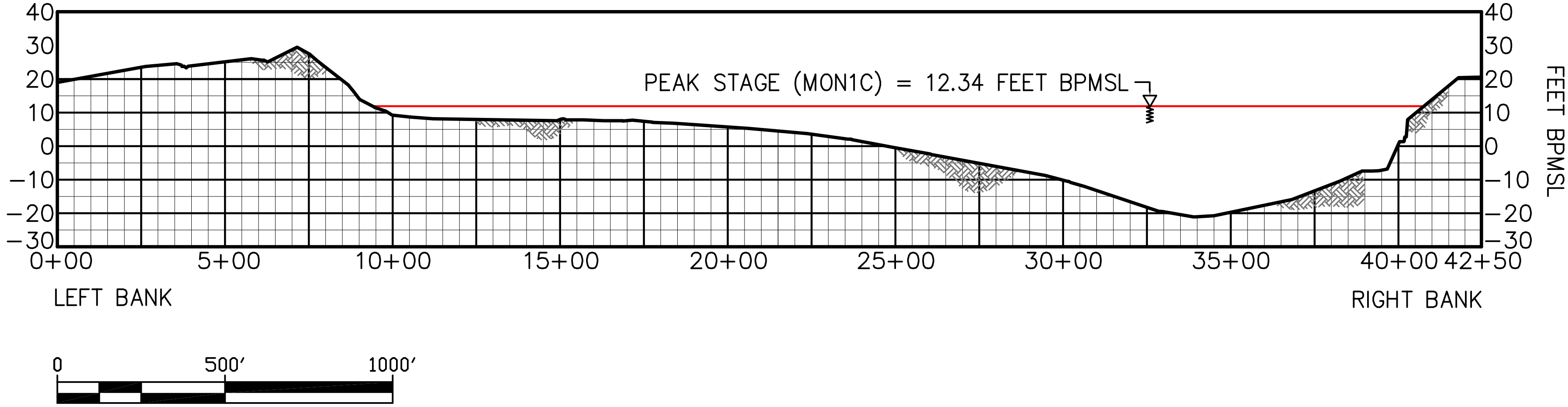
DATE:	10/16/2021	PROJECT:	183660
DRAWN:	DTR	FILE:	MON1 X-SECTIONS.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP
MONUMENT 1 DOWNSTREAM
PROFILE

(SHEET 2 OF 4)

NOTES
1. BASIS OF ELEVATION, MONUMENT 1.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY UMIAQ (KUUKPIK/LCMF INC.)



1C COLVILLE RIVER AT MON1 CENTERLINE CROSS–SECTION

ConocoPhillips Alaska, Inc.

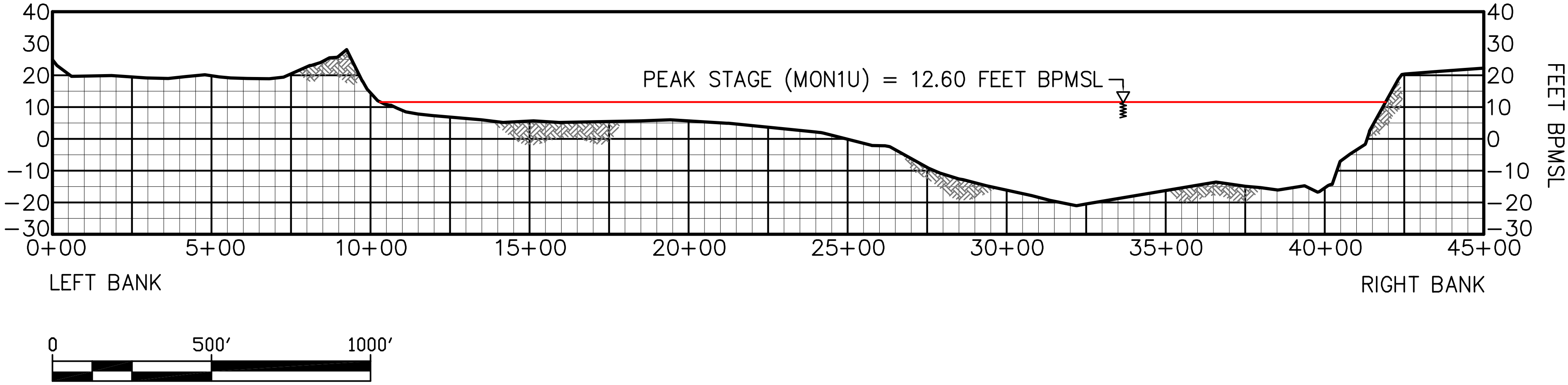
DATE:	10/16/2021	PROJECT:	183660
DRAWN:	DTR	FILE:	MON1 X-SECTIONS.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273–1600
Fax: (907) 273–1699

2021 SPRING BREAKUP
MONUMENT 1 CENTERLINE
PROFILE

(SHEET 3 OF 4)

NOTES
1. BASIS OF ELEVATION, MONUMENT 1.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY UMIAQ (KUUKPIK/LCMF INC.)



1U COLVILLE RIVER AT MON1 UPSTREAM CROSS-SECTION

ConocoPhillips Alaska, Inc.

DATE:	10/16/2021	PROJECT:	183660
DRAWN:	DTR	FILE:	MON1 X-SECTIONS.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP
MONUMENT 1 UPSTREAM
PROFILE

NUMBER
(SHEET 4 OF 4)

1) PEAK DISCHARGE DATA

Peak discharge at MON9 was calculated using the Normal Depth method. The energy grade-line was approximated by the water surface slope between MON9 and MON9D. Manning's n roughness values used were 0.021 for the low flow channel and 0.023 for the main channel.

2) PLAN & PROFILE

Michael Baker
INTERNATIONAL
Michael Baker International, Inc.
3900 C Street, Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

Feet
0 1,000 2,000

Gage Location	Pipeline
Flow Direction	Facility
Cross Section Alignment	

Imagery from CPAI 2019

ConocoPhillips
Alaska

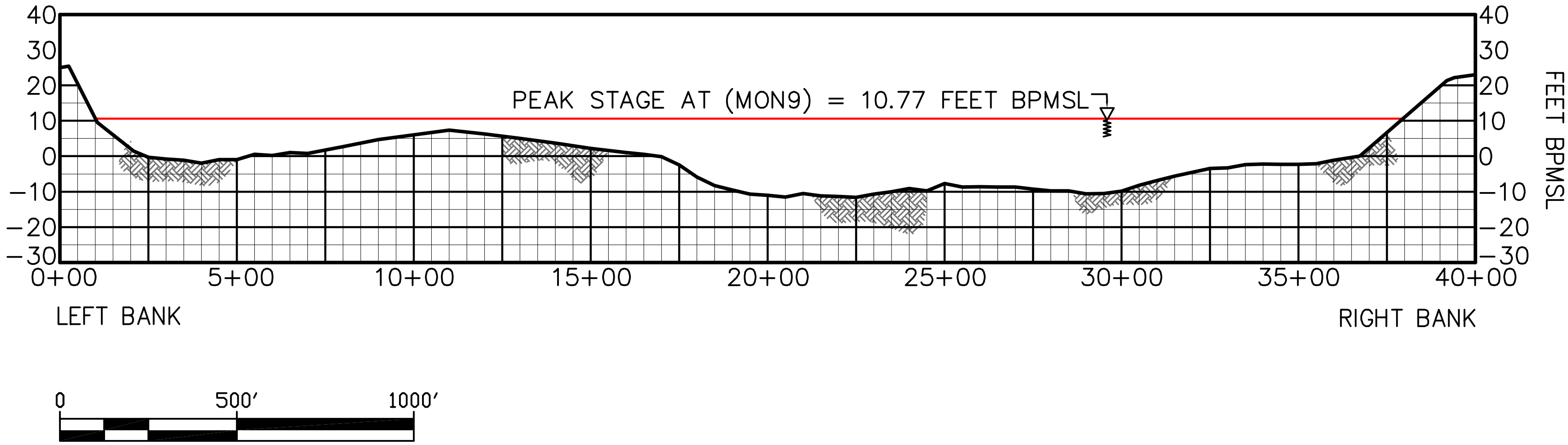
2021 SPRING BREAKUP
COLVILLE RIVER DELTA

MON9 & HDD Plan View

Date:	9/27/2021	Scale:	1 Inch = 1,000 feet
Drawn:	JEM	Project:	183660
Checked:	GCY	File:	Mon9.mxd

FIGURE C.2.2 | Sheet 1 of 2

NOTES
1. BASIS OF ELEVATION, MONUMENT 9.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED NOVEMBER 2009 BY UMIAQ (KUUKPIK/LCMF INC.)



1 COLVILLE EAST CHANNEL AT MON9 CROSS–SECTION

ConocoPhillips Alaska, Inc.

DATE:	10/16/2021	PROJECT:	183660
DRAWN:	DTR	FILE:	MON9 X-SECTION.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273–1600
Fax: (907) 273–1699

2021 SPRING BREAKUP
MONUMENT 9 / HDD
PROFILE

(SHEET 2 OF 2)

C.2.3 NIGLIQ BRIDGE

1) MEASURED DISCHARGE

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Date: June 8, 2021
Computed By: SAO
Checked By: HLR

Location Name: Nigliq Bridge

Party: KDB, NBS Start: 9:35 AM Finish: 12:05 PM

Temp: 32 °F Weather: OVERCAST 15-20 MPH WINDS

Channel Characteristics:

Width: 1545 ft Area: 16246 sq ft Velocity: 1.7 fps Discharge: 28220 cfs

Method: Mid-section technique Number of Sections: 25 Count: varies

Spin Test: OK minutes after OK minutes Meter: Price AA

GAGE READINGS			
Gage	Start	Finish	Change

Meter: 0.9 ft above bottom of weight

Weight: 50 lbs

Wading **Cable** Ice Boat

Upstream or Downstream side of bridge

GPS Data:
Left Edge of Water: West bridge abutment
Right Edge of Water: East bridge abutment

LE Floodplain: ° ' . "
RE Floodplain: ° ' . "

Measurement Rated: Excellent Good Fair Poor based on "Descriptions"

Descriptions:

Cross Section:

Flow:

Remarks:

Nigliq Bridge
June 8, 2021

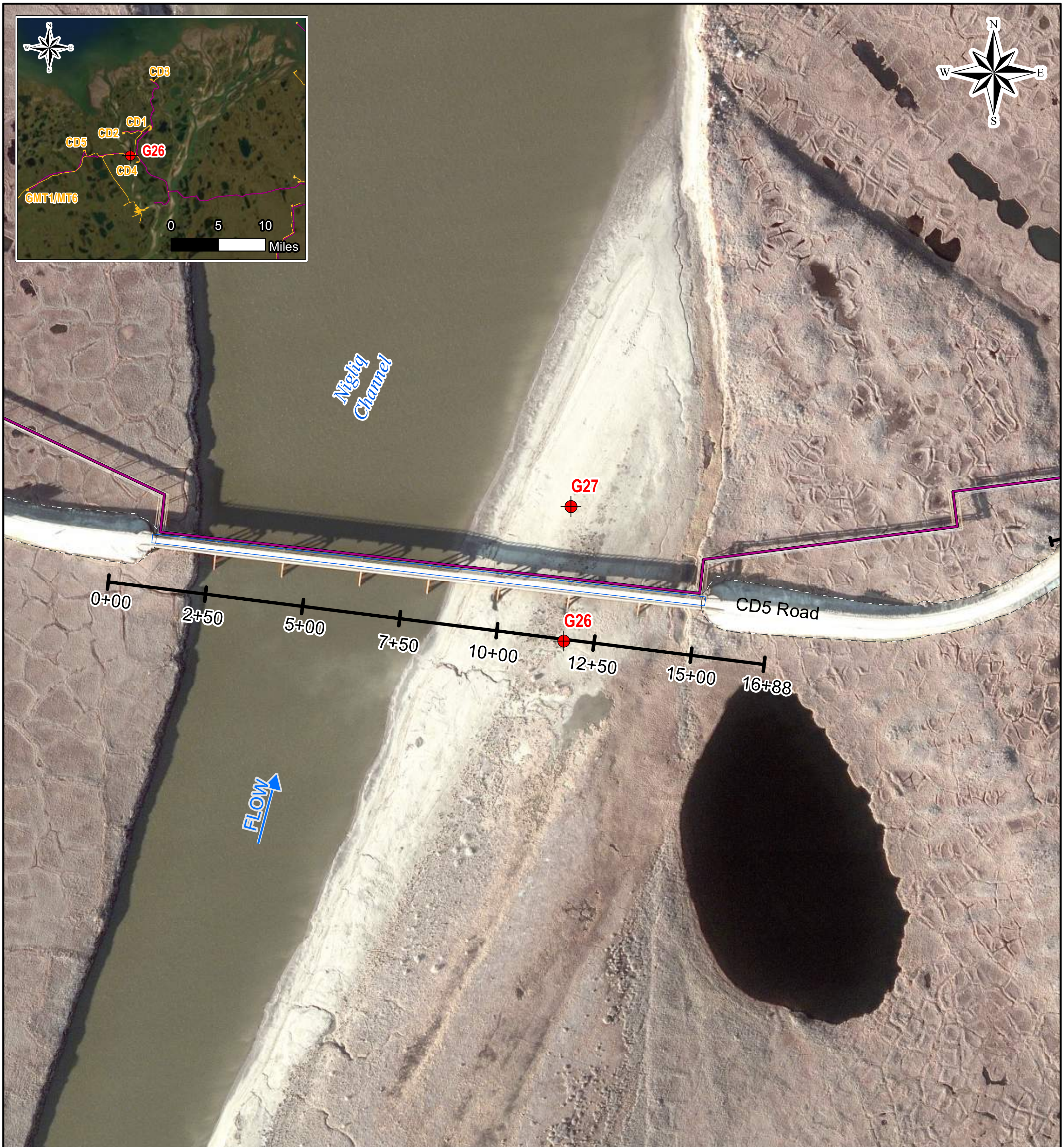
Angle Coeff	Distance from Initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
-	0	-	No flow between 0 and 100 ft, LEW @ 100 ft								
-	100	112.5									
1	125	25.0	8.9	7.1 1.8	25 25	46 48	1.2 1.2	1.2	1.2	223	265
1	150	25.0	23.4	18.7 4.7	25 40	44 42	1.3 2.1	1.7	1.7	585	991
1	175	25.0	26.4	21.1 5.3	50 50	55 47	2.0 2.4	2.2	2.2	660	1447
1	200	25.0	26.9	21.5 5.4	40 50	44 46	2.0 2.4	2.2	2.2	673	1492
1	225	25.0	27.1	21.7 5.4	40 50	42 40	2.1 2.8	2.4	2.4	678	1657
1	250	25.0	27.0	21.6 5.4	40 50	40 41	2.2 2.7	2.5	2.5	675	1664
1	275	25.0	27.0	21.6 5.4	40 60	47 48	1.9 2.8	2.3	2.3	675	1575
1	300	25.0	29.0	23.2 5.8	40 50	50 41	1.8 2.7	2.2	2.2	725	1627
1	325	25.0	28.9	23.1 5.8	40 50	46 41	1.9 2.7	2.3	2.3	723	1677
1	350	25.0	28.5	22.8 5.7	40 50	50 45	1.8 2.5	2.1	2.1	713	1514
1	375	25.0	25.1	20.1 5.0	40 50	46 42	1.9 2.6	2.3	2.3	628	1436
1	400	37.5	24.4	19.5 4.9	40 50	51 44	1.7 2.5	2.1	2.1	915	1954
1	450	50.0	24.4	19.5 4.9	40 50	50 44	1.8 2.5	2.2	2.2	1220	2626
1	500	50.0	27.2	21.8 5.4	40 50	53 48	1.7 2.3	2.0	2.0	1360	2717
1	550	62.5	31.8	25.4 6.4	30 40	45 46	1.5 1.9	1.7	1.7	1988	3401
1	625	75.0	16.0	12.8 3.2	20 30	40 47	1.1 1.4	1.3	1.3	1200	1527
0.9	700	50.0	22.4	17.9 4.5	15 5	52 57	0.7 0.2	0.4	0.4	1120	436
0.96	725	25.0	17.4	13.9 3.5	7 7	49 57	0.3 0.3	0.3	0.3	435	130
0.9	750	87.5	7.1	5.7 1.4	3 3	86 72	0.1 0.1	0.1	0.1	621	57
0.85	800	120.0	3.6	2.9 0.7	3 -	120	0.1	0.1	0.1	432	27
1	900	120.0	0.9	upstream/ineffective flow between 810 ft and 1120 ft							
1	990	135.0	0.0								
1	1170	105.0	0.0								
1	1200	65.0	0.3								
-	1250	75.0	0.4								
	1300	100.0	0.4								
-	1375	-									

Highest depth averaged velocity 2.5
Average Velocity: 1.7 Total Discharge: 28220

2) PEAK DISCHARGE DATA

Peak discharge at the Nigliq Bridge was calculated using the Normal Depth method. The channel geometry applied in the Normal Depth calculation was from Transect 10 surveyed for the *Monitoring Plan with an Adaptive Management Strategy* in August 2021 (UMIAQ 2021c). The friction slope used in the Normal Depth calculation was based on WSEs at gages G27 and G28. The channel roughness values used were calibrated from the measured discharge. Manning's n values used were 0.095 for the left overbank, 0.06 for the right overbank, and 0.034 for the main channel. Main channel roughness is relatively high to account for minor obstructions from the bridge piers and scour holes.

3) PLAN & PROFILE



Michael Baker
INTERNATIONAL

Michael Baker International, Inc.
3900 C Street, Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

Date:	9/27/2021	Scale:	1 Inch = 333.3 feet
Drawn:	JEM	Project:	183660
Checked:	GCY	File:	Nigliq.mxd

Feet
0 740

Gage Location
Flow Direction
Cross Section Alignment
Pipeline
Road Shoulder
Bridge Deck
Facility

Imagery from CPAI 2019

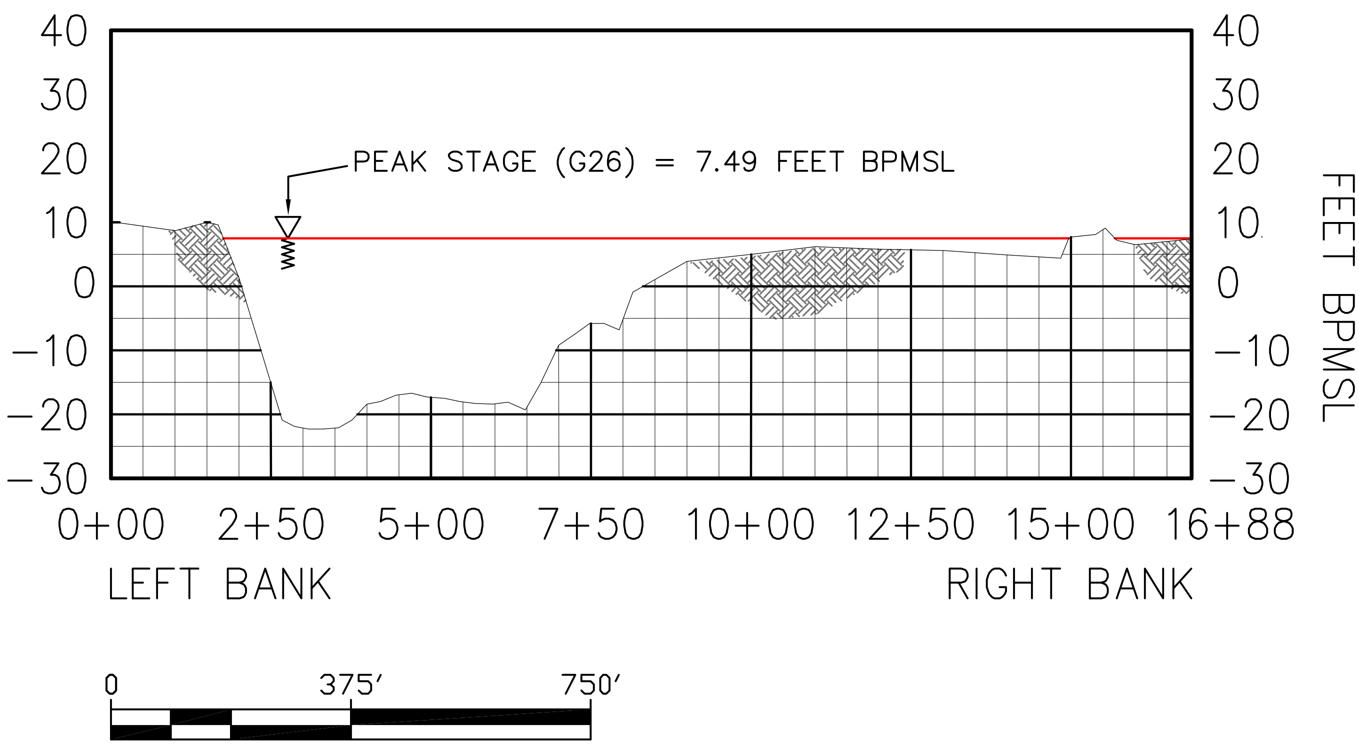
ConocoPhillips
Alaska

2021 SPRING BREAKUP
COLVILLE RIVER DELTA

Nigliq Channel Plan View

FIGURE C.2.3 | Sheet 1 of 2

NOTES
1. BASIS OF ELEVATION, MONUMENT 26.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2021 BY UMIAQ (KUUKPIK/LCMF INC.)



1 CD5 CROSSING – NIGLIQ CHANNEL CENTERLINE CROSS-SECTION
TRANSECT 10 (DOC LCMF-156 CD5 BRIDGE TRANSECTS REV9)

ConocoPhillips Alaska, Inc.

DATE:	10/16/2021	PROJECT:	183660
DRAWN:	DTR	FILE:	NIGLIQ X-SECTION.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2021 SPRING BREAKUP
NIGLIQ CHANNEL
TRANSECT 10 PROFILE

(SHEET 2 OF 2)

C.2.4 NIGLIAGVIK BRIDGE

1) MEASURED DISCHARGE

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Date: June 8, 2021
Computed By: SAO
Checked By: HLR

Location Name: Nigliagvik Bridge

Party: NBS, KDB   Start: 2:32 PM   Finish: 3:50 PM

Temp: 32 °F   Weather: Overcast 15-20 mph winds

Channel Characteristics:

Width: 188.75 ft   Area: 1012 sq ft   Velocity: 1.1 fps   Discharge: 1144 cfs

Method: Mid-section technique   Number of Sections: 25   Count: varies

Spin Test: OK minutes and OK seconds   Meter: Price AA

GAGE READINGS			
Gage	Start	Finish	Change
G38	5.68	5.50	-0.18
G39	5.66	5.48	-0.18

Meter: 0.9 ft above bottom of weight

Weight: 30 lbs

Wading **Cable** Ice Boat

Upstream or Downstream side of bridge

GPS Data:

Left Edge of Water: East bridge abutment   LE Floodplain: ° ' . "

Right Edge of Water: West bridge abutment   RE Floodplain: ° ' . "

Measurement Rated: Excellent **Good** Fair Poor based on "Descriptions"

Descriptions:

Cross Section:

Flow:

Remarks:

Nigliagvik Bridge
June 8, 2021

Angle Coeff	Distance from Initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
1	0	-	-	-	-	-	-	-	-	-	-
1	10	10.0	2.4	1.4	20	43	1.0	1.0	1.0	24.0	25.0
1	20	10.0	4.1	2.5	20	40	1.1	1.1	1.1	41.0	45.9
1	30	10.0	5.1	4.1 1.0	25 30	46 47	1.2 1.4	1.3	1.3	51.0	67.4
1	40	10.0	6.4	5.1 1.3	20 30	41 45	1.1 1.5	1.3	1.3	64.0	82.6
1	50	10.0	6.6	5.3 1.3	25 25	45 40	1.2 1.4	1.3	1.3	66.0	87.1
1	60	10.0	6.5	5.2 1.3	25 25	44 41	1.3 1.4	1.3	1.3	65.0	85.6
0.99	70	10.0	7.3	5.8 1.5	20 25	46 40	1.0 1.4	1.2	1.2	73.0	85.7
0.97	80	10.0	8.9	7.1 1.8	20 20	44 40	1.0 1.1	1.1	1.0	89.0	92.4
0.96	90	10.0	6.9	5.5 1.4	25 25	46 40	1.2 1.4	1.3	1.3	69.0	86.5
0.94	100	10.0	6.2	5.0 1.2	25 25	45 44	1.2 1.3	1.3	1.2	62.0	73.2
0.94	110	10.0	6.3	5.0 1.3	25 25	50 42	1.1 1.3	1.2	1.2	63.0	72.6
0.94	120	10.0	6.1	4.9 1.2	20 25	45 44	1.0 1.3	1.1	1.1	61.0	65.0
0.94	130	10.0	6.3	5.0 1.3	25 25	48 44	1.2 1.3	1.2	1.1	63.0	72.1
0.92	140	10.0	5.5	4.4 1.1	25 25	45 43	1.2 1.3	1.3	1.2	55.0	64.3
0.87	150	10.0	4.2	2.5	25	45	1.2	1.2	1.1	42.0	45.4
0.85	160	10.0	4.0	2.4	20	44	1.0	1.0	0.9	40.0	34.7
0.92	170	7.5	4.6	2.8	20	42	1.1	1.1	1.0	34.5	33.9
0.98	175	5.0	4.8	2.9	15	60	0.6	0.6	0.6	24.0	13.4
0.85	180	6.3	4.0	2.4	10	44	0.5	0.5	0.4	25.0	11.0
1	187.5	10.0	0.9	-	-	-	-	-	-	-	-
-	200	-	-	-	-	-	-	-	-	-	-

Total Discharge: 1144 cfs

1) PEAK DISCHARGE DATA

Peak discharge was calculated using the Normal Depth method. The channel geometry applied in the Normal Depth calculation was from Transect 27 surveyed for the *Monitoring Plan with an Adaptive Management Strategy* July 2021 (UMIAQ 2021c). The slope used in the normal depth calculation was based on WSE's at G38 and G39 PT. Manning's n roughness value used was 0.025.

2) PLAN & PROFILE

Michael Baker INTERNATIONAL

Michael Baker International, Inc.
3900 C Street, Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

Date: 9/27/2021	Scale: 1 Inch = 166.7 feet
Drawn: JEM	Project: 183660
Checked: GCY	File: Nigliagvik.mxd

Feet
0 100 200 300

- Gage Location
- Flow Direction
- Cross Section Alignment
- Pipeline
- Road Shoulder
- Bridge Deck
- Facility

Imagery from CPAI 2019

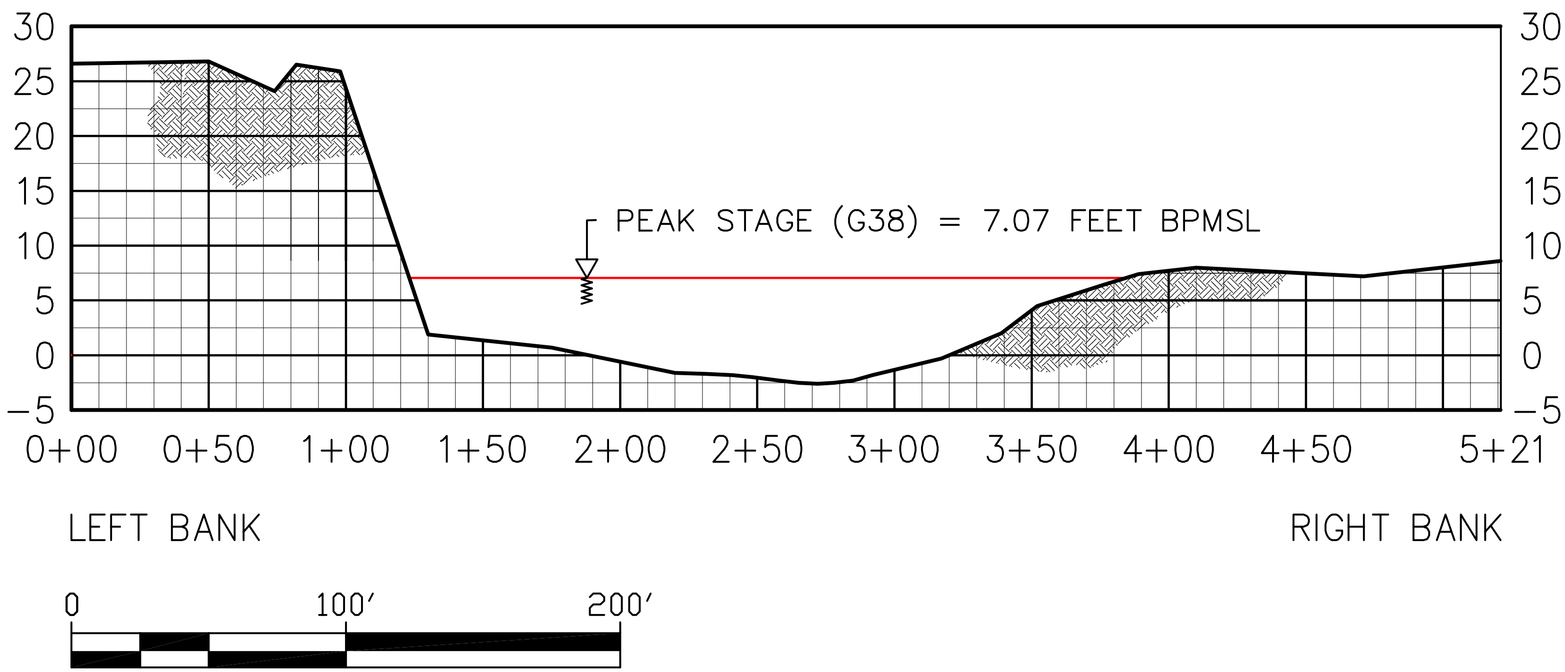
ConocoPhillips Alaska

2021 SPRING BREAKUP
COLVILLE RIVER DELTA
Nigliagvik Channel
Plan View

FIGURE C.2.4 | Sheet 1 of 2

NOTES

1. BASIS OF ELEVATION, MONUMENT 29.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2021 BY UMIAQ (KUUKPIK/LCMF INC.)



1 CD5 CROSSING – NIGLIAGVIK CENTERLINE CROSS–SECTION
TRANSECT 27 (DOC LCMF–156 CD5 BRIDGE TRANSECTS REV9)

ConocoPhillips Alaska, Inc.

DATE:	10/16/2021	PROJECT:	183660
DRAWN:	DTR	FILE:	NIGLIAGVIK X-SECTION.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Michael Baker INTERNATIONAL
Michael Baker International
3900 C Street, Suite 900
Anchorage, Alaska 99503
Phone: (907) 273–1600
Fax: (907) 273–1699

2021 SPRING BREAKUP
NIGLIAGVIK CHANNEL
TRANSECT 27 PROFILE

C.2.5 LONG SWALE BRIDGE

3) MEASURED DISCHARGE

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Date: June 7, 2021
Computed By: SAO
Checked By: HLR

Location Name: Long Swale Bridge

Party: KDB, NBS, MGW   Start: 4:00 PM   Finish: 6:30 PM

Temp: 34 °F   Weather: 20 MPH WINDS, OVERCAST

Channel Characteristics:

Width: 436.5 ft   Area: 1773 sq ft   Velocity: 1.07 fps   Discharge: 1895 cfs

Method: Mid-section technique   Number of Sections: Count:

Spin Test: 3 minutes after 40 seconds   Meter: Price AA

Meter: 0.9 ft above bottom of weight

Weight: 30 lbs

Wading **Cable** Ice Boat

Upstream or Downstream side of bridge

GAGE READINGS			
Gage	Start	Finish	Change
G3	6.09	6.09	0.00
G4	5.97	5.97	0.00

GPS Data:

Left Edge of Water:

Right Edge of Water:

LE Floodplain: ° ' . "

RE Floodplain: ° ' . "

Measurement Rated: Excellent Good **Fair** Poor based on "Descriptions"

Descriptions:

Cross Section: Bridge Opening

Flow: Ice chunks flowing unobstructed under bridge during measurement

Remarks: Scour hole filled in winter of 2021

Long Swale Bridge
June 7, 2021

Angle Coeff	Distance from Initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
1	0	-	-	-	-	-					
0.2	10	12.5	1.1	0.66	-	-	-	-	-	-	-
0.2	25	20.0	2.5	1.5	-	-	-	-	-	-	-
0.98	50	17.5	2.6	1.56	30	44	1.52	1.52	1.49	45.5	67.82
0.98	60	12.5	3.3	1.98	40	41	2.17	2.17	2.13	41.3	87.67
0.99	75	13.8	2.8	1.68	45	42	2.38	2.38	2.36	38.5	90.72
0.98	87.5	12.5	4.0	2.4	40	44	2.02	2.02	1.98	50.0	99.09
0.98	100	7.5	2.6	1.56	50	49	2.27	2.27	2.22	19.5	43.33
0.92	102.5	6.3	4.0	2.4	30	52	1.29	1.29	1.19	25.0	29.67
0.99	112.5	11.3	3.4	2.04	50	49	2.27	2.27	2.24	38.3	85.87
0.98	125	12.5	3.8	2.28	40	45	1.98	1.98	1.94	47.5	92.06
0.97	137.5	12.5	4.0	2.4	40	45	1.98	1.98	1.92	50.0	95.91
0.97	150	18.8	4.0	2.4	40	49	1.82	1.82	1.76	75.0	132.23
1	175	25.0	4.9	3.92 0.98	25 25	42 43	1.33 1.30	1.31	1.31	122.5	161.08
1	200	25.0	5.0	4 1	10 15	60 67	0.39 0.51	0.45	0.45	125.0	56.04
1	225	25.0	5.6	4.48 1.12	25 40	44 53	1.27 1.68	1.48	1.48	140.0	206.66
0.97	250	25.0	6.0	4.8 1.2	10 20	42 56	0.54 0.81	0.67	0.65	150.0	98.07
1	275	25.0	5.9	4.72 1.18	5 1	50 60	0.24 0.05	0.15	0.15	147.5	21.60
0.99	300	25.0	4.8	2.88	10	49	0.47	0.47	0.46	120.0	55.57
1	325	25.0	5.1	4.08 1.02	20 30	41 49	1.09 1.37	1.23	1.23	127.5	156.89
1	350	18.8	4.2	2.52	20	45	1.00	1.00	1.00	78.8	78.57
0.98	362.5	12.5	4.3	2.58	15	44	0.77	0.77	0.75	53.8	40.53
0.97	375	12.5	4.2	2.52	15	46	0.74	0.74	0.71	52.5	37.52
0.97	387.5	12.5	4.2	2.52	15	48	0.71	0.71	0.69	52.5	35.99
0.99	400	12.5	4.5	2.7	15	45	0.75	0.75	0.75	56.3	41.92
1	412.5	12.5	3.9	2.34	15	43	0.79	0.79	0.79	48.8	38.36
1	425	12.8	3.4	2.04	15	45	0.75	0.75	0.75	43.4	32.63
0.99	438	10.0	2.4	1.44	10	57	0.40	0.40	0.40	24.0	9.61
	445										

Total Discharge: 1895.42 cfs

C.2.6 CULVERTS

1) MEASURED DISCHARGE

Date	Time	Culvert ID	Flow Conditions	Flow Direction	Total Depth (ft)	Measured Depth (ft)	v1 (ft/s)	v2 (ft/s)	v3 (ft/s)	Upstream Gage	Upstream WSE (ft BPMSL)	Downstream Gage	Downstream WSE (ft BPMSL)	Notes
6/7/2021	15:45	CD2-23	Free Flowing	South to North	0.95	0.88	5.58	5.52	5.54	G3	6.07	G4	5.96	
6/7/2021	14:55	CD2-24	Free Flowing	South to North	1.00	0.40	5.51	5.53	5.48	G3	6.07	G4	5.96	
Note: Any culvert not listed was observed to either be stagnant or dry at the time of the discharge measurements														

APPENDIX D ADDITIONAL PHOTOGRAPHS

D.1 EROSION SURVEY

D.1.1 CD2 ROADS

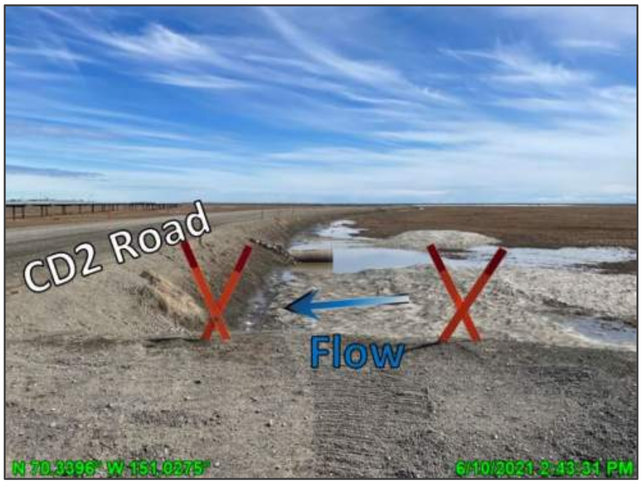


Photo D.1: CD2 road embankment in the vicinity of culvert CD2-8, looking east; June 10, 2021

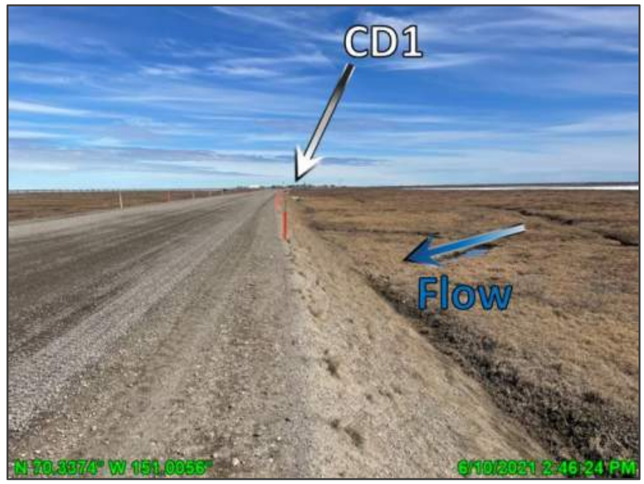


Photo D.2: CD2 road embankment in the vicinity of culvert CD2-16, looking southeast; June 10, 2021

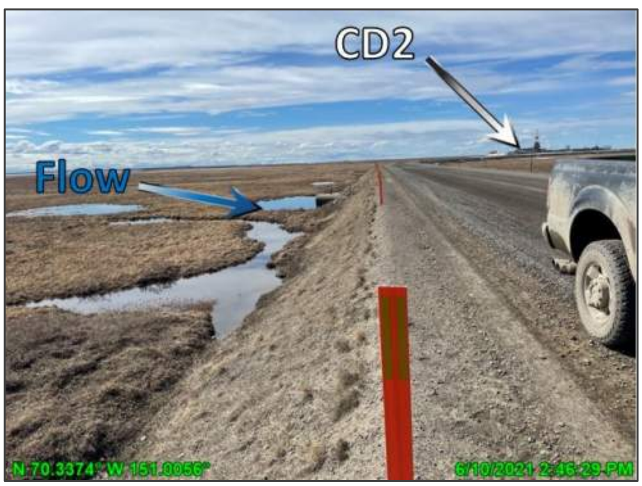


Photo D.3: CD2 road embankment in the vicinity of culvert CD2-16, looking northwest; June 10, 2021

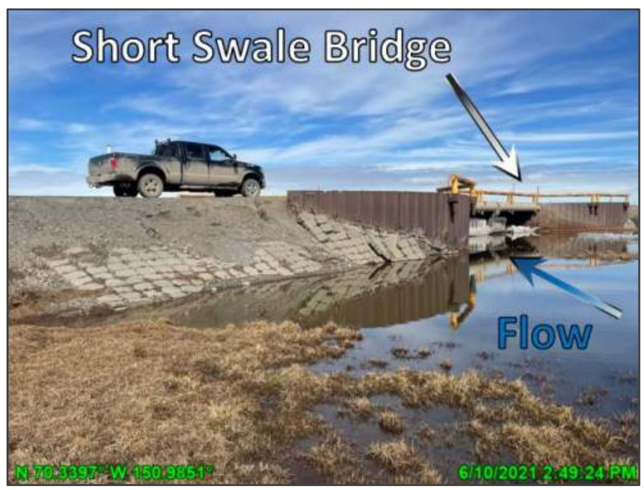


Photo D.4: CD2 road short swale bridge SW abutment, looking northeast; June 10, 2021

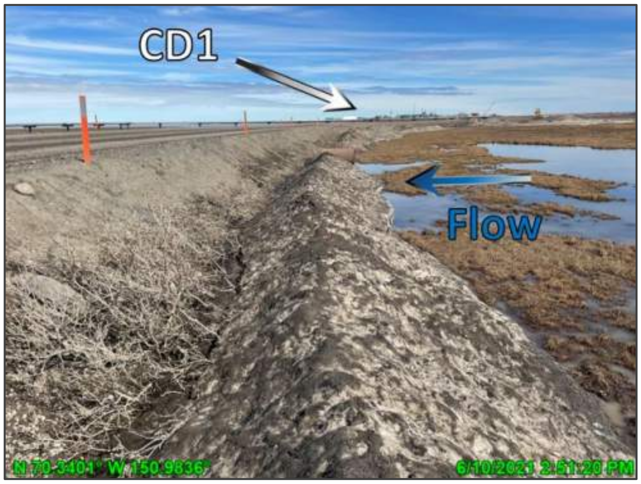


Photo D.5: CD2 road embankment in between the long swale and short swale bridge post-breakup, looking southeast; June 10, 2021

Photo D.6: CD2 road embankment in between the long swale and short swale bridge post-breakup, looking east; June 10, 2021

Photo D.7: Road in vicinity of culvert CD2-23 post-breakup, looking southeast; June 10, 2021

Photo D.8: Road in vicinity of culvert CD2-23 post-breakup, looking northwest; June 10, 2021

Photo D.9: CD2 road embankment in the vicinity of the long swale bridge, looking south east; June 10, 2021

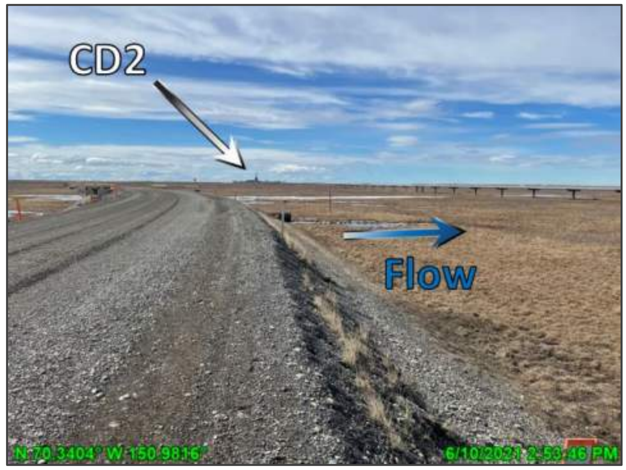


Photo D.10: CD2 road embankment in between the short and long swale bridge, looking west; June 10, 2021

Photo D.11: CD2 long swale SW abutment, looking north; June 10, 2021

Photo D.12: CD2 long swale SE abutment, looking north; June 10, 2021

D.1.2 CD4 ROADS

Photo D.13: CD4 road in vicinity of G15 culverts post-breakup, looking southwest; June 10, 2021

Photo D.14: CD4 road in vicinity of G15 culverts post-breakup, looking west; June 10, 2021

Photo D.15: CD4 road in vicinity of G15 culverts post-breakup, looking west; June 10, 2021

Photo D.16: CD4 road embankment in the vicinity of G15 post-breakup, looking north; June 10, 2021

D.1.3 CD5 ROAD

Photo D.17: Nigliagvik SW abutment post-breakup, looking north; June 9, 2021

Photo D.18: Nigliq SW abutment post-breakup, looking north; June 9, 2021

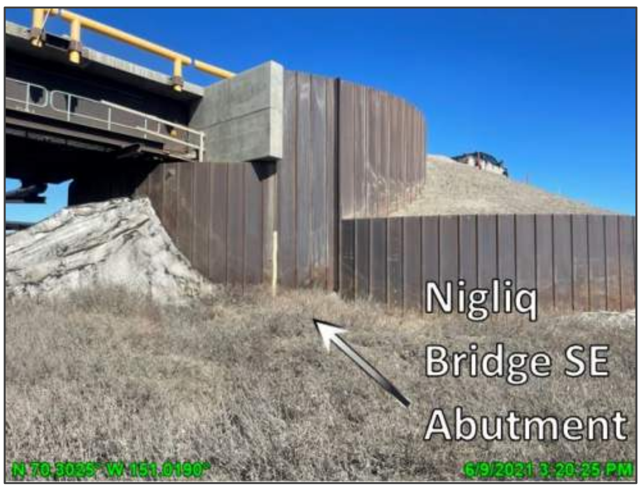


Photo D.19: Nigliq SE abutment post-breakup, looking northeast; June 9, 2021

Photo D.20: CD5 road in between Lake L9341 and Nigliq Channel post-breakup, looking south; June 14, 2021

Photo D.21: CD5 road near Nigliagvik Bridge post-breakup, looking south; June 14, 2021

Photo D.22: CD5 road west of the Nigliagvik bridge, looking southwest; June 14, 2021

Photo D.23: West bank of Nigliq Channel south of CD5 road during bank erosion survey, looking north; August 12, 2021

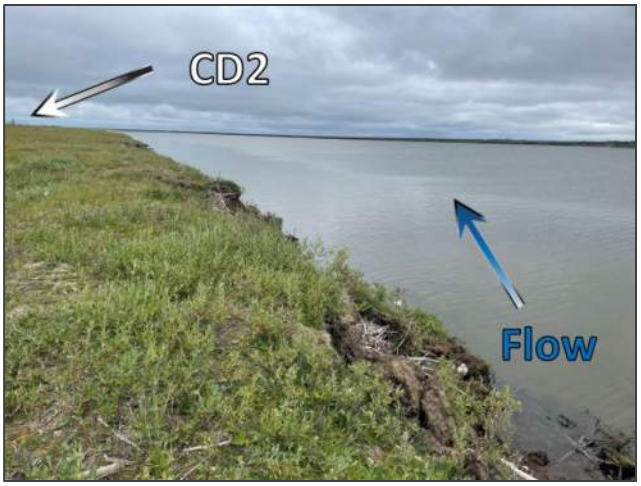


Photo D.24: West bank of Nigliq Channel north of CD5 road during fall setup, looking north; August 12, 2021

D.2 ICE ROAD CROSSINGS BREAKUP

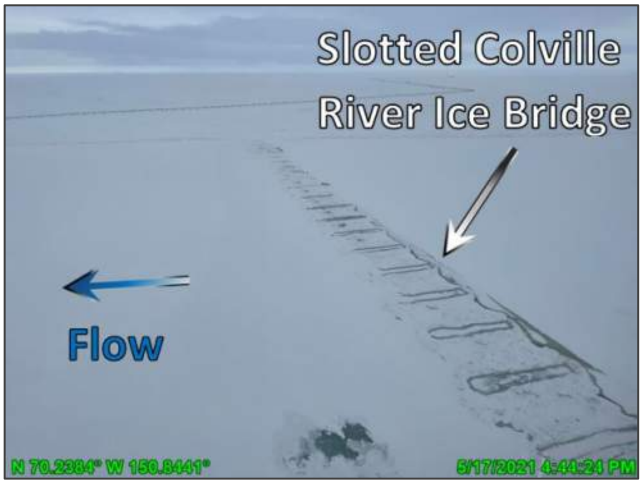


Photo D.25: Slotting through the Colville River Ice Bridge, looking east; May 17, 2021

Photo D.26: Local melt near the slotted Colville River Ice Bridge, looking northwest; May 2, 2021

Photo D.27: Meltwater progression through the slotted Colville River Ice Bridge, looking south (upstream); June 6, 2021

Photo D.28: Open channel at Colville River Ice Bridge, looking south (upstream); June 9, 2021

Photo D.29: Peak flow in Nigliq Channel heavy haul ice road, looking west; June 7, 2021

Photo D.30: Peak stage near the Nigliq Channel ice road at Lake L9323 crossing, looking northeast; June 7, 2021

Photo D.31: Pre-breakup conditions at the slotted Toolbox creek ice road crossing, looking south; May 23, 2021

Photo D.32: Peak stage near the slotted Toolbox creek ice road crossing, looking southwest; June 7, 2021

Photo D.33: Pre-breakup conditions at the slotted Kachemach ice road crossing, looking northeast; May 23, 2021

Photo D.34: Pre-breakup conditions near the slotted Kachemach ice road crossing, looking northeast (downstream); May 31, 2021

Photo D.35: Pre-breakup conditions at the slotted Silas Slough ice road crosing, looking north; May 23, 2021

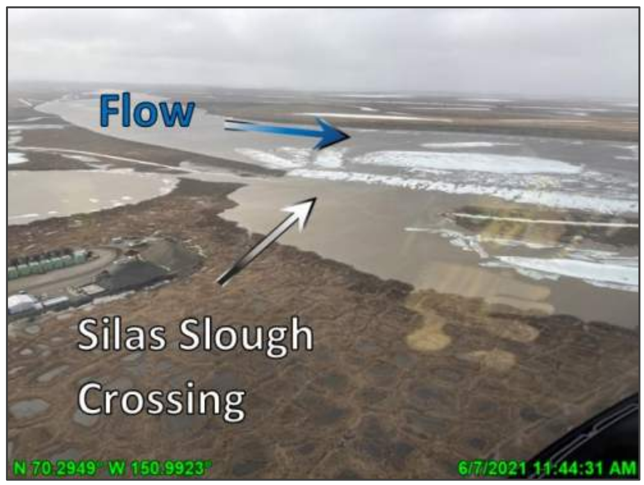


Photo D.36: Peak stage near the slotted Silas Slough ice road crossing, looking southwest; June 7, 2021

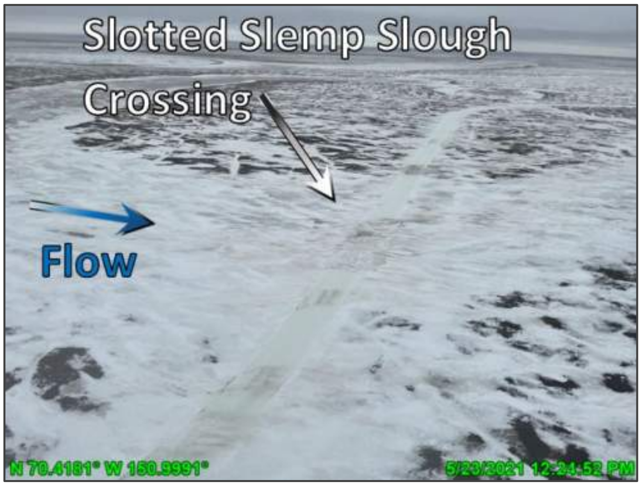


Photo D.37: Pre-breakup conditions at the slotted Slemp Slough ice road crossing, looking south; May 23, 2021

Photo D.38: Peak stage near the Slemp Slough ice road crossing, looking south; June 6, 2021

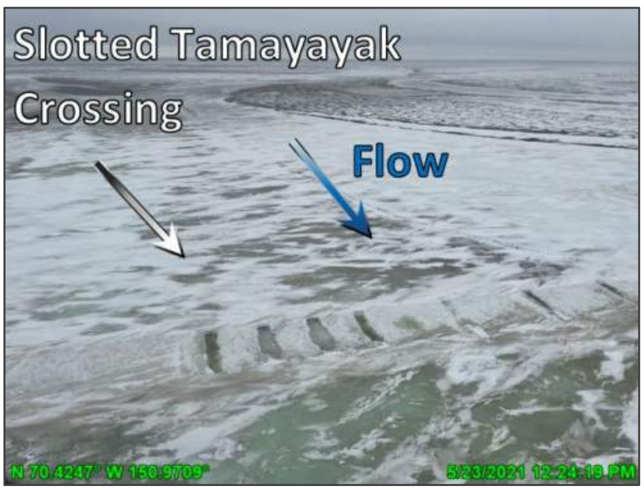


Photo D.39: Pre-breakup conditions at the slotted Tamayayak ice road crossing, looking south (upstream); May 23, 2021

Photo D.40: Peak stage near the slotted Tamayayak ice road crossing, looking east; June 6, 2021

Photo D.41: Pre-breakup conditions at the slotted Pineapple Gulch (West Ulamnigiaq Channel) ice road crossing, looking north (downstream); May 23, 2021

Photo D.42: Peak stage near the Pineapple Gulch (West Ulamnigiaq Channel) ice road crossing, looking north (downstream); June 6, 2021

Photo D.43: Pre-breakup conditions at the slotted Crea Creek ice road crossing, looking south; May 21, 2021

Photo D.44: Pre-breakup conditions at the slotted Tinmiaqsiugvik Bypass ice road crossing, looking southwest; May 23, 2021

Photo D.45: Pre-breakup conditions at the slotted Tinmiaqsiugvik Bypass ice road crossing, looking south; May 23, 2021

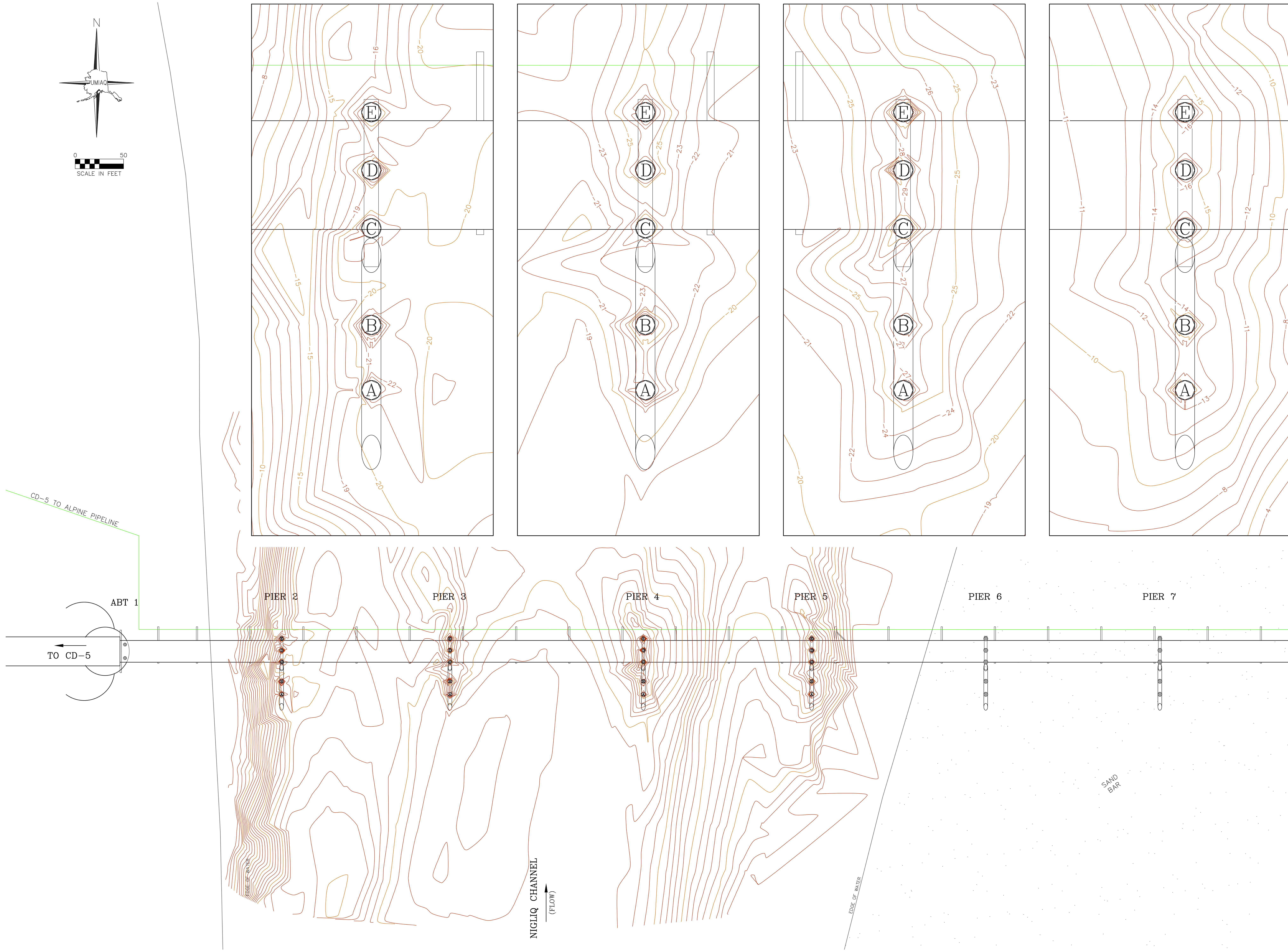
Photo D.46: Post-breakup conditions at the Tinmiaqsiugvik Bypass ice road crossing, looking northwest; June 10, 2021

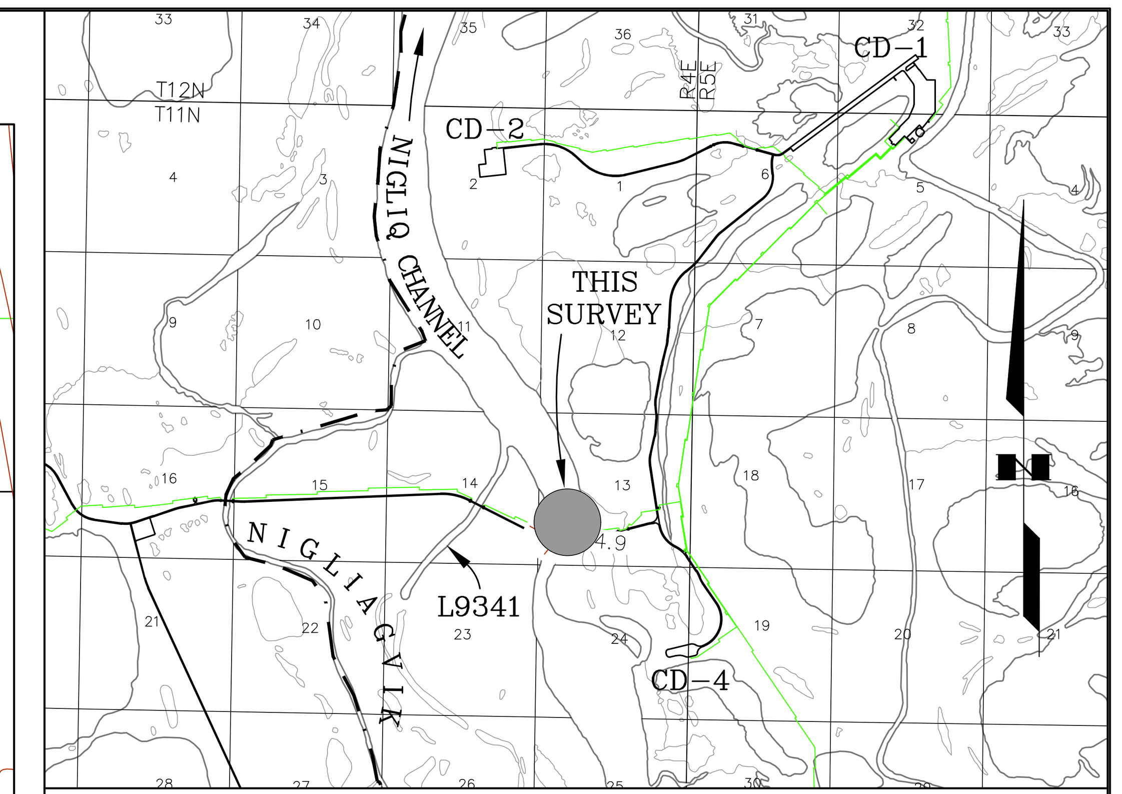
APPENDIX E CD5 PIER SCOUR, BANK EROSION, & BATHYMETRY

E.1 PIER SCOUR

E.1.1 NIGLIQ BRIDGE

JOB NO: – SUB JOB NO: – DRAWING NO: CE-CD50-1022





VICINITY MAP 1" = 1 MILE

NOTES:

1. DATES OF SURVEY: AUGUST 10 & 18, 2021
2. REFERENCE FIELD BOOK: 2021–19, PGS. 38–59; 2021–20, PG. 5
3. ELEVATIONS ARE BRITISH PETROLEUM MEAN SEAL LEVEL (B.P.M.S.L.)
4. AVERAGE WATER SURFACE ELEVATION DURING SURVEY IS 2.021'.
5. HORIZONTAL DATUM IS NAD 83 ALASKA STATE PLANE ZONE 4.

LEGEND:

—18—	1' CONTOUR
—20—	5' CONTOUR
x–15.6	SPOT ELEVATION

KUUKPIK UMIAQ
ALPINE SURVEY OFFICE
PHONE : 907-670-4739

ConocoPhillips
Alaska, Inc.

ALPINE MODULE: CD50 UNIT: CD

CD–5 ACCESS ROAD
NIGLIQ BRIDGE
SCOUR MONITORING

REDRAWN FROM: CONSTRUCTION SHEET OF

DO NOT SCALE — ABOVE SCALE FOR REFERENCE ONLY

FORM: DSIZE

DATE:	DRAWN:	DESIGN:	ECM NO:
08/23/14	CZ	GD	K140003ACS
SCALE: 1" = 50'	CHECKED: –		CC NO: –
	APPROVAL: –		CADD FILE NO. 14-08-12-1AW
JOB NO: –	SUB JOB NO: –	DRAWING NO: CE–CD50–1022	PART: 1 OF 1 REV: 8

REFERENCE DWG NO/SHT NO:

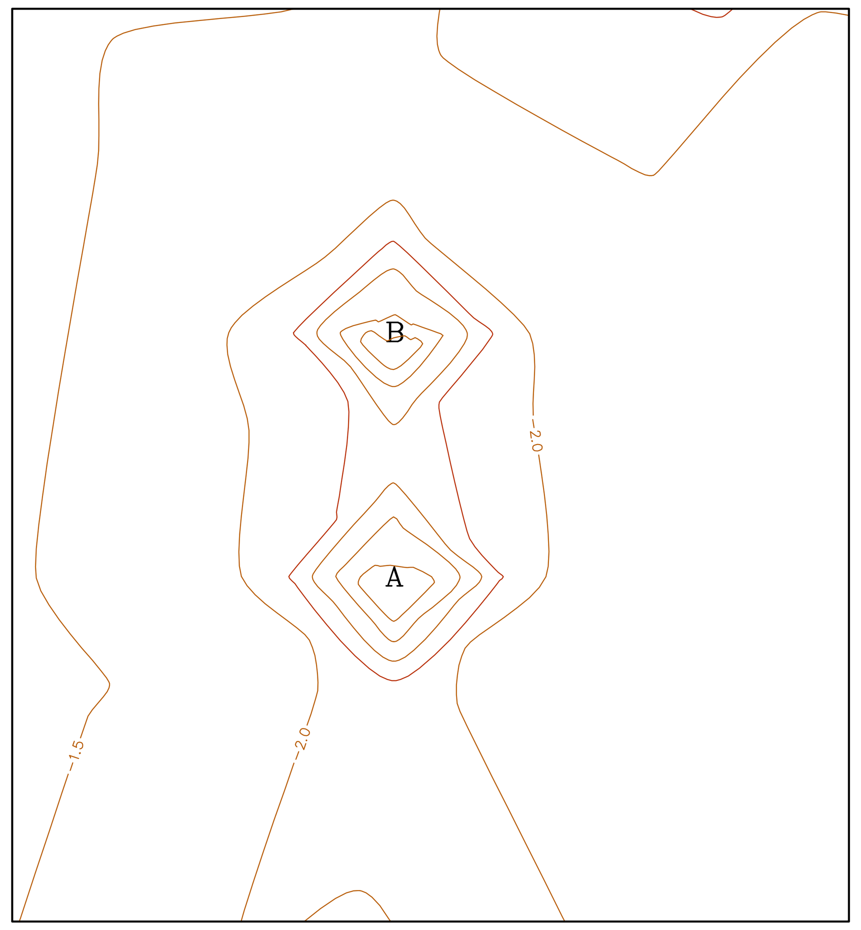
REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
8	8/19/2021	UPDATED PER K210003ACS	CS/RD	BS/RD			
7	8/31/2020	UPDATED PER K20000ACS	KR	CZ			

REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
6	08/31/19	UPDATED PER K190003ACS	SZ	CZ			
5	8/21/18	UPDATED PER K180003ACS	SZ	DB			
4	8/4/17	UPDATED PER K170003ACS	CZ	GD			
3	8/10/16	UPDATED PER K160003ACS	TRB	DB			
2	8/30/15	UPDATED PER 20968257ACS	TB	DB			
1	08/25/14	ISSUED PER K140003ACS	CZ	GD			

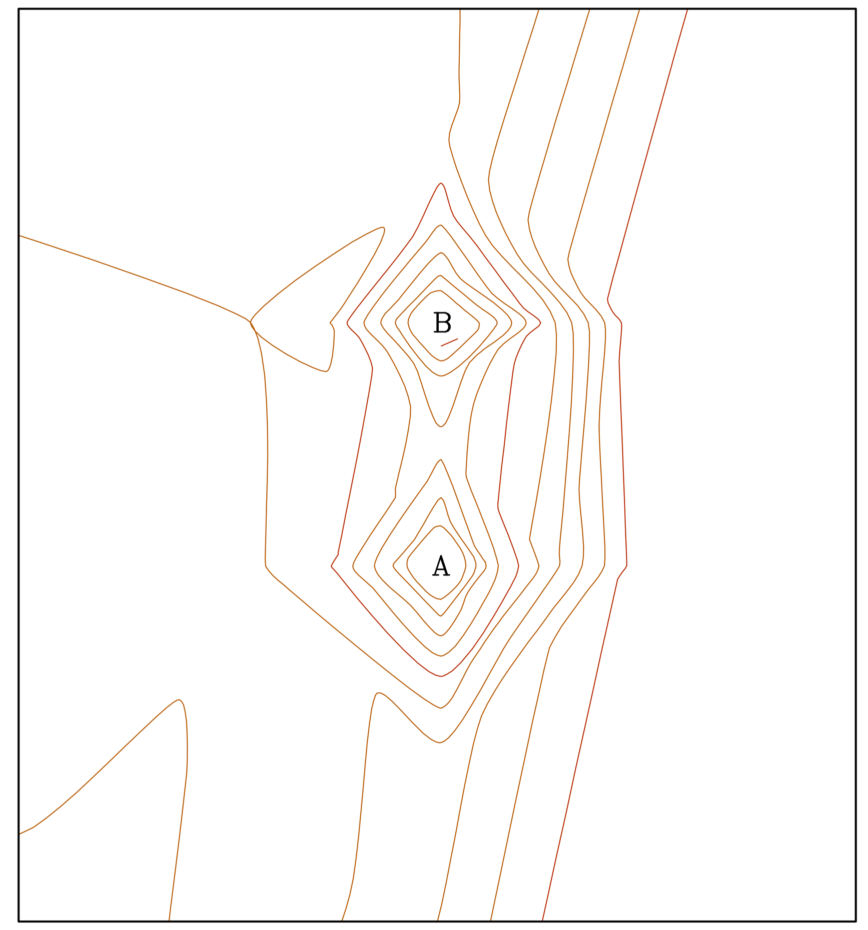
E.1.2 NIGLIAGVIK BRIDGE

JOB NO:	SUB JOB NO:	DRAWING NO:
–	–	CE–CD50–1023

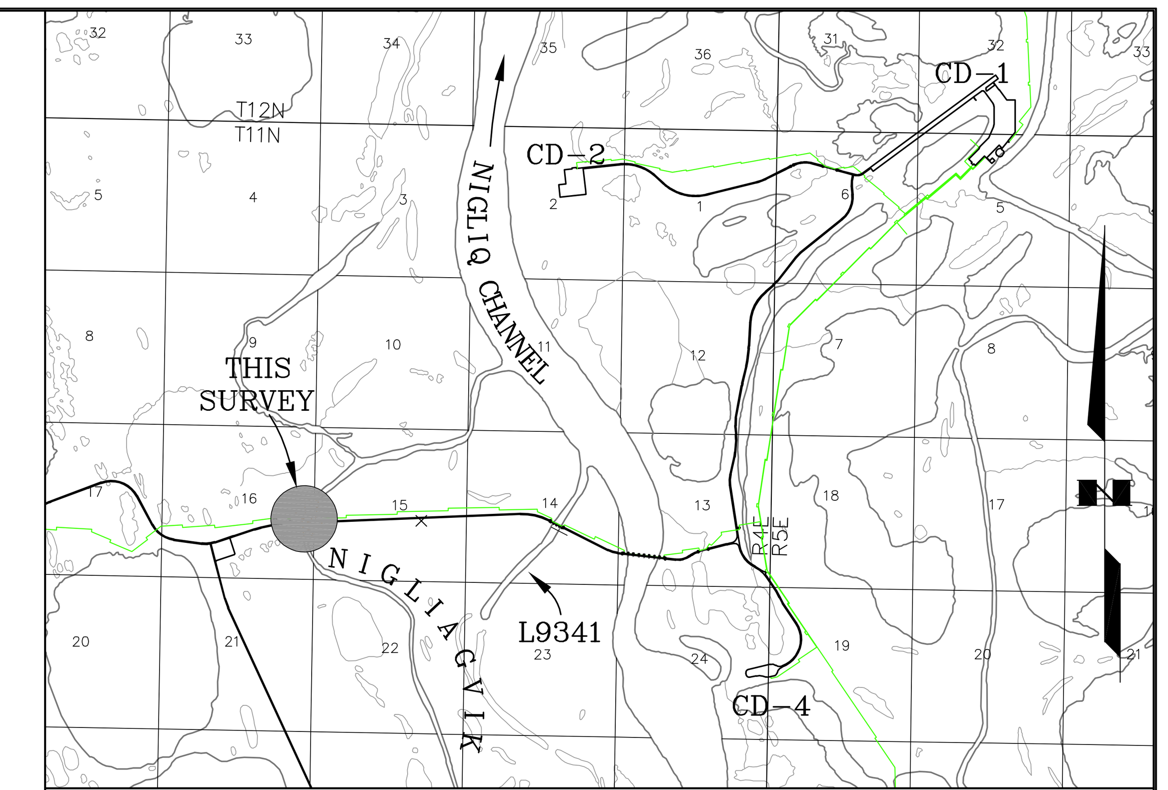
PIER 3
SCALE: 1" = 10'



PIER 4
SCALE: 1" = 10'



LEGEND:
0.5' CONTOUR
2.5' CONTOUR



VICINITY MAP

NOTES

1. DATE OF SURVEY: August 13, 2021.
2. REFERENCE FIELD BOOKS: 2021–19 PGS. 68–75
3. ELEVATIONS ARE BRITISH PETROLEUM MEAN SEAL LEVEL (B.P.M.S.L.)
4. HORIZONTAL DATUM IS NAD 83 ALASKA STATE PLANE ZONE 4.

KUUKPIK UMIAQ
ALPINE SURVEY OFFICE

ConocoPhillips Alaska, Inc.

ALPINE MODULE: CD50 UNIT: CD

CD–5 ACCESS ROAD
NIGLIAGVIK BRIDGE
SCOUR MONITORING

REDRAWN FROM:

CONSTRUCTION SHEET OF

DO NOT SCALE — ABOVE SCALE FOR REFERENCE ONLY

FORM: DSIZE

DATE:	DRAWN:	DESIGN:	ECM NO:
8/25/14	CZ	–	K140003ACS
	CHECKED: GD		CC NO: –
SCALE: 1" = 20'	APPROVAL: –		CADD FILE NO. 14–08–12–1CW
JOB NO: – / SUB JOB NO: –	DRAWING NO: CE–CD50–1023		PART: 1 OF 1 / REV: 8

REFERENCE DWG NO/SHT NO:

REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
8	8/17/2021	UPDATED PER K210003ACS	RTD	BGS			
7	8/26/20	UPDATED PER K200003ACS	KR	CZ			
6	09/03/19	UPDATED PER K190003ACS	SZ	CZ			
5	08/12/18	UPDATED PER K180003ACS	RR	CZ			
4	9/21/17	UPDATER PER K170003ACS	RR	DB			
3	7/31/16	UPDATED PER K160003ACS	CZ	DB			
2	9/8/15	UPDATED PER 20968257ACS	CZ	DB			
1	08/25/14	ISSUED PER K140003ACS	CZ	GD			

E.2 BANK EROSION

E.2.1 NIGLIQ CHANNEL WEST & EAST BANK TABULATED DATA

Calc'd By: RTD
Date: 08/14/21
Chk'd: BGS
RPT-CE-CD-112 REV11

Alpine AP00
West Bank Nigliq
Streambank Monitor

KUUKPIK UMIAQ
Doc.LCMF-155 REV11

West Bank Monitor - Top of Bank Locations
See Drawing CE-AP00-1126 Rev 8 for Survey Baseline Location

Baseline Station	8/21/2013	8/24/2014	8/27/2015	7/6/2016	8/24/2017	8/24/2018	8/13/2019	8/29/2020	8/12/2021	Description
0+00	180.2			153.6	147.0	147.0	144.6	135.1	133.1	Baseline Offset (In Feet)
				-26.6	-6.6	0.0	-2.4	-9.5	-2.0	Incremental Change
				-26.6	-33.2	-33.2	-35.6	-45.1	-47.1	Cumulative Change
1+00	191.0			168.5	168.5	164.8	155.8	148.2	143.6	Baseline Offset (In Feet)
				-22.5	0.0	-3.7	-9.0	-7.6	-4.6	Incremental Change
				-22.5	-22.5	-26.2	-35.2	-42.7	-47.4	Cumulative Change
2+00	193.1			184.4	181.6	177.7	173.1	158.2	158.0	Baseline Offset (In Feet)
				-8.7	-2.8	-3.9	-4.6	-14.9	-0.2	Incremental Change
				-8.7	-11.5	-15.4	-20.0	-34.9	-35.1	Cumulative Change
3+00	189.2			186.1	186.1	183.4	178.6	165.1	164.9	Baseline Offset (In Feet)
				-3.1	0.0	-2.7	-4.8	-13.5	-0.2	Incremental Change
				-3.1	-3.1	-5.8	-10.6	-24.1	-24.3	Cumulative Change
4+00	192.2			187.7	187.7	185.7	182.4	174.8	174.8	Baseline Offset (In Feet)
				-4.5	0.0	-2.0	-3.3	-7.6	0.0	Incremental Change
				-4.5	-4.5	-6.5	-9.8	-17.4	-17.4	Cumulative Change
4+55								174.3	172.2	Baseline Offset (In Feet)
									-2.1	Incremental Change
									-2.1	Cumulative Change
4+65								168.5	158.0	Baseline Offset (In Feet)
									-10.5	Incremental Change
									-10.5	Cumulative Change
4+75								174.8	168.6	Baseline Offset (In Feet)
									-6.2	Incremental Change
									-6.2	Cumulative Change
5+00	202.9			197.1	194.8	191.3	188.0	181.8	181.8	Baseline Offset (In Feet)
				-5.8	-2.3	-3.5	-3.3	-6.2	0.0	Incremental Change
				-5.8	-8.1	-11.6	-14.9	-21.1	-21.1	Cumulative Change
6+00	224.0			207.8	203.8	203.8	203.8	196.4	193.5	Baseline Offset (In Feet)
				-16.2	-4.0	0.0	0.0	-7.4	-2.9	Incremental Change
				-16.2	-20.2	-20.2	-20.2	-27.6	-30.5	Cumulative Change
7+00	228.9			209.3	206.0	202.7	202.7	198.7	196.8	Baseline Offset (In Feet)
				-19.6	-3.3	-3.3	0.0	-4.0	-1.9	Incremental Change
				-19.6	-22.9	-26.2	-26.2	-30.2	-32.1	Cumulative Change
8+00	232.9			219.1	215.1	212.3	212.3	208.1	204.1	Baseline Offset (In Feet)
				-13.8	-4.0	-2.8	0.0	-4.2	-4.0	Incremental Change
				-13.8	-17.8	-20.6	-20.6	-24.8	-28.8	Cumulative Change

Calc'd By: RTD
Date: 08/14/21
Chk'd: BGS
RPT-CE-CD-112 REV11

Alpine AP00
West Bank Nigliq
Streambank Monitor

KUUKPIK UMIAQ

Doc.LCMF-155 REV11

West Bank Monitor - Top of Bank Locations										
Baseline	See Drawing CE-AP00-1126 Rev 8 for Survey Baseline Location									
Station	8/21/2013	8/24/2014	8/27/2015	7/6/2016	8/24/2017	8/24/2018	8/13/2019	8/29/2020	8/12/2021	Description
9+00	220.0			217.9	217.9	217.9	219.4	211.7	209.4	Baseline Offset (In Feet)
				-2.1	0.0	0.0	1.5	-7.7	-2.3	Incremental Change
				-2.1	-2.1	-2.1	-0.6	-8.2	-10.6	Cumulative Change
10+00	216.8	216.8	213.5	213.5	213.5	210.9	209.5	209.5	207.3	Baseline Offset (In Feet)
		0.0	-3.3	0.0	0.0	-2.6	-1.4	0.0	-2.2	Incremental Change
		0.0	-3.3	-3.3	-3.3	-5.9	-7.3	-7.3	-9.5	Cumulative Change
10+67A								195.5	196.5	Baseline Offset (In Feet)
1.2									1.0	Incremental Change
									1.0	Cumulative Change
10+67B								158.9	158.9	Baseline Offset (In Feet)
9.2									0.0	Incremental Change
									0.0	Cumulative Change
10+67C								158.1	158.1	Baseline Offset (In Feet)
									0.0	Incremental Change
									0.0	Cumulative Change
10+80								189.5	189.0	Baseline Offset (In Feet)
									-0.5	Incremental Change
									-0.5	Cumulative Change
11+00	209.1	209.1	204.9	204.8	204.8	204.8	204.8	202.6	202.6	Baseline Offset (In Feet)
		0.0	-4.2	-0.1	0.0	0.0	0.0	-2.2	0.0	Incremental Change
		0.0	-4.2	-4.3	-4.3	-4.3	-4.3	-6.5	-6.5	Cumulative Change
11+30					206.1	206.1	206.1	203.7	205.7	Baseline Offset (In Feet)
						0.0	0.0	-2.4	2.0	Incremental Change
						0.0	0.0	-2.4	-0.4	Cumulative Change
11+50					206.9	206.9	206.9	204.5	205.8	Baseline Offset (In Feet)
						0.0	0.0	-2.4	1.3	Incremental Change
						0.0	0.0	-2.4	-1.1	Cumulative Change
11+70					203.8	203.8	202.6	200.7	201.6	Baseline Offset (In Feet)
						0.0	-1.2	-1.9	0.9	Incremental Change
						0.0	-1.2	-3.1	-2.2	Cumulative Change
11+90					195.7	195.7	193.2	192.8	190.4	Baseline Offset (In Feet)
						0.0	-2.5	-0.4	-2.4	Incremental Change
						0.0	-2.5	-2.9	-5.3	Cumulative Change

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Alpine AP00
West Bank Nigliq
Streambank Monitor

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Baseline	West Bank Monitor - Top of Bank Locations See Drawing CE-AP00-1126 Rev 8 for Survey Baseline Location									
Station	8/21/2013	8/24/2014	8/27/2015	7/6/2016	8/24/2017	8/24/2018	8/13/2019	8/29/2020	8/12/2021	Description
12+00	199.0	199.0	199.0	199.8	189.8	189.7	187.0	187.0	184.3	Baseline Offset (In Feet)
		0.0	0.0	0.8	-10.0	-0.1	-2.7	0.0	-2.7	Incremental Change
		0.0	0.0	0.8	-9.2	-9.3	-12.0	-12.0	-14.7	Cumulative Change
12+10					182.2	181.5	180.0	180.0	179.2	Baseline Offset (In Feet)
						-0.7	-1.5	0.0	-0.8	Incremental Change
						-0.7	-0.8	-2.2	-3.0	Cumulative Change
12+15								180.5	178.9	Baseline Offset (In Feet)
									-1.6	Incremental Change
									-1.6	Cumulative Change
12+20					187.1	183.3	183.3	183.3	181.9	Baseline Offset (In Feet)
						-3.8	0.0	0.0	-1.4	Incremental Change
						-3.8	-3.8	-3.8	-5.2	Cumulative Change
12+30					193.8	192.2	188.0	188.0	185.6	Baseline Offset (In Feet)
						-1.6	-4.2	0.0	-2.4	Incremental Change
						-1.6	-5.8	-5.8	-8.2	Cumulative Change
12+50					194.5	192.1	192.1	190.2	189.5	Baseline Offset (In Feet)
						-2.4	0.0	-1.9	-0.7	Incremental Change
						-2.4	-2.4	-4.3	-5.0	Cumulative Change
12+70								191.5	191.1	Baseline Offset (In Feet)
									-0.4	Incremental Change
									-0.4	Cumulative Change
12+87									183.3	Baseline Offset (In Feet)
										Incremental Change
										Cumulative Change
12+93									171.6	Baseline Offset (In Feet)
										Incremental Change
										Cumulative Change
12+97B									186.5	Baseline Offset (In Feet)
3.0										Incremental Change
										Cumulative Change
13+00	192.1	192.1	192.1	192.1	188.3	188.3	188.6	184.4	182.3	Baseline Offset (In Feet)
		0.0	0.0	0.0	-3.8	0.0	0.3	-4.2	-2.1	Incremental Change
		0.0	0.0	0.0	-3.8	-3.8	-3.5	-7.7	-9.8	Cumulative Change
13+35								180.0	174.6	Baseline Offset (In Feet)
									-5.4	Incremental Change
									-5.4	Cumulative Change
13+45								167.8	166.1	Baseline Offset (In Feet)
									-1.7	Incremental Change
									-1.7	Cumulative Change

Doc LCMF-155 Nigliq Streambank Monitor Rev11.xlsx 3 of 5 West Bank Monitor

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Alpine AP00
West Bank Nigliq
Streambank Monitor

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Baseline	West Bank Monitor - Top of Bank Locations See Drawing CE-AP00-1126 Rev 8 for Survey Baseline Location									
Station	8/21/2013	8/24/2014	8/27/2015	7/6/2016	8/24/2017	8/24/2018	8/13/2019	8/29/2020	8/12/2021	Description
14+00	200.9			198.8	193.7	193.7	194.4	191.5	191.5	Baseline Offset (In Feet)
				-2.1	-5.1	0.0	0.7	-2.9	0.0	Incremental Change
				-2.1	-7.2	-7.2	-6.5	-9.3	-9.4	Cumulative Change
14+80								176.1	176.3	Baseline Offset (In Feet)
									0.2	Incremental Change
									0.2	Cumulative Change
15+00	190.0			190.0	186.2	186.2	184.8	184.8	184.6	Baseline Offset (In Feet)
				0.0	-3.8	0.0	-1.4	0.0	-0.2	Incremental Change
				0.0	-3.8	-3.8	-5.2	-5.2	-5.4	Cumulative Change
15+50								200.1	199.3	Baseline Offset (In Feet)
									-0.8	Incremental Change
									-0.8	Cumulative Change
16+00	211.0			209.5	203.3	203.3	202.3	202.3	201.5	Baseline Offset (In Feet)
				-1.5	-6.2	0.0	-1.0	0.0	-0.8	Incremental Change
				-1.5	-7.7	-7.7	-8.7	-8.7	-9.5	Cumulative Change
17+00	204.0			204.0	202.9	200.6	200.8	198.7	198.1	Baseline Offset (In Feet)
				0.0	-1.1	-2.3	0.2	-2.1	-0.6	Incremental Change
				0.0	-1.1	-3.4	-3.2	-5.3	-5.9	Cumulative Change
18+00	212.0			208.3	208.3	208.3	208.6	207.3	207.3	Baseline Offset (In Feet)
				-3.7	0.0	0.0	0.3	-1.3	0.0	Incremental Change
				-3.7	-3.7	-3.7	-3.4	-4.6	-4.7	Cumulative Change
19+00	221.9			221.9	221.9	221.9	222.0	222.0	222.3	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.1	0.0	0.3	Incremental Change
				0.0	0.0	0.0	0.1	0.1	0.4	Cumulative Change
20+00	232.9			232.9	232.9	232.9	230.1	225.7	225.7	Baseline Offset (In Feet)
				0.0	0.0	0.0	-2.8	-4.4	0.0	Incremental Change
				0.0	0.0	0.0	-2.8	-7.2	-7.2	Cumulative Change

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West Bank Nigliq
Streambank Monitor

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Baseline Station	West Bank Monitor - Top of Bank Locations See Drawing CE-AP00-1126 Rev 8 for Survey Baseline Location									Description
	8/21/2013	8/24/2014	8/27/2015	7/6/2016	8/24/2017	8/24/2018	8/13/2019	8/29/2020	8/12/2021	
21+00	233.9			227.5	227.5	227.5	227.7	227.7	227.0	Baseline Offset (In Feet)
				-6.4	0.0	0.0	0.2	0.0	-0.7	Incremental Change
				-6.4	-6.4	-6.4	-6.2	-6.2	-6.9	Cumulative Change
22+00	237.8			233.3	233.3	233.3	233.4	233.4	233.7	Baseline Offset (In Feet)
				-4.5	0.0	0.0	0.1	0.0	0.3	Incremental Change
				-4.5	-4.5	-4.5	-4.4	-4.4	-4.1	Cumulative Change
23+00	237.9			233.0	233.0	233.0	233.4	233.4	232.9	Baseline Offset (In Feet)
				-4.9	0.0	0.0	0.4	0.0	-0.5	Incremental Change
				-4.9	-4.9	-4.9	-4.5	-4.5	-5.0	Cumulative Change
24+00	229.9			229.9	229.9	229.9	230.5	230.5	225.1	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.6	0.0	-5.4	Incremental Change
				0.0	0.0	0.0	0.6	0.6	-4.8	Cumulative Change
25+00	214.1			214.1	214.1	214.1	214.4	214.4	213.8	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.3	0.0	-0.6	Incremental Change
				0.0	0.0	0.0	0.3	0.3	-0.3	Cumulative Change
25+11	213.9			213.9	213.9	213.9	214.1	212.6	212.6	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.2	-1.5	0.0	Incremental Change
				0.0	0.0	0.0	0.2	-1.3	-1.3	Cumulative Change

***Note: Survey completed on 8/22/13 was used for baseline data to compute incremental /Cumulative Change. Negative numbers indicate erosion.
Staitons 10+67A, B, and C are on an angle point on the baseline. Which distorts the stationing.
10+67B is 1.2' from A and 10+67C is 9.1' from B
Station 12+97 is an angle point. 12+97B is 3.0' from station 12+97

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Alpine AP00
East Bank Nigliq
Streambank Monitor

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East Bank Monitor - Top of Bank Locations
See Drawing CE-AP00-1126 Rev 8 for Survey Baseline Location

Baseline Station	8/22/2013	8/24/2014	8/27/2015	7/6/2016	8/24/2017	8/25/2018	8/13/2019	8/28/2020	8/12/2021	Description
0+00	169.9			169.9	169.9	169.9	169.8	169.9	169.0	Baseline Offset (In Feet)
				0.0	0.0	0.0	-0.1	0.1	-0.9	Incremental Change
				0.0	0.0	0.0	-0.1	0.0	-0.9	Cumulative Change
1+00	174.0			174.0	174.0	174.0	173.9	174.0	174.3	Baseline Offset (In Feet)
				0.0	0.0	0.0	-0.1	0.1	0.3	Incremental Change
				0.0	0.0	0.0	-0.1	0.0	0.3	Cumulative Change
2+00	178.9			178.9	178.9	178.9	179.0	178.9	179.2	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.1	-0.1	0.3	Incremental Change
				0.0	0.0	0.0	0.1	0.0	0.3	Cumulative Change
3+00	191.0			191.0	191.0	191.0	191.0	191.0	191.2	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.0	0.0	0.2	Incremental Change
				0.0	0.0	0.0	0.0	0.0	0.2	Cumulative Change
4+00	188.0			188.0	188.0	188.0	188.0	188.0	188.3	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.0	0.0	0.3	Incremental Change
				0.0	0.0	0.0	0.0	0.0	0.3	Cumulative Change
5+00	196.1			196.1	196.1	196.1	196.3	196.1	196.4	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.2	-0.2	0.3	Incremental Change
				0.0	0.0	0.0	0.2	0.0	0.3	Cumulative Change
6+00	201.1			201.1	201.1	201.1	201.1	201.1	201.3	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.0	0.0	0.2	Incremental Change
				0.0	0.0	0.0	0.0	0.0	0.2	Cumulative Change
7+00	208.1			208.1	208.2	208.2	208.3	208.1	208.2	Baseline Offset (In Feet)
				0.0	0.1	0.0	0.1	-0.2	0.1	Incremental Change
				0.0	0.1	0.1	0.2	0.0	0.1	Cumulative Change
8+00	199.8			199.8	199.9	199.9	199.8	199.8	200.0	Baseline Offset (In Feet)
				0.0	0.1	0.0	-0.1	0.0	0.2	Incremental Change
				0.0	0.1	0.1	0.0	0.0	0.2	Cumulative Change
9+00	406.2			406.2	406.0	406.0	406.0	406.2	406.1	Baseline Offset (In Feet)
				0.0	-0.2	0.0	0.0	0.2	-0.1	Incremental Change
				0.0	-0.2	-0.2	-0.2	0.0	-0.1	Cumulative Change
10+00	280.9			280.7	280.6	280.6	280.7	280.7	283.4	Baseline Offset (In Feet)
				-0.2	-0.1	0.0	0.1	0.0	2.7	Incremental Change
				-0.2	-0.3	-0.3	-0.2	-0.2	2.5	Cumulative Change

Calc'd By: RTG
Date: 08/12/21
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Alpine AP00
East Bank Nigliq
Streambank Monitor

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East Bank Monitor - Top of Bank Locations
See Drawing CE-AP00-1126 Rev 8 for Survey Baseline Location

Baseline Station	8/22/2013	8/24/2014	8/27/2015	7/6/2016	8/24/2017	8/25/2018	8/13/2019	8/28/2020	8/12/2021	Description
11+00	192.2			192.0	192.0	192.0	192.1	192.0	191.7	Baseline Offset (In Feet)
				-0.2	0.0	0.0	0.1	-0.1	-0.3	Incremental Change
				-0.2	-0.2	-0.2	-0.1	-0.2	-0.5	Cumulative Change
12+00	100.1			107.9	107.6	107.6	108.1	108.1	107.2	Baseline Offset (In Feet)
				7.8	-0.3	0.0	0.5	0.0	-0.9	Incremental Change
				7.8	7.5	7.5	8.0	8.0	7.1	Cumulative Change
13+00	192.0	192.0	192.0	192.0	191.8	191.8	191.9	192.0	195.8	Baseline Offset (In Feet)
		0.0	0.0	0.0	-0.2	0.0	0.1	0.1	3.8	Incremental Change
		0.0	0.0	0.0	-0.2	-0.2	-0.1	0.0	3.8	Cumulative Change
13+84				208.0	208.0	208.0	207.7	208.1	208.1	Baseline Offset (In Feet)
					0.0	0.0	-0.3	0.4	0.0	Incremental Change
					0.0	0.0	-0.3	0.1	0.1	Cumulative Change
14+00	210.0	210.0	210.0	*Unable to	205.8	205.8	205.8	205.8	205.8	Baseline Offset (In Feet)
		0.0	0.0		-4.2	0.0	0.0	0.0	0.0	Incremental Change
		0.0	0.0		-4.2	-4.2	-4.2	-4.2	-4.2	Cumulative Change
15+00	192.0	192.0	192.0	192.0	192.0	192.0	191.9	192.0	192.0	Baseline Offset (In Feet)
		0.0	0.0	0.0	0.0	0.0	-0.1	0.1	0.0	Incremental Change
		0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	Cumulative Change
15+56	195.4			195.4	195.4	195.4	195.4	195.4	195.8	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.0	0.0	0.4	Incremental Change
				0.0	0.0	0.0	0.0	0.0	0.4	Cumulative Change

***Note: Survey completed on 8/22/13 was used for baseline data to compute Incremental/Cumulative Change.
Negative numbers indicate erosion.
Positive numbers indicate erosion Sta 9+00 to 12+00.

E.2.2 NIGLIAGVIK CHANNEL WEST & EAST BANK TABULATED DATA

Calc'd By: RTD
Date: 08/12/2021
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RPT-CE-CD-111 REV9

Alpine AP00
West Bank Nigliagvik
Streambank Monitor

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Doc.LCMF-154 REV9

Baseline Station	West Bank Monitor - Top of Bank Locations See Drawing CE-AP00-1126 Rev 9 for Survey Baseline Location									Description
	8/21/2013	8/21/2014	8/28/2015	7/6/2016	8/24/2017	8/25/2018	8/13/2019	8/26/2020	8/12/2021	Date
0+00	110.0			100.7	100.7	100.7	101.1	100.7	101.0	Baseline Offset (In Feet)
				-9.3	0.0	0.0	0.4	-0.4	0.3	Incremental Change
				-9.3	-9.3	-9.3	-8.9	-9.3	-9.0	Cumulative Change
1+00	103.0			97.9	97.9	97.9	98.2	97.9	98.1	Baseline Offset (In Feet)
				-5.1	0.0	0.0	0.3	-0.3	0.2	Incremental Change
				-5.1	-5.1	-5.1	-4.8	-5.1	-4.9	Cumulative Change
2+00	99.6			99.6	97.5	97.5	97.5	97.5	97.7	Baseline Offset (In Feet)
				0.0	-2.1	0.0	0.0	0.0	0.2	Incremental Change
				0.0	-2.1	-2.1	-2.1	-2.1	-1.9	Cumulative Change
3+00	98.8			91.3	91.3	91.3	91.4	91.3	91.6	Baseline Offset (In Feet)
				-7.5	0.0	0.0	0.1	-0.1	0.3	Incremental Change
				-7.5	-7.5	-7.5	-7.4	-7.5	-7.2	Cumulative Change
3+41									99.6	Baseline Offset (In Feet)
										Incremental Change
										Cumulative Change
3+71									88.1	Baseline Offset (In Feet)
										Incremental Change
										Cumulative Change
4+00	106.0	106.0	106.0	102.4	102.4	102.4	99.7	99.7	99.7	Baseline Offset (In Feet)
		0.0	0.0	-3.6	0.0	0.0	-2.7	0.0	0.0	Incremental Change
		0.0	0.0	-3.6	-3.6	-3.6	-6.3	-6.3	-6.3	Cumulative Change

Calc'd By: RTD
Date: 08/12/2021
Chk'd: BGS
RPT-CE-CD-111 REV9

Alpine AP00
West Bank Nigliagvik
Streambank Monitor

KUUKPIK UMIAQ
Doc.LCMF-154 REV9

Baseline Station	West Bank Monitor - Top of Bank Locations See Drawing CE-AP00-1126 Rev 9 for Survey Baseline Location									Description
	8/21/2013	8/21/2014	8/28/2015	7/6/2016	8/24/2017	8/25/2018	8/13/2019	8/26/2020	8/12/2021	Date
4+70					100.3	100.3	97.9	97.9	97.9	Baseline Offset (In Feet)
						0.0	-2.4	0.0	0.0	Incremental Change
						0.0	-2.4	-2.4	-2.4	Cumulative Change
4+75					99.9	83.4	83.6	83.6	83.9	Baseline Offset (In Feet)
						-16.5	0.2	0.0	0.3	Incremental Change
						-16.5	-16.3	-16.3	-16.0	Cumulative Change
5+00	102.0	93.5	93.5	81.1	81.1	81.1	81.1	81.1	81.4	Baseline Offset (In Feet)
		-8.4	0.0	-12.4	0.0	0.0	0.0	0.0	0.3	Incremental Change
		-8.4	-8.4	-20.9	-20.9	-20.9	-20.9	-20.9	-20.6	Cumulative Change
5+05					99.3	80.7	80.7	80.7	80.7	Baseline Offset (In Feet)
						-18.6	0.0	0.0	0.0	Incremental Change
						-18.6	-18.6	-18.6	-18.6	Cumulative Change
5+10					99.5	99.6	99.4	99.4	99.4	Baseline Offset (In Feet)
						0.1	-0.2	0.0	0.0	Incremental Change
						0.1	-0.1	-0.1	-0.1	Cumulative Change
5+44									93.2	Baseline Offset (In Feet)
										Incremental Change
										Cumulative Change
6+00	94.4	90.4	90.4	87.9	87.9	87.9	98.2	98.2	103.5	Baseline Offset (In Feet)
		-4.0	0.0	-2.5	0.0	0.0	10.3	0.0	5.3	Incremental Change
		-4.0	-4.0	-6.5	-6.5	-6.5	3.8	3.8	9.1	Cumulative Change

Doc LCMF-154 Nigliagvik Streambank Monitor Rev9.xlsx 2 of 3 West Bank Monitor

Calc'd By: RTD
Date: 08/12/2021
Chk'd: BGS
RPT-CE-CD-111 REV9

Alpine AP00
West Bank Nigliagvik
Streambank Monitor

KUUKPIK UMIAQ
Doc.LCMF-154 REV9

Baseline Station	West Bank Monitor - Top of Bank Locations See Drawing CE-AP00-1126 Rev 9 for Survey Baseline Location									Description
	8/21/2013	8/21/2014	8/28/2015	7/6/2016	8/24/2017	8/25/2018	8/13/2019	8/26/2020	8/12/2021	Date
7+00	107.1			107.1	107.1	107.1	101.5	101.5	102.9	Baseline Offset (In Feet)
				0.0	0.0	0.0	-5.6	0.0	1.4	Incremental Change
				0.0	0.0	0.0	-5.6	-5.6	-4.2	Cumulative Change
8+00	115.0			112.8	112.8	112.8	112.9	112.8	113.3	Baseline Offset (In Feet)
				-2.2	0.0	0.0	0.1	-0.1	0.5	Incremental Change
				-2.2	-2.2	-2.2	-2.1	-2.2	-1.7	Cumulative Change
9+00	96.1			91.8	91.8	91.8	92.0	91.8	92.1	Baseline Offset (In Feet)
				-4.3	0.0	0.0	0.2	-0.2	0.3	Incremental Change
				-4.3	-4.3	-4.3	-4.1	-4.3	-4.0	Cumulative Change
10+00	106.1			106.1	106.1	105.2	106.4	106.1	106.1	Baseline Offset (In Feet)
				0.0	0.0	-0.9	1.2	-0.3	0.0	Incremental Change
				0.0	0.0	-0.9	0.3	0.0	0.0	Cumulative Change
10+28	112.0			112.0	112.0	107.8	107.8	107.8	107.7	Baseline Offset (In Feet)
				0.0	0.0	-4.2	0.0	0.0	-0.1	Incremental Change
				0.0	0.0	-4.2	-4.2	-4.2	-4.3	Cumulative Change

Notes:

Calc'd By: RTD
Date: 08/12/2021
Chk'd: BGS
RPT-CE-CD-111 REV9

Alpine AP00
East Bank Nigliagvik
Streambank Monitor

KUUKPIK UMIAQ
Doc.LCMF-154 REV9

Baseline Station	East Bank Monitor - Top of Bank Locations See Drawing CE-AP00-1126 Rev 8 for Survey Baseline Location									Description
	8/21/2013	8/21/2014	8/28/2015	7/6/2016	8/24/2017	8/24/2018	8/13/2019	8/26/2020	8/12/2021	Date
0+00	165.1			165.1	165.3	165.3	165.4	165.3	165.3	Baseline Offset (In Feet)
				0.0	0.2	0.0	0.1	-0.1	0.0	Incremental Change
				0.0	0.2	0.2	0.3	0.2	0.2	Cumulative Change
1+00	185.0			185.0	185.0	185.0	185.0	185.0	185.0	Baseline Offset (In Feet)
				0.0	0.0	0.0	0.0	0.0	0.0	Incremental Change
				0.0	0.0	0.0	0.0	0.0	0.0	Cumulative Change
2+00	165.0			165.0	165.1	165.1	165.0	165.0	165.2	Baseline Offset (In Feet)
				0.0	0.1	0.0	-0.1	0.0	0.2	Incremental Change
				0.0	0.1	0.1	0.0	0.0	0.2	Cumulative Change
3+00	162.3			162.3	162.2	162.2	162.4	162.3	162.3	Baseline Offset (In Feet)
				0.0	-0.1	0.0	0.2	-0.1	0.0	Incremental Change
				0.0	-0.1	-0.1	0.1	0.0	0.0	Cumulative Change
4+00	154.9	154.9	154.9	147.6	147.6	147.6	147.7	147.6	147.5	Baseline Offset (In Feet)
		0.0	0.0	-7.3	0.0	0.0	0.1	-0.1	-0.1	Incremental Change
		0.0	0.0	-7.3	-7.3	-7.3	-7.2	-7.3	-7.4	Cumulative Change
5+00	141.0	141.0	138.4	Under	143.7	143.7	143.7	143.7	140.6	Baseline Offset (In Feet)
		0.0	-2.7	Bridge	5.3	0.0	0.0	0.0	-3.1	Incremental Change
		0.0	-2.7		2.7	2.7	2.7	2.7	-0.4	Cumulative Change
5+23				143.2	141.9	141.9	141.7	143.2	143.2	Baseline Offset (In Feet)
					-1.3	0.0	-0.2	1.5	0.0	Incremental Change
					-1.3	-1.3	-1.5	0.0	0.0	Cumulative Change

Calc/d By: RTD
Date: 08/12/2021
Chk'd: BGS
RPT-CE-CD-111 REV9

Alpine AP00
East Bank Nigliagvik
Streambank Monitor

KUUKPIK UMIAQ
Doc.LCMF-154 REV9

Baseline Station	East Bank Monitor - Top of Bank Locations See Drawing CE-AP00-1126 Rev 8 for Survey Baseline Location									Description
	8/21/2013	8/21/2014	8/28/2015	7/6/2016	8/24/2017	8/24/2018	8/13/2019	8/26/2020	8/12/2021	Date
6+00	120.9	120.9	120.9	120.9	121.1	121.1	121.0	120.9	121.1	Baseline Offset (In Feet)
		0.0	0.0	0.0	0.2	0.0	-0.1	-0.1	0.2	Incremental Change
		0.0	0.0	0.0	0.2	0.2	0.1	0.0	0.2	Cumulative Change
7+00	119.0			119.0	119.5	119.5	119.3	119.5	119.5	Baseline Offset (In Feet)
				0.0	0.5	0.0	-0.2	0.2	0.0	Incremental Change
				0.0	0.5	0.5	0.3	0.5	0.5	Cumulative Change
8+00	120.9			120.9	121.3	121.3	121.2	121.3	121.3	Baseline Offset (In Feet)
				0.0	0.4	0.0	-0.1	0.1	0.0	Incremental Change
				0.0	0.4	0.4	0.3	0.4	0.4	Cumulative Change
8+91	115.7			115.7	116.1	116.1	116.0	116.1	116.1	Baseline Offset (In Feet)
				0.0	0.4	0.0	-0.1	0.1	0.0	Incremental Change
				0.0	0.4	0.4	0.3	0.4	0.4	Cumulative Change

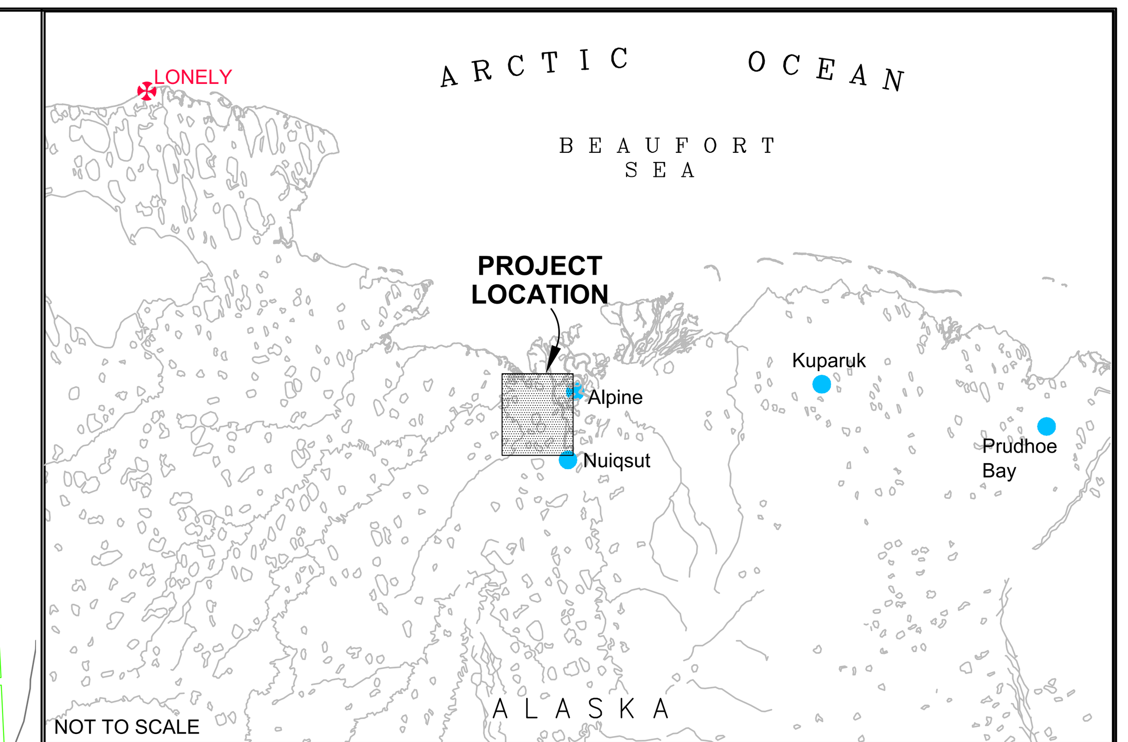
***Note: Survey completed on 8/21/13 was used for baseline data to compute Incremental/Cumulative Change. Negative numbers indicate eros

***Note: Based on field evaluations and review of aerial imagery, the 2013 top of bank point at station 3+00 along the east bank is considered a misrepresentation of the bank at the time of survey. There is no visible erosion at this location and the 2013 top of bank was repositioned to align with the 2016 top of bank.

E.3 BATHYMETRY

E.3.1 TRANSECT PROFILES

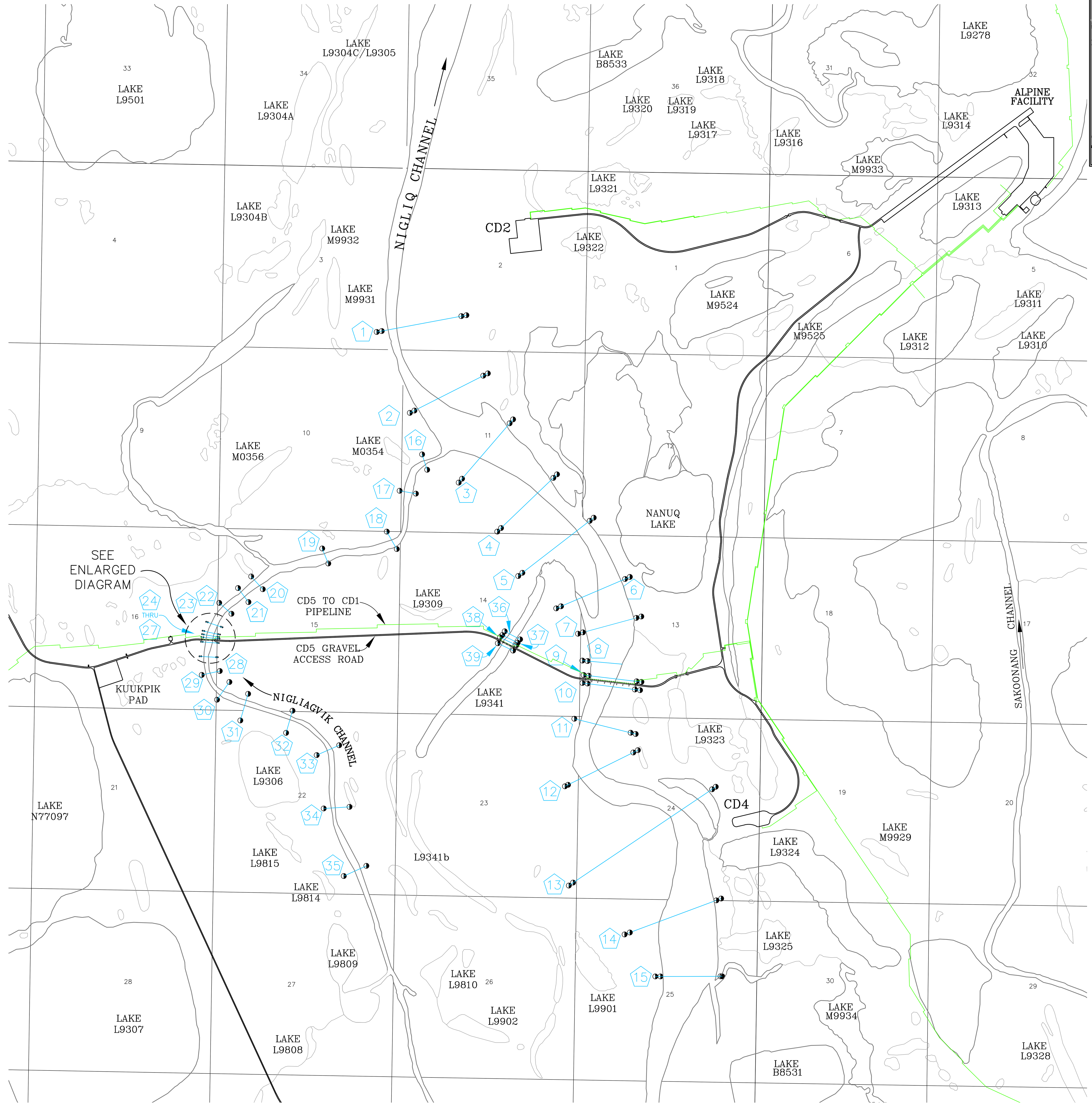
JOB NO.	SUB JOB NO.	DRAWING NO.
02-204	–	CE-CD50-1004

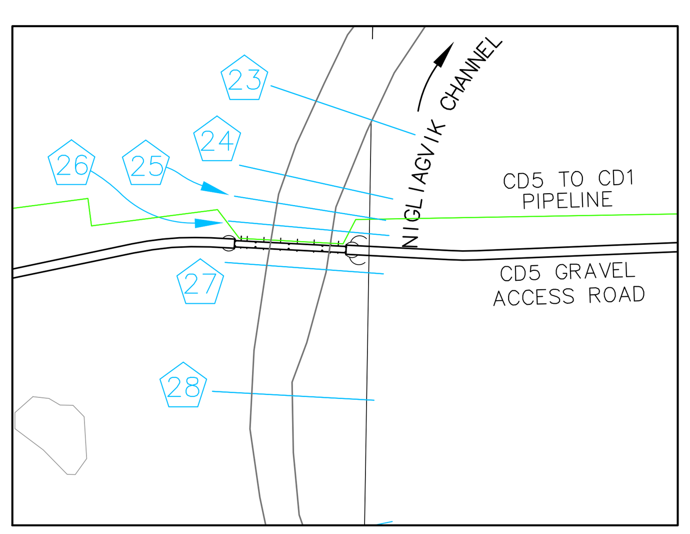


VICINITY MAP

CD5 2017 TRANSECT CONTROL

NORTHING	EASTING	ELEV	DESCRIPTION	NORTHING	EASTING	ELEV	DESCRIPTION
5,971,410.079	1,507,156.531	8.39	01-LB200 Al Cap Flush	5,963,972.572	1,503,814.158	7.59	20-RB50 Al Cap Flush
5,971,437.609	1,507,304.061	8.37	01-LB50 Al Cap Flush	5,963,970.131	1,503,127.991	24.55	21-LB100 Al Cap Flush
5,971,895.666	1,509,763.389	9.13	01-RB200 Al Cap Flush	5,963,929.997	1,503,157.807	20.75	21-LB50 Al Cap Flush
5,971,868.384	1,509,615.796	9.28	01-RB50 Al Cap Flush	5,963,562.385	1,503,430.606	8.83	21-RB100 Al Cap Flush
5,969,060.212	1,508,119.663	8.87	02-LB200 Al Cap Flush	5,963,602.552	1,503,400.707	9.12	21-RB50 Al Cap Flush
5,969,127.986	1,508,253.629	7.65	02-LB50 Al Cap Flush	5,963,540.635	1,502,578.236	26.09	22-LB110 Al Cap Flush
5,970,206.007	1,510,386.350	9.26	02-RB200 Al Cap Flush	5,963,500.929	1,502,623.041	24.05	22-LB50 Al Cap Flush
5,970,138.188	1,510,252.432	8.96	02-RB50 Al Cap Flush	5,963,224.550	1,502,936.061	8.70	22-RB100 Al Cap Flush
5,967,032.227	1,509,538.697	9.67	03-LB200 Al Cap Flush	5,963,257.784	1,502,898.581	9.16	22-RB50 Al Cap Flush
5,967,145.969	1,509,636.499	10.13	03-LB50 Al Cap Flush	5,962,989.540	1,502,198.702	25.27	23-LB100 Al Cap Flsh
5,968,868.865	1,511,117.892	9.41	03-RB200 Al Cap Flush	5,962,973.551	1,502,246.078	25.13	23-LB50 Al Cap Flush
5,968,755.138	1,511,019.833	9.05	03-RB50 Al Cap Flush	5,962,828.919	1,502,671.911	10.17	23-RB100 Al Cap Flush
5,965,610.351	1,510,661.003	12.54	04-LB200 Al Cap Flush	5,962,844.993	1,502,624.671	7.92	23-RB50 Al Cap Flush
5,965,716.677	1,510,772.064	13.71	04-LB50 Al Cap Flush	5,962,728.640	1,502,095.594	26.72	24-LB100 Al Cap Flush
5,967,272.750	1,512,396.862	10.36	04-RB200 Al Cap Flush	5,962,717.858	1,502,144.429	26.98	24-LB50 Al Cap Flush
5,967,169.020	1,512,288.517	10.23	04-RB50 Al Cap Flush	5,962,617.871	1,502,598.118	8.97	24-RB100 Al Cap Flush
5,964,321.998	1,511,269.867	11.98	05-LB200 Al Cap Flush	5,962,628.701	1,502,549.442	8.00	24-RB50 Al Cap Flush
5,964,413.665	1,511,388.462	13.14	05-LB50 Al Cap Flush	5,962,627.134	1,502,078.374	27.36	25-LB100 Al Cap Flush
5,966,013.940	1,513,463.318	8.66	05-RB200 Al Cap Flush	5,962,619.297	1,502,127.805	26.22	25-LB50 Al Cap Flush
5,965,922.233	1,513,344.473	8.66	05-RB50 Al Cap Flush	5,962,548.009	1,502,575.213	8.13	25-RB100 Al Cap Flush
5,963,381.239	1,512,373.965	11.39	06-LB200 Al Cap Flush	5,962,555.885	1,502,525.978	8.08	25-RB50 Al Cap Flush
5,963,439.930	1,512,511.976	13.14	06-LB50 Al Cap Flush	5,962,545.552	1,502,059.146	27.31	26-LB110 Al Cap Flush
5,964,291.972	1,514,511.882	9.79	06-RB250 Al Cap Flush	5,962,540.029	1,502,118.494	27.21	26-LB50 Al Cap Flush
5,964,233.822	1,514,375.381	10.19	06-RB50 Al Cap Flush	BURRIED UNDER GRAVEL			26-RB100 Al Cap Flush
5,962,644.628	1,513,005.197	10.72	07-LB200 Al Cap Flush	5,962,502.417	1,502,535.991	9.40	26-RB50 Al Cap Flush
5,962,683.997	1,513,149.917	12.36	07-LB50 Al Cap Flush	5,962,409.840	1,502,047.832	26.69	27-LB100 Al Cap Flush
5,963,144.351	1,514,844.945	10.56	07-RB200 Al Cap Flush	5,962,406.393	1,502,097.689	26.92	27-LB50 Al Cap Flush
5,963,105.246	1,514,700.397	9.90	07-RB50 Al Cap Flush	5,962,371.836	1,502,567.565	8.51	27-RB100 Al Cap Flush
5,961,864.665	1,513,132.738	10.35	08-LB200 Al Cap Flush	5,962,375.576	1,502,517.753	7.31	27-RB50 Al Cap Flush
5,961,851.284	1,513,282.157	10.12	08-LB50 Al Cap Flush	5,961,986.379	1,502,006.081	20.98	28-LB100 Al Cap Flush
5,961,442.295	1,513,168.264	10.50	09-LB200 Al Cap Flush	5,961,983.603	1,502,055.994	21.16	28-LB50 Al Cap Flush
5,961,424.719	1,513,317.431	10.08	09-LB50 Al Cap Flush	5,961,957.194	1,502,536.500	9.11	28-RB100 Al Cap Flush
5,961,244.647	1,514,849.158	9.13	09-RB200 Al Cap Flush	5,961,959.887	1,502,486.585	8.59	28-RB50 Al Cap Flush
5,961,260.962	1,514,709.975	8.19	09-RB60 Al Cap Flush	5,961,446.898	1,502,073.299	24.32	29-LB100 Al Cap Flush
5,961,214.551	1,513,133.956	10.13	10-LB200 Al Cap Flush	5,961,457.481	1,502,122.198	23.74	29-LB50 Al Cap Flush
5,961,195.621	1,513,282.771	10.00	10-LB50 Al Cap Flush	5,961,559.094	1,502,596.981	9.95	29-RB100 Al Cap Flush
5,961,004.269	1,514,808.574	7.37	10-RB200 Al Cap Flush	5,961,548.539	1,502,547.942	8.74	29-RB50 Al Cap Flush
5,961,023.112	1,514,659.873	8.10	10-RB50 Al Cap Flush	5,960,727.323	1,502,515.764	23.70	30-LB100 Al Cap Flush
5,960,173.813	1,512,898.140	10.87	11-LB200 Al Cap Flush	5,960,768.246	1,502,544.713	23.31	30-LB50 Al Cap Flush
	DESTROYED		11-LB50 Al Cap Flush	5,961,239.638	1,502,877.149	10.09	30-RB100 Al Cap Flush
5,959,731.052	1,514,682.745	9.82	11-RB200 Al Cap Flush	5,961,198.817	1,502,848.288	9.62	30-RB50 Al Cap Flush
5,959,767.242	1,514,537.080	9.00	11-RB50 Al Cap Flush	5,960,124.411	1,503,193.299	8.62	31-LB100 Al Cap Flush
5,958,209.440	1,512,625.576	11.02	12-LB200 Al Cap Flush	5,960,172.274	1,503,207.266	9.61	31-LB50 Al Cap Flush
5,958,254.040	1,512,715.127	10.92	12-LB100 Al Cap Flush	5,960,896.074	1,503,418.951	10.76	31-RB100 Al Cap Flush
5,959,260.219	1,514,746.099	9.87	12-RB200 Al Cap Flush	5,960,848.125	1,503,404.834	11.27	31-RB50 Al Cap Flush
5,959,193.533	1,514,611.494	8.71	12-RB50 Al Cap Flush	5,959,762.546	1,504,523.242	8.41	32-LB100 Al Cap Flush
5,955,329.125	1,512,738.208	11.43	13-LB200 Al Cap Flush	5,959,810.524	1,504,537.152	7.89	32-LB50 Al Cap Flush
5,955,412.750	1,512,862.609	12.06	13-LB50 Al Cap Flush	5,960,406.267	1,504,711.424	10.85	32-RB100 Al Cap Flush
5,958,195.963	1,517,009.777	10.14	13-RB200 Al Cap Flush	5,960,358.129	1,504,697.371	11.51	32-RB50 Al Cap Flush
5,958,123.467	1,516,901.811	11.55	13-RB70 Al Cap Flush	5,959,118.940	1,505,412.996	10.03	33-LB100 Al Cap Flush
5,953,908.305	1,514,359.013	13.31	14-LB215 Al Cap Flush	5,959,138.921	1,505,458.863	8.59	33-LB50 Al Cap Flush
5,953,965.587	1,514,513.819	15.69	14-LB50 Al Cap Flush	5,959,403.885	1,506,064.808	10.64	33-RB120 Al Cap Flush
5,954,950.427	1,517,166.196	9.37	14-RB200 Al Cap Flush	5,959,375.851	1,506,000.615	10.61	33-RB50 Al Cap Flush
5,954,898.227	1,517,025.567	9.62	14-RB50 Al Cap Flush	5,957,567.999	1,505,617.468	12.62	34-LB100 Al Cap Flush
5,952,688.560	1,515,253.984	13.81	15-LB200 Al Cap Flush	5,957,571.228	1,505,667.234	12.76	34-LB50 Al Cap Flush
5,952,688.785	1,515,404.124	16.65	15-LB50 Al Cap Flush	5,957,615.360	1,506,366.139	10.14	34-RB100 Al Cap Flush
5,952,691.528	1,517,195.155	12.55	15-RB100 Al Cap Flush	5,957,612.187	1,506,316.238	10.73	34-RB50 Al Cap Flush
5,952,691.504	1,517,145.172	12.62	15-RB50 Al Cap Flush	5,955,603.337	1,506,200.646	12.56	35-LB100 Al Cap Flush
5,967,852.411	1,508,476.570	9.97	16-LB100 Al Cap Flush	5,955,624.160	1,506,246.181	13.00	35-LB50 Al Cap Flush
5,967,804.830	1,508,492.228	9.22	16-LB50 Al Cap Flush	5,955,901.753	1,506,854.754	10.25	35-RB100 Al Cap Flush
5,967,407.583	1,508,622.098	9.35	16-RB100 Al Cap Flush	5,955,880.833	1,506,809.440	9.42	35-RB50 Al Cap Flush
5,967,455.156	1,508,606.495	8.81	16-RB50 Al Cap Flush	5,962,713.562	1,510,877.357	8.14	36-LB100 Al Cap Flush
5,966,795.092	1,507,822.806	8.49	17-LB100 Al Cap Flush	5,962,690.396	1,510,921.695	7.90	36-LB50 Al Cap Flush
5,966,786.414	1,507,872.068	8.36	17-LB50 Al Cap Flush	5,962,479.473	1,511,322.888	9.39	36-RB100 Al Cap Flush
5,966,712.462	1,508,294.932	8.55	17-RB100 Al Cap Flush	5,962,502.709	1,511,278.659	8.89	36-RB50 Al Cap Flush
5,966,720.904	1,508,245.574	8.57	17-RB50 Al Cap Flush	5,962,603.138	1,510,806.681	8.31	37-LB100 Al Cap Flush
5,965,609.736	1,507,451.191	8.67	18-LB100 Al Cap Flush	5,962,580.899	1,510,851.601	8.27	37-LB50 Al Cap Flush
5,965,566.246	1,507,475.943	8.64	18-LB50 Al Cap Flush	5,962,382.914	1,511,254.351	9.40	37-RB100 Al Cap Flush
5,965,103.321	1,507,739.424	7.92	18-RB100 Al Cap Flush	5,962,405.072	1,511,209.390	8.81	37-RB50 Al Cap Flush
5,965,146.872	1,507,714.623	7.65	18-RB50 Al Cap Flush	5,962,540.247	1,510,738.266	7.45	38-LB100 Al Cap Flush
5,965,119.506	1,505,573.364	8.71	19-LB100 Al Cap Flush	5,962,518.495	1,510,783.408	7.55	38-LB50 Al Cap Flush
5,965,073.146	1,505,592.274	8.72	19-LB50 Al Cap Flush	5,962,311.243	1,511,215.086	9.24	38-RB100 Al Cap Flush
5,964,684.662	1,505,750.583	8.18	19-RB100 Al Cap Flush	5,962,332.728	1,511,169.935	8.85	38-RB50 Al Cap Flush
5,964,730.844	1,505,731.763	8.59	19-RB50 Al Cap Flush	5,962,367.922	1,510,674.689	8.13	39-LB100 Al Cap Flush
5,964,307.555	1,503,508.766	13.76	20-LB100 Al Cap Flush	5,962,346.127	1,510,719.731	7.17	39-LB50 Al Cap Flush
5,964,270.636	1,503,542.458	15.57	20-LB50 Al Cap Flush	5,962,154.431	1,511,119.189	9.21	39-RB100 Al Cap Flush
5,963,935.619	1,503,847.844	7.68	20-RB100 Al Cap Flush	5,962,176.176	1,511,074.056	9.04	39-RB50 Al Cap Flush





ENLARGED DIAGRAM

NOTES:

1. DATE OF SURVEY: AUGUST 29 TO SEPTEMBER 18, 2013; OCTOBER 21, 2013; JUNE 29 TO JULY 26, 2016; JULY 26, 2017 TO AUGUST 24, 2017; AUGUST 12 TO AUGUST 19, 2018; AUGUST 19 TO AUGUST 31, 2019; AUGUST 27 TO AUGUST 30, 2020; AUGUST 11 TO AUGUST 15, 2021.
2. COORDINATES SHOWN ARE ALASKA STATE PLANE, ZONE 4 N.A.D. 83, IN FEET.
3. ELEVATIONS SHOWN ARE BRITISH PETROLEUM MEAN SEA LEVEL (B.P.M.S.L.) DATUM.
4. REFERENCE FIELD BOOK 2013–18, PGS. 57–59, 67, 70–72. 2013–20 PGS. 4–14; 2013–21, PG. 29; 2016–11, PG. 76, 2016–12, PGS. 17–20, 26–28, 36–37 & 59; 2017–13, PGS. 70–73, 2017–14, PGS. 15–17, 2017–15, PGS. 3–27; 2018–18, PG. 2–4; 2018–13, PG. 35–38; 2018–17, PG. 19–20; 2019–28, PGS. 56–67; 2019–29, PG. 43–44; 2019–34, PG.4; 2020–26, PGS 27–39; 2021–19, PGS 60, 61, 66, 67, 76; 2021–20, PGS 01

LEGEND:

◑ 2" ALUMINUM CAP ON 5/8" x 30" REBAR (TYPICAL 4 REBAR ON EACH TRANSECT)

ConocoPhillips Alaska, Inc.

ALPINE | MODULE: CD50 | UNIT: CD

CD-5 ROAD
MONITORING PLAN BASELINES
ALPINE, ALASKA

REDRAWN FROM: | CONSTRUCTION SHEET OF

1 2 3 4 5 6
DO NOT SCALE | ABOVE SCALE FOR REFERENCE ONLY

FORM: DSIZE

DATE: 8/26/13	DRAWN: CZ	DESIGN: –	ECM NO: –
SCALE: 1" = 2000'	CHECKED: DB		CC NO: –
	APPROVAL: –		CADD FILE NO. 13-08-07-1 –
JOB NO: 02-204	SUB JOB NO: –	DRAWING NO: CE-CD50-1004	PART: 1 of 6	REV: 7

REFERENCE DWG NO/SHT NO:

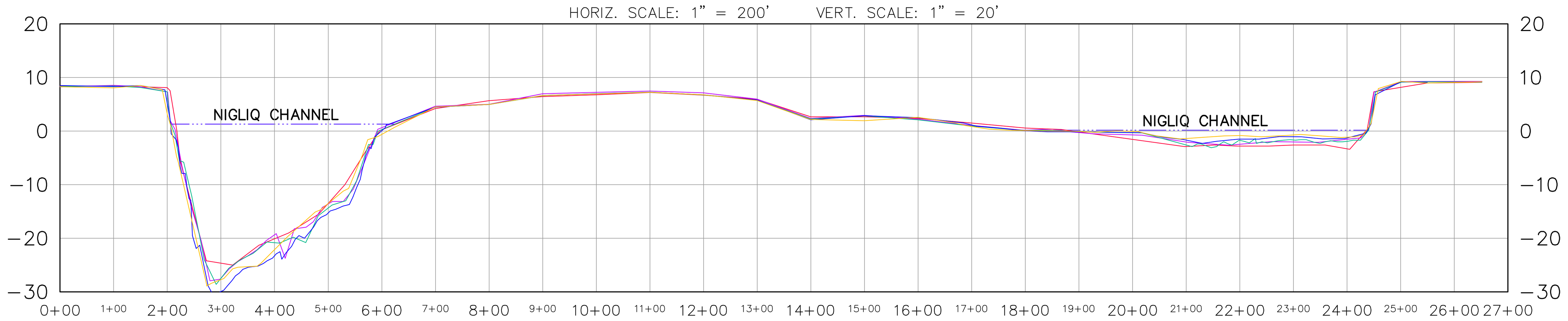
REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
7	8/20/21	UPDATE PER K210003ACS	RTD	CZ			

REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
6	08/31/20	UPDATED PER K200003ACS	CSS	CZ			
5	09/02/19	UPDATED PER K190003ACS	SZ	CZ			
4	08/20/18	UPDATED PER K180003ACS	SZ	CZ			
3	10/9/17	UPDATED PER K170003ACS	KD	CZ			
2	7/29/16	UPDATED PER K160003ACS	CZ	DB			
1	10/22/13	ISSUED PER K130003ACS	AG	DB			

JOB NO:	SUB JOB NO:	DRAWING NO:
–	–	CE-CD50-1004

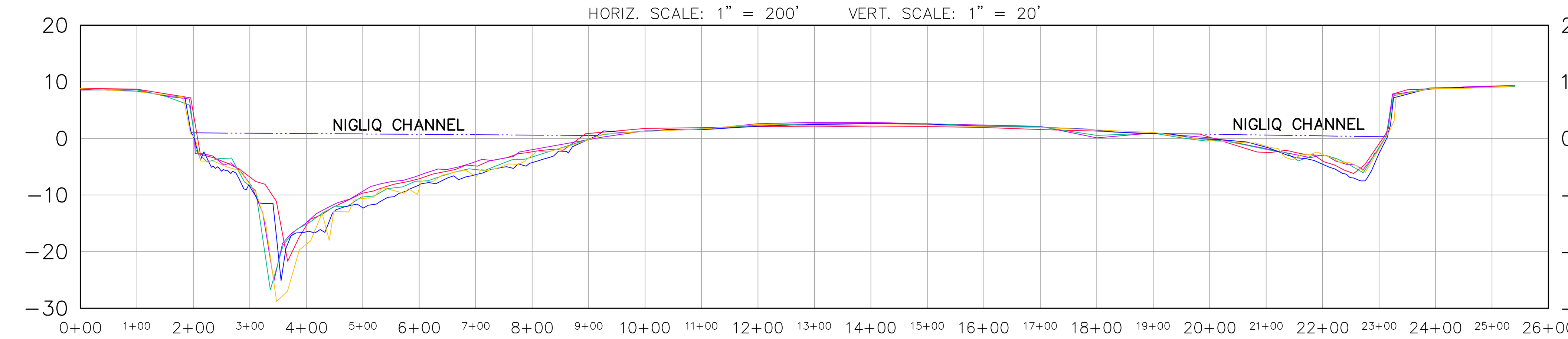
Profile View of Transect-1

HORIZ. SCALE: 1" = 200' VERT. SCALE: 1" = 20'



Profile View of Transect-2

HORIZ. SCALE: 1" = 200' VERT. SCALE: 1" = 20'

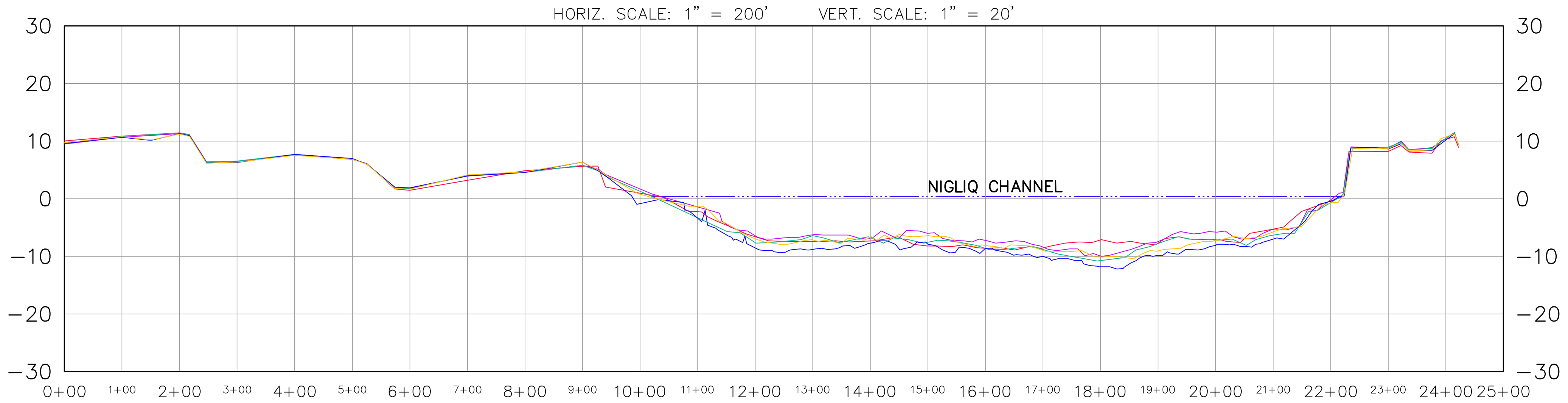


LEGEND:
VIEW LOOKING DOWNSTREAM

- 2013 TRANSECT PROFILE
- 2017 TRANSECT PROFILE
- 2018 TRANSECT PROFILE
- 2019 TRANSECT PROFILE
- 2020 TRANSECT PROFILE
- 2021 TRANSECT PROFILE

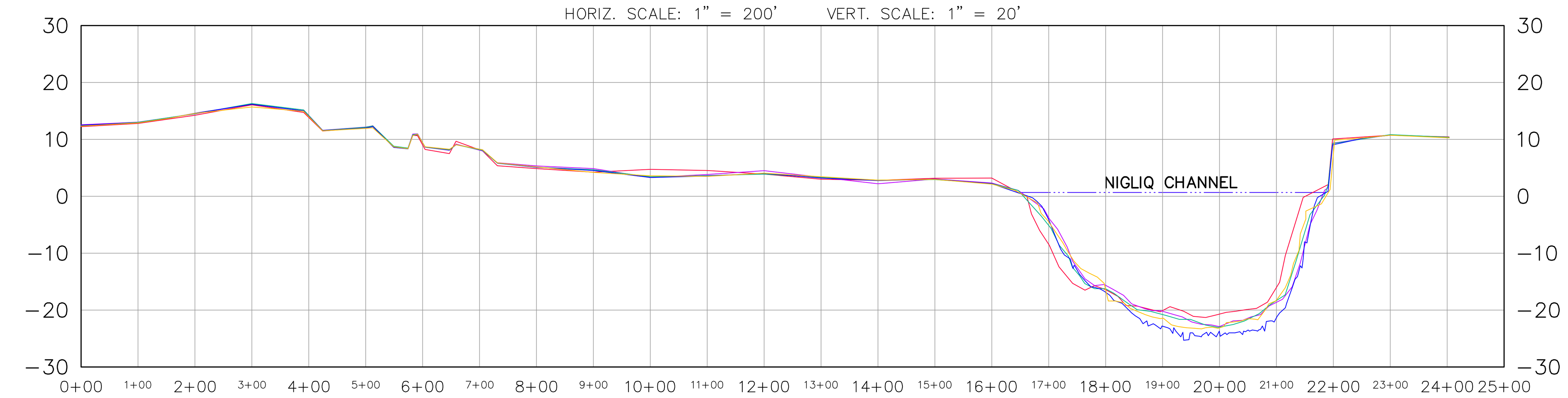
Profile View of Transect-3

HORIZ. SCALE: 1" = 200' VERT. SCALE: 1" = 20'



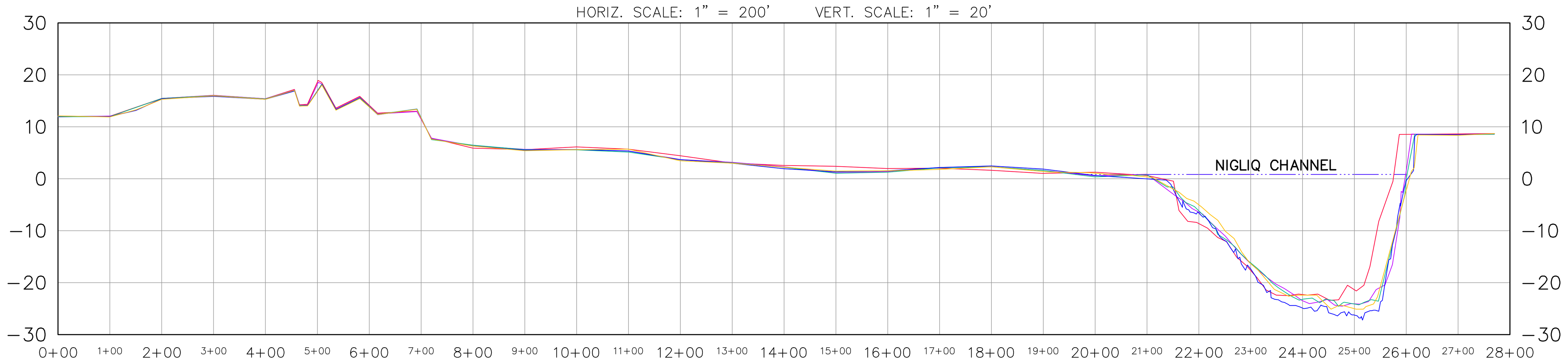
Profile View of Transect-4

HORIZ. SCALE: 1" = 200' VERT. SCALE: 1" = 20'



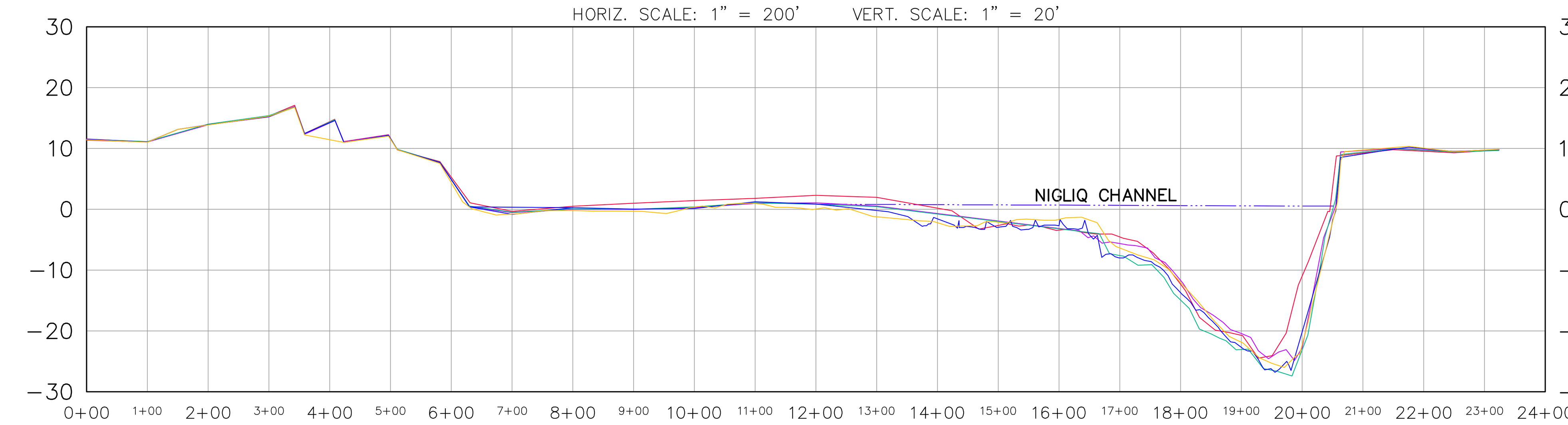
Profile View of Transect-5

HORIZ. SCALE: 1" = 200' VERT. SCALE: 1" = 20'



Profile View of Transect-6

HORIZ. SCALE: 1" = 200' VERT. SCALE: 1" = 20'



KUUKPIK UMIAQ
ALPINE SURVEY OFFICE
PHONE: 907-670-4739

FORM: DSIZEPID

REFERENCE DWG NO/SHT NO:

REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
4	09/02/2019	UPDATED PER K190003ACS	SZ	CZ			
3	8/20/18	UPDATED PER K180003ACS	SZ	CZ			
2	10/9/17	UPDATED PER K170003ACS	KD	CZ			
1	7/29/16	UPDATED PER K160003ACS	CZ	DB			

ECM NO: K160003ACS
CC NO: –
CADD FILE NO. 13-08-07-1 –
SCALE: 1" = 200'
DATE: 7/01/2016

ConocoPhillips
Alaska, Inc.

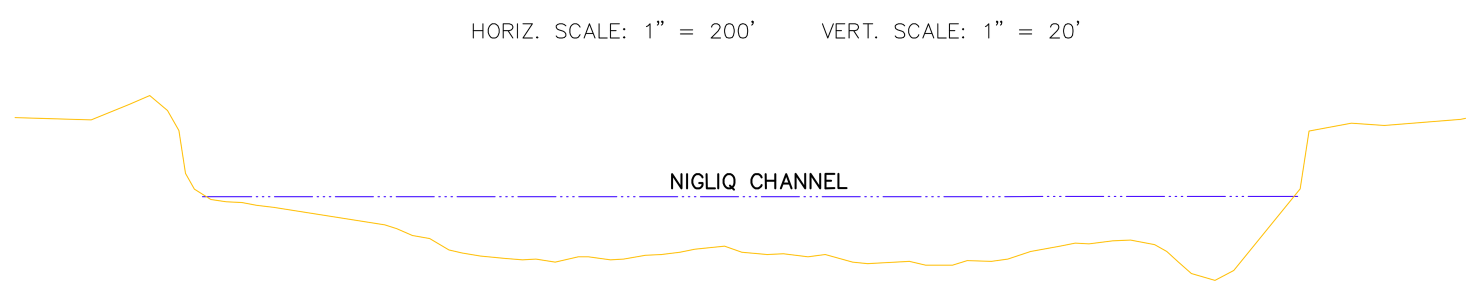
DRAWN: CZ
DESIGN: –
CHECKED: DB
REDRAWN FROM: –
APPROVAL: –

ALPINE
MODULE: CD50
UNIT: CD

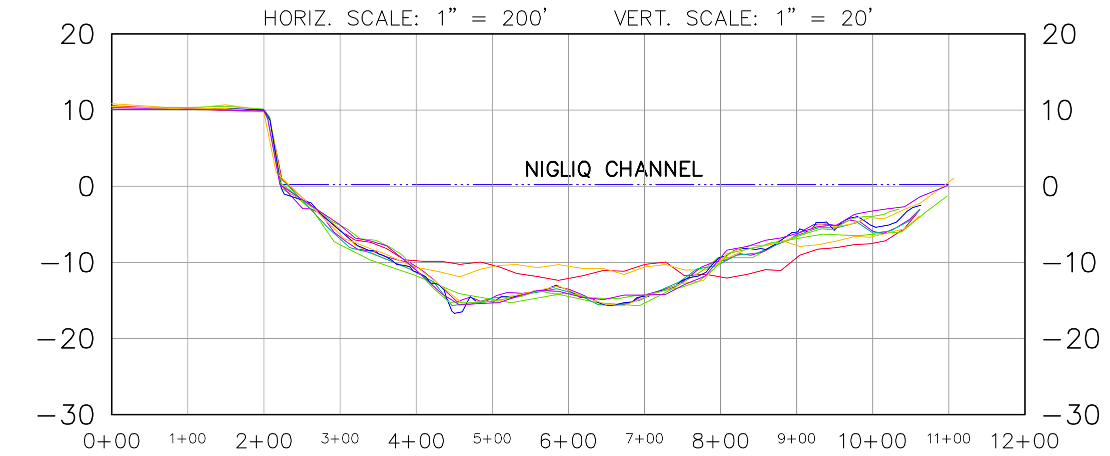
CD-5 ROAD
MONITORING PROFILE BASELINES
ALPINE, ALASKA

JOB NO:	SUB JOB NO:	DRAWING NO:	PART:	REV:
–	–	CE-CD50-1004	2 of 6	4

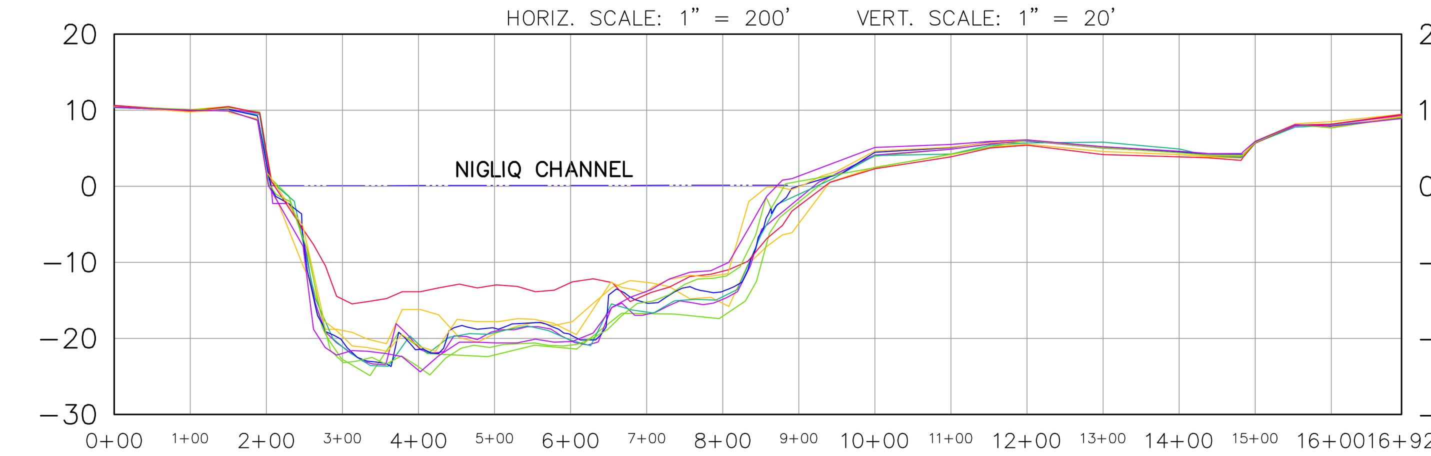
JOB NO:	SUB JOB NO:	DRAWING NO:
–	–	CE-CD50-1004



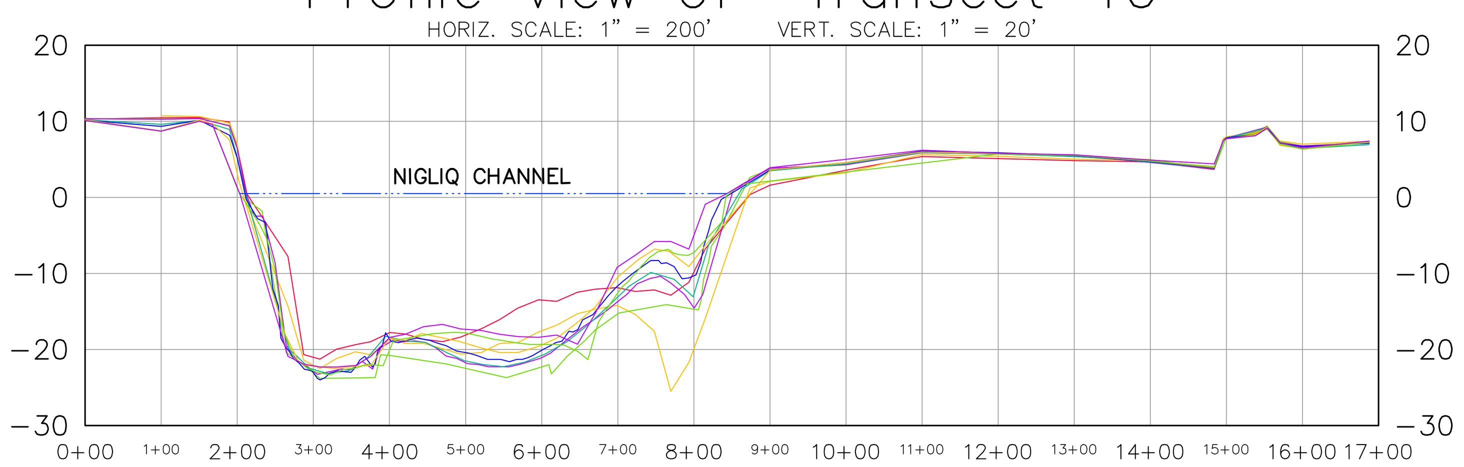
Profile View of Transect-8



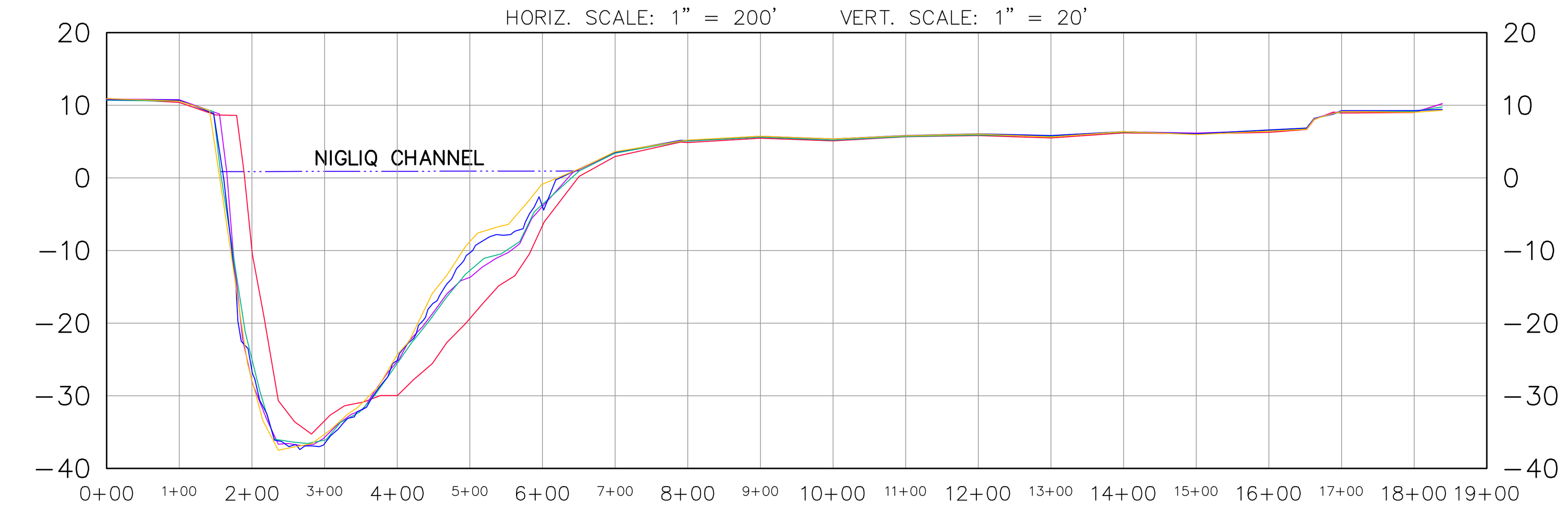
Profile View of Transect-9



Profile View of Transect-10

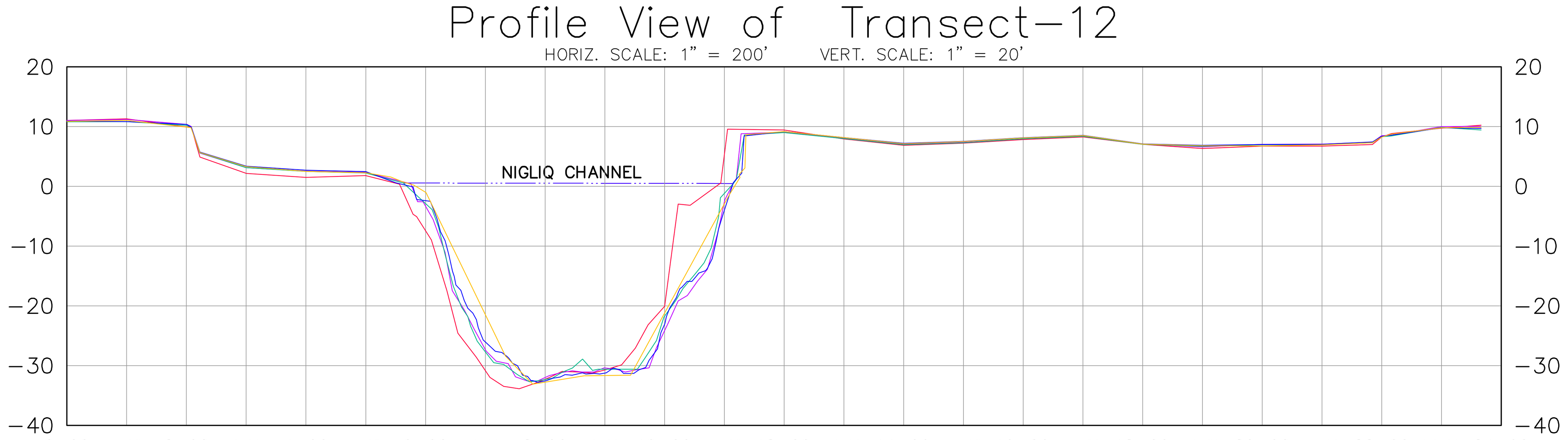


Profile View of Transect-11



LEGEND:
VIEW LOOKING DOWNSTREAM
- 2013 TRANSECT PROFILE
- 2017 TRANSECT PROFILE
- 2018 TRANSECT PROFILE
- 2019 TRANSECT PROFILE
- 2020 TRANSECT PROFILE
- 2021 TRANSECT PROFILE

Profile View of Transect-12



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ALPINE SURVEY OFFICE
PHONE: 907-670-4739

FORM: DSIZEPID

REFERENCE DWG NO/SHT NO:

REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
6	08/31/20	UPDATED PER K200003ACS	CSS	CZ			
5	08/30/20	UPDATED PER K200003ACS	WJ	CZ			
4	09/02/19	UPDATED PER K190003ACS	SZ	CZ			
3	8/20/18	UPDATED PER K180003ACS	SZ	CZ			
2	10/9/17	UPDATED PER K170003ACS	KD	CZ			
7	8/20/21	UPDATED PER K210003ACS	RTD	CZ			

ECM NO: K160003ACS
CC NO: –
CADD FILE NO. 13-08-07-1 –
SCALE: 1" = 200'
DATE: 7/01/2016

ConocoPhillips
Alaska, Inc.

DRAWN: CZ
DESIGN: –
CHECKED: DB
REDRAWN FROM: –
APPROVAL: –

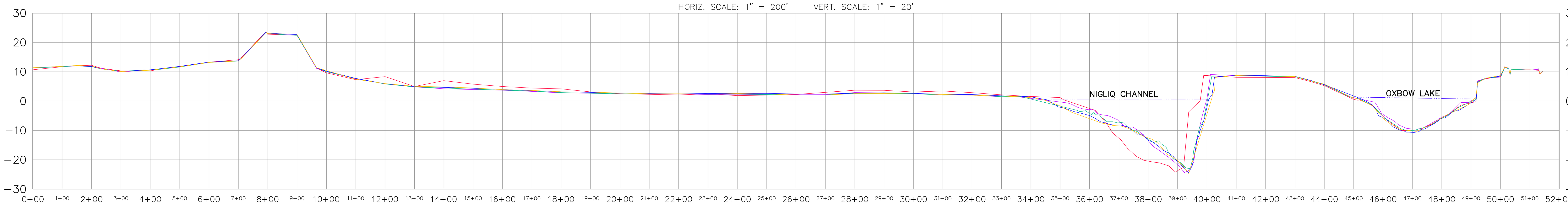
ALPINE
MODULE: CD50
UNIT: CD
CD-5 ROAD
MONITORING PROFILE BASELINES
ALPINE, ALASKA

JOB NO:	SUB JOB NO:	DRAWING NO:	PART:	REV:
–	–	CE-CD50-1004	3 of 6	7

JOB NO: – | SUB JOB NO: – | DRAWING NO: CE-CD50-1004

Profile View of Transect-13

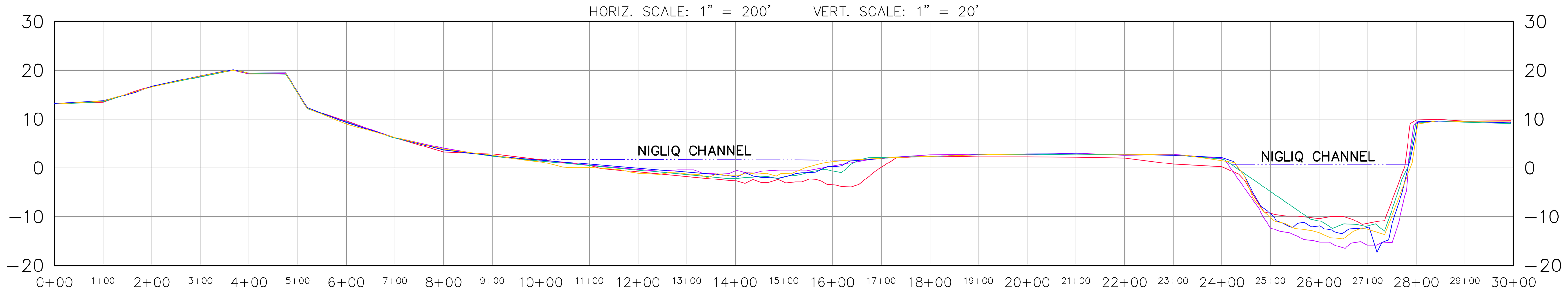
HORIZ. SCALE: 1" = 200' VERT. SCALE: 1" = 20'



LEGEND:
VIEW LOOKING DOWNSTREAM
2013 TRANSECT PROFILE
2017 TRANSECT PROFILE
2018 TRANSECT PROFILE
2019 TRANSECT PROFILE
2020 TRANSECT PROFILE
2021 TRANSECT PROFILE

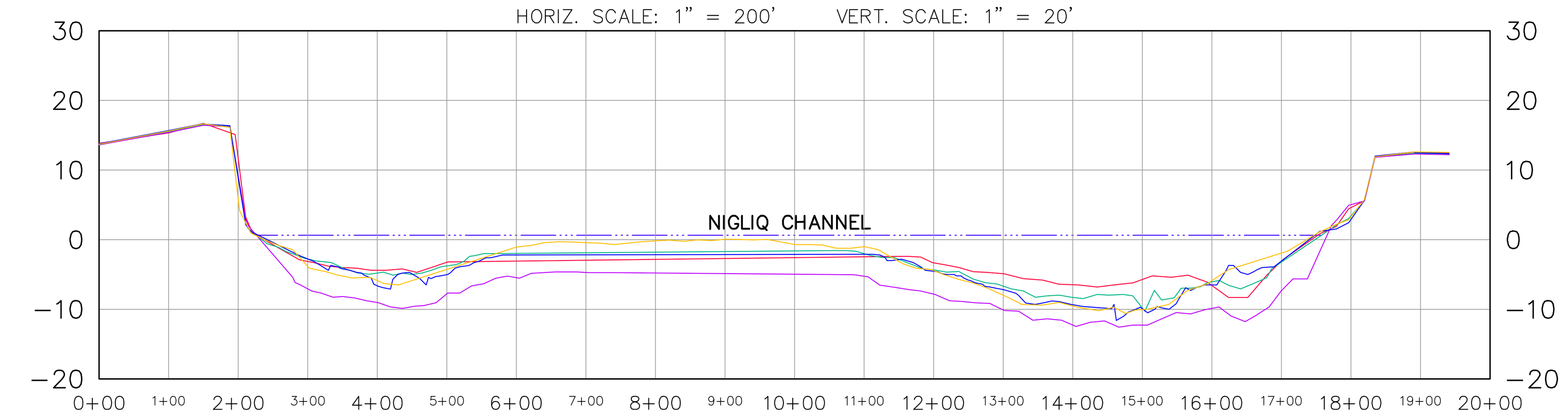
Profile View of Transect-14

HORIZ. SCALE: 1" = 200' VERT. SCALE: 1" = 20'



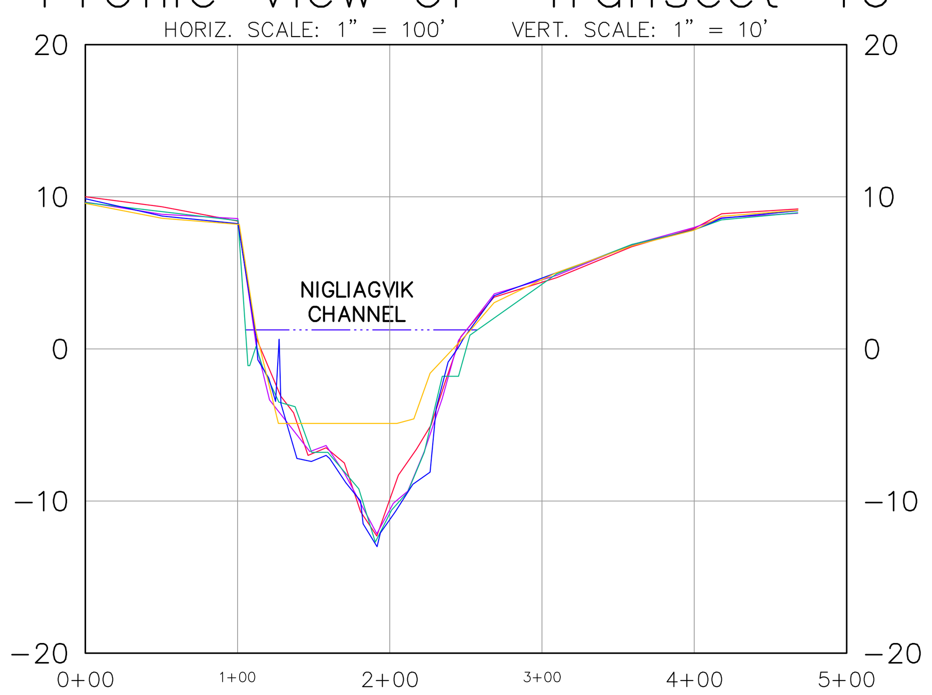
Profile View of Transect-15

HORIZ. SCALE: 1" = 200' VERT. SCALE: 1" = 20'



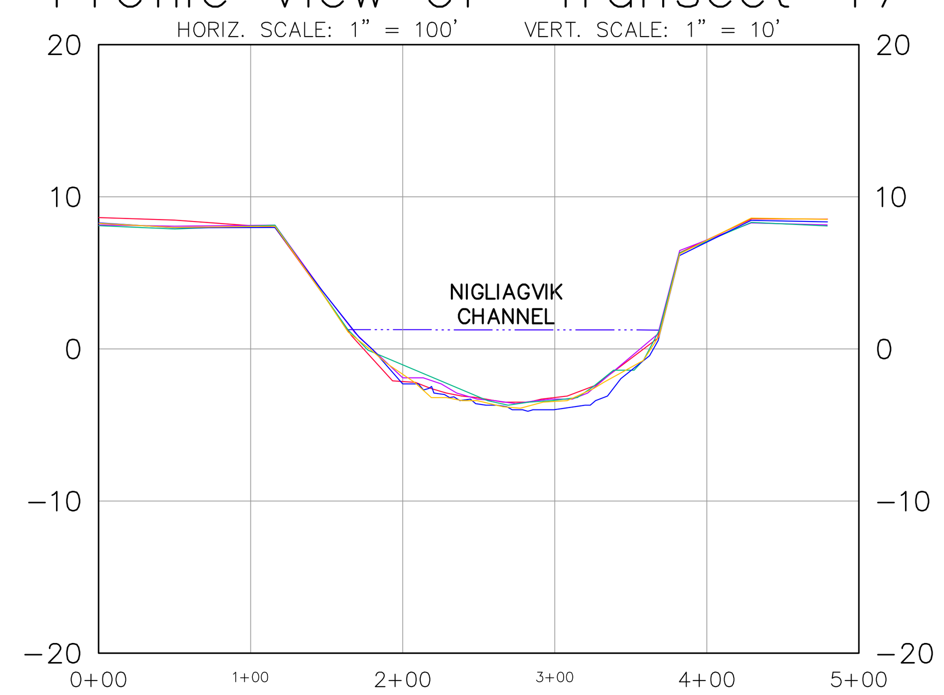
Profile View of Transect-16

HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



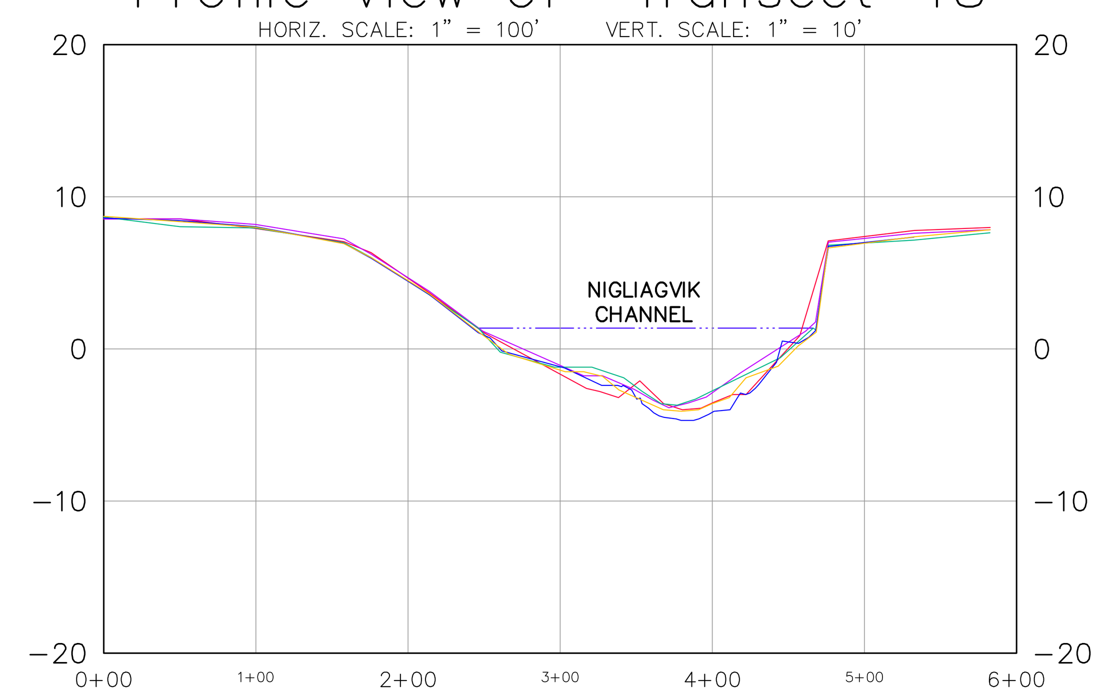
Profile View of Transect-17

HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



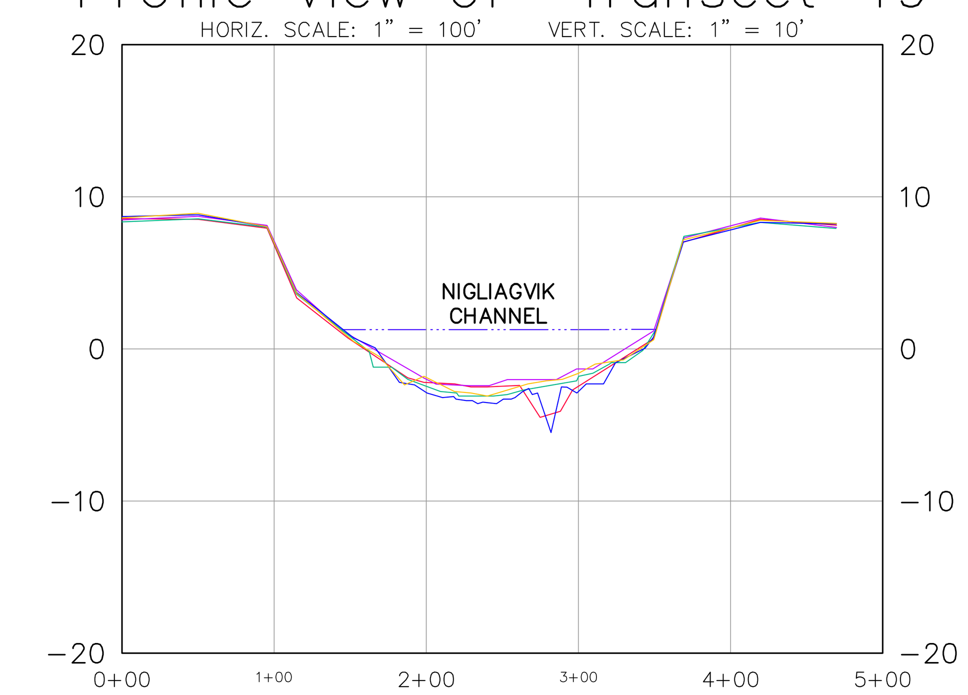
Profile View of Transect-18

HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



Profile View of Transect-19

HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



KUUKPIK UMIAQ
ALPINE SURVEY OFFICE
PHONE: 907-670-4739

FORM: DSIZEPID

REFERENCE DWG NO/SHT NO:

REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
4	09/02/19	UPDATED PER K190003ACS	SZ	CZ			
3	8/20/18	UPDATED PER K180003ACS	SZ	CZ			
2	10/9/17	UPDATED PER K170003ACS	KD	CZ			
1	7/29/16	UPDATED PER K160003ACS	CZ	DB			

ECM NO: K160003ACS
CC NO: –
CADD FILE NO. 13-08-07-1 –
SCALE: VARIES
DATE: 7/01/2016

ConocoPhillips
Alaska, Inc.

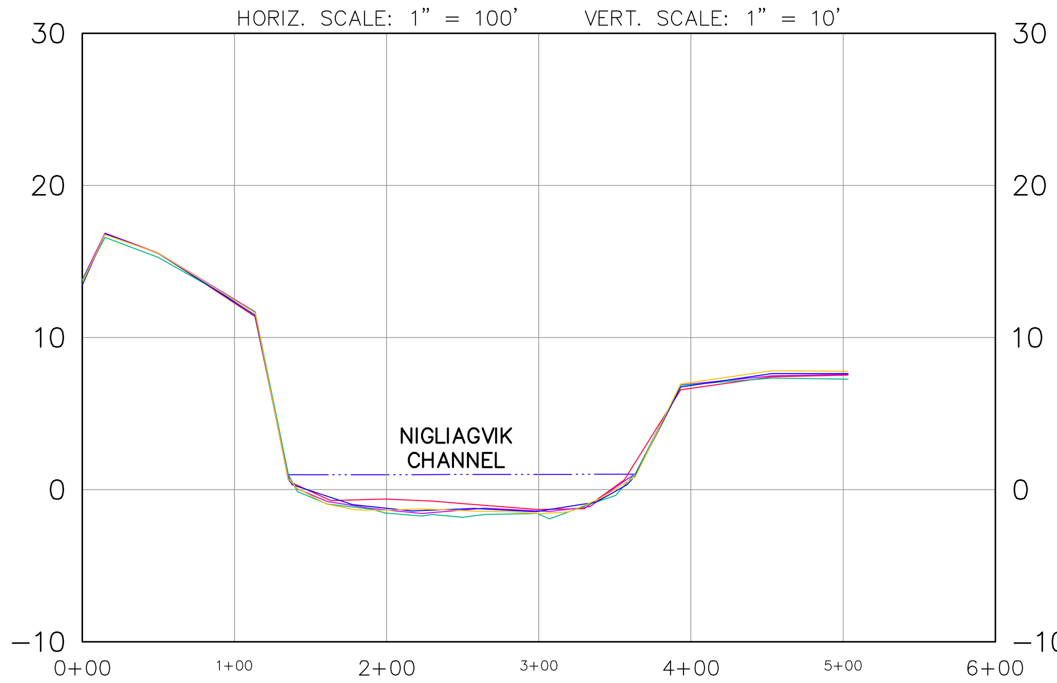
DRAWN: CZ
DESIGN: –
CHECKED: DB
REDRAWN FROM: –
APPROVAL: –

ALPINE
MODULE: CD50
UNIT: CD
CD-5 ROAD
MONITORING PROFILE BASELINES
ALPINE, ALASKA

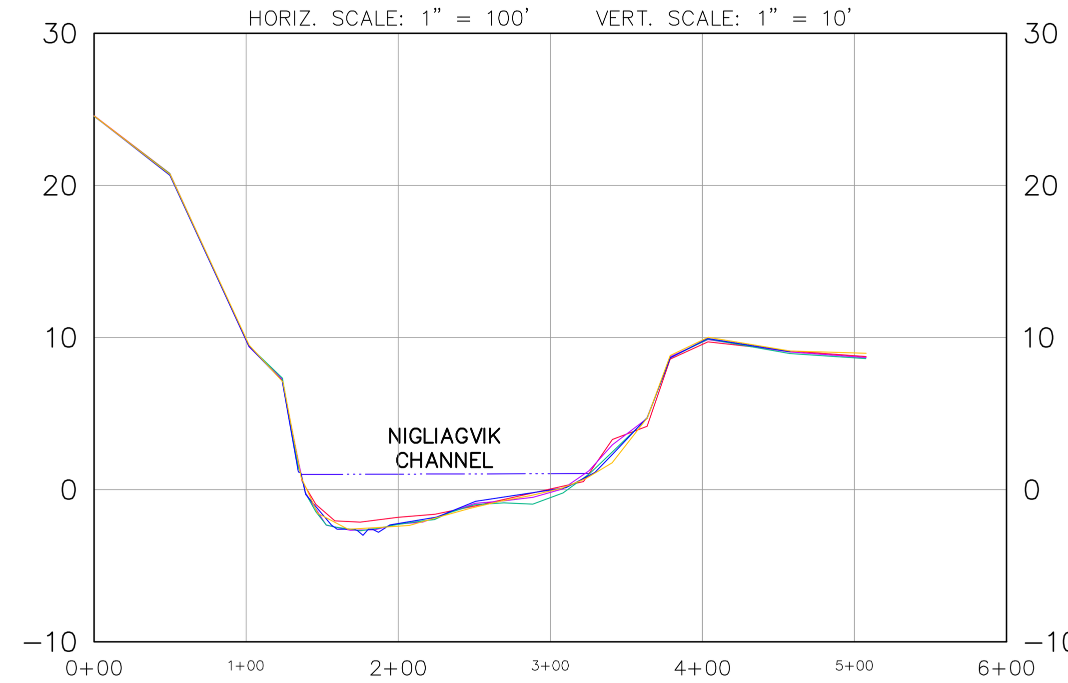
JOB NO: –
SUB JOB NO: –
DRAWING NO: CE-CD50-1004
PART: 4 of 6
REV: 4

DRAWING NO:	SUB JOB NO:	JOB NO:
CE-CD50-1004	–	–

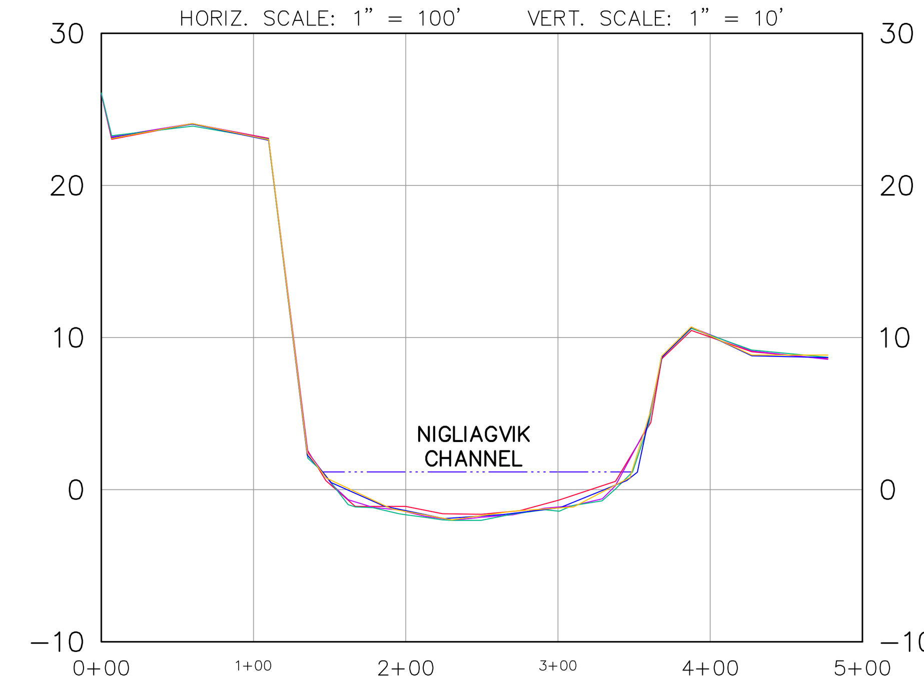
Profile View of Transect–20
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



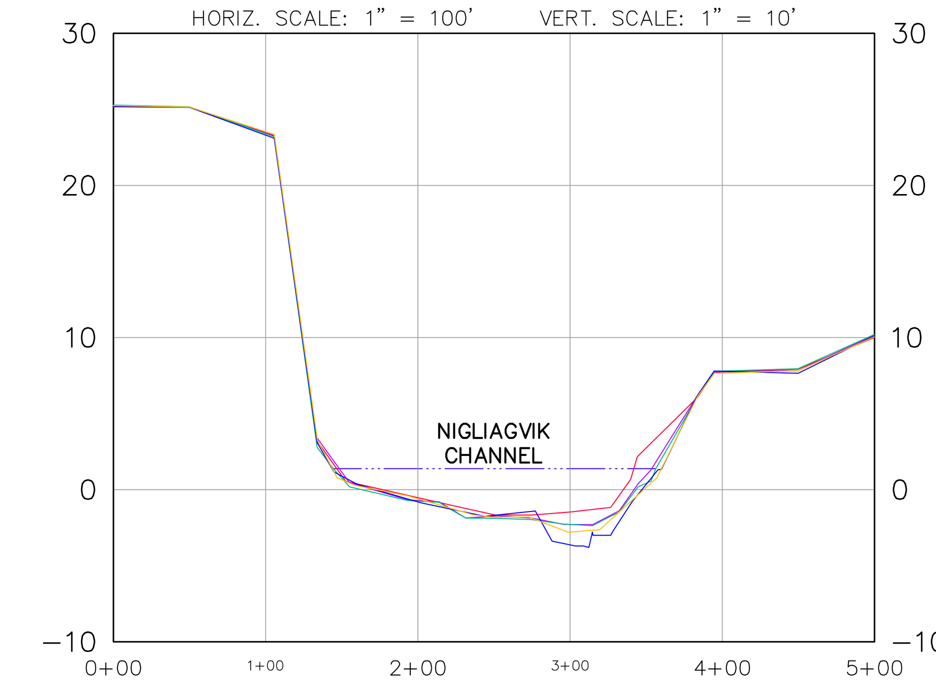
Profile View of Transect–21
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



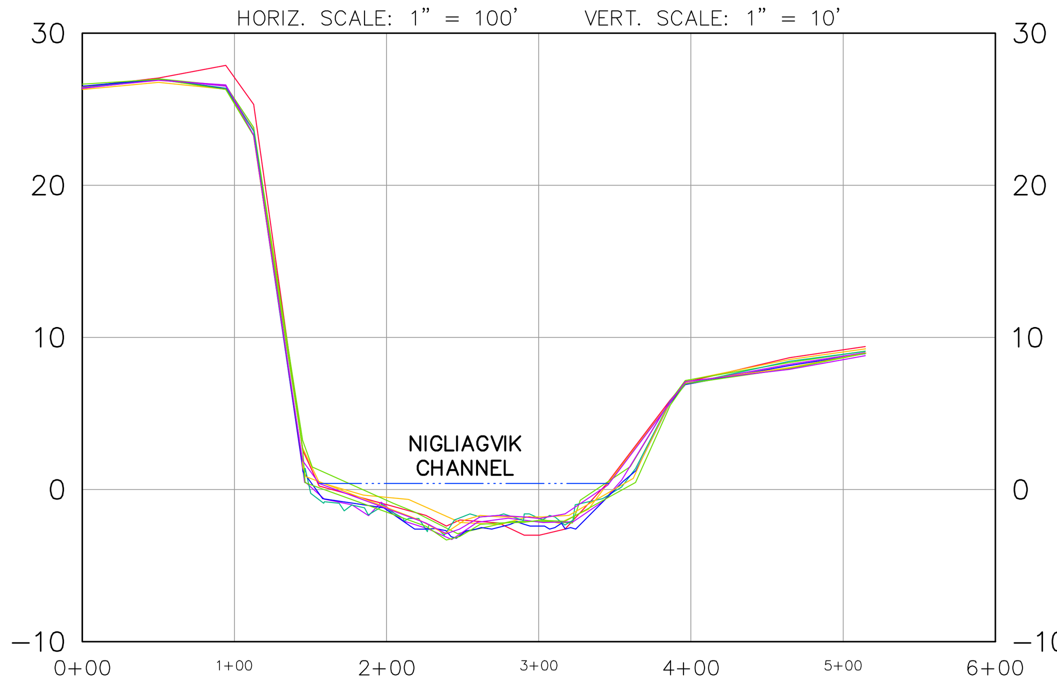
Profile View of Transect–22
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



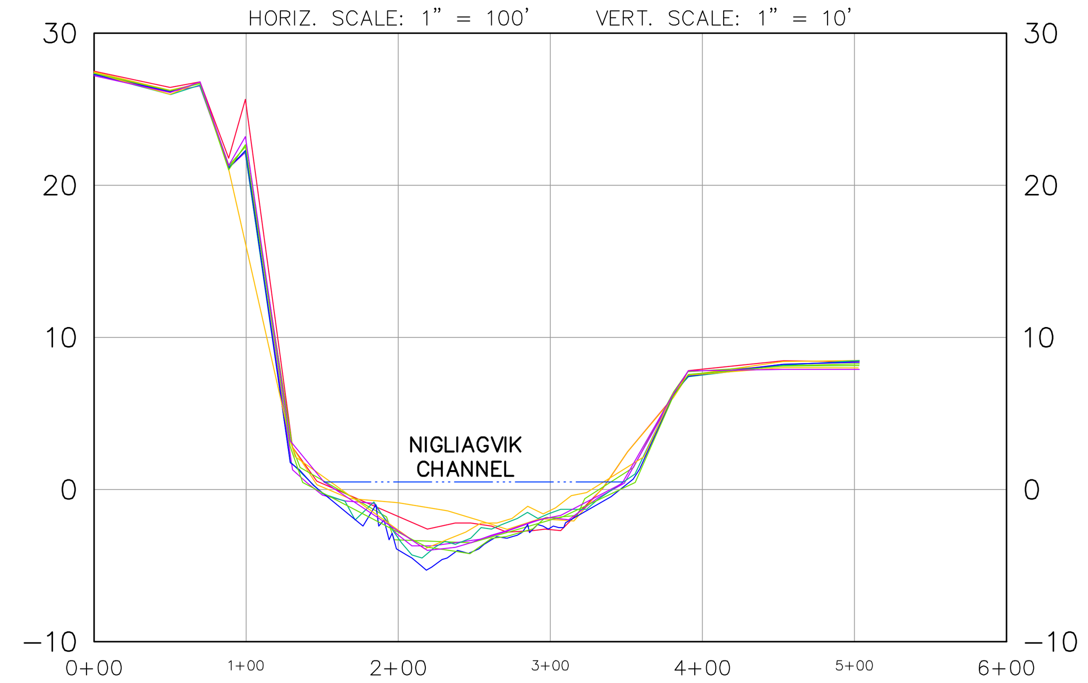
Profile View of Transect–23
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



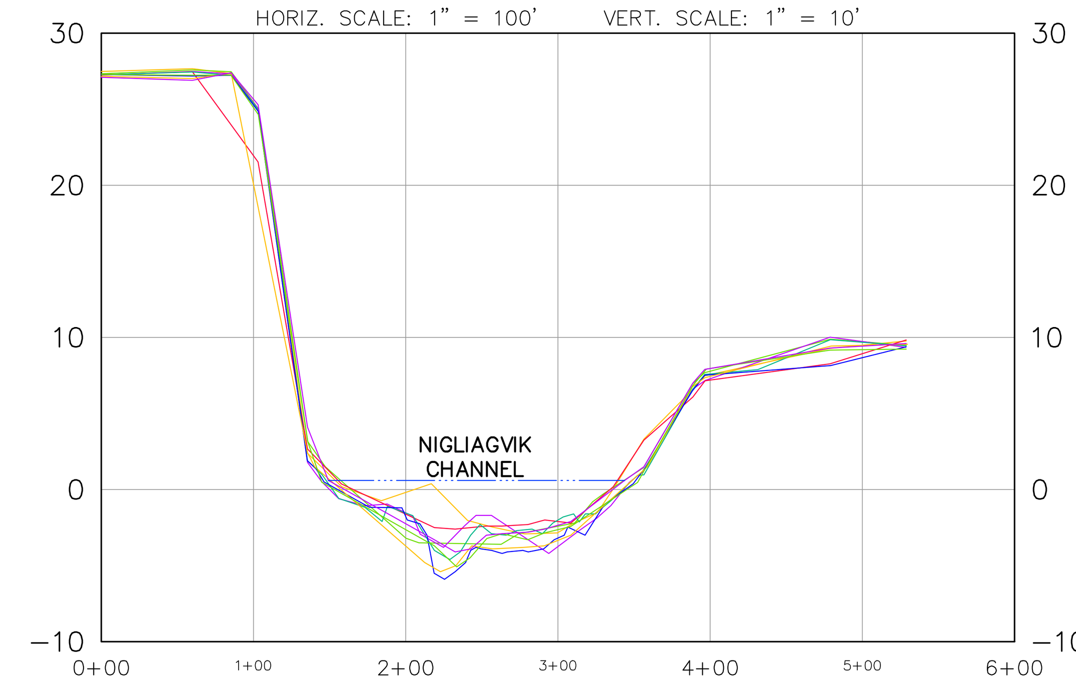
Profile View of Transect–24
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



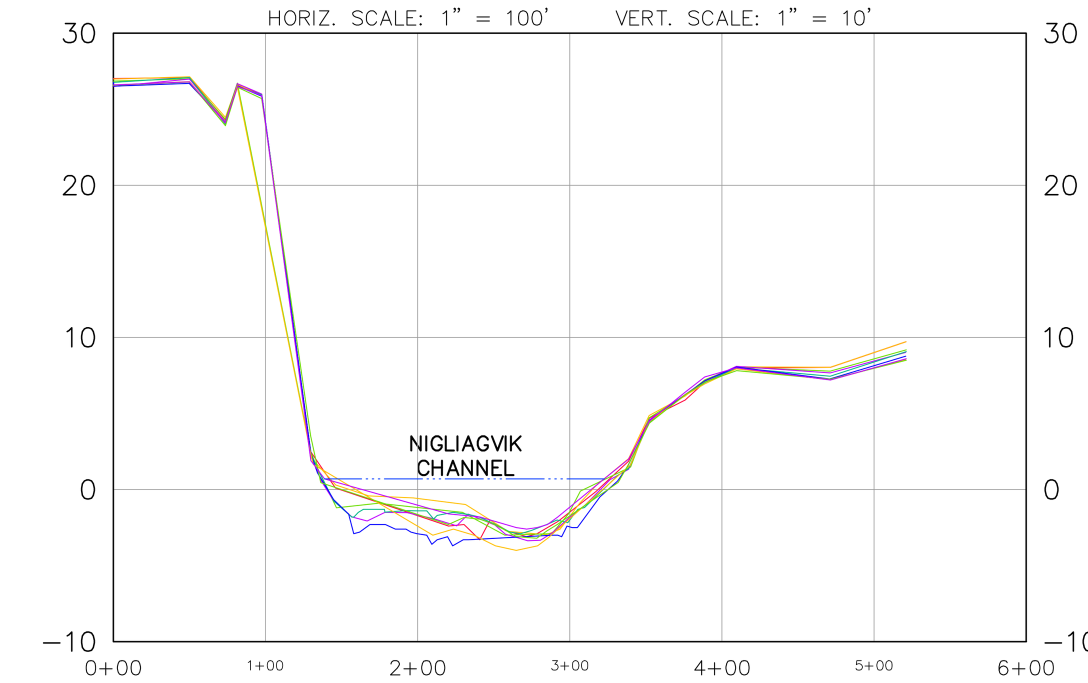
Profile View of Transect–25
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



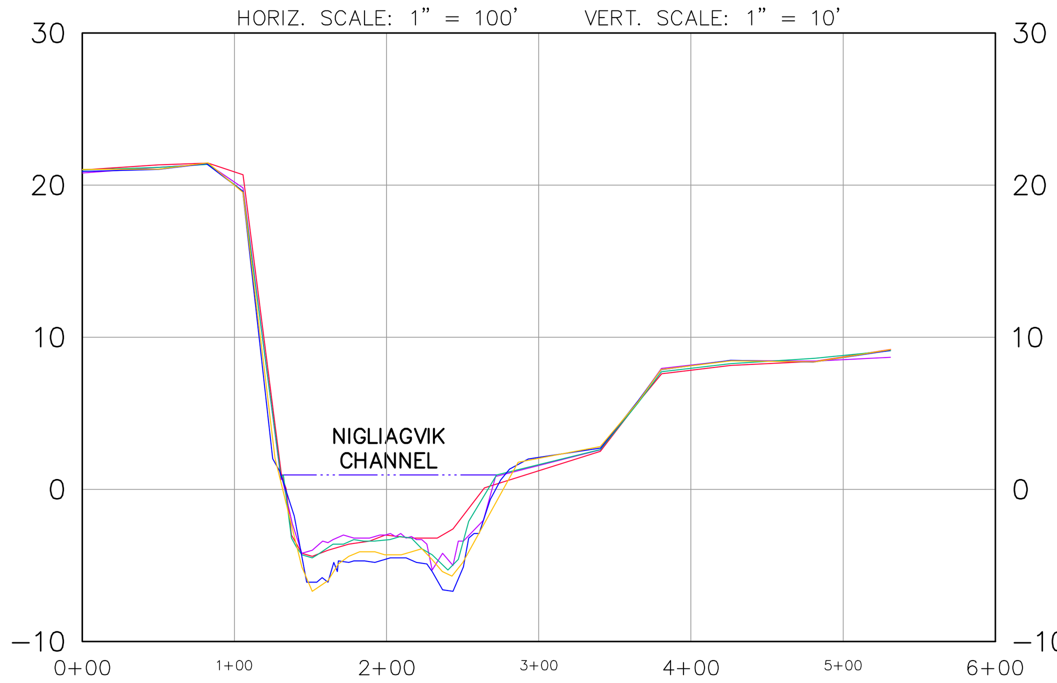
Profile View of Transect–26
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



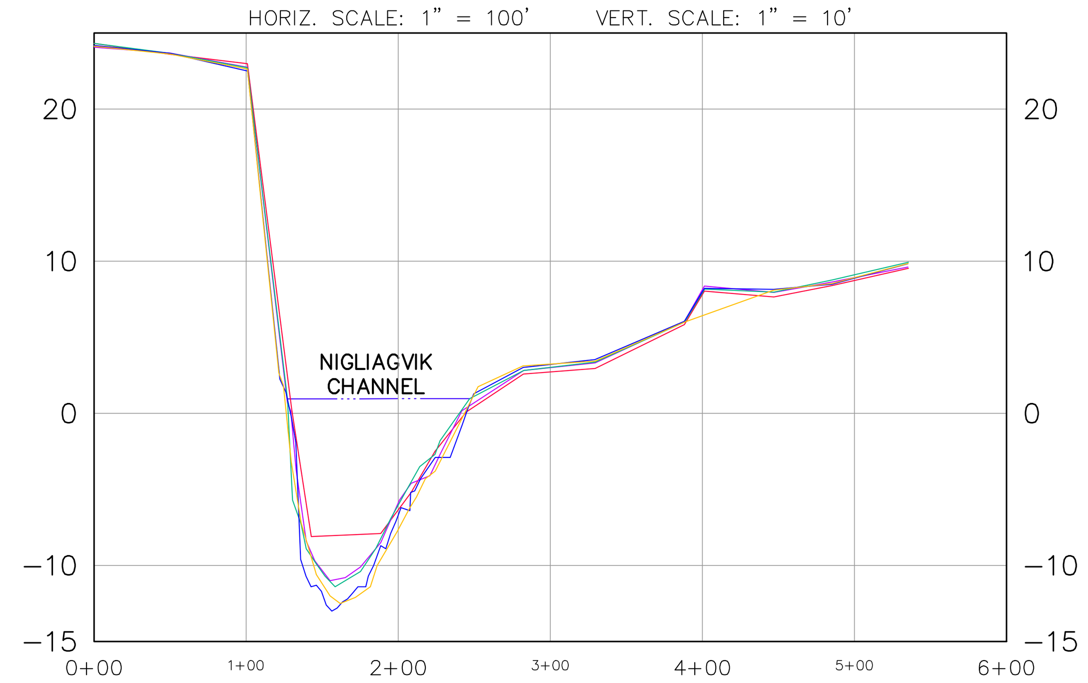
Profile View of Transect–27
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



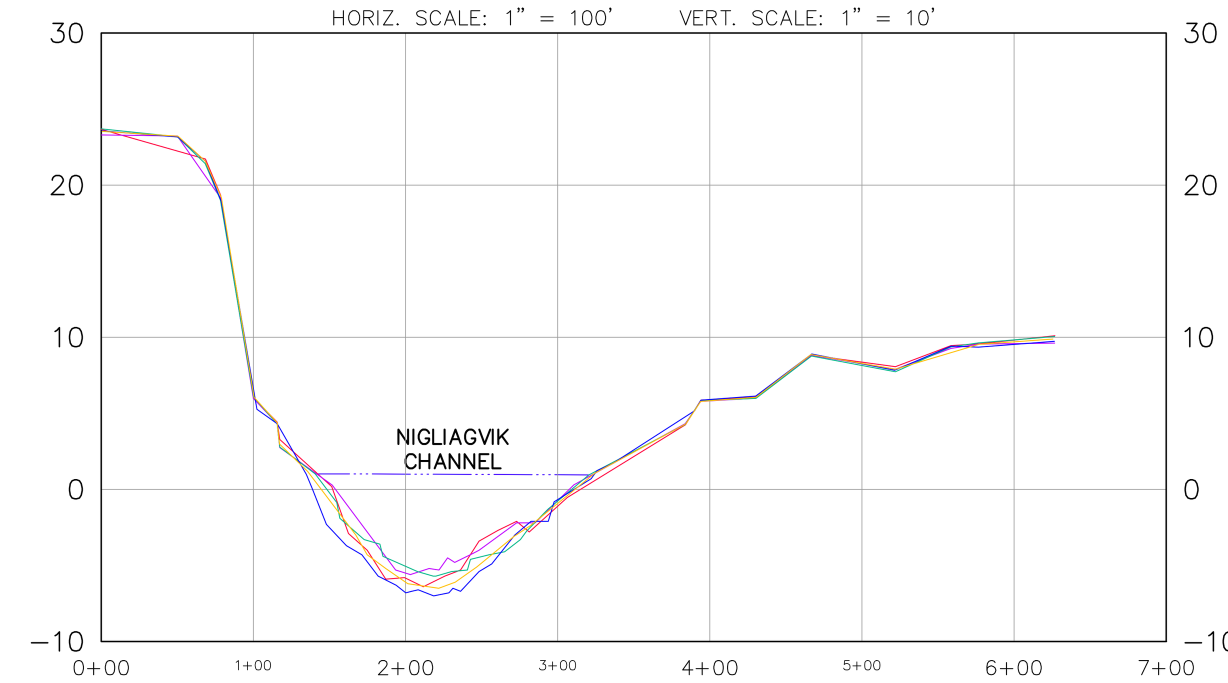
Profile View of Transect–28
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



Profile View of Transect–29
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



Profile View of Transect–30
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



LEGEND:
VIEW LOOKING DOWNSTREAM
- 2013 TRANSECT PROFILE
- 2017 TRANSECT PROFILE
- 2018 TRANSECT PROFILE
- 2019 TRANSECT PROFILE
- 2020 TRANSECT PROFILE
- 2021 TRANSECT PROFILE

KUUKPIK UMIAQ
ALPINE SURVEY OFFICE
PHONE: 907-670-4739

FORM: DSIZEPID

REFERENCE DWG NO/SHT NO:

REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
6	08/20/21	UPDATED PER K210003ACS	RTD	CZ			
5	08/31/20	UPDATED PER K200003ACS	CSS	CZ			
4	09/02/19	UPDATED PER K190003ACS	SZ	CZ			
3	8/20/18	UPDATED PER K180003ACS	SZ	CZ			
2	10/9/17	UPDATED PER K170003ACS	KD	CZ			
1	7/29/16	UPDATED PER K160003ACS	CZ	DB			

ECM NO: K160003ACS
CC NO: –
CADD FILE NO. 13-08-07-1 –
SCALE: 1" = 200' DATE: 7/01/2016

ConocoPhillips Alaska, Inc.

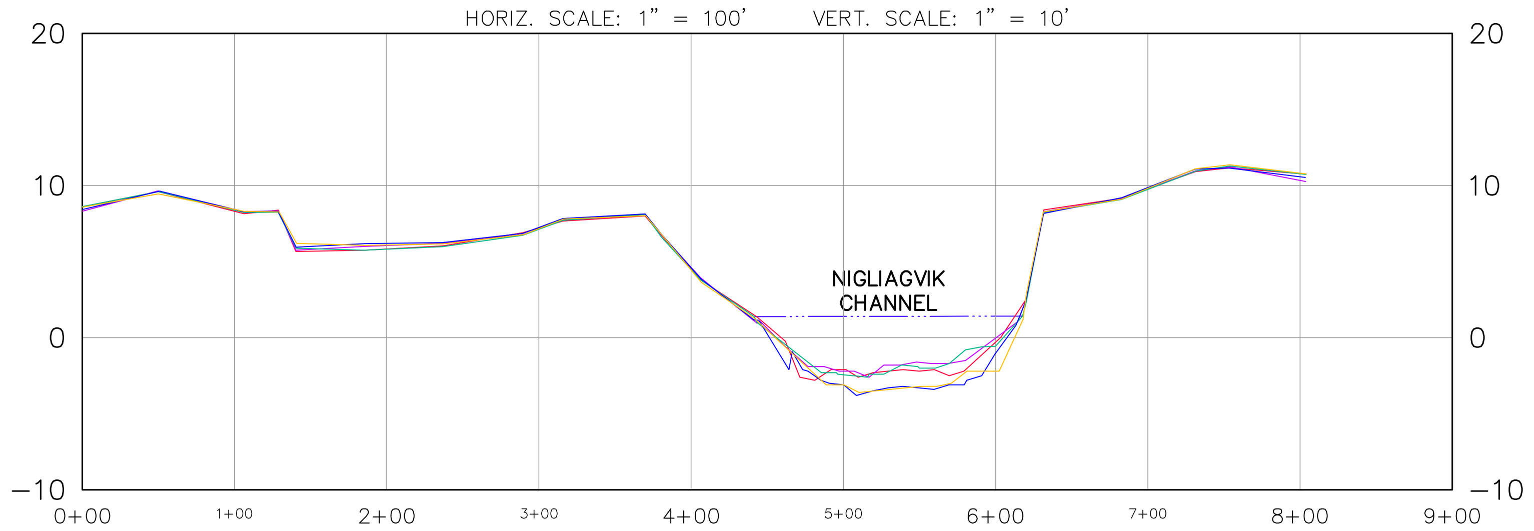
DRAWN: CZ DESIGN: – CHECKED: DB
REDRAWN FROM: – APPROVAL: –

ALPINE MODULE: CD50 UNIT: CD
CD-5 ROAD
MONITORING PROFILE BASELINES
ALPINE, ALASKA

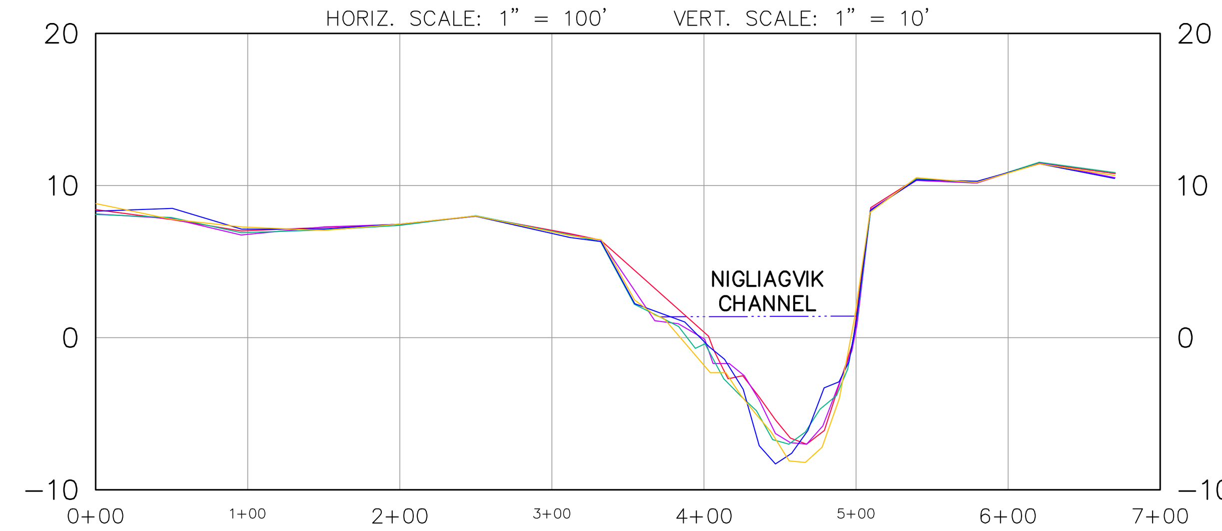
JOB NO:	SUB JOB NO:	DRAWING NO:	PART:	REV:
–	–	CE-CD50-1004	5 of 6	6

JOB NO:	SUB JOB NO:	DRAWING NO:
–	–	CE-CD50-1004

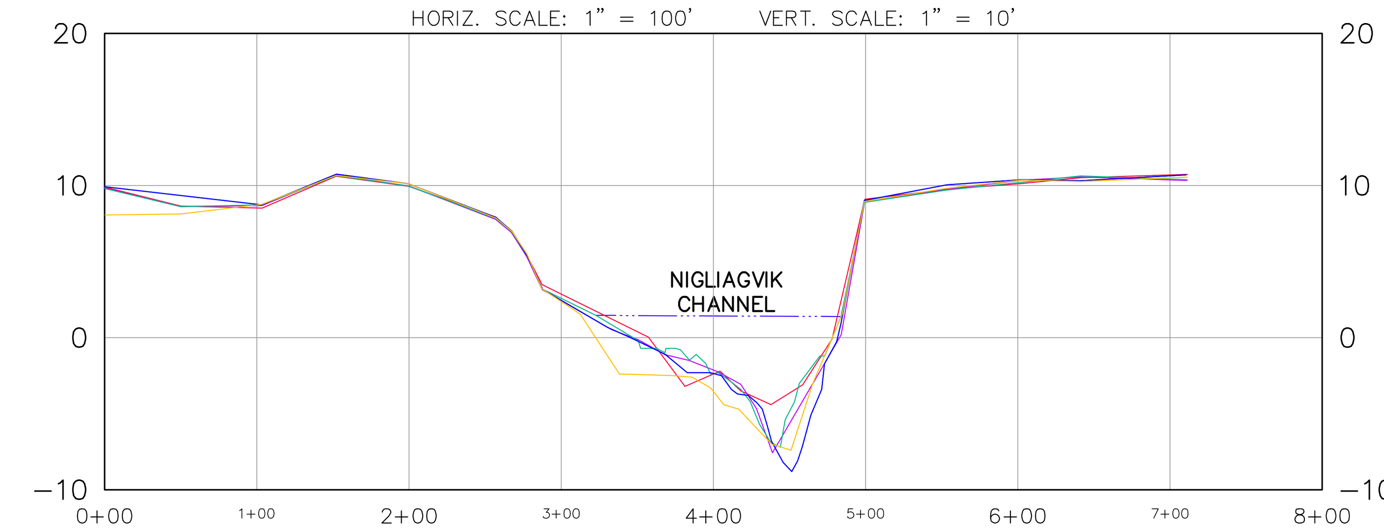
Profile View of Transect-31
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



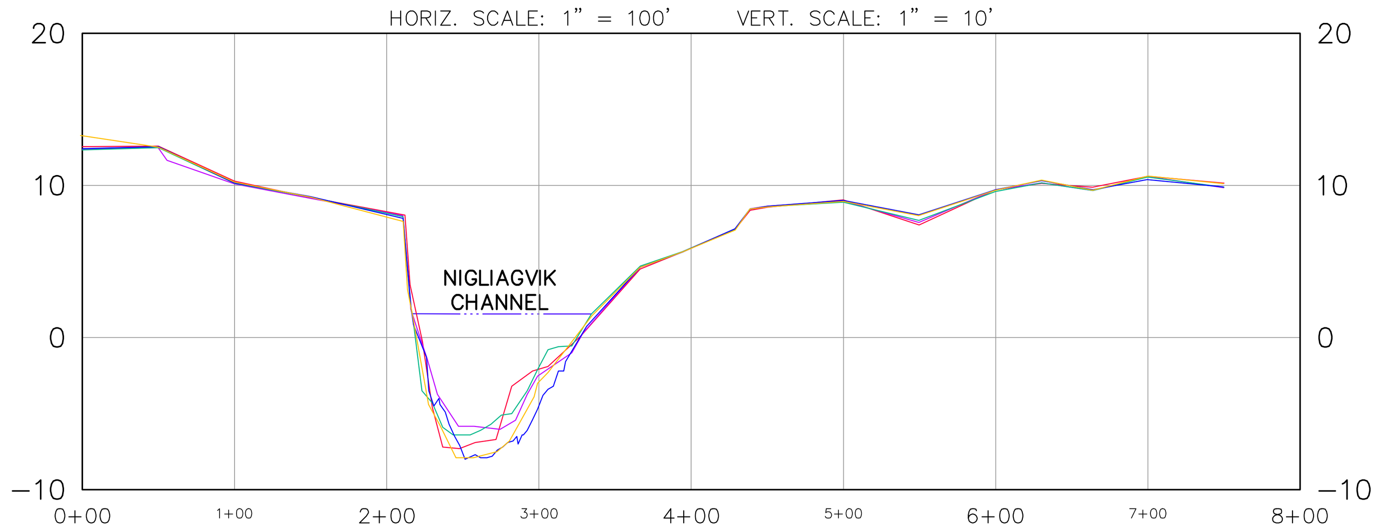
Profile View of Transect-32
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



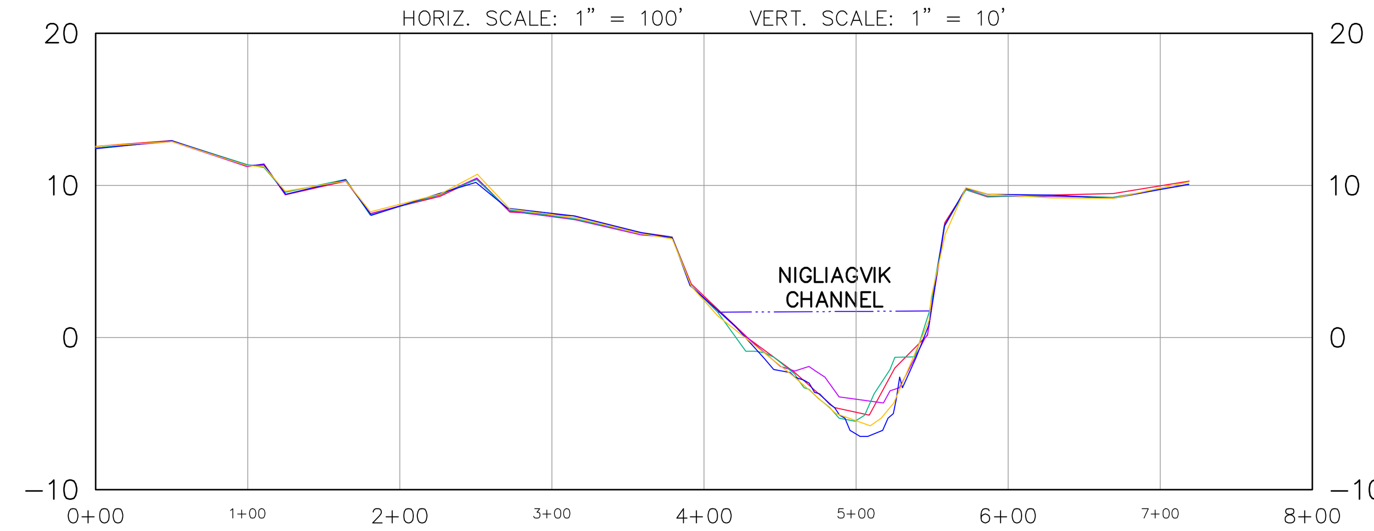
Profile View of Transect-33
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



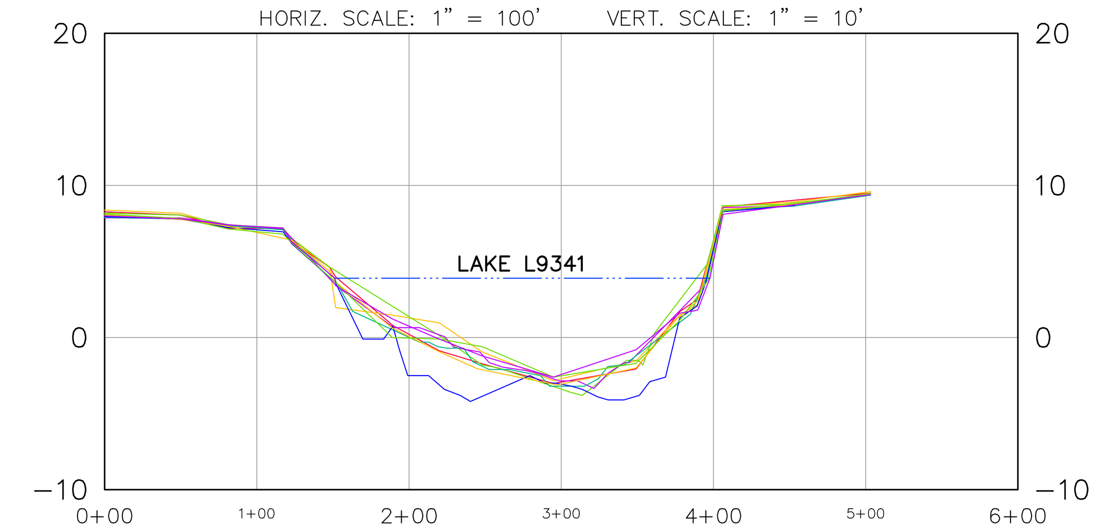
Profile View of Transect-34
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



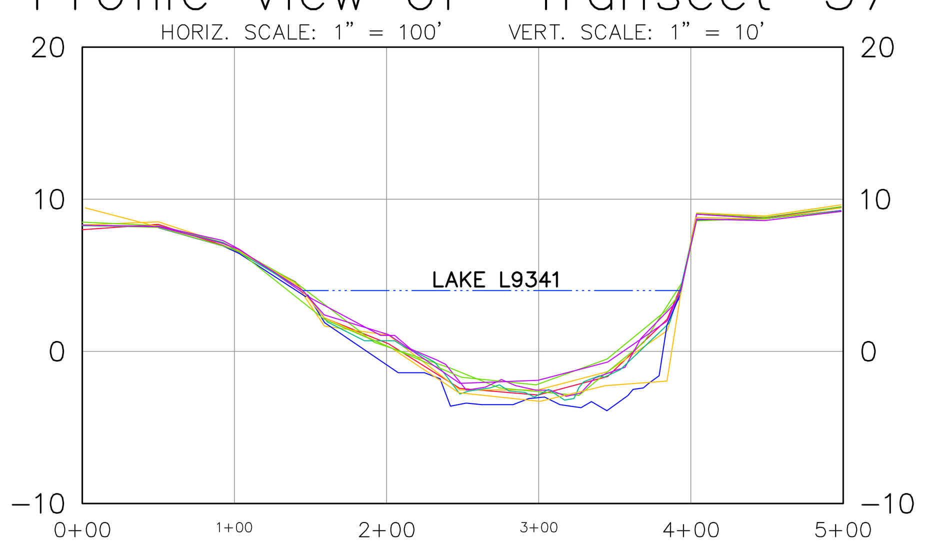
Profile View of Transect-35
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



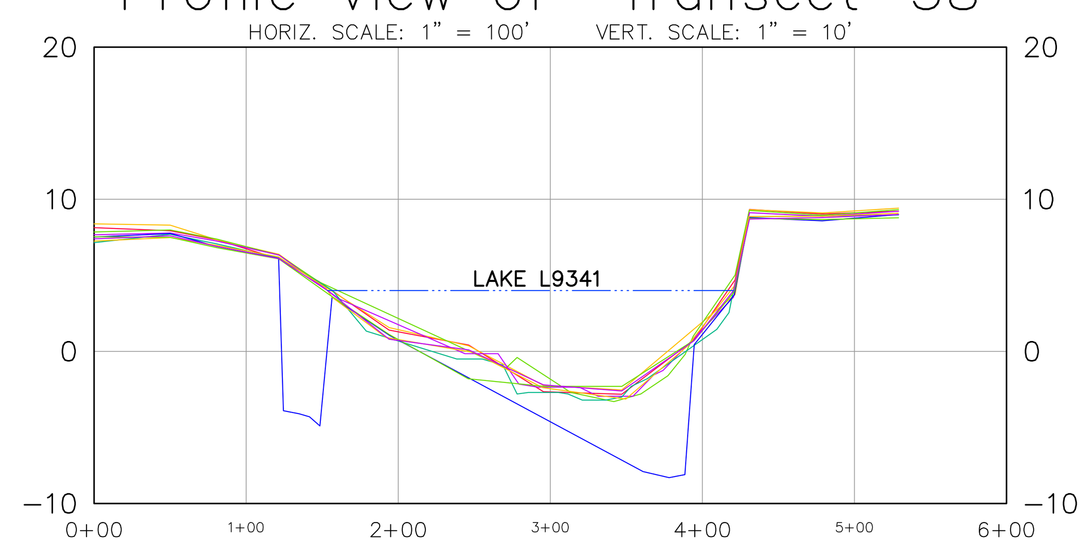
Profile View of Transect-36
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



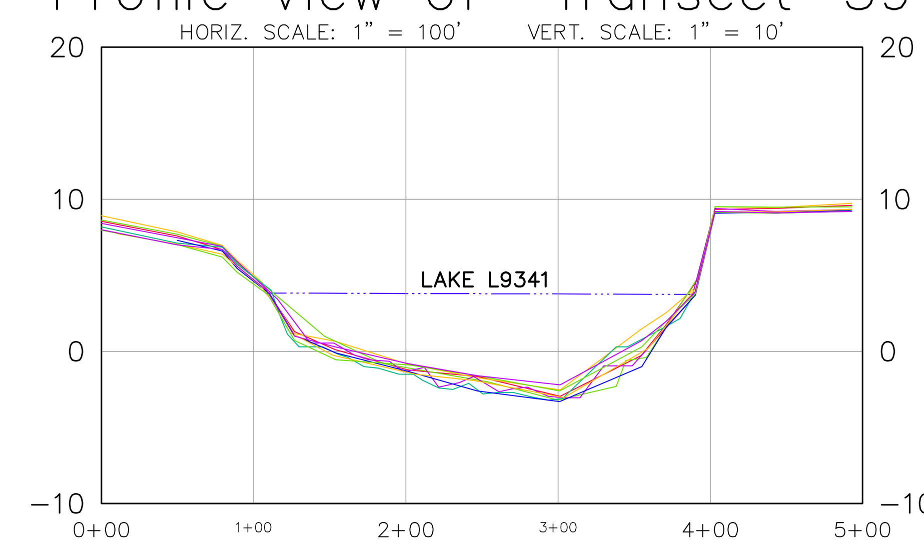
Profile View of Transect-37
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



Profile View of Transect-38
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



Profile View of Transect-39
HORIZ. SCALE: 1" = 100' VERT. SCALE: 1" = 10'



LEGEND:
VIEW LOOKING DOWNSTREAM
- 2013 TRANSECT PROFILE
- 2017 TRANSECT PROFILE
- 2018 TRANSECT PROFILE
- 2019 TRANSECT PROFILE
- 2020 TRANSECT PROFILE
- 2021 TRANSECT PROFILE

KUUKPIK UMIAQ
ALPINE SURVEY OFFICE
PHONE : 907-670-4739
FORM: DSIZEPID

REFERENCE DWG NO/SHT NO:

REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
6	8/20/21	UPDATED PER K210003ACS	RTD	CZ			
5	9/02/20	UPDATED PER K200003ACS	CS	KR			
4	09/02/19	UPDATED PER K190003ACS	SZ	CZ			
3	8/20/18	UPDATED PER K180003ACS	SZ	CZ			
2	10/9/17	UPDATED PER K170003ACS	KD	CZ			
1	7/29/16	UPDATED PER K160003ACS	CZ	DB			

ECM NO: K160003ACS
CC NO: –
CADD FILE NO. 13-08-07-1 –
SCALE: 1" = 200'
DATE: 7/01/2016

ConocoPhillips Alaska, Inc.

DRAWN: CZ
DESIGN: –
CHECKED: DB
REDRAWN FROM: –
APPROVAL: –

ALPINE
MODULE: CD50
UNIT: CD
CD-5 ROAD
MONITORING PROFILE BASELINES
ALPINE, ALASKA

JOB NO:	SUB JOB NO:	DRAWING NO:	PART:	REV:
–	–	CE-CD50-1004	6 of 6	6

E.3.2 NIGLIQ CHANNEL & BRIDGE TABULATED DATA (TRANSECTS 7 – 10)

Calc'd By: RTD
Date: 08/17/21
RPT-CE-CD-114 REV9

CD-5 Michael Baker
Bridge Transects
Transect 7

KUUKPIK UMIAQ
DOC LCMF-156 REV9

STA	2013	2014	2015	2016	2017	2018	2019	2020	2021	Description
0+00	10.6	10.9	10.7	10.7	10.5	10.6	10.7	10.6	10.6	Ground Shot
1+00	10.1	10.4	10.4	10.3	10.3	10.3	10.4	10.4	10.4	Ground Shot
1+50	12.2	12.4	12.4	12.3	12.3	12.4	12.4	12.3	12.4	Ground Shot
1+77	13.4	13.7	13.7	13.5	13.5	13.5	13.6	13.4	13.6	Grade Break
2+00	11.3	11.6	11.7	11.6	11.6	11.6	11.6	11.6	11.7	Ground Shot
2+15	-	-	-	-	-	-	9.0	8.7	8.6	Top of Bank
2+19	-	-	-	-	-	-	-	4.4	-	Toe of Bank (2019)
2+20	-	-	8.4	8.3	8.0	8.1	-	-	-	Top of Bank (2018)
2+23	8.1	8.1	-	-	-	-	-	-	-	Top of Bank (2014)
2+24	-	-	-	-	-	-	3.4	-	3.5	Toe of Bank
2+30	2.8	3.0	3.7	3.3	2.9	3.1	-	-	-	Toe of Bank (2018)
Varies	0.6	0.5	0.8	0.3	1.0	-0.3	1.3	0.5	0.3	Edge of Water
4+93	-2.5	-4.1	-4.2	-4.0	-4.0	-3.9	-3.7	-3.9	-3.5	River Bottom
5+06	-2.5	-4.4	-4.6	-4.0	-4.5	-4.4	-4.1	-4.5	-4.5	River Bottom
5+25	-2.6	-3.6	-5.0	-4.3	-5.0	-5.0	-4.9	-5.7	-5.4	River Bottom
5+45	-2.7	-3.7	-5.3	-4.7	-5.0	-5.2	-5.2	-7.3	-7.6	River Bottom
5+68	-3.7	-3.8	-6.6	-5.6	-6.2	-6.8	-6.5	-7.9	-7.3	River Bottom
5+91	-4.5	-5.2	-7.0	-7.0	-7.0	-7.1	-7.1	-7.5	-7.7	River Bottom
6+17	-5.8	-7.6	-7.3	-7.5	-7.6	-7.6	-7.5	-9.0	-9.7	River Bottom
6+42	-7.4	-7.2	-7.7	-7.3	-7.7	-7.7	-7.8	-10.2	-9.7	River Bottom
6+65	-7.7	-7.4	-7.7	-7.2	-7.2	-8.0	-8.0	-10.0	-9.4	River Bottom
6+88	-7.2	-6.3	-7.7	-6.4	-6.7	-7.6	-8.2	-10.0	-9.8	River Bottom
7+11	-6.8	-6.0	-7.6	-6.6	-6.7	-8.2	-8.3	-8.6	-8.7	River Bottom
7+37	-5.4	-5.5	-7.6	-6.8	-6.9	-7.8	-7.7	-7.1	-7.1	River Bottom
7+56	-5.1	-6.3	-7.6	-7.2	-7.3	-7.9	-7.5	-7.5	-7.3	River Bottom
7+82	-4.9	-7.1	-7.6	-7.3	-7.7	-7.7	-8.0	-7.7	-7.4	River Bottom
8+02	-4.3	-7.1	-7.6	-6.7	-7.3	-7.8	-7.8	-7.1	-6.8	River Bottom
8+25	-3.6	-5.6	-7.6	-7.5	-6.9	-7.9	-7.5	-7.6	-7.0	River Bottom
8+50	-4.2	-5.9	-7.5	-7.0	-6.8	-7.1	-7.3	-7.7	-6.4	River Bottom
8+74	-5.6	-6.2	-7.5	-7.2	-7.5	-7.0	-7.0	-7.0	-7.8	River Bottom
9+03	-5.9	-6.1	-7.4	-7.5	-7.9	-8.0	-0.6	-5.9	-7.5	River Bottom
9+32	-7.6	-5.5	-7.2	-7.8	-7.6	-7.8	-6.2	-6.0	-7.1	River Bottom
9+58	-7.0	-6.7	-7.0	-7.3	-7.6	-6.6	-7.0	-6.7	-6.8	River Bottom
9+84	-9.8	-7.4	-6.9	-8.2	-7.9	-6.2	-7.1	-7.3	-6.1	River Bottom
10+10	-9.9	-10.8	-7.4	-7.8	-8.0	-6.2	-7.2	-7.2	-7.8	River Bottom
10+39	-9.5	-10.5	-8.0	-8.2	-8.5	-6.7	-7.6	-6.7	-7.4	River Bottom
10+68	-8.7	-9.2	-7.8	-7.5	-7.9	-7.9	-7.3	-7.2	-7.1	River Bottom
10+91	-8.3	-9.3	-7.6	-7.8	-7.9	-9.6	-8.2	-7.5	-7.5	River Bottom
11+21	-8.9	-9.4	-7.4	-7.8	-8.4	-9.3	-8.5	-6.4	-7.5	River Bottom
11+50	-9.2	-9.7	-9.4	-7.5	-8.4	-8.6	-8.3	-8.4	-7.7	River Bottom
11+76	-9.4	-10.5	-10.3	-7.2	-7.7	-9.0	-8.2	-7.1	-7.7	River Bottom
12+02	-11.0	-10.7	-9.9	-8.4	-8.6	-8.6	-8.7	-6.2	-7.2	River Bottom
12+31	-11.6	-10.7	-9.5	-8.1	-8.4	-8.6	-8.7	-7.2	-7.5	River Bottom
12+57	-10.4	-9.4	-9.1	-7.5	-8.0	-8.6	-8.2	-7.4	-7.5	River Bottom
12+83	-9.0	-9.5	-8.8	-7.7	-7.9	-8.4	-8.2	-7.1	-7.6	River Bottom
13+09	-8.4	-8.7	-8.0	-7.2	-7.4	-7.9	-7.8	-7.2	-7.9	River Bottom
13+35	-7.6	-8.1	-7.6	-6.8	-6.8	-7.0	-6.9	-7.0	-7.2	River Bottom
13+64	-6.7	-7.2	-7.2	-6.4	-6.5	-6.5	-6.4	-6.2	-6.1	River Bottom
13+87	-6.3	-6.7	-6.5	-6.1	-6.3	-6.4	-6.0	-5.5	-5.5	River Bottom
14+17	-5.7	-6.5	-6.3	-5.6	-5.7	-5.7	-5.8	-4.9	-5.1	River Bottom
14+40	-5.9	-6.2	-6.2	-5.4	-5.5	-5.6	-5.5	-5.3	-5.1	River Bottom
14+69	-6.6	-6.5	-6.3	-5.7	-5.7	-5.4	-5.4	-4.6	-4.6	River Bottom
14+98	-7.8	-7.9	-7.8	-6.5	-6.4	-6.1	-6.0	-4.7	-4.8	River Bottom
15+24	-10.7	-10.6	-9.2	-7.8	-8.6	-7.9	-7.6	-5.6	-5.4	River Bottom
15+53	-13.6	-13.3	-11.8	-10.9	-10.9	-10.5	-10.0	-7.6	-7.9	River Bottom
15+79	-14.7	-13.9	-12.6	-12.2	-11.9	-11.5	-10.7	-8.8	-8.7	River Bottom
16+02	-11.1	-12.3	-12.3	-12.3	-12.2	-11.8	-9.4	-9.1	-9.3	River Bottom
Varies	0.7	0.5	0.2	0.3	1.0	-0.2	1.3	0.5	0.3	Edge of Water
16+95	8.5	8.4	8.4	8.3	-	-	-	-	-	Top of Bank (2016)
16+97	-	-	-	-	8.7	7.9	-	-	-	Top of Bank (2018)
17+00	-	-	-	-	-	-	8.9	7.7	7.7	Top of Bank
17+00	9.2	9.5	9.4	9.3	9.2	8.9	8.9	8.3	8.2	Ground Shot
17+57	10.1	10.3	10.0	9.7	9.6	9.8	9.9	9.7	9.7	Ground Shot
18+00	9.4	9.6	9.6	9.5	9.4	9.5	9.7	9.5	9.6	Ground Shot
19+00	10.2	10.5	10.6	10.4	10.2	10.3	10.4	10.3	10.5	Ground Shot

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CD-5 Michael Baker
Bridge Transects
Transect 7

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STA	2013	2014	2015	2016	2017	2018	2019	2020	2021	Description
19+07	10.8	10.9	10.7	10.5	10.3	10.5	10.6	10.5	10.4	Ground Shot

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CD-5 Michael Baker
Bridge Transects
Transect 8

KUUKPIK UMIAQ
DOC LCMF-156 REV9

STA	2013	2014	2015	2016	2017	2018	2019	2020	2021	Description
0+00	10.6	10.8	10.3	10.3	10.1	10.1	10.1	10.1	10.1	Ground Shot
1+00	10.1	10.2	10.3	10.2	10.1	10.1	10.2	10.1	10.1	Ground Shot
2+00	9.8	10.0	10.1	10.0	9.9	10.0	9.8	9.8	9.9	Ground Shot
2+00	-	-	-	-	-	-	9.8	8.9	8.8	Top of Bank
2+08	8.9	9.0	9.0	9.0	8.9	8.7	-	-	-	Top of Bank (2018)
Varies	0.9	0.2	-0.4	0.2	1.3	-0.2	1.8	0.5	0.2	Edge of Water
2+99	-5.8	-5.5	-7.3	-6.6	-6.6	-3.7	-6.6	-5.0	-5.0	River Bottom
3+20	-7.1	-7.7	-8.7	-8.3	-8.3	-7.8	-7.4	-6.2	-6.8	River Bottom
3+40	-7.4	-8.8	-9.7	-8.6	-8.8	-8.4	-8.1	-7.0	-7.2	River Bottom
3+61	-8.2	-9.6	-10.4	-9.2	-9.8	-9.1	-8.9	-7.7	-7.8	River Bottom
3+85	-9.7	-10.5	-11.2	-9.9	-10.6	-10.4	-10.0	-9.3	-9.7	River Bottom
4+09	-9.9	-10.8	-12.1	-11.2	-11.6	-11.5	-11.3	-11.6	-11.8	River Bottom
4+33	-9.9	-11.3	-13.1	-13.6	-13.5	-12.9	-12.9	-14.3	-14.1	River Bottom
4+57	-10.3	-11.9	-14.1	-15.2	-15.6	-16.5	-15.8	-15.2	-15.6	River Bottom
4+85	-10.0	-10.9	-14.3	-15.3	-15.2	-15.3	-15.2	-15.3	-15.4	River Bottom
5+09	-10.6	-10.4	-15.0	-14.4	-14.6	-14.9	-15.1	-14.9	-15.3	River Bottom
5+33	-11.5	-10.3	-15.2	-14.0	-14.4	-14.5	-14.4	-14.6	-14.5	River Bottom
5+60	-11.9	-10.7	-14.7	-13.8	-14.0	-13.6	-13.7	-13.7	-13.7	River Bottom
5+87	-12.4	-10.3	-14.2	-13.2	-13.5	-13.2	-13.1	-14.0	-13.8	River Bottom
6+19	-11.8	-10.8	-14.9	-14.3	-14.6	-14.6	-14.5	-14.4	-14.6	River Bottom
6+46	-11.1	-10.8	-15.4	-15.6	-15.6	-15.4	-15.3	-14.7	-14.9	River Bottom
6+73	-11.2	-11.6	-15.6	-15.5	-15.6	-15.3	-15.7	-14.5	-14.3	River Bottom
7+01	-10.3	-10.6	-15.3	-14.4	-14.7	-14.5	-14.5	-14.1	-14.3	River Bottom
7+28	-10.0	-10.3	-13.9	-13.5	-13.5	-13.6	-13.3	-13.7	-14.2	River Bottom
7+53	-11.8	-11.0	-12.5	-12.4	-12.2	-12.4	-12.8	-13.2	-12.9	River Bottom
7+80	-11.6	-11.0	-11.1	-10.5	-10.7	-11.3	-12.0	-11.7	-11.8	River Bottom
8+08	-12.1	-9.5	-9.4	-9.7	-9.8	-9.1	-8.9	-9.1	-8.4	River Bottom
8+36	-11.6	-8.2	-9.4	-9.1	-9.0	-8.2	-8.0	-8.2	-7.9	River Bottom
8+59	-11.0	-7.8	-8.5	-8.6	-8.4	-8.3	-7.8	-7.7	-7.1	River Bottom
8+79	-11.1	-7.1	-7.2	-7.5	-7.6	-7.2	-7.4	-7.3	-6.8	River Bottom
9+04	-9.1	-7.9	-6.8	-7.1	-6.5	-5.6	-6.4	-6.6	-6.1	River Bottom
9+28	-8.3	-7.7	-6.3	-5.0	-5.5	-4.8	-5.0	-5.8	-5.3	River Bottom
9+53	-8.1	-7.2	-6.4	-5.2	-5.5	-5.4	-5.3	-5.4	-5.1	River Bottom
9+76	-7.7	-6.6	-6.5	-4.6	-4.9	-4.1	-4.5	-4.2	-3.7	River Bottom
9+96	-7.6	-6.7	-6.4	-5.6	-5.0	-5.1	-4.1	-4.0	-3.3	River Bottom
10+17	-7.2	-6.2	-6.2	-6.2	-5.8	-5.2	-4.3	-3.6	-3.0	River Bottom
10+42	-5.6	-5.6	-6.0	-4.8	-4.3	-3.3	-3.5	-3.0	-2.7	River Bottom
10+62	-3.1	-3.9	-3.4	-3.1	-3.1	-2.5	-2.2	-2.2	-1.4	River Bottom

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RPT-CE-CD-114 REV9

CD-5 Michael Baker
Bridge Transects
Transect 9

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STA	2013	2014	2015	2016	2017	2018	2019	2020	2021	Description
0+00	10.6	10.6	10.6	10.6	10.3	10.4	10.5	10.4	10.4	Ground Shot
1+00	9.9	10.0	10.0	9.9	10.0	9.8	9.8	10.1	10.0	Ground Shot
1+50	10.5	10.5	10.3	10.1	10.0	10.1	10.0	10.0	9.9	Ground Shot
1+89	-	-	-	-	-	-	8.9	8.6	8.7	Top of Bank
1+92	9.6	9.6	9.7	9.6	9.4	9.2	-	-	-	Top of Bank (2018)
Varies	0.6	0.0	0.9	0.7	0.8	-0.2	2.0	0.3	0.1	Edge of Water
2+48	-5.7	-10.5	-7.1	-5.7	-7.0	-5.5	-5.2	-6.6	-7.9	River Bottom
2+62	-7.7	-13.4	-13.8	-15.3	-14.6	-14.3	-14.0	-12.3	-18.8	River Bottom
2+78	-10.5	-18.8	-18.7	-19.2	-17.4	-19.1	-17.7	-19.0	-21.2	River Bottom
2+92	-14.5	-18.8	-21.6	-20.6	-20.2	-20.1	-19.5	-22.5	-22.2	River Bottom
3+13	-15.5	-19.2	-23.5	-21.8	-21.9	-22.0	-21.0	-23.1	-21.6	River Bottom
3+33	-15.2	-20.1	-24.9	-23.0	-23.2	-23.0	-21.2	-22.7	-21.7	River Bottom
3+58	-14.8	-20.7	-21.4	-23.5	-23.5	-23.3	-21.7	-23.4	-22.0	River Bottom
3+79	-13.9	-16.2	-19.2	-19.4	-21.7	-19.8	-19.5	-22.3	-22.4	River Bottom
4+03	-13.9	-16.2	-21.4	-21.5	-20.8	-21.4	-21.1	-23.7	-24.4	River Bottom
4+26	-13.4	-16.9	-22.1	-22.0	-20.0	-22.0	-21.0	-23.7	-22.3	River Bottom
4+54	-12.9	-19.9	-22.2	-19.8	-19.5	-18.4	-17.5	-21.4	-20.5	River Bottom
4+78	-13.4	-20.5	-22.3	-20.2	-19.4	-18.8	-17.8	-20.9	-20.5	River Bottom
5+02	-13.0	-19.3	-22.4	-19.0	-19.0	-18.8	-17.9	-21.0	-20.6	River Bottom
5+30	-13.2	-18.4	-21.5	-19.0	-18.6	18.1	-17.5	-20.7	-20.6	River Bottom
5+54	-13.9	-17.9	-20.9	-18.5	-18.5	-17.9	-17.5	-20.6	-20.1	River Bottom
5+79	-13.7	-18.3	-21.3	-18.8	-19.4	-18.6	-18.0	-20.9	-20.5	River Bottom
6+02	-12.6	-17.8	-19.7	-20.6	-20.3	-19.7	-19.0	-20.9	-20.4	River Bottom
6+30	-12.2	-15.4	-17.7	-20.7	-21.0	-20.2	-18.8	-20.0	-19.3	River Bottom
6+55	-12.7	-13.3	-16.7	-16.0	-15.5	-14.0	-12.6	-18.2	-15.9	River Bottom
6+79	-15.2	-12.4	-16.8	-16.5	-16.3	-14.5	-16.5	-16.2	-14.6	River Bottom
7+06	-14.0	-12.7	-17.0	-16.7	-16.6	-15.3	-13.6	-15.1	-13.6	River Bottom
7+30	-13.3	-13.2	-16.8	-15.7	-15.6	-14.6	-12.3	-14.3	-12.2	River Bottom
7+57	-11.9	-14.8	-17.0	-15.3	-14.8	-13.2	-11.7	-12.7	-11.3	River Bottom
7+84	-11.6	-14.6	-17.3	-15.4	-14.9	-14.0	-12.1	-12.1	-11.1	River Bottom
8+08	-11.0	-15.8	-16.6	-14.5	-13.9	-13.5	-10.8	-11.8	-10.0	River Bottom
8+33	-9.9	-10.3	-15.1	-10.5	-15.9	-11.0	-6.1	-8.6	-5.7	River Bottom
8+58	-6.9	-7.9	-6.2	-5.1	-5.1	-4.2	-0.1	-2.9	-1.3	River Bottom
8+78	-5.2	-6.4	-4.1	-3.5	-2.3	-2.6	-0.3	0.0	0.8	River Bottom
8+91	-3.3	-6.1	-2.8	-2.4	-2.0	-1.5	-0.5	0.2	1.2	River Bottom
Varies	0.5	0.5	1.2	0.5	0.9	-0.3	2.0	0.3	-	Edge of Water
10+00	2.3	2.5	4.0	4.1	4.0	4.4	4.6	5.0	5.1	Sand Bar
11+00	3.9	4.1	4.9	4.9	4.2	5.1	5.1	5.3	5.5	Sand Bar
11+52	5.0	5.2	5.5	5.6	5.4	5.8	5.7	5.8	5.9	Edge of Vegetation
12+00	5.4	5.5	6.0	6.0	5.7	5.9	6.0	6.0	6.1	Ground Shot
13+00	4.2	4.6	5.0	5.0	5.8	5.2	5.1	5.1	5.2	Ground Shot
14+00	3.9	4.1	4.5	4.5	4.9	4.5	4.4	4.4	4.6	Ground Shot
14+39	3.7	3.9	4.0	4.0	4.0	4.1	4.0	4.1	4.3	Edge of Water
14+82	3.4	3.7	3.9	3.8	3.8	4.2	4.0	4.1	4.3	Edge of Water
14+84	3.8	4.1	4.2	4.0	4.0	4.2	4.1	4.0	4.5	Toe of Bank
15+00	5.7	5.9	5.7	5.7	5.7	5.8	5.9	5.7	5.9	Top of Bank
15+52	8.0	8.2	8.0	7.9	7.8	8.0	8.2	8.1	8.1	Ground Shot
16+00	8.2	8.5	8.1	8.1	8.0	7.9	7.7	7.7	7.9	Ground Shot
16+92	9.4	9.4	9.3	9.3	9.0	7.8	9.2	9.1	8.9	Ground Shot

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CD-5 Michael Baker
Bridge Transects
Transect 10

KUUKPIK UMIAQ
DOC LCMF-156 REV9

STA	2013	2014	2015	2016	2017	2018	2019	2020	2021	Description
0+00	10.3	10.4	10.3	10.3	10.2	10.1	10.2	10.1	10.1	Ground Shot
1+00	10.4	10.7	10.3	10.3	9.6	9.3	8.7	8.7	8.7	Ground Shot
1+50	10.5	10.6	10.4	10.3	10.1	10.1	10.1	10.0	10.0	Ground Shot
1+67	-	-	-	-	-	-	9.7	9.6	9.6	Top of Bank
1+90	9.9	9.7	9.5	9.4	8.9	8.2	-	-	-	Top of Bank (2018)
2+00	6.7	7.0	6.5	6.4	5.3	5.1	4.0	1.2	1.3	Ground Shot
Varies	0.5	-0.8	-0.3	0.7	1.2	-0.2	2.0	-0.5	0.5	Edge of Water
2+67	-7.8	-14.3	-20.4	-19.5	-19.9	-20.2	-19.7	-19.1	-20.9	River Bottom
2+87	-20.7	-21.4	-21.3	-22.3	-21.6	-22.6	-21.7	-21.7	-21.9	River Bottom
3+09	-21.3	-22.5	-23.8	-23.3	-23.2	-24.0	-22.3	-23.1	-22.3	River Bottom
3+30	-20.0	-21.2	-23.8	-22.6	-23.1	-22.8	-23.1	-22.9	-22.3	River Bottom
3+55	-19.4	-20.3	-23.7	-22.7	-22.4	-22.3	-22.2	-22.4	-22.1	River Bottom
3+76	-19.0	-20.7	-23.7	-22.6	-21.1	-22.3	-22.1	-22.0	-20.9	River Bottom
4+00	-17.8	-18.6	-20.8	-18.8	-18.3	-18.9	-18.5	-20.5	-18.4	River Bottom
4+21	-18.0	-19.2	-21.1	-19.0	-18.9	-18.8	-18.8	-18.5	-18.0	River Bottom
4+45	-18.7	-19.2	-21.5	-19.1	-19.1	-18.6	-18.0	-18.2	-17.0	River Bottom
4+70	-19.0	-19.9	-21.9	-20.9	-20.3	-19.3	-18.2	-17.8	-16.7	River Bottom
4+94	-18.4	-20.6	-22.3	-21.9	-21.2	-20.3	-20.4	-17.8	-17.3	River Bottom
5+21	-17.3	-20.4	-23.0	-22.0	-22.0	-21.3	-19.8	-18.2	-17.5	River Bottom
5+45	-16.1	-19.2	-23.7	-22.3	-22.2	-21.3	-20.4	-18.7	-18.0	River Bottom
5+69	-14.6	-19.1	-23.2	-22.0	-21.5	-21.3	-20.4	-19.1	-18.3	River Bottom
5+96	-13.5	-17.7	-22.4	-21.2	-20.1	-20.4	-19.6	-19.3	-18.4	River Bottom
6+20	-13.7	-16.8	-21.5	-20.5	-19.8	-19.1	-18.5	-19.3	-18.1	River Bottom
6+47	-12.5	-15.3	-19.7	-18.2	-17.9	-17.4	-16.5	-20.2	-19.3	River Bottom
6+71	-12.1	-14.7	-17.4	-16.2	-16.2	-15.4	-14.0	-16.9	-15.2	River Bottom
6+99	-11.9	-14.2	-15.2	-13.8	-13.2	-11.8	-11.0	-12.7	-9.2	River Bottom
7+23	-12.4	-15.4	-14.8	-11.4	-10.8	-9.5	-8.8	-9.9	-7.6	River Bottom
7+48	-12.2	-17.6	-14.4	-10.7	-9.7	-8.3	-7.1	-7.5	-5.8	River Bottom
7+70	-12.9	-25.5	-14.1	-11.3	-10.5	-9.1	-7.1	-7.0	-5.8	River Bottom
7+94	-11.2	-21.7	-14.8	-14.6	-12.7	-10.6	-9.1	-7.6	-6.8	River Bottom
8+15	-6.8	-15.9	-10.8	-12.8	-7.9	-6.5	-6.3	-5.6	-0.9	River Bottom
Varies	0.4	1.2	2.6	0.8	1.1	-0.3	1.9	0.1	0.4	Edge of Water
9+00	1.6	2.1	3.7	3.8	3.5	3.6	3.6	3.8	3.9	Sand Bar
10+00	3.6	3.2	4.3	4.3	4.4	4.6	4.6	4.9	5.0	Sand Bar
11+00	5.4	5.6	5.8	5.9	5.9	6.1	6.0	6.2	6.2	Edge of Vegetation
12+00	5.1	5.4	5.7	5.7	5.7	5.9	5.8	5.7	5.8	Ground Shot
13+00	4.8	5.0	5.4	5.4	5.3	5.5	5.6	5.5	5.6	Ground Shot
14+00	4.6	4.8	5.0	5.1	5.0	4.7	4.8	4.8	4.9	Ground Shot
14+84	3.7	3.8	3.7	3.7	3.8	3.9	4.0	4.0	4.4	Toe of Bank
14+96	7.7	7.7	6.8	7.5	7.4	7.5	7.5	7.4	7.5	Top of Bank
15+00	7.8	8.0	7.9	7.8	7.7	7.8	7.7	7.7	7.7	Ground Shot
15+38	8.6	8.5	8.4	8.8	8.4	8.2	8.2	8.0	8.1	Ground Shot
15+53	9.1	9.4	9.4	9.2	9.1	9.2	9.2	9.0	9.1	Grade Break
15+71	7.2	7.4	7.3	7.2	7.2	7.1	6.8	7.0	7.2	Grade Break
16+00	6.7	7.0	6.8	6.7	6.4	6.6	6.4	6.3	6.5	Ground Shot
16+88	7.2	7.4	7.2	7.2	6.9	7.1	7.3	7.2	7.4	Ground Shot

Doc LCMF-156 CD5 Bridge Transects Rev10.xlsx 1 of 1 Transect_10

E.3.3 NIGLIAGVIK CHANNEL & BRIDGE TABULATED DATA (TRANSECTS 24 – 27)

Calc'd By: RTD
Date: 08/17/21
RPT-CE-CD-114 REV10

CD-5 Michael Baker
Bridge Transects
Transect 24

KUUKPIK UMIAQ
ALPINE SURVEY OFFICE

DOC LCMF-156 REV10

STA	2013	2014	2015	2016	2017	2018	2019	2020	2021	Description
0+00	26.5	26.5	26.4	26.4	26.4	26.5	26.3	26.6	26.4	Ground Shot
0+50	27.0	27.0	27.0	26.9	27.0	27.0	26.8	27.0	26.9	Ground Shot
0+94	27.9	26.4	26.5	26.5	26.4	26.3	26.3	26.3	26.6	Ground Shot
1+13	25.3	23.6	23.8	23.6	23.5	23.3	23.3	23.2	23.3	Top of Bank
1+45	2.6	2.7	3.2	0.5	0.8	1.4	1.5	2.7	1.9	Toe of Bank
Varies	0.2	0.5	1.5	0.5	1.4	1.2	0.8	0.5	0.4	Edge of Water
2+26	-1.7	-1.2	-1.9	-2.6	-2.7	-2.6	-2.5	-2.4	-2.2	River Bottom
2+39	-2.4	-1.8	-2.6	-3.3	-2.8	-2.7	-2.9	-3.3	-2.9	River Bottom
2+48	-2.0	-2.2	-2.9	-2.9	-1.9	-3.2	-2.2	-3.1	-2.6	River Bottom
2+61	-2.1	-2.2	-2.6	-2.2	-1.8	-2.5	-1.7	-2.3	-1.8	River Bottom
2+74	-2.2	-2.3	-2.3	-2.1	-1.7	-2.5	-1.8	-2.2	-1.7	River Bottom
2+90	-3.0	-1.9	-2.1	-2.0	-2.0	-2.8	-1.8	-2.2	-1.8	River Bottom
3+00	-3.0	-1.9	-2.1	-2.2	-1.9	-2.4	-1.8	-2.0	-1.9	River Bottom
3+17	-2.6	-2.0	-2.2	-2.1	-2.3	-2.2	-1.7	-2.1	-1.6	River Bottom
Varies	0.3	0.2	1.5	0.6	1.4	1.3	0.7	0.5	0.4	Edge of Water
3+86	5.9	5.7	5.8	5.8	5.7	5.6	5.7	5.5	5.7	Edge of Vegetation
3+96	7.1	7.2	7.2	7.0	6.9	6.9	6.9	6.9	7.1	Top of Bank
4+65	8.7	8.5	8.3	8.2	8.4	8.2	8.0	7.9	7.9	Ground Shot
5+15	9.4	9.2	9.1	9.0	9.1	8.9	9.0	8.9	8.8	Ground Shot

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Calc'd By: RTD
Date: 08/17/21
RPT-CE-CD-114 REV10

CD-5 Michael Baker
Bridge Transects
Transect 25

KUUKPIK UMIAQ
DOC LCMF-156 REV10

STA	2013	2014	2015	2016	2017	2018	2019	2020	2021	Description
0+00	27.5	27.4	27.3	27.3	27.3	27.3	27.2	27.4	27.2	Ground Shot
0+50	26.4	26.2	26.2	26.1	26.0	26.1	26.0	26.2	26.1	Ground Shot
0+70	26.8	26.7	26.7	26.5	26.6	26.7	26.8	26.7	26.8	Grade Break
0+89	21.8	21.3	21.3	21.2	21.2	21.1	21.1	21.0	21.3	Grade Break
1+00	25.7	22.2	22.5	22.1	22.2	22.3	22.3	22.7	23.2	Top of Bank
1+29	-	-	-	-	1.8	1.7	3.3	2.9	3.2	Toe of Bank
1+31	2.8	2.8	2.7	1.3	-	-	-	-	-	Toe of Bank (2016)
Varies	0.6	0.3	1.4	0.4	1.0	1.3	2.2	0.5	0.5	Edge of Water
2+19	-2.6	-1.2	-3.4	-3.7	-3.0	-5.2	-3.9	-3.8	-4.0	River Bottom
2+38	-2.2	-1.6	-3.5	-3.5	-3.6	-4.0	-3.2	-4.1	-3.8	River Bottom
2+48	-2.2	-1.9	-3.5	-3.4	-3.2	-4.2	-2.8	-4.2	-3.5	River Bottom
2+61	-2.4	-2.9	-3.2	-3.1	-2.6	-3.3	-2.2	-3.2	-3.0	River Bottom
2+72	-2.8	-2.6	-2.8	-2.8	-2.1	-3.2	-2.0	-3.1	-2.7	River Bottom
2+89	-2.7	-2.1	-2.3	-2.1	-1.7	-2.8	-1.2	-2.6	-2.1	River Bottom
2+97	-2.6	-1.9	-2.1	-1.8	-1.7	-2.6	-1.6	-1.9	-1.9	River Bottom
3+07	-2.7	-2.0	-1.8	-1.9	-1.3	-2.2	-1.2	-1.9	-1.7	River Bottom
Varies	0.1	0.1	1.5	0.4	1.0	1.3	2.1	0.5	0.5	Edge of Water
3+51	2.5	2.5	-	-	-	-	-	-	-	Ground Shot (2014)
3+81	6.1	6.1	6.4	6.2	6.3	6.2	6.3	6.2	6.3	Edge of Vegetation
3+91	7.8	7.5	7.7	7.5	7.4	7.4	7.5	7.6	7.8	Top of Bank
4+53	8.5	8.3	8.1	8.2	8.2	8.3	8.0	8.1	7.9	Ground Shot
5+03	8.4	8.4	8.3	8.4	8.5	8.4	8.5	8.2	7.9	Ground Shot

Calc'd By: RTD
Date: 08/17/21
RPT-CE-CD-114 REV10

CD-5 Michael Baker
Bridge Transects
Transect 26

KUUKPIK UMIAQ
ALPINE SURVEY OFFICE

DOC LCMF-156 REV10

STA	2013	2014	2015	2016	2017	2018	2019	2020	2021	Description
0+00	24.0	27.5	27.3	27.3	27.3	27.3	27.2	27.3	27.1	Ground Shot
0+60	24.1	27.7	27.6	27.5	27.4	27.2	27.2	27.2	26.9	Ground Shot
0+85	24.0	27.3	27.5	27.3	27.2	27.2	27.4	27.2	27.4	Ground Shot
1+03	21.5	24.9	25.0	25.0	25.0	24.9	24.9	24.7	25.3	Top of Bank
1+36	2.7	2.4	3.1	1.8	1.9	1.9	2.4	3.2	4.1	Toe of Bank
Varies	0.4	0.2	1.5	0.5	1.0	1.4	1.5	0.5	0.6	Edge of Water
2+19	-2.5	0.2	-3.5	-3.5	-4.0	-3.0	-5.1	-3.7	-3.3	River Bottom
2+32	-2.6	-1.2	-3.5	-3.0	-4.4	-5.4	-5.0	-5.1	-4.1	River Bottom
2+43	-2.5	-2.1	-3.6	-1.7	-3.0	-4.0	-3.7	-4.5	-3.9	River Bottom
2+53	-2.4	-2.4	-3.6	-1.7	-2.6	-3.9	-3.8	-3.2	-3.0	River Bottom
2+63	-2.4	-2.6	-3.6	-2.1	-3.0	-4.2	-3.9	-2.9	-2.9	River Bottom
2+80	-2.3	-2.9	-2.8	-3.3	-2.6	-4.1	-3.8	-3.3	-2.8	River Bottom
2+91	-2.0	-2.9	-2.6	-4.0	-2.8	-3.9	-3.7	-2.9	-2.6	River Bottom
3+08	-2.2	-2.3	-2.2	-3.2	-1.7	-2.5	-3.0	-2.4	-2.1	River Bottom
Varies	0.2	0.0	1.4	0.5	0.9	1.4	1.5	0.5	0.6	Edge of Water
3+57	3.2	3.3	-	1.2	1.0	-	-	1.2	1.5	Ground Shot
3+89	6.1	6.6	7.0	6.6	6.6	6.5	6.7	6.8	7.0	Edge of Vegetation
3+97	7.1	7.5	7.7	7.2	7.6	7.5	7.3	7.9	7.9	Top of Bank
4+79	8.3	9.3	9.9	10.0	9.9	8.1	9.4	9.2	9.3	Ground Shot
5+29	9.8	9.8	9.5	9.4	9.4	9.4	9.5	9.2	9.6	Ground Shot

Station 4+79 falls in Slope of Gravel Road

Calc'd By: CZ
Date: 08/29/20
RPT-CE-CD-114 REV10

CD-5 Michael Baker
Bridge Transects
Transect 27

KUUKPIK UMIAQ
DOC LCMF-156 REV10

STA	2013	2014	2015	2016	2017	2018	2019	2020	2021	Description
0+00	27.0	27.0	26.8	26.5	26.8	26.6	26.5	26.6	26.6	Ground Shot
0+50	27.1	27.1	27.0	27.0	27.1	26.7	26.8	26.8	26.8	Ground Shot
0+74	24.3	24.5	24.3	24.1	24.0	24.1	24.1	23.9	24.1	Grade Break
0+82	26.6	26.6	26.7	26.7	26.5	26.5	26.6	26.5	26.5	Grade Break
0+98	26.0	25.9	25.9	26.0	26.0	25.9	25.9	25.7	25.9	Top of Bank
1+30	2.5	2.1	2.5	2.2	2.3	2.3	2.3	3.5	1.9	Toe of Bank
Varies	0.1	0.3	1.5	0.5	1.0	1.3	1.7	0.5	0.7	Edge of Water
2+20	-2.4	-0.8	-1.4	-2.2	-1.6	-3.1	-2.8	-2.3	-1.6	River Bottom
2+31	-2.3	-1.0	-1.5	-1.6	-1.6	-3.3	-2.8	-1.8	-1.7	River Bottom
2+41	-3.3	-1.6	-2.1	-1.9	-1.8	-3.3	-3.0	-2.0	-1.8	River Bottom
2+48	-2.0	-1.7	-2.5	-2.3	-2.2	-3.3	-3.7	-2.2	-2.0	River Bottom
2+58	-2.7	-2.7	-3.0	-2.9	-2.7	-3.3	-3.8	-2.7	-2.3	River Bottom
2+65	-2.9	-2.7	-3.0	-3.2	-2.9	-3.0	-4.0	-3.1	-2.5	River Bottom
2+72	-3.1	-2.8	-3.0	-3.4	-2.8	-3.0	-4.0	-3.2	-2.6	River Bottom
2+78	-2.9	-2.8	-2.9	-3.3	-2.6	-3.0	-3.7	-3.2	-2.5	River Bottom
2+85	-2.5	-3.0	-2.9	-2.8	-2.3	-3.0	-3.2	-2.7	-2.3	River Bottom
2+92	-2.1	-2.6	-2.4	-2.5	-2.0	-3.0	-	-2.3	-1.8	River Bottom
Varies	-0.1	0.2	1.5	0.6	0.9	1.5	1.6	0.5	0.7	Edge of Water
3+39	1.9	2.0	-	1.3	1.4	-	-	1.7	2.0	Ground Shot
3+52	4.7	4.9	4.7	4.6	4.4	4.5	4.5	4.4	4.5	Ground Shot
3+76	5.9	6.1	6.2	6.3	6.2	6.2	6.2	6.2	6.4	Edge of Vegetation
3+89	7.0	7.2	7.2	7.1	7.0	7.2	6.9	7.1	7.4	Top of Bank
4+10	8.0	8.1	8.0	8.1	8.0	8.0	7.9	7.8	8.0	Ground Shot
4+71	8.0	8.0	7.8	7.7	7.4	7.3	7.2	7.3	7.2	Ground Shot
5+21	9.7	9.7	9.2	9.0	9.1	8.8	8.5	8.5	8.6	Ground Shot

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2021 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment