EXECUTIVE SUMMARY

This report presents the observations and results from the 2023 Colville River Delta Spring Breakup Monitoring and Hydrological Assessment 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. The analyses provide data to support design, permitting, and operation of oilfield development.

The 2023 monitoring and hydrological assessment is the 32nd consecutive year of spring breakup investigations and the 37th 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.

This year’s spring breakup flood was characterized as a long duration, historically low magnitude event with two notable crests in stage. Initial floodwater arrived in the delta on May 21. An initial crest in stage occurred in the MON1 reach on May 26 as floodwater accumulated and resulted in peak stage at MON1C.

On May 23, two ice jams were observed; one at Ocean Point and one at the Horseshoe Bend. These two ice jams were not holding back water and no overbank flooding was observed. Cooler air temperatures in the region slowed the melting process from May 24 to May 28. The Ocean Point ice jam remained in place until May 30, and the Horseshoe Bend ice jam remained until May 31 when rising water levels flushed the downstream intact channel ice. On May 31, an ice jam formed in the MON1 reach resulting in a second crest in stage and peak stage at MON1U due to backwater. Later in the day, the ice jam released in the MON1 reach, resulting in peak discharge. A smaller ice jam formed in the East Channel of the Colville River near the Sakoonang Channel bifurcation on June 1 and minor backwater was documented at upstream monitoring locations. In the Nigliq Channel, a small ice jam formed near the village of Nuiqsut, but no notable flooding was observed.

Peak conditions throughout the delta occurred between May 26 and June 2. Peak stage at MON1C occurred on May 26 and was 14.17 ft. British Petroleum Mean Sea Level (BPMSL), having an estimated recurrence interval of less than 2 years. Peak discharge at MON1C occurred on May 31 and was estimated at 234,000 cubic ft per second, having an estimated 1.6-year recurrence interval. Recurrence intervals are relative to design basis values.

During peak conditions, overbank flooding and floodplain inundation were not observed, and stage remained well below bankfull. Overall, ice jamming, flooding, and associated backwater effects were minimal during 2023 breakup.
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<tr>
<td>ADF&amp;G</td>
<td>Alaska Department of Fish and Game</td>
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<tr>
<td>Baro PT</td>
<td>barometric pressure transducer</td>
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<td>BPMSL</td>
<td>British Petroleum Mean Sea Level</td>
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<td>CD</td>
<td>Colville Delta</td>
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<td>CFDD</td>
<td>cumulative freezing degree days</td>
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<tr>
<td>cfs</td>
<td>cubic feet per second</td>
</tr>
<tr>
<td>CPAI</td>
<td>ConocoPhillips Alaska, Inc.</td>
</tr>
<tr>
<td>CRD</td>
<td>Colville River Delta</td>
</tr>
<tr>
<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
</tr>
<tr>
<td>fps</td>
<td>feet per second</td>
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<tr>
<td>ft</td>
<td>feet</td>
</tr>
<tr>
<td>gage</td>
<td>hydrologic staff gage</td>
</tr>
<tr>
<td>GPS</td>
<td>Global positioning system</td>
</tr>
<tr>
<td>HDD</td>
<td>Horizontal directionally drilled</td>
</tr>
<tr>
<td>HWM</td>
<td>High water mark</td>
</tr>
<tr>
<td>Michael Baker</td>
<td>Michael Baker International</td>
</tr>
<tr>
<td>MON</td>
<td>Monument</td>
</tr>
<tr>
<td>MP-AMS</td>
<td>Monitoring Plan with an Adaptive Management Strategy</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NRCS</td>
<td>Natural Resources Conservation Service</td>
</tr>
<tr>
<td>NPR-A</td>
<td>National Petroleum Reserve of Alaska</td>
</tr>
<tr>
<td>OSA</td>
<td>Oil Search (Alaska) LLC, a subsidiary of Santos Limited</td>
</tr>
<tr>
<td>PT</td>
<td>pressure transducer</td>
</tr>
<tr>
<td>RM</td>
<td>river mile</td>
</tr>
<tr>
<td>RTFM</td>
<td>Real-Time Flood Monitoring</td>
</tr>
<tr>
<td>SAK</td>
<td>Sakoonang</td>
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<td>TAM</td>
<td>Tamayayak</td>
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<tr>
<td>ULAM</td>
<td>Ulamnigiaq</td>
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<tr>
<td>UMI AQ</td>
<td>Umiaq, LLC</td>
</tr>
<tr>
<td>USACE</td>
<td>U.S. Army Corps of Engineers</td>
</tr>
<tr>
<td>USGS</td>
<td>U.S. Geological Survey</td>
</tr>
<tr>
<td>VSM</td>
<td>Vertical support member</td>
</tr>
<tr>
<td>WSE</td>
<td>Water surface elevation</td>
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1. INTRODUCTION

The Colville River is the largest river on the North Slope. It originates in the DeLong Mountains on the north side of the Brooks Range, runs north and east through the Arctic Coastal Plain, and forms the Colville River Delta (CRD) where it 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 2023 monitoring and hydrological assessment is the 32nd consecutive year of CRD spring breakup investigations.

The 2023 field program took place from April 24 to June 12. The setup work for the spring breakup program began on April 24 and concluded on May 22. Spring breakup monitoring began on May 23 and concluded on June 12. Primary field tasks included documenting the distribution of floodwater and measuring water levels and discharge at select locations. Observations of ice jams and floodwater effects throughout the CRD were recorded.

Umiaq, LLC (UMIAQ), CPAI Alpine and Ice Road 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.
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 set forth by U.S. Army Corps of Engineers (USACE) and the Alaska Department of Fish and Game (ADF&G).

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 of Alpine facilities during spring breakup. Permit stipulations include documentation of annual hydrologic conditions, direct measurements, 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 refers to a Monitoring Plan with an Adaptive Management Strategy (MP-AMS) (Michael Baker and ABR 2013) which includes monitoring of channel sedimentation and erosion specific to the CD5 development. Observations of functionality and flooding effects to the CD2 road bridges are also recorded to satisfy ADF&G permit FG97-III-0260-Amendment #3. 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 2023 monitoring locations and gage stations are the same as those studied in 2022 (Michael Baker 2022). 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.
### Table 1.1: Monitoring & Gage Station Locations

<table>
<thead>
<tr>
<th>CRD Monitoring Locations</th>
<th>Colville River</th>
<th>East Channel Bilocations</th>
<th>Nigliq Channel Bilocations</th>
<th>Table Facilities Monitoring Locations</th>
<th>Alpine Facilities Monitoring Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring Location</td>
<td>Location Description</td>
<td>Gage Station</td>
<td>Description</td>
<td>Location Description</td>
<td>Gage Station</td>
</tr>
<tr>
<td>Head of the CRD</td>
<td>MON1U</td>
<td>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 by a distance of approximately 1 mile.</td>
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<td></td>
<td>MON1C</td>
<td>West bank, adjacent to horizontal directionally drilled (HDD) West pipeline crossing, downstream of Nigliq Channel bifurcation</td>
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<tr>
<td></td>
<td>MON1D</td>
<td>West bank, downstream (north) of HDD West, upstream of Colville River bifurcation</td>
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<tr>
<td></td>
<td>MON09</td>
<td>East side of Helmericks Homestead, Kupigruk Channel just upstream of the coastline, farthest downstream gage station</td>
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<tr>
<td></td>
<td>MON0D</td>
<td>West bank, RM 12.9, upstream of the Eastlrove Channel anabranch</td>
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<tr>
<td></td>
<td>MON35</td>
<td>East bank, RM 1.3, in the vicinity of the Nuna/DSIT Pad, farthest downstream gage station</td>
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<td></td>
<td>EC1.3</td>
<td>East bank, upstream (south) of CD4 pad, upstream of Toolbox Creek</td>
<td></td>
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<tr>
<td></td>
<td>MON20</td>
<td>West bank, upstream of Nigliagvik Channel tributary</td>
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<tr>
<td></td>
<td>MON22</td>
<td>West bank, downstream of Nigliagvik Channel tributary, downstream (northwest) of CD2 pad</td>
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<tr>
<td></td>
<td>MON23</td>
<td>East bank, downstream of Nigliagvik Channel tributary, downstream (northwest) of CD2 pad</td>
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<tr>
<td></td>
<td>MON28</td>
<td>Eastern tributary channel at Harrison Bay, farthest downstream gage station</td>
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<tr>
<td>Lake L9312</td>
<td>CD2 Pad &amp; Road</td>
<td>G9</td>
<td>Northwest side of lake, southwest of CD1 pad</td>
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<tr>
<td>Lake L9311</td>
<td></td>
<td>G10</td>
<td>East side of lake, adjacent to CD1 pad</td>
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<tr>
<td>CD1 Pad</td>
<td>G1</td>
<td>East bank of Sakoonang Channel, east side of CD1 pad</td>
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<tr>
<td>East Channel</td>
<td>G6</td>
<td>South side of road, between Lake L9322 and Lake L9321</td>
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<tr>
<td>Bridge</td>
<td>G7</td>
<td>North side of road, between Lake L9322 and Lake L9321</td>
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<tr>
<td>Bridge</td>
<td>G12</td>
<td>South side of road, downstream of Naniu Lake</td>
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<tr>
<td>Bridge</td>
<td>G13</td>
<td>North side of road, downstream of Naniu Lake</td>
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<tr>
<td>Gage Station</td>
<td>G8</td>
<td>Northwest side of CD2 pad, adjacent to Nigliq Channel</td>
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<tr>
<td>Pipeline</td>
<td>G11</td>
<td>South side of CD3 pad, adjacent to north side of East Lamiagvik Channel</td>
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<tr>
<td>Crossings</td>
<td>G15</td>
<td>East side of road, between Lake L9322 and Lake L9325</td>
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<tr>
<td>Long &amp; Short</td>
<td>G16</td>
<td>West side of road, between Lake L9323 and Lake L9325</td>
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<td>Swale Bridge</td>
<td>G17</td>
<td>North side of road, between Sakoonang Channel and Lake L9323</td>
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<tr>
<td>Culverts</td>
<td>G18</td>
<td>South side of road, between Sakoonang Channel and Lake L9323</td>
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<td>CD2 Pad</td>
<td>G40</td>
<td>West side of road, between Lake L9325 and Laniu Lake</td>
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<td>CD3 Pad</td>
<td>G41</td>
<td>East side of road, between Lake L9325 and Laniu Lake</td>
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<td>Pipeline</td>
<td>G42</td>
<td>West side of road, between Lake L9325 and Laniu Lake</td>
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<td>CD2 Pad</td>
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<td>CD4 Pad</td>
<td>G19</td>
<td>South side of CD4 pad, north side of Lake L9324</td>
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<td>CD4 Pad</td>
<td>G20</td>
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<td>Culverts</td>
<td>G30</td>
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<td>CD5 Road</td>
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<td>Lake L9332</td>
<td>G34</td>
<td>South side of road, west of Lake L9341</td>
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<tr>
<td>Bridge</td>
<td>G35</td>
<td>North side of road, west of Lake L9341</td>
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<tr>
<td>Bridge</td>
<td>G36</td>
<td>East side of road, east of Nigliagvik Channel</td>
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<tr>
<td>Bridge</td>
<td>G37</td>
<td>North side of road, east of Nigliagvik Channel</td>
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<tr>
<td>Lake L9323</td>
<td>CD5 Road</td>
<td>G1</td>
<td>South side of road, between Oil Lake and Lake MB0301, outside of the CRD</td>
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<td>Bridge</td>
<td>G21</td>
<td>North side of road, between Oil Lake and Lake MB0301, outside of the CRD</td>
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<td>Bridge</td>
<td>G24</td>
<td>Northeast side of Lake L9323, 200 ft upstream of bridge centerline</td>
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<td>Bridge</td>
<td>G25</td>
<td>Northeast side of Lake L9323, 30 ft downstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G26</td>
<td>West side of Nigliq Channel, 2,600 ft upstream of bridge centerline</td>
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<td>Bridge</td>
<td>G27</td>
<td>East side of Nigliq Channel, 200 ft upstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G28</td>
<td>West side of Nigliq Channel, 160 ft upstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G29</td>
<td>West side of Nigliq Channel, 2,300 ft downstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G30</td>
<td>West side of Nigliq Channel, 350 ft upstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G31</td>
<td>East side of Nigliq Channel, 300 ft downstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G32</td>
<td>West side of Nigliq Channel, 180 ft upstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G33</td>
<td>West side of Nigliq Channel, 300 ft downstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G34</td>
<td>Under Bridge #1/Lake L9323</td>
<td></td>
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<tr>
<td>Bridge</td>
<td>G35</td>
<td>Under Bridge #2/Nigliq Channel Bridge</td>
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<tr>
<td>Bridge</td>
<td>G36</td>
<td>Under Bridge #3/Lake L9341</td>
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<td>Bridge</td>
<td>G37</td>
<td>Under Bridge #4/Nigliq Channel Bridge</td>
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<tr>
<td>Bridge</td>
<td>G38</td>
<td>East side of Nigliq Channel, 350 ft upstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G39</td>
<td>East side of Nigliq Channel, 300 ft downstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G40</td>
<td>West side of the Tinnaqaquvik Channel 500 ft downstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G41</td>
<td>Under Bridge #1/Tinnaqauvik Channel Bridge</td>
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<tr>
<td>Bridge</td>
<td>G42</td>
<td>On the pair of the Tinnaqauvik Bridge</td>
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<tr>
<td>Bridge</td>
<td>G43</td>
<td>West side of the Tinnaqauvik channel 600 ft upstream of bridge centerline</td>
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<tr>
<td>Bridge</td>
<td>G44</td>
<td>South (C) side of the Crea Bridge</td>
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<tr>
<td>Bridge</td>
<td>G45</td>
<td>North (A) and South (C) sides of the Crea Bridge</td>
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</tbody>
</table>

**2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment**

**Final Report**

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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 from this site were used during spring break up monitoring to help forecast the arrival of floodwater and timing of peak conditions in the CRD study area. Reconnaissance flights to Ocean Point and to 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, and interactions between floodwaters and infrastructure were recorded in field notebooks (Photo 2.1). Photographic documentation of breakup conditions was 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 a game camera installed on the west bank of the Nigliq Bridge and at Real-Time Flood Monitoring (RTFM) stations installed at MON9/HDD West and at MON1.

UMIAQ provided Hägglund tracked 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 monitoring locations by road.

![Photo 2.1: Field crew recording observations during gage installation; April 27, 2023](image1)

![Photo 2.2: Hägglund track vehicle transporting crew to Nigliq Channel; April 29, 2023](image2)

2.2 Water Surface Elevations

**HYDROLOGIC STAFF GAGES**

WSE data was collected using hydrologic staff gages (gage) 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 pressure transducers. Gage readings were recorded on field phones using an ESRI Survey 123 data collection application. Site visits were performed as needed and as conditions allowed. 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 maintained 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 BPMSL elevation and surveyed by UMIAQ. Survey is used to determine if correction factors must be applied to adjust WSE 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).

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).

**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 three locations in the CRD (G18, Lake L9312, and MON9 (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.
2.3 Discharge

MEASURED DISCHARGE

Discharge was measured as close to observed peak stage at the following locations:

- Colville River at MON1
- Nigliq Bridge/CD5 Bridge #2
- Nigliagvik Bridge/CD5 Bridge #4
- CD2 Road Long Swale Bridge
- CD2 Road Culverts (that were observed conveying flow)
- CD5 Road Culverts (that were observed conveying flow)
- MT6 Road Culverts (that were observed conveying flow)

Discharge was not measured at the Lake L9323 Bridge/CD5 Bridge #1, Lake L9341 Bridge/CD5 Bridge #3 or the Short Swale Bridge (CD2 Road) because either significant ice was present at the crossing, or the channel was only hydraulically connected for a brief period.

Discharge at MON1 was measured using a boat mounted Acoustic Doppler Current Profiler (ADCP [Photo 2.8]). Flow depth and velocity were measured at the Nigliq, Nigliagvik, and CD2 Road 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 2.9]). 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). Measured discharge methods are further detailed in Appendix C.
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 coefficient (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, which include drainage structures where breakup flow was observed:

- 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

<table>
<thead>
<tr>
<th>Quality Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>Open channel/drainage structure free of ice and snow, no backwater effects from downstream ice jamming, uniform channel/drainage structure through reach</td>
</tr>
<tr>
<td>Fair</td>
<td>Some ice floes and/or snow in the channel/drainage structure, some backwater effects, fairly uniform conditions through reach</td>
</tr>
<tr>
<td>Poor</td>
<td>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</td>
</tr>
</tbody>
</table>

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

Scour is measured at the base of bridge piers during and after breakup flooding. These measurements satisfy the requirement for annual pier scour monitoring during spring breakup and other large flood events at the Nigliq Bridge and Nigliagvik Bridge (Michael Baker and ABR 2013) and are critical for ensuring safe bridge operations. Maximum scour occurs during peak velocities, typically during spring breakup. The scour holes around the piers often infills after spring breakup due to sediment deposition. For this reason, real-time soundings are collected during peak flood conditions to capture maximum scour.

The Nigliq Bridge is supported by two bridge abutments (abutments 1 and 9) and seven bridge piers (piers 2 through 8) with pier 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 breakers, 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 and therefore are considered to be more susceptible to scour.

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 2022a).
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 at these installations are measured annually 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 data 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. These scour survey 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 from 2016 to present (UMIAQ 2016, 2017b, 2018a, 2019, 2020, 2021, 2022, 2023). Maximum and average rates of erosion between 2013 and 2023 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 are 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. Ice roads were mechanically slotted prior to breakup, to facilitate the melt and flow of water at the crossings.
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

<table>
<thead>
<tr>
<th>Monitoring Location</th>
<th>Gage Station</th>
<th>Real-Time Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colville River</td>
<td>• MON1U</td>
<td>Stage</td>
</tr>
<tr>
<td></td>
<td>• MON1C</td>
<td>River conditions and staff gage measurements via remote camera images</td>
</tr>
<tr>
<td></td>
<td>• MON1D</td>
<td></td>
</tr>
<tr>
<td>Alpine Drinking Water Lakes</td>
<td>• L9312 (G9)</td>
<td>Stage</td>
</tr>
<tr>
<td></td>
<td>• L9313 (G10)</td>
<td></td>
</tr>
<tr>
<td>CD2 Road Swale Bridges</td>
<td>• G3</td>
<td>Stage</td>
</tr>
<tr>
<td>CD4 Road/CD4 Pad</td>
<td>• G18</td>
<td>Stage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Barometric pressure</td>
</tr>
<tr>
<td>CD5 Road</td>
<td>• Nigliq Bridge</td>
<td>Stage</td>
</tr>
<tr>
<td></td>
<td>• Nigliagvik Bridge</td>
<td>Pier scour</td>
</tr>
<tr>
<td>GMT1/MT6 Road</td>
<td>• Tinmiaqsiugvik Bridge</td>
<td>Stage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>River conditions via remote camera images</td>
</tr>
</tbody>
</table>
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 or subsistence hunting activities. Remote cameras were also installed to observe conditions at the Tinmiaqsiugvik Bridge and MON9, at the west bank and east bank of the Colville HDD crossing (Photo 2.11).
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.

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 for transmitting 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 2.11: Remote camera setup at MON1-U; May 4, 2023

Photo 2.12: Remote stage monitoring equipment at Lake L9313 (G10); May 16, 2023

Photo 2.13: Installing pier scour sonar equipment on the Nigliq Bridge; May 24, 2023
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 Michael Baker staff and Alpine Operations personnel if stage or pier scour reached certain values associated with an action or reporting requirement at select monitoring locations. If alarms were triggered, notifications were automatically 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 relative to the current Basis of Design (BOD) 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 BOD flood frequency results (Michael Baker 2002). Peak stage at select monitoring locations was compared to results of the most current stage frequency analysis as well as results from the 2D CRD surface water model. Stage recurrence intervals were assigned to this year’s peak stage relative to these results.
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 approximately 2 miles west of GMT1/MT6, the 2022-2023 (September – June) winter temperatures were 7th warmest on record, with respect to freezing degree days, over the past 22 years (Graph 3.1, ICE 2023).

North Slope snowpack data was limited to snow depths this year since snow water equivalent (SWE) data was not available due to the USDA Natural Resources Conservation Service National Water and Climate Center SNOTEL site at Prudhoe Bay not being fully operational. Observed snow depths for the 2022-2023 winter were at or below the median for the North Slope relative to data collected between 2011-2023 (NWS 2023).

In the Upper Colville River watershed, recorded at Umiat, a warming trend started at the end of April and ended the second week of May. Temperatures during this time reached above freezing during the daytime highs, but the nighttime lows were around 5-10°F Fahrenheit (F). From May 8-12, cold and cloudy weather kept the daytime high temperatures between 20-25°F. After May 13, daytime highs were above freezing (40-50°F) with nighttime lows around 25°F. This trend lasted until May 24 and progressed breakup melting. A cooling trend from May 24-28 stalled breakup as daytime highs hovered around freezing. After May 28, overnight lows remained above freezing and daytime highs ranged from 40-60°F. This second warming trend melted off the rest of the snow in the region.

The Colville River Delta area experienced a similar temperature pattern as Umiat. Day time highs reached above freezing beginning May 14 until May 24. The cooler weather was from May 24-28 as daytime highs remained at or
below freezing. From May 28-June 2, daytime highs were above freezing (35-40° Fahrenheit), but nighttime lows were near freezing. After June 3, the daytime highs increased to 40-60° Fahrenheit, but nighttime lows remained near freezing 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] 2023 and Meteostat 2023). Data not reported was missing from NOAA records.

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

During a reconnaissance flight on May 19, the leading edge of floodwater in the Colville River was first observed downstream of Ocean Point. The Chandler and Anaktuvuk River were the main contributors as little to no flow was observed in the Colville River upstream of the Anaktuvuk River confluence. By May 21, a reconnaissance flight showed the leading edge in the Colville River had progressed downstream to the Horseshoe Bend (Photo 3.1) The USGS Colville River stream gauge at Umiat recorded a sharp 3-foot spike in stage that day. On May 22, the leading edge had progressed into the CRD (Photo 3.2) and by the afternoon had reached the mouth at Harrison Bay.

On May 23, two ice jams formed in the Colville River upstream of the CRD. An ice jam was observed downstream of Ocean Point measuring approximately 6 river miles (RM) long, (Photo 3.3) and a second jam approximately 0.5 RM long was upstream of the Horseshoe Bend (Photo 3.4). Upstream of Ocean Point the sand bars were still exposed, indicating that water levels were below bankfull. Stage at Umiat continued to rise throughout the day.

On May 24, the two ice jams grew in length as more ice floes accumulated. The Ocean Point ice jam was approximately 8.5 RM long and persisted downstream. The Horseshoe Bend ice jam was approximately 4 RM long and also persisted downstream. Stage at Umiat peaked at 10:15 PM on May 24 at a stage of 55.4 ft NAVD88.

Photo 3.1: Initial flood water moving through Horseshoe Bend, looking south (upstream); May 21, 2023

Photo 3.2: Flood waters entering the delta upstream of HDD crossing near the Putu Island, looking south (upstream); May 22, 2023
On May 25, the two ice jams remained in place, similar to the prior day’s observations. Water levels on the Colville River at Ocean Point approached bankfull and flooded low-lying areas and secondary channels. The Umiat gage recorded greater than a 1-ft decrease in stage over the course of the day. Water levels in the Nigliq Channel were high enough to flow into Nanuq Lake (Photo 3.5). Bottomfast ice in the Nigliq Channel began to lift in the upstream vicinity of the Nigliq Bridge. Water levels in the Sakoonang Channel had increased such that it formed hydraulic connections between Lakes L9324 and M9525 (Photo 3.6).

On May 26, the two ice jams persisted in the Colville River upstream of the CRD and had not significantly changed since initial observations. Stranded ice indicated that there was a small decrease in water levels upstream of Ocean Point. At the head of the delta (MON1C), stage peaked at 14.17 ft in the morning (Photo 3.7). Temperatures dropped below freezing overnight and cloud cover developed.

From May 26-28 water levels dropped as colder and cloudy weather stalled the breakup processes. Stranded ice was observed in the East Channel of the Colville River and the two ice jams upstream of the CRD remained in place (Photo 3.8).
On May 28, temperatures in the afternoon exceeded freezing, but water levels in the delta continued to drop. On May 29, stage at Umiat began to rise again. Downstream of the ice jams, the channel ice remained intact; however, transverse cracks were beginning to form, suggesting the intact ice was weakening (Photo 3.9). On May 30, the Ocean Point ice jam released, and floes accumulated behind the Horseshoe Bend ice jam (Photo 3.10).

On the morning of May 31, the Horseshoe Bend ice jam released and reformed near MON1. A large ice pan was blocking the Colville River East Channel at the Nigliq Channel bifurcation (Photo 3.11), and the ice jam extended upstream past MON1. Backwater, related to this ice jam, was minimal and did not result in any observed overbank flooding. The East Channel, between MON1 and the HDD crossing, was ice-free. Downstream of the HDD crossing, floes began to jam between the Sakoonang and Tamayak Channel bifurcations. In the evening, the ice jam at MON1 released, causing a second crest in stage at MON1C of 13.92 ft.
On June 1, a small ice jam was present in the East Channel of the Colville River, downstream of the Sakoonang bifurcation (Photo 3.12). Stranded ice was observed along the banks upstream of the ice jam. In the Nigliq Channel, a small ice jam had formed near the village of Nuiqsut.

On June 2, ice in the Nigliq Channel was observed moving downstream of the Nigliq Bridge. On June 3, ice in the East Channel had cleared past the Tamayayak Channel bifurcation (Photo 3.13). Stage had dropped such that sand bars were exposed on the west bank at the HDD crossing. In the Nigliq Channel, the channel ice had cleared through the Nigliq Bridge. On June 4, the East Channel was ice-free to the Kupigruak Channel and the Nigliq Channel was ice-free to Harrison Bay.
Photo 3.13: Ice moving downstream of the Tamayayak Channel bifurcation; looking north (downstream); June 3, 2023

In general, peak stage occurred at monitoring sites in the CRD between May 25 and June 2. Water remained within channel banks during peak conditions and no overbank flooding was observed. Hydraulic connections that typically form between lakes and channels during breakup occurred. Overall, ice jamming in the CRD was limited with no significant backwater effects observed.
Figure 3.1: Spring Breakup Hydrologic Timeline

- Peak stage at MON1 and MON2.
- Peak stage at MON1 and MON2, and MON3.
- Peak stage at COD and CO2.
- Peak stage at TAK and ULAM.
- Peak stage at TAK and ULAM, and ULAM.
- Peak stage at all channels along COD road.
- Ice jam observed at Horsethief Bend.
- Ice jam observed at Horsethief Bend & Crown Point, large continues for two with nunavars expected.
- Ice jams growing in length and size increasing, submerging smaller.
- Ice jams persist with stage peaking, temperatures stay below freezing, night with stage decreases.
- Stage metre decreases, horizon begins to move, stage quality improves, ice jams present, ice jam releases and moves upstream.
- Discharge measured at MON1 with outwash peak.
- Ice jam observed, stages initiated, snow or ice interference.
- Ice jam observed near bridge and progresses to 100.
- Ice jam observed moving through bridge crossing.
- Ice jam observed moving through bridge crossing.
- Discharge measured at the Long Snake Bridge and unload.
- Discharge measured at the Long Snake Bridge junction.
### 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 where applicable.

<table>
<thead>
<tr>
<th>Monitoring Location</th>
<th>Monitoring Location Description</th>
<th>Gage Station</th>
<th>Peak Stage</th>
<th>Measured Discharge</th>
<th>Peak Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage ft BPHSL</td>
<td>Date &amp; Time</td>
<td>Discharge cfs</td>
</tr>
<tr>
<td>Colville River</td>
<td>Upstream of Anaktuvuk &amp; Chukchi River Confluences</td>
<td>Umiat²</td>
<td>55.33</td>
<td>5/24 8:45pm</td>
<td>109,000</td>
</tr>
<tr>
<td>Colville River</td>
<td>Head of the CRD</td>
<td>MON1U</td>
<td>113.00</td>
<td>5/31 2:00am</td>
<td>12.72</td>
</tr>
<tr>
<td>Colville River</td>
<td>East Channel Distributary</td>
<td>MON1D²</td>
<td>11.76</td>
<td>5/31 4:30pm</td>
<td>12.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MON9D³</td>
<td>11.39</td>
<td>5/26 1:30pm</td>
<td>11.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MON2S</td>
<td>5.13</td>
<td>5/26 4:30pm</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EC1.3</td>
<td>8.27</td>
<td>5/26 5:15pm</td>
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</tr>
<tr>
<td>Nigliq Channel</td>
<td>Nigliq Channel Distributary</td>
<td>MON20ª</td>
<td>9.18</td>
<td>5/26 12:45pm</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MON23ª</td>
<td>7.12</td>
<td>5/26 12:30pm</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MON28ª</td>
<td>3.47</td>
<td>6/2 7:45am</td>
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</tr>
<tr>
<td>CD1 Pad &amp; Drinking Water Lakes</td>
<td>CD1 Pad</td>
<td>G1</td>
<td>6.50</td>
<td>6/2 8:00am</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G9</td>
<td>7.92</td>
<td>6/29 1:45am</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G10</td>
<td>7.22</td>
<td>6/2 6:00am</td>
<td>--</td>
</tr>
<tr>
<td>CD2 Pad &amp; Road</td>
<td>Short Swale Bridge</td>
<td>G3</td>
<td>6.54</td>
<td>5/17 10:45pm</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Long Swale Bridge</td>
<td>G4</td>
<td>6.45</td>
<td>5/26 1:00am</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Culverts</td>
<td>G5</td>
<td>6.54</td>
<td>5/26 10:45pm</td>
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</tr>
<tr>
<td></td>
<td>Culverts</td>
<td>G6</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Culverts</td>
<td>G7</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Culverts</td>
<td>G8</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>CD3 Pad &amp; Pipeline</td>
<td>Pipeline Crossings</td>
<td>SAK</td>
<td>6.27</td>
<td>6/2 9:15am</td>
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</tr>
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<td></td>
<td>Pipeline Crossings</td>
<td>TAM²</td>
<td>6.94</td>
<td>5/26 5:30pm</td>
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<tr>
<td></td>
<td>CD3 Pad</td>
<td>G11</td>
<td>Dry</td>
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</tr>
<tr>
<td></td>
<td>CD3 Pad</td>
<td>G16⁴</td>
<td>7.42</td>
<td>6/2 10:45am</td>
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<tr>
<td></td>
<td>CD3 Pad</td>
<td>G17</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CD3 Pad</td>
<td>G18</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CD3 Pad</td>
<td>G40</td>
<td>Dry</td>
<td>--</td>
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</tr>
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<td></td>
<td>CD3 Pad</td>
<td>G41</td>
<td>Dry</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>CD3 Pad</td>
<td>G42</td>
<td>Dry</td>
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<td></td>
</tr>
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<td></td>
<td>CD3 Pad</td>
<td>G43</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>CD4 Pad</td>
<td>CD4 Pad</td>
<td>G19</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CD4 Pad</td>
<td>G20</td>
<td>8.76</td>
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<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CD4 Pad</td>
<td>G31</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CD4 Pad</td>
<td>G32</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CD4 Pad</td>
<td>G33</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CD4 Pad</td>
<td>G34</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CD4 Pad</td>
<td>G35</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CD4 Pad</td>
<td>G36</td>
<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
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<td>Dry</td>
<td>--</td>
<td></td>
</tr>
<tr>
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<tr>
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</tr>
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<td></td>
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<td>G32</td>
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<td></td>
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<td></td>
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<td></td>
<td>Lake L9341 Bridge (CD5 Bridge #3)</td>
<td>G39</td>
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<td>GMT1/MT6 Road</td>
<td>Timsaquyvik Bridge</td>
<td>U86.7</td>
<td>7.70</td>
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<tr>
<td></td>
<td>Timsaquyvik Bridge</td>
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<td>Timsaquyvik Bridge</td>
<td>U86.9</td>
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</tr>
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<td></td>
<td>Crea Bridge</td>
<td>S5-C²</td>
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</tr>
<tr>
<td></td>
<td>Crea Bridge</td>
<td>S5-A²</td>
<td>15.81</td>
<td>6/10 3:30pm</td>
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</tr>
</tbody>
</table>

**Notes:**
1. Stage difference between MON9 and MON9D due to ice jam between sites.
2. Preliminary data obtained from USGS Umiat gage station 15875000 and referenced to NAVD88 vertical datum. Highest recorded stage and discharge reported and is not representative of peak stage timing or magnitude.
3. Highest recorded stage, PT malfunctioned during monitoring.

Gray cells indicate that discharge was not measured or calculated. Reasons for this vary but include that location is not a conveyance channel, discharge data was not included in program scope, significant ice influence at discharge cross section during and after peak, and/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 arrival 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 and timing of flooding at Umiat and in the CRD do not necessarily correlate.

The USGS Umiat gage began measuring stage on May 16 and stage remained low until May 20. The reconnaissance flight on May 19 showed little to no flow in the Colville River upstream of the Anaktuvuk River confluence. On May 20, stage rose over 2-feet and continued to increase over the next two days. On May 22, stage spiked in response to an ice jam release near the gage. On May 24, stage peaked at 55.3 ft NAVD88, below the action stage (57.5 ft NAVD88) and flood stage (59.0 ft NAVD88). Stage dropped after peak as colder weather moved through the area. On May 28, air temperatures started to warm up above freezing and by May 29 stage began to increase again. Stage crested at 54.0 ft NAVD88 on May 31. Stage and temperature data for the Umiat gage station are presented in Graph 4.1.

The discharge data begins on May 24 as the channel ice cleared with peak reported discharge of 108,000 cfs. The crest on May 31 resulted in a discharge value around 83,000 cfs. Provisional discharge data is presented in Graph 4.2.

![Graph 4.1: Colville River at Umiat Stage (USGS 2023)](image-url)
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 within the MON1 reach on May 21 which appeared as clear, non-turbid water along the edges of the channel (Photo 4.1). By May 22, the leading edge of turbid water passed the MON1 gages and into the delta. On May 23, two ice jams formed upstream of MON1 at the Horseshoe Bend and downstream of Ocean Point. Floodwater first reached the MON1 PT’s on May 24 as stage increased, submerging the sandbars in front of MON1 (Photo 4.2). Stage continued to increase and peaked at the MON1C (center) gage on May 26 with a stage of 14.17 ft BPMSL. The upstream ice jams were still present at this time and channel ice remained intact within the MON1 reach (Photo 4.3).

 Cooler temperatures stalled the melting process and stage decreased over the coming days. By May 28, daytime temperatures increased above freezing, but stage did not increase until May 30. The Ocean Point ice jam released on May 30 and the Horseshoe Bend ice jam released on May 31. An ice jam formed downstream of MON1 on the morning of May 31 behind a large pan of ice blocking the Colville River East Channel at the Nigliq Channel bifurcation (Photo 4.4). This ice jam extended through the MON1 reach and the resulting backwater caused MON1U (upstream gage) to peak at 15.32 ft BPMSL. Stage at MON1C measured 13.92 ft BPMSL during this time, which was 0.25 ft below peak stage recorded on May 26. Flood waters remained within the banks and the ice jam in the MON1 reach released that evening (Photo 4.5). Stage decreased rapidly and dropped below the PT’s on June 2. Water levels were not high enough to reach the MON1D PT. By June 4, sand bars in the MON1 reach were exposed (Photo 4.6).
Discharge was measured at MON1 on June 1 with minimal ice and snow interference (Photo 4.7). Stage and discharge results at MON1 are presented in Graph 4.3. Discharge measurement data and plan and profile drawings at the measurement location are provided in Appendix C.

Photo 4.1: Initial floodwater traveling along the edges of the channel ice, looking north (downstream); May 21, 2023

Photo 4.2: Increasing stage at MON1, looking south (upstream); May 24, 2023

Photo 4.3: Intact Channel ice extending through the MON1 reach during peak stage, looking south (upstream); May 26, 2023

Photo 4.4: Ice jam at Putu Island extending upstream through MON1, looking north (downstream); May 31, 2023
Photo 4.5: MON1 reach after the Putu ice jam released, looking west; June 1, 2023

Photo 4.6: Flood water decreasing as sand bars become exposed in the MON1 reach, looking north (downstream); June 4, 2023

Photo 4.7: Field crews preparing to measuring discharge on the Colville River, looking east; June 1, 2023
4.2 Colville River East Channel

MON9 is located in the Colville River East Channel at the 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 to monitor stage at the outer extents of the CRD since 1999. EC1.3 and EC12.9 are located in the East Channel between the coast and the Tamayayak Channel bifurcation. These sites were previously monitored as part of the OSA Pikka project on the east side of the Colville River.

Meltwater was first observed within the MON9 reach on May 21, around the slotted ice road crossing, and around the edges of the channel (Photo 4.8). The leading edge of floodwater passed MON9 and reached the MON9 PTs on the morning of May 22. Aerial observations from late morning on May 23 showed the intact channel ice had lifted (Photo 4.9). Overflights on May 24 and May 25 revealed intact channel ice persisting along the east bank through the MON9 reach. Stage continued to rise until it peaked at the MON9 and MON9D gages on May 26 with a stage of 11.67 ft. BPMSL and 11.39 ft. BPMSL, respectively. Channel ice remained intact during peak stage (Photo 4.10). In the Colville East Channel, peak stage is often the result of an inundation associated with an ice jam release or backwater, however channel ice remained intact through peak.

Temperatures around the CRD cooled to below freezing, stalling the melting process, and causing stage to drop. Stage did not increase again at MON9 until May 30. On May 31, channel ice was showing signs of degradation with
floes observed in the channel near HDD East. An ice jam of large ice pans started to form downstream of MON9 on the afternoon of May 31, resulting in backwater and rising stage at MON9 (Photo 4.11). The MON1 ice jam released on the evening of May 31 and passed through the MON9 reach in the morning of June 1. As the ice passed through, a second peak of stage occurred at the MON9 and MON9D gages (Photo 4.12). This second crest at MON9 was 11.54 ft. BPMSL and 11.37 ft. BPMSL at MON9D. A new ice jam formed the morning of June 1 in the East Channel downstream of the HDD crossing near the Sakoonang distributary channel, but associated backwater effects did not cause water to flow into the overbanks. This ice jam released late-morning on June 1. Peak discharge at MON9 was estimated to have occurred after this ice jam released. By June 3, this ice jam had cleared past the Tamayayak Channel bifurcation (Photo 4.13). Stage decreased rapidly and dropped below the PTs on June 5. Flood waters remained within the banks of East Channel and no overbank flooding was observed.

Peak stage at MON35 occurred on May 26, three hours after peak stage at MON9. During peak stage, channel ice persisted in the adjacent channel (Photo 4.14). Channel ice persisted through the MON35 reach and a second crest in stage occurred on June 1 (Photo 4.15). By June 4, the channel was mostly clear of ice.

East Channel (EC) 12.9 and 1.3 monitoring sites recorded peak stage on May 26, the same day as MON9. A second crest occurred on June 1, similar to MON9. Channel ice was observed at EC12.9 while open water conditions were observed at EC1.3 (Photo 4.16, Photo 4.17, Photo 4.18, & Photo 4.19).

Stage and calculated 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. Plan and profile drawings are provided in Appendix C.
Photo 4.10: Peak stage with channel ice extending through the MON9 reach, looking southwest; May 26, 2023

Photo 4.11: Ice jam downstream of MON9D by Sakoonang Channel tributary, looking east; May 31, 2023

Photo 4.12: Ice jam moving through East Channel at MON9 reach, looking northeast (downstream); June 1, 2023

Photo 4.13: Small ice jam near the East Channel’s Tamayayak Channel bifurcation, looking north (downstream); June 3, 2023
Photo 4.14: MON35 during peak stage, looking west; May 26, 2023

Photo 4.15: MON35 just before the crest stage, looking southwest (upstream); May 31, 2023

Photo 4.16: EC12.9 during peak stage, looking east; May 26, 2023

Photo 4.17: EC1.3 during peak stage, looking north (downstream); May 26, 2023
Photo 4.18: EC12.9 near second stage crest, looking west; May 31, 2023

Photo 4.19: EC1.3 near second stage crest, looking north (downstream); May 31, 2023

Graph 4.4: Colville River East Channel Stage & Discharge

<table>
<thead>
<tr>
<th>Date 2023</th>
<th>Stage (ft. BPMSL)</th>
<th>Spring Peak Stage (ft. BPMSL)</th>
<th>Date &amp; Time</th>
</tr>
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<tbody>
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<td>5/22</td>
<td>7.5</td>
<td>MON9</td>
<td>5/26 12:30 PM</td>
</tr>
<tr>
<td>5/24</td>
<td>7.3</td>
<td>MON9D</td>
<td>5/26 1:30 PM</td>
</tr>
<tr>
<td>5/26</td>
<td>11.67</td>
<td>MON35</td>
<td>5/26 4:30 PM</td>
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<td>MON9 Gage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.39</td>
<td>MON9D Gage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.13</td>
<td>MON35 Gage</td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>Discharge (cfs)</th>
<th>Peak Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/1 11:30 AM</td>
<td>191,000</td>
<td></td>
</tr>
</tbody>
</table>
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.

Initial floodwater was first observed in the Nigliq Channel on May 23. By May 24, floodwater had reached the PT’s at MON20, MON22, and MON23. Stage was quickly rising, submerging sandbars along the Nigliq Channel (Photo 4.20). The MON28 PT sensor malfunctioned from May 24 to May 30. On May 25, stage continued to increase, and aerial observations show bottom-fast ice lifting from the channel bed upstream of the Nigliq Bridge (Photo 4.21). Peak stage occurred mid-day on May 26 for MON20, MON22, and MON23. Channel ice was still present during peak stage (Photo 4.22). Stage at MON28 was too high for field crews to land at the site on May 26 (Photo 4.23). After peak stage, water levels decreased until May 30 (Photo 4.24). Stage began to increase again on May 30. In the morning of June 1, a small ice jam was observed near the village of Nuiqsut and by the evening it had progressed downstream in the vicinity of the MON20 gage (Photo 4.25). No backwater effects or overbank flooding were observed from the ice jam. Stage crested on the evening of June 1 in the Nigliq Channel and was slightly lower than peak stage on May 26. MON20 stage crested at 8.40 ft BPMSL, 0.78 ft below the peak stage; MON22 crested at 7.45 ft BPMSL, 0.93 ft below peak stage; and MON23 crested at 6.45 ft BPMSL, 0.67 ft below peak stage. On June 2, a small ice jam was observed upstream of the Nigliq Bridge and in the afternoon, ice was observed moving through the bridge crossing (Photo 4.26). Soon after, water levels began to recede. On June 3, the channel ice had
cleared downstream of the Nigliq Bridge crossing to MON23 (Photo 4.27). By June 4, the Nigliq Channel was ice-free and most of the PT’s were dry. Stage continued to recede throughout the monitoring period.

Discharge was measured on June 3 at the Nigliq Bridge, between MON20 and MON22, with minimal snow or ice interference. Stage at MON20, MON22, MON23, MON28, along with the measured discharge and calculated peak discharge values in the Nigliq Channel are presented in Graph 4.6. Plan and profile drawings are provided in Appendix C.
Photo 4.24: Stage decreasing and sandbars reemerging, looking south (upstream); May 28, 2023

Photo 4.25: Small ice jam in the Nigliq Channel upstream of MON20, looking south (upstream); June 1, 2023

Photo 4.26: Small ice jam upstream of the Nigliq Bridge, looking south (upstream); June 2, 2023

Photo 4.27: Channel ice moving downstream near MON23, looking north (downstream); June 3, 2023
Graph 4.6: Nigliq Channel Stage and Discharge

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<th>Date 2023</th>
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<tr>
<td>MON22</td>
<td>8.38</td>
<td>5/26 12:15 PM</td>
</tr>
<tr>
<td>MON23</td>
<td>7.12</td>
<td>5/26 12:30 PM</td>
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<tr>
<td>MON23^1</td>
<td>3.47</td>
<td>6/2 7:45 AM</td>
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<tr>
<td>Peak Discharge</td>
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Notes:
1. MON28 sensor malfunction from 5/23 to 5/30. Highest recorded stage.
4.4 Alpine Facilities

Conditions in 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. The extent of inundation is dependent on local stage relative to topography. This is greatly influenced by ice jamming and, to a lesser degree, vegetation.

Drainage structures are kept free of ice, snow accumulation, and debris blockages through regular maintenance by CPAI. Plywood covers or inflatable bags are installed at the culvert inlets and outlets at the onset of winter and removed prior to breakup. Snow is also mechanically removed from the immediate upstream and downstream areas of all culverts and the CD5 Road bridges (Photo 4.28). Snow could not be cleared from under the CD2 Road bridges due to low clearance issues.

Culverts were monitored to assess flow conditions and culvert performance. Almost all culvert covers and inflatable bags were removed prior to the arrival of floodwater, with the exception of a few that were frozen in place. Snow and ice were cleared at all culvert inlets and outlets prior to breakup. Limited flow restrictions were observed related to piles of removed snow and ice placed near culvert entrances and exits. Culvert locations and proximity to gages are shown in Appendix A. Detailed culvert discharge measurements, calculations, and field notes on performance are provided in Appendix C.

Photo 4.28: Snow removed from infront of culverts on the CD4 road; May 16, 2023
**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. Aerial observations from May 30 showed active flow through the Sakoonang Channel with stage below bankfull (Photo 4.29). Peak stage at G1 occurred on the morning of June 2 after the MON1 ice jam released (Photo 4.30). Stage at gage G1 is presented in Graph 4.7.

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, with additional contributions through snowmelt and rainfall from within each drainage basin. Stage did not exceed bankfull elevation in Lake L9312 during spring breakup (Photo 4.31) but did recharge from snowmelt and rainfall on June 15. Spring breakup overbank flow reached and recharged Lake L9313 above bankfull elevation. Lake L9313 became hydraulically connected to Lake M9525 on May 28, when stage first exceeded bankfull elevation (Photo 4.32). Peak stage at Lake L9313 occurred on June 2 and generally correlated with peak stage in the Sakoonang Channel. Peak stage at Lake L9312 occurred after spring breakup on June 29. Stage at gage G9 (L9312) and gage G10 (L9313) is presented in Graph 4.8.

**Photo 4.29:** Channel ice in Sakoonang Channel at G1, looking north (downstream); May 30, 2023

**Photo 4.30:** G1 gage near peak conditions; June 2, 2023
Graph 4.7: CD1 Pad (Gage G1) Stage
Photo 4.31: Lake L9312 before peak conditions with persisting ice, looking northeast; May 30, 2023

Photo 4.32: Lake L9313 hydraulically connected to Lake M9525, looking northeast; May 28, 2023

Graph 4.8: Lakes L9312 (Gage G9) and L9313 (Gage G10) Spring Stage

<table>
<thead>
<tr>
<th></th>
<th>Peak Stage (ft. BPMSL)</th>
<th>Date &amp; Time</th>
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<tbody>
<tr>
<td>G9 (L9312)</td>
<td>7.92</td>
<td>6/29 1:45 AM</td>
</tr>
<tr>
<td>G10 (L9313)</td>
<td>7.22</td>
<td>6/2 6:00 AM</td>
</tr>
</tbody>
</table>
CD2 ROAD & PAD

Stage data and observations of breakup processes have been collected along the CD2 road and pad intermittently since 1998. Gage stations G3/G4 are located in between the Long Swale Bridge and the Short Swale Bridge. Gages G12/G13 are located near a series of three culverts immediately northwest of Nanuq Lake. Gages G6/G7 are located at a culvert battery that conveys flow between Lake L9322 and Lake L9321.

Floodwater reached the CD2 road around the long and short swale bridges on May 25 and by the evening staged had dropped. On May 26, stage rose again as the long swale bridge (Photo 4.33) 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 4.34). The short swale bridge did not convey flow as snow under the bridge impeded flow. Peak stage along the CD2 occurred in the evening of May 26 and early morning of May 27. During peak conditions, snow was observed around both bridge abutments and minimal snow was around the roads (Photo 4.35). Stage remained below the tops of the roads and pads Stage dropped after May 27 (Photo 4.36) but began to increase again on June 1. Stage crested on the morning of June 2 and was approximately 0.2-ft below peak stage. Discharge was measured at the long swale bridge on May 28 and June 1. Discharge was measured at culverts on June 1 and no culverts were flowing on May 28. One culvert (CD2-24) was observed to be conveying flow on June 1. The rest of the culverts were dry or iced up.

The discharge measurement at the Long Swale Bridge on May 28 was not used to calculate peak discharge as stage had equalized and flow was minimal through the bridge opening. The average velocity measured at the long swale bridge on June 1 was 0.95 ft per second (fps) and the highest depth averaged velocity within a single section was 1.3 fps with a maximum depth of 8.6 feet. The bridge was clear of snow and ice and there were no berms reducing the conveyance capacity of the bridge opening. The short swale bridge had no measurable flow on May 28 or June 1. Ice floes were minimal, and flow was unobstructed under the bridges during the measurements. The June 1 measurement quality rating was classified as good.

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 May 26.

Floodwater did not reach gages G6, G7, G8, G12 and G13 during the monitoring period and only local melt was observed. No overbank flooding from the Nigliq Channel was observed in the area.
Stage and discharge values at CD2 bridge and culverts are provided in Graph 4.9. Measured discharge and peak discharge at culverts conveying flow is summarized in Table 4.2 and Table 4.3. Measured discharge and peak discharge at the Long Swale bridge is summarized in Table 4.4. 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.
Graph 4.9: CD2 Road Bridges and Culverts (Gages G3 & G4) Stage & Discharge

Table 4.2: CD2 Road Culverts Measured Discharge

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<tr>
<th>Culvert</th>
<th>Measurement Date &amp; Time</th>
<th>Total Depth of Flow (ft)</th>
<th>Measurement Depth (ft)</th>
<th>Flow Direction</th>
<th>Measured Velocity (ft/s)</th>
<th>Calculated Discharge (cfs)</th>
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Notes:
2. Measurement taken at 0.4 of total depth of flow.
3. Flow direction at time of measurement.
Table 4.3: CD2 Road Culverts Peak Discharge

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<tr>
<th>Culvert ¹</th>
<th>Calculated Date &amp; Time</th>
<th>WSE Differential (ft)²</th>
<th>Total Depth of Flow (ft)</th>
<th>Flow Depth</th>
<th>Calculated Velocity (ft/s)</th>
<th>Calculated Discharge³ (cfs)</th>
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<tr>
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<td>1.4</td>
<td>Less than Half Full</td>
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<td>14</td>
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</table>

Notes:
2. Calculated during peak stage differential between upstream and downstream gages most proximal to culverts.
3. Positive values indicated flow was south to north.

Table 4.4: CD2 Road Bridges Measured and Peak Discharge

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Measurement Date &amp; Time</th>
<th>Measured Discharge (cfs)</th>
<th>Stage (ft. BPMSL)¹</th>
<th>Peak Date &amp; Time</th>
<th>Peak Discharge (cfs)</th>
<th>Stage (ft. BPMSL)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Swale</td>
<td>5/28 11:00am</td>
<td>109</td>
<td>5.80</td>
<td>5/26 3:30pm</td>
<td>2,310</td>
<td>6.54</td>
</tr>
<tr>
<td>Long Swale</td>
<td>6/1 1:37pm</td>
<td>2,218</td>
<td>6.05</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

Initial meltwater and subsequent rise in stage were first observed on May 24 at the TAM and SAK PTs. The ULAM PT malfunctioned during the monitoring period, but the gage readings are similar to the TAM gage readings, therefore a similar stage progression most likely occurred. Stage continued to rise and stage peaked at the TAM gage (Photo 4.37) and most likely ULAM gage site on May 26 (Photo 4.38). Stage at the SAK gage crested on May 26 (Photo 4.39). Channel ice was present in the channels and saturated snow was along the banks during this time. Stage dropped after May 26 as the cooler weather stalled the melting process. On May 30, stage began to rise again in the Tamayayak Channel and on May 31 in the Sakoonang Channel. Site visit on June 1 shows intact channel ice in the Sakoonang Channel (Photo 4.40). Peak stage at the SAK gage occurred on the morning of June 2 with intact channel ice within the channel. During peak conditions, no overbank flooding was observed at any of the pipeline crossing locations, and stage remained below bankfull. On June 4 intact channel ice was presisting at the SAK gage site as stage was dropping. By June 9, no channel ice and open channel conditions were observed at all CD3 monitoring locations. Stages at the SAK, TAM, and ULAM are presented in Graph 4.10. No HWM was observed at G11, indicating floodwater did not reach the CD3 pad.
Photo 4.37: Channel ice and saturated snow in the channel at TAM crossing near peak stage, looking northeast; May 26, 2023

Photo 4.38: Channel ice and saturated snow in the channel at ULAM crossing near peak stage, looking southeast; May 26, 2026

Photo 4.39: Channel ice and saturated snow in the channel at SAK crossing at first crest in stage, looking southeast (upstream); May 26, 2023

Photo 4.40: Intact channel ice in the Sakoonang Channel before peak stage, looking southwest; June 1, 2023
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 intersection in a flow path between lakes L9323 and M9525. Gages G17/G18 are at the south culvert battery near the CD4 pad in a flow path between the Sakoonang Channel and Lake L9323. Gages G19/G20 are on the south and west sides of the CD4 pad, adjacent to Lake L9324 and the Nigliq Channel at Tapped Lake, respectively. Gages G40/G41 and G42/G43 are located between the CD2 and CD5 road intersections.

Initial floodwater was observed in Lake M9525 via Sakoonang Channel on May 27 and the G15 PT at north culvert battery showed a sharp rise in stage (Photo 4.41). The G16 PT malfunctioned during the monitoring period. Stage crested on May 28 as cooler air temperatures stalled the melting process. Stage at G15 decreased from May 28 to 31 and started to rise again on May 31. Peak stage at G15 occurred on the morning of June 2. The culvert battery to the west was completely submerged during the site visit and the culvert battery to the east was approximately half full (Photo 4.42 & Photo 4.43). Lake L9323 and M9525 were not hydraulically connected, and no flow was observed through the north culvert battery, only equalized backwater from Lake M9525.

Only local melt was observed at gages G17 and G18 near the CD4 Pad (Photo 4.45 & Photo 4.46). No water or HWMs were observed at gages G40/41 or G42/G43.
At the CD4 pad, peak stage occurred in the morning of May 26 at G20 and coincided with peak stage in the Nigliq Channel (Photo 4.45). Floodwater remained within the banks of the Nigliq Channel and Lake L9324 and did not reach G19 gage site.

Stage data for the CD4 road gages G15/G16 and CD4 pad gages G19/G20 are provided in Graph 4.11 and Graph 4.12, respectively.

Photo 4.41: Floodwater along the CD4 road from Lake M9525 via Sakoonang Channel, looking north; May 27, 2023

Photo 4.42: CD4 culverts equalizing flow at G15/G16 near peak, looking north; June 2, 2023

Photo 4.43: CD4 culverts with equalized backwater at G15/G16 near peak, looking south; June 2, 2023

Photo 4.44: CD4 pad during peak stage; looking south; May 26, 2023
Photo 4.45: Dry conditions along the CD4 road near the CD4 pad, looking south; May 26, 2023

Photo 4.46: Local melt at G18, looking south; June 2, 2023

Graph 4.11: CD4 Road Culverts (Gages G15 & G16) Stage & Discharge

<table>
<thead>
<tr>
<th>Peak Stage (ft. BPLMSL)</th>
<th>Date &amp; Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>G15</td>
<td>7.70</td>
</tr>
<tr>
<td>G16 ( ^1 )</td>
<td>7.62</td>
</tr>
</tbody>
</table>

Notes:
\( ^1 \) PT malfunctioned. Highest recorded stage.
Graph 4.12: CD4 Pad (Gages G19 & G20) Stage

<table>
<thead>
<tr>
<th>Peak Stage (ft. BPMSL)</th>
<th>Date &amp; Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>G19 *</td>
<td>N/A</td>
</tr>
<tr>
<td>G20</td>
<td>8.70</td>
</tr>
</tbody>
</table>

Notes:
1. Floodwater did not reach G19
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 2023 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, gage G25 is north/downstream of the bridge, and gage G44 is underneath the bridge.

Only local melt was observed near Lake L9323 Bridge (Photo 4.47). Lake L9323 did not became hydraulically connected to either the Sakoonang Channel or the Nigliq Channel (Photo 4.48). Lake L9323 snow and ice melted throughout the monitoring period and did not reach the PT elevations.

Nigliq Bridge

The Bridge #2 crosses the Nigliq Channel. On average, the Nigliq Channel typically conveys approximately 20% of Colville River flow. Gage G26 is immediately south (upstream) and gage G27 is immediately north (downstream) of the bridge. Gage G28 is 2,600-ft south of the bridge and gage G29 is 2,450-ft to the north of the bridge.

Initial floodwater was first recorded by PTs on May 23. Stage quickly rose and peaked mid-day on May 26. During peak stage intact channel ice was within the channel (Photo 4.49 & Photo 4.50). After peak, stage dropped, and channel ice remained intact within the channel. On May 30, stage began to rise again and bottomfast ice had lifted upstream of the bridge. By June 1 stage had crested and was 0.61-ft below peak stage (Photo 4.51) with channel ice starting to degrade. The channel ice deteriorated and moved downstream throughout the day on June 2 and by June 3 the channel ice had cleared downstream of the Nigliq Bridge. Game camera pictures at peak revealed...
minimal ice floes through the channel (Photo 4.52). Stage remained below bankfull, and no backwater effects were observed around the bridge during peak conditions. After the crest on June 1, stage quickly receded (Photo 4.53).

Discharge was measured on June 3 on the upstream side of the Nigliq Bridge. At the time of measurement, the channel was free of ice and minimal saturated snow remained along the west bank. Conditions were considered steady and uniform, with minimal effects from ice and snow. The quality of the measurement was classified as fair due to these conditions. Indirect discharge calculated at the time of the direct measurement was 28% lower than the measured discharge and PTs at gage sites G26 and G27 where dry during the direct measurement.

Nigliq Bridge stage and discharge data is provided in Graph 4.13. A summary of the discharge measurement, peak discharge calculation methods, and plan and profile drawings are presented in Appendix C.

![Photo 4.49: Channel ice in the Nigliq Channel during peak stage, looking south (upstream); May 26, 2023](image)

![Photo 4.50: Channel ice in the Nigliq Channel during peak stage, looking north (downstream); May 26, 2023](image)
Photo 4.51: Conditions at the Nigliq Bridge just prior to the crest, looking south (upstream); June 1, 2023

Photo 4.52: Channel ice moving downstream, looking east; June 2, 2023

Photo 4.53: Open water conditions in the Nigliq Channel near the Nigliq Bridge, looking northeast; June 4, 2023
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) of the bridge, gage G33 is north (downstream) of the bridge and gage G46 is under the bridge. G30 (south) and G31 (north) are situated on the overbank between Lake L9341 and the Nigliq Channel.

PT data shows local melt between May 21 and May 24. By May 24 stage began to rise, coinciding with stage rise at G29 in the Nigliq Channel, indicating backwater was entering the lake from the north end (Photo 4.54). By May 26, peak stage occurred coinciding with peak stage in the Nigliq Channel. During peak stage, the lake ice was intact and was limited to backwater entering the north end of the lake from the Nigliq Channel (Photo 4.55 & Photo 4.56). Stage dropped after peak and began to rise again on May 30. Stage increased and crested in the evening of June 1. Lake ice persisted during the crest and stage was approximately 0.8 ft below peak stage. Stage receded through the remainder of the monitoring period and the lake ice remained intact (Photo 4.57).

Since Lake L9341 was not hydraulically connected with the Nigliq Channel on the south end, discharge was not measured. Discharge calculations are also not typically performed here due to the persistent intact ice.

Lake L9341 Bridge stage data is provided in Graph 4.14. Plan and profile drawings are presented in Appendix C.
Photo 4.54: Floodwater from the Nigliq Channel backwatering into the Lake L9341 from the north end of the lake, looking southeast; May 24, 2023

Photo 4.55: Lake L9341 at peak stage with lake ice present and snow berms around abutments, looking north; May 26, 2023

Photo 4.56: Lake L9341 with intact channel ice persisting during peak stage, looking south; May 26, 2023

Photo 4.57: Channel ice persisting in Lake L9341 throughout the monitoring period, looking south; June 9, 2023
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 with south to north flow, but Nigliq Channel backwater is common at the bridge during the onset of spring breakup flooding. Gage G38 is south (upstream) of the bridge, gage G39 is north (downstream) of the bridge, and gage G47.

Local melt was first observed on May 19 over saturated snow in the channel (Photo 4.58). Initial floodwater reached the PTs on May 23 and rose sharply. Peak stage occurred midday on May 26. At the time of peak stage saturated snow was along the banks and water levels remained below the banks (Photo 4.59). After peak stage, water levels dropped in the channel before rising again on May 30. Stage continued to rise and crested on the evening of June 2. Stage was approximately 0.8 ft below the peak stage at the crest. Stage receded after the crest on June 2. On June 4, bottomfast ice was observed to lift upstream of the bridge (Photo 4.60). This lifted ice remained in place throughout the monitoring period (Photo 4.61).

Peak stage at the Nigliagvik Bridge lagged peak stage in the Nigliq Channel by a couple of hours. Peak discharge is estimated to have occurred during the crest on June 1 as the stage differential between G38 and G39 was higher.
during this time indicating higher velocities in the channel. Calculated peak discharge was assigned a poor-quality rating based on the presence of ice and snow during peak conditions. Discharge was measured on the upstream side of the Nigliagvik Bridge on June 2. At the time of the measurement, the Nigliagvik Channel at the discharge location was mostly clear of ice and snow but bottomfast ice remained anchored to the bed and channel ice was present just upstream of the bridge. The quality of the measurement was classified as poor due to the channel conditions.

Nigliagvik Bridge stage data is provided in Graph 4.15. A summary of the discharge measurement, peak discharge calculation methods, and plan and profile drawings are presented in Appendix C.

Photo 4.58: Local melt over saturated snow at the Nigliagvik Bridge, looking east; May 19, 2023

Photo 4.59: Peak stage at the Nigliagvik Bridge with saturated snow along the banks, looking south (upstream); May 26, 2023

Photo 4.60: Bottomfast ice lifting in the channel upstream of the Nigliagvik Bridge, looking east; June 4, 2023

Photo 4.61: Stage below bankfull in the Nigliagvik Channel with lifted bottomfast ice, looking north (downstream); June 5, 2023
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.

Observations near peak stage on the CD5 road showed no overbank flooding of the Nigliq (Photo 4.63) and Nigliagvik Channels (Photo 4.62) therefore culverts surrounding the bridges were limited to equalizing local melt. Localized flow was observed at the culverts along the CD5 pad turnoff and at the S1 gage site (Photo 4.64 & Photo 4.65). A summary of the culvert discharge measurements is in Table 4.5. PTs deployed along the CD5 road remained dry throughout the monitoring period.

Graph 4.15: Nigliagvik Bridge (Gages G38 & G39) Stage
### Table 4.5: CD5 Culvert Discharge Measurements

<table>
<thead>
<tr>
<th>Culvert</th>
<th>Measurement Date &amp; Time</th>
<th>Total Depth of Flow (ft)</th>
<th>Measurement Depth (^1) (ft)</th>
<th>Flow Direction(^2)</th>
<th>Measured Velocity (ft/s)</th>
<th>Calculated Discharge (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD5-03</td>
<td>5/31 9:52am</td>
<td>1.2</td>
<td>0.48</td>
<td>East to West</td>
<td>2.2</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Notes:
1. Measurement taken at 0.4 of total depth of flow.
3. Flow direction at time of measurement.

---

**Photo 4.62:** Local melt along the CD5 road between Lake L9341 and Nigliagvik Bridge at peak stage, looking east; May 26, 2023

**Photo 4.63:** CD5 road near Nigliq Channel with no overbank flooding at peak stage, looking east; May 26, 2023

**Photo 4.64:** Crew measuring discharge at culvert on the CD5 pad turnoff, looking south; May 31, 2023

**Photo 4.65:** Flow through culverts at the S1 gage site, looking west; June 4, 2023
Tinmiaqsiugvik Bridge

The UB6.7, UB6.8, and UB6.9 gage stations are located in the Tinmiaqsiugvik River at RM 6.7 (downstream of the Tinmiaqsiugvik Bridge), RM 6.8 on the pier of the bridge, and at RM 6.9 (upstream of the Tinmiaqsiugvik Bridge), respectively, 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.

Local melt was first observed on top of channel ice on May 19 and recorded on the PT’s on May 20. Stage slowly rose over the next 4 days. By May 24, aerial observations show flow overtop channel ice around the Tinmiaqsiugvik Bridge (Photo 4.66). Stage continued to slowly rise. On May 27, PT’s show a sharp rise in stage which crested in the evening of May 27. Stage dropped until the evening of May 29. Another sharp rise in stage began that evening and peak stage occurred on June 1. During peak stage, channel ice was present in the channel with bottomfast ice anchored to the channel bed (Photo 4.67). Floodwater entered the lakes downstream of the bridge, but floodwater was confined within the banks around the bridge. Stage slowly dropped throughout the monitoring period. Aerial observations from June 5 show channel ice persisting around the bridge (Photo 4.68). By June 8, the channel ice began to move downstream (Photo 4.69) and by June 10 the channel was open and free of ice around the bridge. Discharge was not measured or calculated in 2023 due to ice and snow blockage directly at the bridge crossing.

Tinmiaqsiugvik Bridge stage data is provided in Graph 4.21.

Photo 4.66: Initial flow through the Tinmiaqsiugvik Bridge, looking north (downstream); May 24, 2023

Photo 4.67: Peak stage with discontinuous channel ice, looking north (downstream); June 1, 2023
Photo 4.68: Tinmiaqsiugvik Bridge with persisting channel ice five days after peak, looking northwest (downstream); June 5, 2023

Photo 4.69: Ice moving downstream in the Tinmiaqsiugvik River, looking north (downstream); June 8, 2023

Graph 4.16: Tinmiaqsiugvik Bridge (UB6.7, UB6.8 & UB6.9) Stage
Crea Bridge
The S5 gage stations are located in Crea Creek upstream (S5-C) and downstream (S5-A) of the Crea Bridge. Crea Creek is a beaded stream that has a drainage area of approximately 4 square miles and flows northeast into the Tinmiaqsiugvik River downstream of the Tinmiaqsiugvik Bridge.

Flow was first observed under the bridge on May 24 with bottomfast ice anchored to the channel bed (Photo 4.70). Both PT’s malfunctioned through the monitoring period and stage data is limited to gage readings. Stage on May 26 was elevated due to the snow and ice in the channel. On May 27, stage dropped below the S5-C gage and was low on S5-A gage. Stage increased and appeared to level off throughout the monitoring period. On May 31, floodwater and snow was observed around the bridge abutments (Photo 4.71) and bottomfast ice had lifted on the pond downstream of the bridge. By June 8, open water conditions were observed in the channel (Photo 4.72).

Crea Bridge stage data is provided in Graph 4.17.

Photo 4.70: Water flowing under Crea Bridge, looking northeast (downstream); May 24, 2023

Photo 4.71: Floodwater and snow around the Crea Bridge abutments, looking northeast; May 31, 2023
Photo 4.72: Open channel conditions on Crea Creek, looking north (downstream); June 8, 2023

Graph 4.17: Crea Bridge (S5) Stage

<table>
<thead>
<tr>
<th>Stage (ft. BPMSL)</th>
<th>Date &amp; Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>S5-C</td>
<td>16.54 6/10 3:45 PM</td>
</tr>
<tr>
<td>S5-A</td>
<td>16.81 6/10 3:30 PM</td>
</tr>
</tbody>
</table>

1. Highest recorded stage
4.5 Peak Discharge Distribution

In general, flow distribution between the East Channel and Nigliq Channel is approximately split 80/20% respectively. Historically, this value is determined at the general time of peak discharge concurrent in 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. Peak discharge in the East Channel and Nigliq Channel is estimated to have occurred on June 1. Peak discharge at MON1 was a result of an ice jam release at Putu Island. In the East Channel, peak discharge was the result of an ice jam release near the Sakoonang Channel. Peak discharge in the Nigliq Channel was the result of a small ice jam release in the Nigliq Channel on June 1. Peak discharge distribution between the East Channel and Nigliq Channel was closer to 90/10% this year due to the smaller ice jams in the East Channel allowing more flow downstream whereas the Nigliq Channel had ice jams covering the channel width, restricting flow.
5. POST-BREAKUP CONDITIONS ASSESSMENT

Alpine roads and pads were inspected for erosion on June 7. On the CD2 road, washlines were noted from previous flooding events on the north side of the road between the Long and Short Swale bridge. For this year’s flood, a high-water mark was noted at the toe of the road embankment consisting of stranded grass and loose vegetation. Photo 5.1 through Photo 5.4 shows the CD2 road after stage had receded, where grass can be seen depicting high-water marks. No discernable erosion directly attributable to 2023 breakup flooding was observed during aerial and ground reconnaissance of the CD2, CD4, and CD5 roads. Floodwaters did not reach the CD5 bridge abutments, only local melt was observed at 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 at the Long Swale bridge between piers E9 and E10 was filled with gravel material. The channel profile was consistent with last year’s discharge measurement indicating no additional scour since the infilling.

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 7, 2023

Photo 5.2: CD2 road post-breakup, looking south; June 7, 2023

Photo 5.3: CD2 road post-breakup, looking northeast; June 7, 2023

Photo 5.4: CD2 road post breakup, looking northeast; June 7, 2023
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 at the Nigliq and Nigliagvik Bridges. Post-breakup pier scour elevations that encompass all piles in each pier group were measured by UMIAQ in August 2023. 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 2023).

Photo 6.1: Pier numbers on the Nigliq Bridge, looking south (upstream); May 26, 2023

Photo 6.2: Pier numbers on the Nigliagvik Bridge, looking south (upstream); May 26, 2023

NIGLIQ BRIDGE

A comparison of design and observed scour elevations are presented in Table 6.1. The deepest post-breakup scour elevation (-29.7ft BPMSL at pier 4, pile D) is 1.1 ft below the 50-year design scour elevation and 3.3 ft above the 200-year scour elevation. Real-time pier scour measurements at piers 2 through 5 and corresponding WSEs during spring breakup monitoring are presented in Graph 6.1 through Graph 6.4. At pier 2, real-time scour measurements recorded no scour from the 2022 post breakup survey elevation. The 2022 post breakup scour measurements suggested there was aggradation around Pier 3 of approximately 4 ft. At pier 4 real-time scour measurements recorded approximately 8 ft of scour from the 2022 post breakup survey elevation. The 2023 breakup scour measurements and the 2023 post breakup scour measurements correspond to values measured in the 2021. At pier 5, real-time scour measurements recorded approximately 0.3 ft of aggradation during spring breakup.
### Table 6.1: Nigliq Bridge Comparison of Design and Observed Pier Scour Elevations

<table>
<thead>
<tr>
<th>Scour Location on Piles</th>
<th>Nigliq Bridge Pier Scour Elevation</th>
<th>Post-Breakup 2023 Elevation (ft-BPMSL)³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pier 2</td>
<td>Pile E</td>
<td>-20.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-18.4</td>
</tr>
<tr>
<td>Pier 3</td>
<td>Pile E</td>
<td>-26.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-26.5</td>
</tr>
<tr>
<td>Pier 4</td>
<td>Pile E</td>
<td>-30.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-29.1</td>
</tr>
<tr>
<td>Pier 5</td>
<td>Pile E</td>
<td>-17.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-15.6</td>
</tr>
</tbody>
</table>

### Deepest Post Breakup 2023 Scour Elevation (ft BPMSL)

<table>
<thead>
<tr>
<th>Scour Location on Piles</th>
<th>Deepest Post Breakup 2023 Scour Elevation (ft BPMSL)³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pier 2</td>
<td>-23.4</td>
</tr>
<tr>
<td>Pier 3</td>
<td>-26.8</td>
</tr>
<tr>
<td>Pier 4</td>
<td>-29.7</td>
</tr>
<tr>
<td>Pier 5</td>
<td>-15.7</td>
</tr>
</tbody>
</table>

### Design 2013 Elevation (ft-BPMSL)⁴,⁵

<table>
<thead>
<tr>
<th>50-year</th>
<th></th>
<th>Elevation (ft-BPMSL)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pier 2-6</td>
<td>-28.9</td>
<td></td>
</tr>
<tr>
<td>Pier 7-8</td>
<td>-7.1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>200-year</th>
<th></th>
<th>Elevation (ft-BPMSL)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pier 2-6</td>
<td>-33.0</td>
<td></td>
</tr>
<tr>
<td>Pier 7-8</td>
<td>-16.4</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1. Deepest channel bed scour elevations recorded by real-time scour system in May and June 2023.
2. Real-time scour measurements at downstream side of downstream pile.
3. Deepest channel bed scour elevations recorded by LCMF in August 2023.
5. Elevations based on LCMF 2008 survey.

---

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

- Upstream (G26) Stage
- Downstream (G27) Stage
- Real-Time Bed Elevation
- Sonar Transducer Elevation
- 2022 Post-Breakup Bed Elevation
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

**NIGLIAVGIK BRIDGE**

The maximum post-breakup scour elevation (-4.7 ft BPMSL at pier 4, pile A) is 9.6 ft above the 50-year design scour elevation and 17.2 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 0.25 ft of active aggradation during peak conditions compared to the 2022 post breakup survey. The change in bed elevation apparent in Graph 6.5 between June 4 and June 8 is the gradual abrasion of the bedfast ice at the base of the pier.

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

<table>
<thead>
<tr>
<th>Scour Location on Piles</th>
<th>During Breakup 2023 Elevation (ft-BPMSL)²</th>
<th>Post-Breakup 2023 Elevation (ft-BPMSL)³</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nigligvik Bridge Pier Scour</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pier 3</td>
<td>Pile B on north side</td>
<td>-3.3</td>
</tr>
<tr>
<td>Scour Location on Piles</td>
<td>Deep Post Breakup 2023 Scour Elevation (ft BPMSL)¹</td>
<td></td>
</tr>
<tr>
<td>Pier 3</td>
<td>Pile A on South side</td>
<td>-4.6</td>
</tr>
<tr>
<td>Pier 4</td>
<td>Pile A on North side</td>
<td>-4.7</td>
</tr>
<tr>
<td><strong>Design 2013</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-year</td>
<td>Pier 3-4</td>
<td>-14.2</td>
</tr>
<tr>
<td>200-year</td>
<td>Pier 3-4</td>
<td>-21.8</td>
</tr>
<tr>
<td><strong>Notes:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>¹Deepest channel bed scour elevations recorded by UMIAQ in August 2023</td>
<td></td>
<td></td>
</tr>
<tr>
<td>²Design values presented in PND 2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>³Elevations based on LCMF 2008 survey</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Graph 6.5: Nigliagvik Bridge Pier 3 (Pile B) Real-Time Scour Elevations
6.2 Bank Erosion

Aerial photos taken post breakup show no visible signs of significant channel migration of the Nigliq and Nigliagvik Channels at the bridges and are shown 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 3. Site conditions during the bank erosion survey at the Nigliq Bridge and Nigliagvik 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. Tabulated data from the bank erosion survey is presented in Appendix E (UMIAQ 2023).
### Table 6.3: Nigliq Channel and Nigliagvik Channel Bank Erosion

<table>
<thead>
<tr>
<th></th>
<th>Nigliq Channel</th>
<th></th>
<th></th>
<th>Nigliagvik Channel</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>West Bank</td>
<td>East Bank</td>
<td>West Bank</td>
<td>East Bank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Station^1 (STA)</td>
<td>Distance (ft)</td>
<td>Rate (ft/yr)</td>
<td>Distance (ft)</td>
<td>Rate (ft/yr)</td>
<td>Distance (ft)</td>
<td>Rate (ft/yr)</td>
</tr>
<tr>
<td>10+00</td>
<td>9.1</td>
<td>--</td>
<td>None</td>
<td>None</td>
<td>--</td>
<td>None</td>
</tr>
<tr>
<td>0+00</td>
<td>55.4</td>
<td>5.5</td>
<td>14+00</td>
<td>4.2</td>
<td>5+00</td>
<td>20.6</td>
</tr>
<tr>
<td>All</td>
<td>--</td>
<td>1.1</td>
<td>All</td>
<td>--</td>
<td>All</td>
<td>--</td>
</tr>
</tbody>
</table>

#### Notes:
1. Stationing begins upstream of bridge

#### All Stations

<table>
<thead>
<tr>
<th>Maximum Incremental Erosion</th>
<th>Nigliq Channel</th>
<th>Nigliagvik Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2022-2023)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10+00</td>
<td>9.1</td>
<td>--</td>
</tr>
<tr>
<td>0+00</td>
<td>55.4</td>
<td>5.5</td>
</tr>
<tr>
<td>All</td>
<td>--</td>
<td>1.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum Cumulative Erosion</th>
<th>Nigliq Channel</th>
<th>Nigliagvik Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2013-2023)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10+00</td>
<td>9.1</td>
<td>--</td>
</tr>
<tr>
<td>0+00</td>
<td>55.4</td>
<td>5.5</td>
</tr>
<tr>
<td>All</td>
<td>--</td>
<td>1.1</td>
</tr>
</tbody>
</table>

#### Average Cumulative Erosion

<table>
<thead>
<tr>
<th>All Stations</th>
<th>Nigliq Channel</th>
<th>Nigliagvik Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2013-2023)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10+00</td>
<td>9.1</td>
<td>--</td>
</tr>
<tr>
<td>0+00</td>
<td>55.4</td>
<td>5.5</td>
</tr>
<tr>
<td>All</td>
<td>--</td>
<td>1.1</td>
</tr>
</tbody>
</table>

#### Notes:
1. Stationing begins upstream of bridge
6.3 Bathymetry

**BATHYMETRY AT BRIDGES**

The 2023 survey results at each CD5 bridge location were compared with the survey results from 2013-2022 to obtain maximum incremental scour and deposition between 2023 and 2022, and maximum cumulative scour and deposition between 2023 and 2013 (Table 6.4). Transect profiles, bathymetric cross-sections, and tabulated data are provided in Appendix E (UMIAQ 2023).

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

<table>
<thead>
<tr>
<th></th>
<th>Nigliq Bridge</th>
<th></th>
<th>Lake L9341 Bridge</th>
<th></th>
<th>Nigliagvik Bridge</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth (ft)</td>
<td>Station (STA)</td>
<td>Transect</td>
<td>Depth (ft)</td>
<td>Station (STA)</td>
<td>Transect</td>
</tr>
<tr>
<td>Maximum Incremental Scour (2022-2023)</td>
<td>-2.8</td>
<td>2+48</td>
<td>9</td>
<td>-1.2</td>
<td>3+49</td>
<td>36</td>
</tr>
<tr>
<td>Maximum Cumulative Scour (2013-2023)</td>
<td>-13.2</td>
<td>2+67</td>
<td>10</td>
<td>-1.9</td>
<td>3+95</td>
<td>38</td>
</tr>
<tr>
<td>Maximum Incremental Deposition (2022-2023)</td>
<td>+2.2</td>
<td>7+30</td>
<td>9</td>
<td>+2.2</td>
<td>3+47</td>
<td>38</td>
</tr>
<tr>
<td>Maximum Cumulative Deposition (2013-2023)</td>
<td>+8.1</td>
<td>7+70</td>
<td>10</td>
<td>+1.4</td>
<td>3+47</td>
<td>38</td>
</tr>
</tbody>
</table>
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. Additional photos of all monitored ice road crossings are presented in Appendix D.
8. HISTORICAL BREAKUP TIMING & MAGNITUDE

8.1 Colville River – Head of the Delta

The longest 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 was recorded intermittently from 1962 to 1992 and annually from 1992 to 2023 (Table 8.1 and Graph 8.1).

2023 peak stage at MON1C was 14.17 ft. BPMSL and occurred on May 26. The average historical peak stage is 16.97 ft. BPMSL, and the average date is May 30. The maximum historical peak stage is 23.47 ft. BPMSL occurring on May 21, 2015.

2023 peak discharge at MON1C was 234,000 cfs and is estimated to have occurred on May 31. The average historical peak discharge is 299,000 cfs and the average date is May 31. The maximum historical peak discharge is 590,000 cfs occurring on May 28, 2011.

Statistical analysis of historical peak stage dates shows 80 percent of the peaks at MON1C occur during a 13-day period from May 23 to June 5. This represents one standard deviation of 6.1 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 4 days ahead of the historical average.
### Table 8.1: Colville River at the Head of the Delta Peak Discharge and Peak Stage Historical Summary

<table>
<thead>
<tr>
<th>Year</th>
<th>Discharge (cfs)</th>
<th>Date</th>
<th>Peak Stage (ft BPMSL)</th>
<th>Date</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2023</td>
<td>234,000</td>
<td>31-May</td>
<td>14.17</td>
<td>26-May</td>
<td>This Report</td>
</tr>
<tr>
<td>2022</td>
<td>320,000</td>
<td>31-May</td>
<td>21.86</td>
<td>31-May</td>
<td>Michael Baker 2022</td>
</tr>
<tr>
<td>2021</td>
<td>220,000</td>
<td>6-Jun</td>
<td>12.34</td>
<td>6-Jun</td>
<td>Michael Baker 2021</td>
</tr>
<tr>
<td>2020</td>
<td>341,000</td>
<td>27-May</td>
<td>21.41</td>
<td>28-May</td>
<td>Michael Baker 2020</td>
</tr>
<tr>
<td>2019</td>
<td>305,000</td>
<td>24-May</td>
<td>16.19</td>
<td>24-May</td>
<td>Michael Baker 2019</td>
</tr>
<tr>
<td>2018</td>
<td>331,000</td>
<td>1-Jun</td>
<td>15.90</td>
<td>2-Jun</td>
<td>Michael Baker 2018</td>
</tr>
<tr>
<td>2017</td>
<td>288,000</td>
<td>30-May</td>
<td>14.79</td>
<td>30-May</td>
<td>Michael Baker 2017</td>
</tr>
<tr>
<td>2016</td>
<td>348,000</td>
<td>23-May</td>
<td>17.16</td>
<td>23-May</td>
<td>Michael Baker 2016</td>
</tr>
<tr>
<td>2015</td>
<td>469,000</td>
<td>22-May</td>
<td>23.47</td>
<td>21-May</td>
<td>Michael Baker 2015</td>
</tr>
<tr>
<td>2014</td>
<td>327,000</td>
<td>1-Jun</td>
<td>15.18</td>
<td>31-May</td>
<td>Michael Baker 2014</td>
</tr>
<tr>
<td>2013</td>
<td>497,000</td>
<td>3-Jun</td>
<td>20.69</td>
<td>3-Jun</td>
<td>Michael Baker 2013</td>
</tr>
<tr>
<td>2012</td>
<td>366,000</td>
<td>1-Jun</td>
<td>14.18</td>
<td>27-May</td>
<td>Michael Baker 2012b</td>
</tr>
<tr>
<td>2011</td>
<td>590,000</td>
<td>28-May</td>
<td>19.56</td>
<td>28-May</td>
<td>Michael Baker 2012a</td>
</tr>
<tr>
<td>2010</td>
<td>320,000</td>
<td>31-May</td>
<td>19.59</td>
<td>1-Jun</td>
<td>Michael Baker 2010</td>
</tr>
<tr>
<td>2009</td>
<td>266,000</td>
<td>23-May</td>
<td>17.65</td>
<td>23-May</td>
<td>Michael Baker 2009b</td>
</tr>
<tr>
<td>2008</td>
<td>221,000</td>
<td>28-May</td>
<td>17.29</td>
<td>30-May</td>
<td>Michael Baker 2008</td>
</tr>
<tr>
<td>2007</td>
<td>270,000</td>
<td>3-Jun</td>
<td>18.97</td>
<td>4-Jun</td>
<td>Michael Baker 2007b</td>
</tr>
<tr>
<td>2006</td>
<td>281,000</td>
<td>30-May</td>
<td>19.83</td>
<td>30-May</td>
<td>Michael Baker 2007a</td>
</tr>
<tr>
<td>2005</td>
<td>195,000</td>
<td>9-Jun</td>
<td>13.18</td>
<td>1-Jun</td>
<td>Michael Baker 2005b</td>
</tr>
<tr>
<td>2004</td>
<td>360,000</td>
<td>26-May</td>
<td>19.54</td>
<td>27-May</td>
<td>Michael Baker 2005a</td>
</tr>
<tr>
<td>2003</td>
<td>232,000</td>
<td>11-Jun</td>
<td>13.76</td>
<td>5-Jun</td>
<td>Michael Baker 2006a</td>
</tr>
<tr>
<td>2002</td>
<td>249,000</td>
<td>27-May</td>
<td>16.87</td>
<td>24-May</td>
<td>Michael Baker 2006a</td>
</tr>
<tr>
<td>2001</td>
<td>255,000</td>
<td>11-Jun</td>
<td>17.37</td>
<td>10-Jun</td>
<td>Michael Baker 2006a</td>
</tr>
<tr>
<td>1999</td>
<td>203,000</td>
<td>30-May</td>
<td>13.97</td>
<td>30-May</td>
<td>Michael Baker 1999</td>
</tr>
<tr>
<td>1998</td>
<td>213,000</td>
<td>3-Jun</td>
<td>18.11</td>
<td>29-May</td>
<td>Michael Baker 1998b</td>
</tr>
<tr>
<td>1997</td>
<td>177,000</td>
<td>-</td>
<td>15.05</td>
<td>29-May</td>
<td>Michael Baker 2002b</td>
</tr>
<tr>
<td>1996</td>
<td>160,000</td>
<td>26-May</td>
<td>17.19</td>
<td>26-May</td>
<td>Shannon &amp; Wilson 1996a</td>
</tr>
<tr>
<td>1995</td>
<td>233,000</td>
<td>-</td>
<td>14.88</td>
<td>16-May</td>
<td>ABR 1996</td>
</tr>
<tr>
<td>1994</td>
<td>159,000</td>
<td>25-May</td>
<td>12.20</td>
<td>25-May</td>
<td>ABR 1996</td>
</tr>
<tr>
<td>1993</td>
<td>379,000</td>
<td>31-May</td>
<td>19.20</td>
<td>31-May</td>
<td>ABR 1996</td>
</tr>
<tr>
<td>1991</td>
<td>407,000</td>
<td>-</td>
<td>19.10</td>
<td>7-Jun</td>
<td>ABR 1996</td>
</tr>
<tr>
<td>1990</td>
<td>478,000</td>
<td>-</td>
<td>-</td>
<td>2-Jun</td>
<td>ABR 1996</td>
</tr>
<tr>
<td>1988</td>
<td>447,000</td>
<td>8-Jun</td>
<td>-</td>
<td>8-Jun</td>
<td>ABR 1996</td>
</tr>
<tr>
<td>1987</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3-Jun</td>
<td>ABR 1996</td>
</tr>
</tbody>
</table>

**Note:** Dates and stages are approximate and may vary slightly from the original data sources.
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. Stage and discharge relationship in the Colville River Delta is greatly influenced by channel ice and ice jams. The rating curve more accurately represents the relationship between stage and discharge at lower stage values when ice-free discharge measurements are possible.
Graph 8.3: Colville River at the Head of the Delta Stage-Discharge Rating Curve with Measured Discharge

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 geometry 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
4. Historical direct discharge measurements are those collected during open water conditions; direct measurements from 2006, 2007, 2008, and 2009 were ice-affected and are not included.
Peak discharge and corresponding stage, between 1992 and 2023, 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 influenced by downstream ice jam backwater effects. Peak discharge in 2023 falls to the left of the rating curve by 6%.

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

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 geometry 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
4. Calculated peak discharge in 1997 was 177,000 cfs; corresponding stage data is not available
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. Measured flow in 2023 through the Long Swale Bridge was 63.7% of the average annual measured flow through both bridges (3,503 cfs). A summary of historical discharge measurements at the CD2 road bridges is presented in Table 8.2.

Calculated peak flow through the Long Swale Bridge was 55.5% of the average annual peak flow through both bridges (4,187 cfs). Table 8.3 summarizes peak stage and calculated peak discharge at the CD2 Long and Short Swale Bridges between 2000 and 2023.

Discharge was not measured through Short Swale Bridge in 2023 due to a lack of flow.
<table>
<thead>
<tr>
<th>Date</th>
<th>Stage¹ (ft)</th>
<th>Stage Differential² (ft)</th>
<th>Width (ft)</th>
<th>Area (ft²)</th>
<th>Mean Velocity (ft/s)³</th>
<th>Discharge (cfs)</th>
<th>Measurement Rating⁴</th>
<th>Number of Sections</th>
<th>Measurement Type</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Swale Bridge (62 ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06/04/22</td>
<td>6.67</td>
<td>0.41</td>
<td>40</td>
<td>215</td>
<td>0.06</td>
<td>12</td>
<td>F</td>
<td>17</td>
<td>Cable</td>
<td>Michael Baker 2022</td>
</tr>
<tr>
<td>2021¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Michael Baker 2021</td>
</tr>
<tr>
<td>05/29/20</td>
<td>9.92</td>
<td>0.81</td>
<td>55</td>
<td>476</td>
<td>5.17</td>
<td>2,460</td>
<td>F</td>
<td>22</td>
<td>Cable</td>
<td>Michael Baker 2020</td>
</tr>
<tr>
<td>05/26/19</td>
<td>7.27</td>
<td>0.02</td>
<td>53</td>
<td>349</td>
<td>0.7</td>
<td>244</td>
<td>G</td>
<td>11</td>
<td>Cable</td>
<td>Michael Baker 2019</td>
</tr>
<tr>
<td>06/03/18</td>
<td>6.63</td>
<td>0.08</td>
<td>36</td>
<td>32</td>
<td>0.22</td>
<td>5.40</td>
<td>P</td>
<td>22</td>
<td>Cable</td>
<td>Michael Baker 2018</td>
</tr>
<tr>
<td>2017²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Michael Baker 2017</td>
</tr>
<tr>
<td>05/25/16</td>
<td>7.39</td>
<td>0.32</td>
<td>53</td>
<td>322</td>
<td>2.11</td>
<td>700</td>
<td>G</td>
<td>27</td>
<td>Cable</td>
<td>Michael Baker 2016</td>
</tr>
<tr>
<td>05/23/15</td>
<td>7.85</td>
<td>0.05</td>
<td>54</td>
<td>373</td>
<td>0.81</td>
<td>302</td>
<td>F</td>
<td>19</td>
<td>Cable</td>
<td>Michael Baker 2015</td>
</tr>
<tr>
<td>06/02/14</td>
<td>7.90</td>
<td>0.12</td>
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<td>F</td>
<td>28</td>
<td>Cable</td>
<td>Michael Baker 2014</td>
</tr>
<tr>
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<td>G</td>
<td>36</td>
<td>Cable</td>
<td>Michael Baker 2013</td>
</tr>
<tr>
<td>06/03/12</td>
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<td>0.17</td>
<td>52</td>
<td>306</td>
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<td>F</td>
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<td>Cable</td>
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<td>Cable</td>
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</tr>
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<td>0.16</td>
<td>55</td>
<td>316</td>
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<td>570</td>
<td>F</td>
<td>28</td>
<td>Cable</td>
<td>Michael Baker 2010</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Michael Baker 2009b</td>
</tr>
<tr>
<td>05/29/08</td>
<td>6.35</td>
<td>0.18</td>
<td>55</td>
<td>211</td>
<td>0.58</td>
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<td>14</td>
<td>Cable</td>
<td>Michael Baker 2008</td>
</tr>
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<td>7.83</td>
<td>0.09</td>
<td>55</td>
<td>292</td>
<td>1.18</td>
<td>350</td>
<td>F</td>
<td>20</td>
<td>Cable</td>
<td>Michael Baker 2007b</td>
</tr>
<tr>
<td>05/31/06</td>
<td>8.49</td>
<td>0.26</td>
<td>55</td>
<td>615</td>
<td>1.59</td>
<td>980</td>
<td>F</td>
<td>20</td>
<td>Cable</td>
<td>Michael Baker 2007a</td>
</tr>
<tr>
<td>2005³</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Michael Baker 2005b</td>
</tr>
<tr>
<td>05/29/04</td>
<td>8.34</td>
<td>0.14</td>
<td>55</td>
<td>451</td>
<td>1.60</td>
<td>720</td>
<td>F</td>
<td>17</td>
<td>Cable</td>
<td>Michael Baker 2005a</td>
</tr>
<tr>
<td>2003⁵</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Michael Baker 2003</td>
</tr>
<tr>
<td>05/25/02</td>
<td>6.74</td>
<td>0.22</td>
<td>56</td>
<td>283</td>
<td>1.52</td>
<td>430</td>
<td>G</td>
<td>17</td>
<td>Cable</td>
<td>Michael Baker 2002b</td>
</tr>
<tr>
<td>06/11/01</td>
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<td>0.56</td>
<td>56</td>
<td>336</td>
<td>1.79</td>
<td>600</td>
<td>G</td>
<td>15</td>
<td>Cable</td>
<td>Michael Baker 2001</td>
</tr>
<tr>
<td>06/10/00</td>
<td>7.87</td>
<td>0.61</td>
<td>47</td>
<td>175</td>
<td>3.30</td>
<td>580</td>
<td>F</td>
<td>13</td>
<td>Cable</td>
<td>Michael Baker 2000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Long Swale Bridge (452 ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>06/01/23</td>
</tr>
<tr>
<td>06/04/22</td>
</tr>
<tr>
<td>06/07/21</td>
</tr>
<tr>
<td>05/30/20</td>
</tr>
<tr>
<td>05/25/19</td>
</tr>
<tr>
<td>06/03/18</td>
</tr>
<tr>
<td>06/01/17</td>
</tr>
<tr>
<td>05/25/16</td>
</tr>
<tr>
<td>05/22/15</td>
</tr>
<tr>
<td>06/02/14</td>
</tr>
<tr>
<td>06/03/13</td>
</tr>
<tr>
<td>06/03/12</td>
</tr>
<tr>
<td>05/29/11</td>
</tr>
<tr>
<td>06/01/10</td>
</tr>
<tr>
<td>05/26/09</td>
</tr>
<tr>
<td>05/29/08</td>
</tr>
<tr>
<td>06/05/07</td>
</tr>
<tr>
<td>05/31/06</td>
</tr>
<tr>
<td>06/02/05</td>
</tr>
<tr>
<td>05/29/04</td>
</tr>
</tbody>
</table>
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 -
5. Bridge obstructed with snow or ice and/or lack of flow; no measurement performed

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

<table>
<thead>
<tr>
<th>Date</th>
<th>Peak Stage (ft BPMSL)</th>
<th>Stage Differential (ft)</th>
<th>Long Swale Bridge (452 ft)</th>
<th>Short Swale Bridge (62 ft)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Peak Discharge (cfs)</td>
<td>Mean Velocity (ft/s)</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>Peak Discharge (cfs)</td>
<td>Mean Velocity (ft/s)</td>
<td></td>
</tr>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Based on gage HWM readings.
2. Source of stage is Gage 3.
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

<table>
<thead>
<tr>
<th>Year</th>
<th>Lake L9323 Bridge</th>
<th>Nigliq Bridge</th>
<th>Lake L9341 Bridge</th>
<th>Nigliagvik Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-Bridge Construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>-1</td>
<td>8.19</td>
<td>23,000</td>
<td>8.26</td>
</tr>
<tr>
<td>2022</td>
<td>290</td>
<td>9.91</td>
<td>67,400</td>
<td>10.97</td>
</tr>
<tr>
<td>2021</td>
<td>-1</td>
<td>-1</td>
<td>34,000</td>
<td>7.49</td>
</tr>
<tr>
<td>2020</td>
<td>1,620</td>
<td>12.43</td>
<td>100,500</td>
<td>12.23</td>
</tr>
<tr>
<td>2019</td>
<td>-1</td>
<td>8.49</td>
<td>95,000</td>
<td>9.16</td>
</tr>
<tr>
<td>2018</td>
<td>-1</td>
<td>9.67</td>
<td>42,200</td>
<td>8.43</td>
</tr>
<tr>
<td>2017</td>
<td>-1</td>
<td>9.54</td>
<td>47,400</td>
<td>8.60</td>
</tr>
<tr>
<td>2016</td>
<td>-1</td>
<td>8.85</td>
<td>65,000</td>
<td>9.05</td>
</tr>
<tr>
<td>2015*</td>
<td>9,100</td>
<td>15.39</td>
<td>112,000</td>
<td>14.50</td>
</tr>
<tr>
<td>2014</td>
<td>-1</td>
<td>8.58</td>
<td>66,000</td>
<td>9.38</td>
</tr>
<tr>
<td>Pre-Bridge Construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>-1</td>
<td>12.40</td>
<td>110,000</td>
<td>12.42</td>
</tr>
<tr>
<td>2012</td>
<td>-1</td>
<td>8.55</td>
<td>94,000</td>
<td>8.82</td>
</tr>
<tr>
<td>2011</td>
<td>-3</td>
<td>-3</td>
<td>141,000</td>
<td>9.89</td>
</tr>
<tr>
<td>2010</td>
<td>-3</td>
<td>-3</td>
<td>134,000</td>
<td>9.65</td>
</tr>
<tr>
<td>2009</td>
<td>-3</td>
<td>-3</td>
<td>57,000</td>
<td>7.91</td>
</tr>
</tbody>
</table>

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.

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 2023, Lake L9313 recharged via flooding from Lake M9525 to a peak WSE of 7.22 ft BPMSL.

Lake L9312 is surrounded by higher terrain 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 #9. In 2023, Lake L9312 did not recharge via floodwater from the Sakoonang Channel. Lake L9312 did reach the recharge elevation via snowmelt and rainfall on June 15.

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 18 of the last 26 years, and Lake L9313 has recharged to bankfull 23 of the last 26 years.
## Table 8.5: Alpine Drinking Water Lakes Historical Recharge Summary

<table>
<thead>
<tr>
<th>Year</th>
<th>Lake L9312 Peak Stage (ft BPMSL)</th>
<th>Bankfull Recharge to 7.8 ft BPMSL</th>
<th>Lake L9313 Peak Stage (ft BPMSL)</th>
<th>Bankfull Recharge to 6.29 ft BPMSL</th>
</tr>
</thead>
<tbody>
<tr>
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<td>7.92</td>
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<td>7.22</td>
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</tr>
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<td>8.42</td>
<td>Yes</td>
<td>9.23</td>
<td>Yes</td>
</tr>
<tr>
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<td>-</td>
<td>No(^3)</td>
<td>6.53</td>
<td>Yes(^3)</td>
</tr>
<tr>
<td>2020</td>
<td>10.08</td>
<td>Yes</td>
<td>10.37</td>
<td>Yes</td>
</tr>
<tr>
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<td>8.09</td>
<td>Yes(^3)</td>
<td>8.72</td>
<td>Yes</td>
</tr>
<tr>
<td>2018</td>
<td>8.10</td>
<td>Yes(^3)</td>
<td>6.29</td>
<td>Yes(^3)</td>
</tr>
<tr>
<td>2017</td>
<td>-</td>
<td>No(^3)</td>
<td>7.40</td>
<td>Yes</td>
</tr>
<tr>
<td>2016</td>
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<td>2015</td>
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<td>Yes</td>
<td>8.59</td>
<td>Yes</td>
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</tr>
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</tr>
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<td>No(^3)</td>
<td>7.12</td>
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<td>2008</td>
<td>7.45</td>
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<td>9.55</td>
<td>Yes</td>
<td>9.95</td>
<td>Yes</td>
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<td>6.12</td>
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<td>9.40</td>
<td>Yes</td>
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<td>2003</td>
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</tr>
<tr>
<td>2002</td>
<td>8.05</td>
<td>Yes</td>
<td>7.98</td>
<td>Yes</td>
</tr>
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<td>2001</td>
<td>7.55</td>
<td>No(^3)</td>
<td>8.31</td>
<td>Yes</td>
</tr>
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<td>2000</td>
<td>-</td>
<td>Yes</td>
<td>-</td>
<td>Yes</td>
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<td>1999</td>
<td>7.93</td>
<td>Yes</td>
<td>6.14</td>
<td>No(^3)</td>
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<td>1998</td>
<td>8.35</td>
<td>Yes</td>
<td>7.35</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Notes:**

1. Bankfull recharge is based on peak stage exceeding 7.8 ft BPMSL per Fish Habitat Permit FG99-III-0051, Amendment #9.
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

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 magnitude values 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 31 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. These values are presented in Table 9.1.

Continuous record and design-magnitude flood frequency analyses for the Colville River at the head of the delta (MON1), were last performed in 2023. 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 2023, the observed record of continuous peak annual discharges was 32 years. Rather than add the uncertainty and error associated with the extrapolated peak values, the 2023 analysis is based entirely on the observed continuous period of record, 1992 through 2023 (Michael Baker 1998-2023, 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 2023 Weibull and 17C distribution for the period of continuous record (1992 to 2023) 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 33 years assigned to the event with the largest peak discharge. This year’s peak discharge of 234,000 cfs has a recurrence interval of <2 years or a >50% chance of occurrence in any given year based on the historical record evaluated using current basis of design flood magnitudes and the 2023 flood frequency results.

Table 9.1: Colville River Flood Frequency Analysis Comparison

<table>
<thead>
<tr>
<th>Annual Exceedance Probability</th>
<th>Return Period</th>
<th>Basis for Current Design Criteria¹</th>
<th>2021 Analysis Values²</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>2-year</td>
<td>240,000</td>
<td>276,000</td>
</tr>
<tr>
<td>20</td>
<td>5-year</td>
<td>370,000</td>
<td>377,000</td>
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<td>10</td>
<td>10-year</td>
<td>470,000</td>
<td>450,000</td>
</tr>
<tr>
<td>4</td>
<td>25-year</td>
<td>610,000</td>
<td>548,000</td>
</tr>
<tr>
<td>2</td>
<td>50-year</td>
<td>730,000</td>
<td>625,000</td>
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<tr>
<td>1</td>
<td>100-year</td>
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<td>707,000</td>
</tr>
<tr>
<td>0.5</td>
<td>200-year</td>
<td>1,000,000</td>
<td>793,000</td>
</tr>
</tbody>
</table>

Notes:
¹ Michael Baker and Hydroconsult 2002
² Michael Baker 2023
Table 9.2: Colville River Flood Frequency Analysis Results

<table>
<thead>
<tr>
<th>Year</th>
<th>Discharge (cfs)</th>
<th>2002 Return Period (Basis of Design) (years)</th>
<th>2021 Log Pearson Type III Return Period (years)</th>
<th>2021 Weibull Return Period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>590,000</td>
<td>22.9</td>
<td>38.6</td>
<td>33.0</td>
</tr>
<tr>
<td>2009</td>
<td>580,000</td>
<td>21.8</td>
<td>35.4</td>
<td>16.5</td>
</tr>
<tr>
<td>2013</td>
<td>497,000</td>
<td>12.9</td>
<td>17.2</td>
<td>11.0</td>
</tr>
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<td>2015</td>
<td>469,000</td>
<td>10.0</td>
<td>12.9</td>
<td>8.3</td>
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<td>1993</td>
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<td>2004</td>
<td>360,000</td>
<td>4.9</td>
<td>4.5</td>
<td>4.7</td>
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<td>4.1</td>
</tr>
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<td>2002</td>
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<tr>
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<td>1996</td>
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</table>
9.2 Stage Frequency

**HIGH MAGNITUDE, LOW FREQUENCY**

The CRD 2D surface water 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. The 2D 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). 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 2023 peak stage at select gage stations were assigned a recurrence interval relative to the 2D model results (Graph 9.1 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 10 years and less.

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. Relative to the 2D model predictions, flood stage recurrence intervals throughout the CRD ranged from below model results (i.e., site-specific areas can be dry during lower magnitude flood-recurrence events) to a maximum of >200-year recurrence.
Graph 9.1: 2D Model Stage and Peak Stage Recurrence Intervals

Notes:
1. This location was dry during 2023
Table 9.3: Peak Stage Frequency Relative to 2D Model Stage Frequency Analysis

<table>
<thead>
<tr>
<th>Gage Station</th>
<th>2D Model Stage Recurrence Intervals&lt;sup&gt;1,2&lt;/sup&gt; (ft BPMSL)</th>
<th>Peak Stage (ft BPMSL)</th>
<th>Peak Stage Recurrence Interval (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-year</td>
<td>10-year</td>
<td>50-year</td>
</tr>
<tr>
<td>Colville River</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MON1C (head of CRD)</td>
<td>13.9</td>
<td>19.2</td>
<td>23</td>
</tr>
<tr>
<td>Colville River East Channel</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>11.5</td>
<td>16.1</td>
<td>19</td>
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<tr>
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</tr>
<tr>
<td>Nigliq Channel</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MON20</td>
<td>7.8</td>
<td>11.4</td>
<td>14.6</td>
</tr>
<tr>
<td>MON22</td>
<td>6.3</td>
<td>9.3</td>
<td>12.1</td>
</tr>
<tr>
<td>MON23</td>
<td>5.1</td>
<td>7.4</td>
<td>10.2</td>
</tr>
<tr>
<td>MON28</td>
<td>3.1</td>
<td>5.4</td>
<td>6.1</td>
</tr>
<tr>
<td>CD1 Pad &amp; Drinking Water Lakes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gage G1 (Sakoonang)</td>
<td>7.3</td>
<td>9.7</td>
<td>12.5</td>
</tr>
<tr>
<td>Gage G9 (Lake L9312)</td>
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<td>10.8</td>
<td>13.4</td>
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<td>Gage G10 (Lake L9313)</td>
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<tr>
<td>CD2 Pad &amp; Road</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Gage G8 (CD2 pad)</td>
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<td>8.7</td>
<td>10.6</td>
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<tr>
<td>Gage G3 (swale bridges)</td>
<td>6.3</td>
<td>9.4</td>
<td>12.0</td>
</tr>
<tr>
<td>Gage G4 (swale bridges)</td>
<td>6.2</td>
<td>8.5</td>
<td>10.1</td>
</tr>
<tr>
<td>Gage G6</td>
<td>\</td>
<td>9.5</td>
<td>12.2</td>
</tr>
<tr>
<td>Gage G7</td>
<td>\</td>
<td>8.4</td>
<td>10.0</td>
</tr>
<tr>
<td>Gage G12</td>
<td>\</td>
<td>9.5</td>
<td>12.1</td>
</tr>
<tr>
<td>Gage G13</td>
<td>\</td>
<td>8.4</td>
<td>10.0</td>
</tr>
<tr>
<td>CD3 Pad &amp; Pipeline</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Gage G11 (CD3 pad)</td>
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<td>6.9</td>
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<tr>
<td>SAK Gage (Pipeline Crossing #2)</td>
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<td>11.2</td>
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<td>TAM Gage (Pipeline Crossing #4)</td>
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<td>9</td>
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<td>ULAM Gage (Pipeline Crossing #5)</td>
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<td>CD4 Pad &amp; Road</td>
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<td></td>
<td></td>
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<td>Gage G15</td>
<td>8.4</td>
<td>10.8</td>
<td>13.5</td>
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<tr>
<td>Gage G16</td>
<td>8.4</td>
<td>11.1</td>
<td>14.2</td>
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<td>Gage G17</td>
<td>\</td>
<td>11.1</td>
<td>14.2</td>
</tr>
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<td>Gage G18</td>
<td>\</td>
<td>11.9</td>
<td>14.8</td>
</tr>
<tr>
<td>Gage G19 (CD4 pad)</td>
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<td>14.7</td>
</tr>
<tr>
<td>Gage G20 (CD4 pad)</td>
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<td>11.1</td>
<td>14.3</td>
</tr>
<tr>
<td>CD5 Road</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Gage G24 (Lake L9323/CD5 Bridge #1)</td>
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<td>11.1</td>
<td>14.1</td>
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<tr>
<td>Gage G26 (Nigliq/CD5 Bridge #2)</td>
<td>6.7</td>
<td>9.8</td>
<td>12.5</td>
</tr>
<tr>
<td>Gage G27 (Nigliq/CD5 Bridge #2)</td>
<td>6.7</td>
<td>9.8</td>
<td>12.5</td>
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<tr>
<td>Gage G30</td>
<td>\</td>
<td>\</td>
<td>13.3</td>
</tr>
<tr>
<td>Gage G32 (Lake L9341/CD5 Bridge #3)</td>
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<td>\</td>
<td>13.3</td>
</tr>
<tr>
<td>Gage G34</td>
<td>\</td>
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<td>13.3</td>
</tr>
<tr>
<td>Gage G36</td>
<td>\</td>
<td>\</td>
<td>13.3</td>
</tr>
<tr>
<td>Gage G38 (Nigliagvik/CD5 Bridge #4)</td>
<td>6.9</td>
<td>10</td>
<td>12.8</td>
</tr>
</tbody>
</table>

Notes:
1. Sites having dry ground in 2D model during lower recurrence intervals are denoted with a backward slash \\"/\"
2. 2D WSEs based on results modeled incorporating the CD5 development
3. Stage attributed to ponded local melt
LOW MAGNITUDE, HIGH FREQUENCY

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 32 years at MON1C. Analyses have been performed every three years as the body of data grows (Michael Baker 2007a, 2009b, 2012b, 2015, 2018, and 2021).

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 onto 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. Results from the most recent stage frequency analysis are compared to this year’s observed peak stages in Table 9.4 and Graph 9.2. Graph 9.3 through Graph 9.6 visually compare the stage frequency analysis and 2D model results to the measured or extrapolated peak annual stage for each selected location.

Table 9.4: Peak Stage Recurrence Relative to Stage Frequency Analysis

<table>
<thead>
<tr>
<th>Monitoring Location</th>
<th>Stage Frequency Recurrence Intervals (ft BPMSL)</th>
<th>Peak Stage (ft BPMSL)</th>
<th>Peak Stage Recurrence Interval (years)</th>
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</thead>
<tbody>
<tr>
<td>MON22 (Nigliq Channel)</td>
<td>8.35 8.99 9.65 10.44 11.15 12.03</td>
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<td>Gage G1 (CD1 Pad)</td>
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<td>dry</td>
<td>-</td>
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</table>
Graph 9.2: Stage Frequency and Peak Stage Recurrence Intervals
Graph 9.3: MON1 Stage Frequency Analysis, 2D Model Results and Peak Annual Stage Data

Graph 9.4: MON22 Stage Frequency Analysis, 2D Model Results and Peak Annual Stage Data
Graph 9.5: Gage 1 Stage Frequency Analysis, 2D Model Results and Peak Annual Stage Data

Graph 9.6: Gage 3 Stage Frequency Analysis, 2D Model Results and Peak Annual Stage Data
10. REFERENCES


——— 2004. Cross-section survey, Colville River at Monument 01. Prepared for Michael Baker Jr., Inc. (Submitted as Kuukpik/UMIAQ LLC, Inc. [UMIAQ]).


## APPENDIX A

### VERTICAL CONTROL, GAGE LOCATIONS, & CULVERT LOCATIONS

#### A.1 VERTICAL CONTROL

<table>
<thead>
<tr>
<th>Control</th>
<th>Elevation (ft BPMSL)</th>
<th>Latitude (NAD83)</th>
<th>Longitude (NAD83)</th>
<th>Control Type</th>
<th>Reference</th>
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<td>CD2-6N</td>
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<td>N 70.3399°</td>
<td>W 151.0292°</td>
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</tr>
<tr>
<td>CD2-6S</td>
<td>8.68</td>
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<td>W 151.0291°</td>
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<tr>
<td>CD2-14N</td>
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<td>W 151.0110°</td>
<td>Culvert top</td>
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</tr>
<tr>
<td>CD2-14S</td>
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<td>W 151.0111°</td>
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<td>UMIAQ 2020</td>
</tr>
<tr>
<td>CD2-22N</td>
<td>9.15</td>
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<td>W 150.9829°</td>
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</tr>
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<td>W 150.9954°</td>
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</tr>
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<td>CD4-22W</td>
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<td>W 150.9930°</td>
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</tr>
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<td>UMIAQ 2016</td>
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<td>W 151.0683°</td>
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<tr>
<td>CD5-40S</td>
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<td>N 70.3048°</td>
<td>W 151.0442°</td>
<td>Culvert top</td>
<td>UMIAQ 2016</td>
</tr>
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<td>8.52</td>
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<td>BAKER 2017</td>
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1. North American Datum of 1983 (NAD83)
## A.2 CRD GAGE LOCATIONS

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Notes:
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### A.3 Alpine Facilities Gage Locations

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A.4 CULVERT LOCATIONS

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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 accounted for using an In-Situ BaroTroll or VanEssen Baro-Diver. A correction of barometric pressure was obtained from the Baro-Diver at MON9 or the BaroTroll at Lake L9312.

The PTs were tested before field mobilization. The PTs were configured using one of the following software prior to placement in the field; software Solinst Levelogger® v4.6.1 for the Solinst Leveloggers, Onset HOBOware v3.7.21 for the HOBO loggers, VanEssen Diver-Office v11.1.0.1 for the baro-diver and TD-diver, and In-Situ VuSitu v 1.23.5 for the BaroTroll. 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 1,200-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 (Dell Latitude 7330) were self-powered via internal batteries.

WinRiverII v2.23 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 WinRiverII. 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 1.62°, which is less than the specified 5° limit and accepted. A loop
test was performed before the discharge measurement to measure the magnitude of moving bed velocity. The moving bed was measured at 0.019 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 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.

A total of four transects were used. The measured discharges varied by 1.04%, 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) or 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:
2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

- Headwater and tailwater elevations at each culvert (hydraulic gradient)
- Culvert diameter and length from UMIAQ as-built surveys (UMIAQ 2002, 2017a)
- Culvert upstream and downstream invert elevations (UMIAQ 2017, 2018b)
- 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 2021 (UMIAQ 2021). 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 L9341 bridge (CD5 bridge #3) and Lake L9323 bridge (CD5 bridge #1) did not become hydraulically connected via the Nigliq Channel therefore discharge calculations were not performed.
C.2  Site Specific Data & Plan & Profile Drawings

C.2.1  MON1

1)  MEASURED DISCHARGE

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<td>113,397</td>
<td>0.00%</td>
<td>2.67</td>
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E.  TRANSECT 001 RAW DATA OUTPUT
F. TRANSECT 002 RAW DATA OUTPUT

G. 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 0.034 for the main channel and 0.06 for the overbanks, based on historical calibration of measured discharge and corresponding stage.

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

HIGHEST RECORDED STAGE (MON1D) = 13.76 FEET BPMSL

COLVILLE RIVER AT MON1 DOWNSTREAM CROSS-SECTION
NOTES
1. BASIS OF ELEVATION, MONUMENT 1.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED
   AUGUST 2004 BY UMIAQ (KUUKPIK/CMIF INC.)

PEAK STAGE (MON1C) = 14.17 FEET BPSNL

SCALE 1" = 500'

COLVILLE RIVER AT MON1 CENTERLINE CROSS-SECTION
NOTES
1. BASIS OF ELEVATION, MONUMENT 1.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED
   AUGUST 2004 BY UMIAQ (KUUKPIK/LCMF INC.)

PEAK STAGE (MON1U) = 15.32 FEET BPMSL

COLVILLE RIVER AT MON1 UPSTREAM CROSS-SECTION
C.2.2 MON9

1) MEASURED DISCHARGE DATA
Discharge was not measured at MON9.

2) PEAK DISCHARGE DATA
Peak discharge at MON9 was calculated indirectly 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 0.023 for the shallower portion of the channel adjacent to the west bank and 0.021 for the main channel.

3) PLAN & PROFILE
NOTES
1. BASIS OF ELEVATION, MONUMENT 9.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED
   NOVEMBER 2009 BY UMAQ (KUKPK/KCMF INC.)

PEAK STAGE AT (MON9) = 11.67 FEET BPLSM

COLVILLE EAST CHANNEL AT MON9 CROSS-SECTION

SCALE 1" = 500'
C.2.3 NIGLIQ BRIDGE

1) MEASURED DISCHARGE

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Discharge Measurement Notes

Date: June 3, 2023
Computed By: CMB
Checked By: CTR

Location Name: Nigliq Bridge
Party: DTR, JAK, MKM
Start: 11:22 AM
Finish: 4:30 PM
Temp: 35°F
Weather: 15 MPH east, cloudy

Width: 710 ft
Area: 13,975 sq ft
Velocity: 1.0 fps
Discharge: 14,588 cfs

Method: Mid-section
Number of Sections: 20
Count: varies

Spin Test: 2-min test

Meter: Price AA

Wading: Cable, Ice, Boat

GPS Data:
Left Edge of N AT STATION 0+00
Right Edge of N AT STATION 7+10

Measurement Rated: Excellent

Cross Section:

Flow:

Remarks:

Pier 3 = 1+91
Pier 4 = 2+90
Pier 5 = 3+70
2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

### Table: Nitlq Bridge

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<th>Time Increment (sec)</th>
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</table>

Highest depth averaged velocity: 1.4
Average Velocity: 1.1
Total Discharge: 14,588
2) PEAK DISCHARGE DATA

Peak discharge in the Nigliq channel was calculated indirectly using Normal Depth method. The channel geometry applied in the Normal Depth calculation was from Transect 10 surveyed in August 2021 for the Monitoring Plan with an Adaptive Management Strategy in (UMIAQ 2021). The energy grade-line used in the Normal Depth calculation was based on the slope between WSEs at gages G28 and G29. The channel roughness values used were calibrated from the measured discharge. Manning’s n value used was 0.032 for the main channel and 0.095 and 0.06 for the left/west and right/east overbanks, respectively. Channel roughness is relatively high to account for obstructions from the bridge piers and scour holes as well as shallow overbank flow.

3) PLAN & PROFILE
C.2.4 NIGLIAGVIK BRIDGE

1) MEASURED DISCHARGE
Discharge Measurement Notes

Location Name: Niglakuk Bridge

Temp: 35 °F
Weather: Cloudy, 5 mph, wind gusts, snow flurries

Party: DTR, JAK, MKM
Start: 2:55 PM
Finish: 6:00 PM

Channel Characteristics:

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<th>Width</th>
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<td>1373 sq ft</td>
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Method: Mid-section
Number of Sections: 23
Count: varies
Spin Test: 2-min test
Weight: 50 lbs

Motor: 0.9 ft above bottom of weight

GAGE READINGS

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GPS Data:
Left Edge: " "
Right Edge: " "
LE Floodplain: " "
RE Floodplain: " "

Measurement Rated: Excellent

Descriptions:
Cross Section:
Flow:

Remarks:

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Highest depth averaged velocity: 0.8
Average Velocity: 0.6
Total Discharge: 737
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 2022 (UMIAQ 2022c). 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
C.2.5 LONG SWALE BRIDGE

1) MEASURED DISCHARGE

Discharge Measurement Notes
Date: May 28, 2023
Computed By: CMB
Checked By: OTR

Location Name: Long Swale Bridge

Party: CSL, GCY, JMV
Start: 11:00 AM
Finish: 1:30 PM
Temp: 33 °F
Weather: overcast, low wind

Channel Characteristics:

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Method: 0.6 & 0.2, 0.8
Number of Sections: 28
Count: varies

Spin Test: 2-min test

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<th>Gage</th>
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<th>Change</th>
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<td>G4</td>
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GPS Data:
Left Edge of Water: E
Right Edge of Water: E

LE Floodplain: " 
RE Floodplain: " 

Measurement Rated: Excellent

Descriptions:
Cross Section: 

Remarks: 

Weight: 30 lbs

Method: Price AA

Wading: Ice Boat
Upstream or Downstream side of bridge

Final Report
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Discharge Measurement Notes

Date: June 1, 2023
Computed By: CMB
Checked By: DTA

Location Name: Long Slake Bridge
Party: VG GCC
Start: 2:30 PM
Finish: 5:00 PM
Temp: 30°F
Weather: lots of upstream wind

Channel Characteristics:

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<tr>
<td>Spin Test:</td>
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<td>Price AA</td>
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<tr>
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<td>0.9 ft above bottom of weight</td>
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<td>Cable</td>
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<td>Upstream</td>
<td>or Downstream side of bridge</td>
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GAGE READINGS

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<td>G4</td>
<td>5.96</td>
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</table>

GPS Data:

- Left Edge of N Water E
- Right Edge of N Water E

Measurement Rated: Excellent

Descriptions:

Cross Section:

Flow:

Remarks:

ConocoPhillips
Michael Baker
International

Final Report
11/28/2023 PAGE C.27
### 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

<table>
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<tr>
<th>Angle Coeff.</th>
<th>Distance from initial point (ft)</th>
<th>Section Width (ft)</th>
<th>Water Depth (ft)</th>
<th>Observed Depth (ft)</th>
<th>Revolution Count</th>
<th>Time Increment (sec)</th>
<th>VELOCITY At Point (fps)</th>
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| 5.1 | Highest depth averaged velocity | 1.6 | 0.84 |
| Average Velocity: | 0.9 | Total Discharge: 2216 |
## C.2.6 CULVERTS

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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 CD2-24, looking northwest; June 7, 2023

*Photo D.2*: CD2 road embankment, looking southwest; June 7, 2023

*Photo D.3*: CD2 road embankment in the vicinity of culvert CD2-23, looking northeast; June 7, 2023

*Photo D.4*: CD2 road short swale bridge SW abutment, looking northeast; June 7, 2023
Photo D.5: CD2 road embankment in the vicinity of culvert CD2-24 post-breakup, looking north; June 7, 2023

Photo D.6: CD2 road embankment in the vicinity of short swale bridge post-breakup, looking north; June 7, 2023

Photo D.7: CD2 road embankment in vicinity of long swale bridge post-breakup, looking east; June 7, 2023

Photo D.8: CD2 road embankment in the vicinity of long swale bridge, looking east; June 7, 2023
Photo D.9: CD2 road embankment in the vicinity of long swale bridge and culvert CD2-24, looking northeast; June 7, 2023

Photo D.10: CD2 road embankment in the vicinity of the short swale bridge, looking west; June 7, 2023

Photo D.11: CD2 road embankment in the vicinity of short swale bridge, looking east; June 7, 2023

Photo D.12: CD2 road embankment in the vicinity of culvert CD2-21, looking west; June 7, 2023
D.1.2 CD4 ROADS

Photo D.13: CD4 road in vicinity of G15 culverts post-breakup, looking southeast; June 2, 2023

Photo D.14: CD4 road in vicinity of G15 culverts post-breakup, looking northwest; June 2, 2023
D.1.3 CD5 ROAD

Photo D.15: Nigliagvik Bridge western bank post-breakup, looking southwest; June 7, 2023

Photo D.16: L9323 Bridge SE abutment post-breakup, looking north; June 3, 2023

Photo D.17: Nigliq Bridge SE abutment post-breakup, looking southwest; June 3, 2023

Photo D.18: Lake L9341 Bridge NW abutment pre-breakup, looking west; May 25, 2023
Photo D.19: CD5 road near the Nigliq Bridge post-breakup, looking east; June 9, 2023

Photo D.20: CD5 road near the L9341 Bridge, looking north; June 8, 2023

Photo D.21: West bank of Nigliq Channel north of CD5 road during bank erosion survey, looking north; August 3, 2023

Photo D.22: West bank of Nigliq Channel south of CD5 road during bank erosion survey, looking north; August 3, 2023
D.2 ICE ROAD CROSSINGS BREAKUP

Photo D.23: Slotting through the Colville River Ice Bridge, looking east; May 19, 2023

Photo D.24: Slotting through the Colville River Ice Bridge, looking south; May 19, 2023

Photo D.25: Meltwater progression through the slotted Colville River Ice Bridge, looking southwest; May 26, 2023

Photo D.26: Open channel at Colville River Ice Bridge, looking east; June 9, 2023
Photo D.27: Pre-breakup conditions at MSIP, looking north; May 19, 2023

Photo D.28: Post-breakup near the Nigliq Heavy Haul ice road crossing, looking southwest; May 31, 2023

Photo D.29: Pre-breakup conditions at the slotted Toolbox creek ice road crossing, looking north; May 19, 2023

Photo D.30: Pre-breakup conditions at the slotted Toolbox creek ice road crossing, looking east; May 19, 2023
Photo D.31: Pre-breakup conditions at the slotted Silas Slough ice road crossing, looking southeast; May 19, 2023

Photo D.32: Right before peak stage near the slotted Silas Slough ice road crossing, looking north; May 26, 2023

Photo D.33: Ice road crossing at Lake L9323, looking north; May 24, 2023

Photo D.34: Near peak stage at ice road crossing at the south end of Lake L9324, looking east; May 25, 2023
Photo D.35: Peak stage near the slotted Tamayayak ice road crossing, looking southwest; May 27, 2023

Photo D.36: Post-breakup near the Tamayayak ice road crossing, looking northwest; June 9, 2023

Photo D.37: Peak stage near the Pineapple Gulch (West Ulamnigiaq Channel) ice road crossing, looking southwest; May 27, 2023

Photo D.38: Post-breakup near the Pineapple Gulch (West Ulamnigiaq Channel) ice road crossing, looking west; June 9, 2023
Photo D.39: Slotted Slemp Slough ice road crossing post-breakup, looking southwest; June 9, 2023

Photo D.40: Pre-breakup conditions at the north side slotted Miluveach ice road crossing, looking northeast; May 19, 2023

Photo D.41: Post-breakup conditions at the north side Miluveach ice road crossing, looking northeast; June 8, 2023

Photo D.42: Pre-breakup conditions at the north side slotted No Name ice road crossing, looking south; May 19, 2023
Photo D.43: Pre-breakup conditions at the north side slotted No Name ice road crossing, looking south; May 25, 2023

Photo D.44: Pre-breakup conditions at the slotted No Name ice road crossing, looking northeast; May 19, 2023

Photo D.45: Pre-breakup conditions at the north side slotted Kachemach ice road crossing, looking north; May 19, 2023

Photo D.46: Post-breakup near the north side slotted Kachemach ice road crossing, looking northeast; June 8, 2023
Photo D.47: Pre-breakup conditions at the slotted Kachemach ice road crossing, looking northeast; May 19, 2023

Photo D.48: Pre-breakup conditions near the slotted Kachemach ice road crossing, looking west; May 19, 2023
APPENDIX E       CD5 PIER SCOUR, BANK EROSION, & BATHYMETRY

E.1       PIER SCOUR

E.1.1       NIGLIQ BRIDGE
## E.2 BANK EROSION

### E.2.1 NIGLIQ CHANNEL WEST & EAST BANK TABULATED DATA

**Alpine AP00**  
West Bank Nigliq  
Streambank Monitor

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## 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

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##### Streambank Monitor

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West Bank Monitor Report
## 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

### West Bank Niglq Streambank Monitor

#### West Bank Monitor - Top of Bank Locations

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### 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

**Alpine AP00**  
**West Bank Niglq**  
Streambank Monitor

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**Note:** Survey completed on 8/22/13 was used for baseline data to compute Incremental /Cumulative Change. Negative numbers indicate erosion. 
Stats 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.
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## 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

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See Drawing CE-AP00-1129 Rev 11 for Survey Baseline Location

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See Drawing CE-AP00-1126 Rev 11 for Survey Baseline Location.

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**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 S0 to 12+00.
E.2.2 NIGLIAGVIK CHANNEL WEST & EAST BANK TABULATED DATA
### 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

#### Alpine AP00
West Bank Nigliagvik Streambank Monitor

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### 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

#### West Bank Nigiagvik

**Streambank Monitor**

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## 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

### Alpine AP00

**East Bank Nigliagvik**

*Streambank Monitor*

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

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

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**Bridge Transsects:**

**CD-5 Michael Baker**

**Transcript:**

Doc LCMF-156 CD5 Bridge Transsects Rev11.xlsx 1 of 2  Transect_07
# 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

**Calc'd By:** CZ  
**Date:** 08/10/2023  
**DOC:** LCMF-156 Rev11  
**CD-5 Michael Baker**  
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2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment  

ConocoPhillips  
Michael Baker  
International  

Doc LCMF-156 CD5 Bridge Transects Rev11.xlsx  
1 of 1 Transect 09
### 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

#### Final Report

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**Doc LCMF-156 CDS Bridge Transects Rev11.xlsx**  1 of 1  Transect 10
### NIGLIAGVIK CHANNEL & BRIDGE TABULATED DATA (TRANSECTS 24 – 27)

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**Date:** 8/11/2023  
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### 2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment

**Calc'd By:** CZ  
**Date:** 08/11/2023  
**DOC LCMF-156 Rev11**

#### CD-5 Michael Baker  
**Bridge Transects**  
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2023 Colville River Delta Spring Breakup Monitoring & Hydrological Assessment