ConocoPhillips
Alaska

2017

GMT1
Spring Breakup & Summer Monitoring & Hydrological Assessment

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EXECUTIVE SUMMARY

This report presents the results from the 2017 GMT1 Spring Breakup and Summer Monitoring and Hydrological Assessment conducted by Michael Baker International for ConocoPhillips Alaska. This monitoring and report is required per the U.S. Army Corps of Engineers (USACE) permit POA-2013-461, stipulation #6.g. Previously, USACE received a culvert monitoring report, as required per the same permit, stipulation #6.c. That report was transmitted to USACE on July 21, 2017. Those results are also included in this report.

Spring breakup typically occurs during a three-week period in May and June. The spring breakup event historically produces flooding, and rapid rise and fall of stage can occur as the result of ice jam formation and release. This year’s spring breakup flood was characterized as a low magnitude, prolonged event, drawn out over three weeks.

Spring breakup and summer conditions were documented on both sides of the GMT1 access road and pad with visual observations and photography from a helicopter and from the roadway. Spring breakup stage, velocity and discharge were measured and peak velocity and discharge were calculated at the Tinmiaqsiugvik Bridge, Crea Bridge, Barely Creek culvert battery, and culverts where flow was present. Summer stage, velocity, and discharge were measured at the Tinmiaqsiugvik Bridge. Continuous summer stage was measured and continuous velocity and discharge were calculated at the Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek culvert battery. Peak spring breakup conditions along the GMT1 access road and pad occurred between May 27 and June 1. During peak conditions, floodwater was generally confined within channels and swales. Stage was receding at all gage stations by June 2. Post-breakup visual inspections showed adequate conveyance of surface water flow and maintenance of natural drainage patterns. Stage and discharge generally declined over the summer months, with occasional increases resulting from precipitation events. Summer peak and minimum conditions at the Tinmiaqsiugvik Bridge, Crea Bridge, Barely Creek culvert battery occurred between mid-July through the end of summer monitoring in mid-September.

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ACRONYMS & ABBREVIATIONS

°F	degrees Fahrenheit
baro	barometric
BPMSL	British Petroleum Mean Sea Level
CD	Colville Delta
CFDD	Cumulative Freezing Degree Days
cfs	cubic feet per second
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
FCB	Fish Creek Basin
fps	feet per second
ft	feet
GMT1	Greater Moose's Tooth 1
GPS	global positioning system
HWM	High water mark
Michael Baker	Michael Baker International
NAD83	North American Datum of 1983
NPR-A	National Petroleum Reserve Alaska
OSW	Office of Surface Water
PT	pressure transducer
RM	river mile
RTFM	Real-Time Flood Monitoring
UMIAQ	UMIAQ, LLC (LCMF)
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VSM	Vertical support member
WSE	Water surface elevation

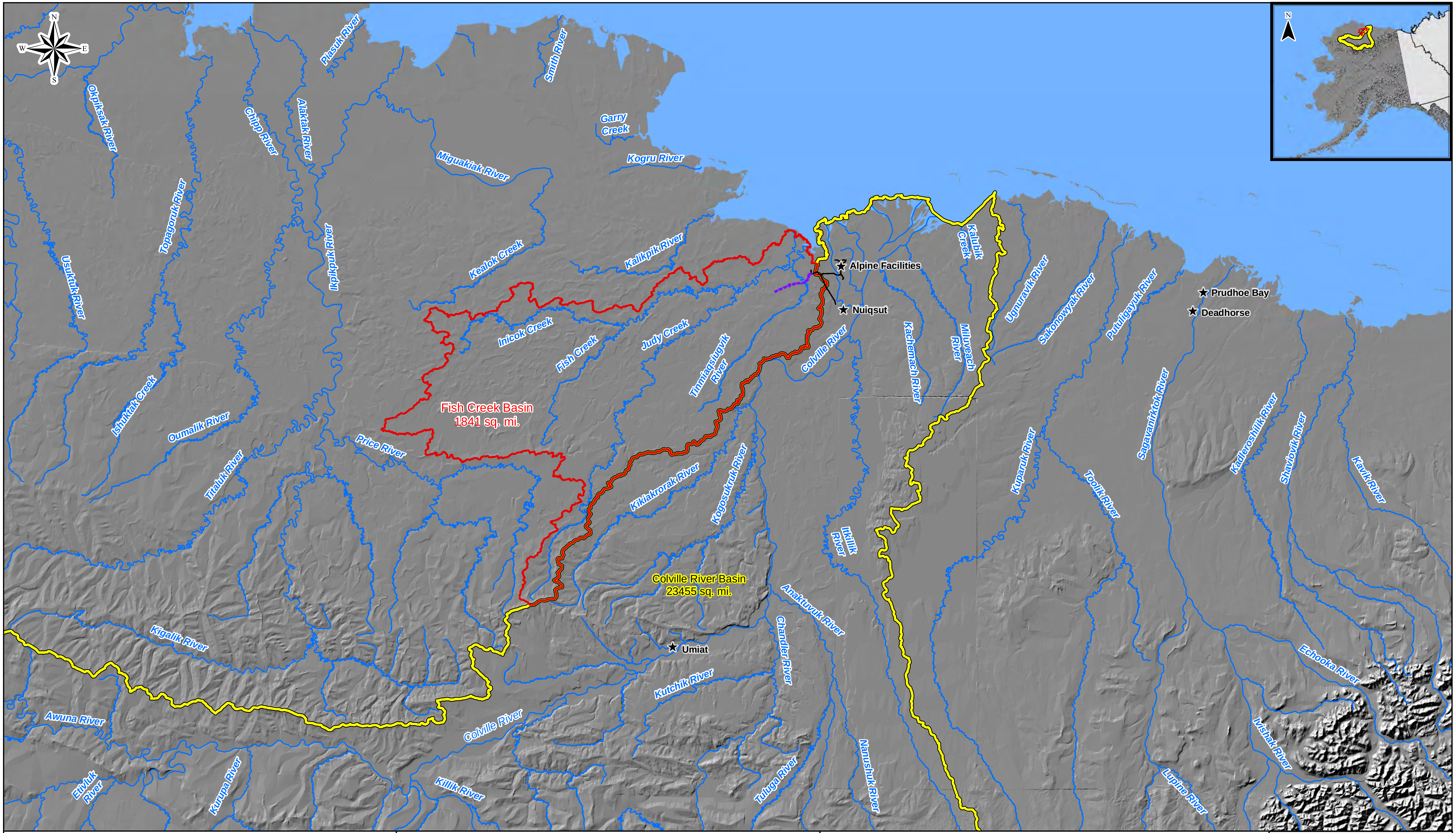
1. INTRODUCTION

The Greater Moose's Tooth 1 (GMT1) Spring Breakup and Summer Monitoring and Hydrological Assessment supports the ConocoPhillips Alaska, Inc. (CPAI) Alpine Satellite Development Plan. Alpine facilities are operated by CPAI and owned by CPAI and Anadarko Petroleum Company and include the Colville Delta (CD) 1 processing facility (Alpine) and the CD2, CD3, CD4, CD5, and GMT1 pads, access roads, and pipelines. The GMT1 pad, access road, and a portion of the pipeline were constructed during the 2016/2017 winter season.

Spring breakup is generally considered the largest annual flooding event in this region of the North Slope and commences with the arrival of meltwater and progresses with a rapid rise in stage which facilitates the breakup and downstream movement of water and ice. Spring breakup typically occurs during a three-week period in May and June. Many areas on the North Slope of Alaska, including the Colville River Delta (CRD) and the Fish Creek Basin (FCB) (Figure 1.1), share similar hydrologic and hydraulic characteristics common to the arctic climate. Spring breakup and summer monitoring is integral to understanding regional hydrology and ice effects, establishing baseline hydrological conditions to support permitting, establishing appropriate design criteria for proposed facilities, and maintaining the continued safety of the environment, oilfield personnel, and existing facilities. Discharge generally declines over the summer months, with occasional increases resulting from precipitation events. Discharge is typically present year-round in the major streams in the FCB. For much of the year, little to no flow is present in many small streams and tributaries in the FCB, and most freeze to the bottom in winter.

Preliminary hydrologic and hydraulic assessments of the Tinmiaqsiugvik (formerly the Ublutuoch) River were completed by URS in 2001 and 2002 (URS 2001, 2002, and 2003). Spring breakup monitoring and hydrologic assessments throughout the proposed GMT1 project area were completed by Michael Baker International (Michael Baker) annually from 2003 to 2006 and from 2009 to 2014, with the exception of 2012 (Michael Baker 2003, 2005, 2007, 2009, 2010, 2011, 2013, 2014). This year marks the first post-construction spring breakup and summer monitoring and hydrological assessment along the newly constructed GMT1 access road and pad.

The 2017 field program took place from April 20 to September 11. Spring breakup setup began on April 20 and concluded on May 6 and monitoring began on May 13 and concluded on June 8. Summer monitoring was split into two field programs; the first program began on June 27 and concluded on June 29 and the second program began on September 5 and concluded on September 11. Primary field tasks included measuring stage and discharge at select locations. Observations of ice jams, ice road crossings degradation, drainage structure performance, and post-breakup floodwater effects on infrastructure were also recorded. Hydrologic observations were documented on both sides of the GMT1 access road and pad and at all drainage structures. UMIAQ, LLC (UMIAQ), CPAI Alpine Field Environmental Coordinators, Alpine Helicopter Coordinators, and Soloy Helicopters, LLC provided support during the field programs and contributed to a safe and productive field season.



ConocoPhillips
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0 7.5 15 30 miles

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Legend

★ Place Name
— Road
~ Stream
⋯ GMT1 Access Road
Fish Creek Basin
Colville River Basin

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Fish Creek & Colville River

Drainage Basins

FIGURE: 1.1

(SHEET 1 of 1)

1.1 MONITORING OBJECTIVES

The primary objective of the GMT1 spring breakup and summer monitoring and hydrological assessment was to monitor and estimate the magnitude of breakup flooding in relation to GMT1 drainage structures. Stage or water surface elevations ([WSE] used interchangeably in this report), velocity, discharge, and observations were used to validate design parameters of existing infrastructure and to satisfy permit requirements.

Permit stipulations by USACE permit POA-2013-461, stipulation #6.c requires the following:

- Monitoring all culverts for the three summer seasons following fill placement:
    - Photo documentation of the GMT1 access road and pad to demonstrate hydrologic conditions during spring breakup and post-breakup (summer) conditions;
    - Identification of areas of ponding, drying, erosion, or stream channel changes adjacent to fill areas;
    - Demonstration of culvert conveyance of surface water flow based on the maintenance of natural drainage patterns and lack of evidence to the contrary (ponding, drying, erosion, stream channel changes);
    - Evaluation of all areas where additional culverts are necessary to maintain natural drainage patterns; and
    - Evaluation of all areas where culvert maintenance, repair, upgrade, setting adjustments, or replacement are necessary to maintain natural drainage patterns

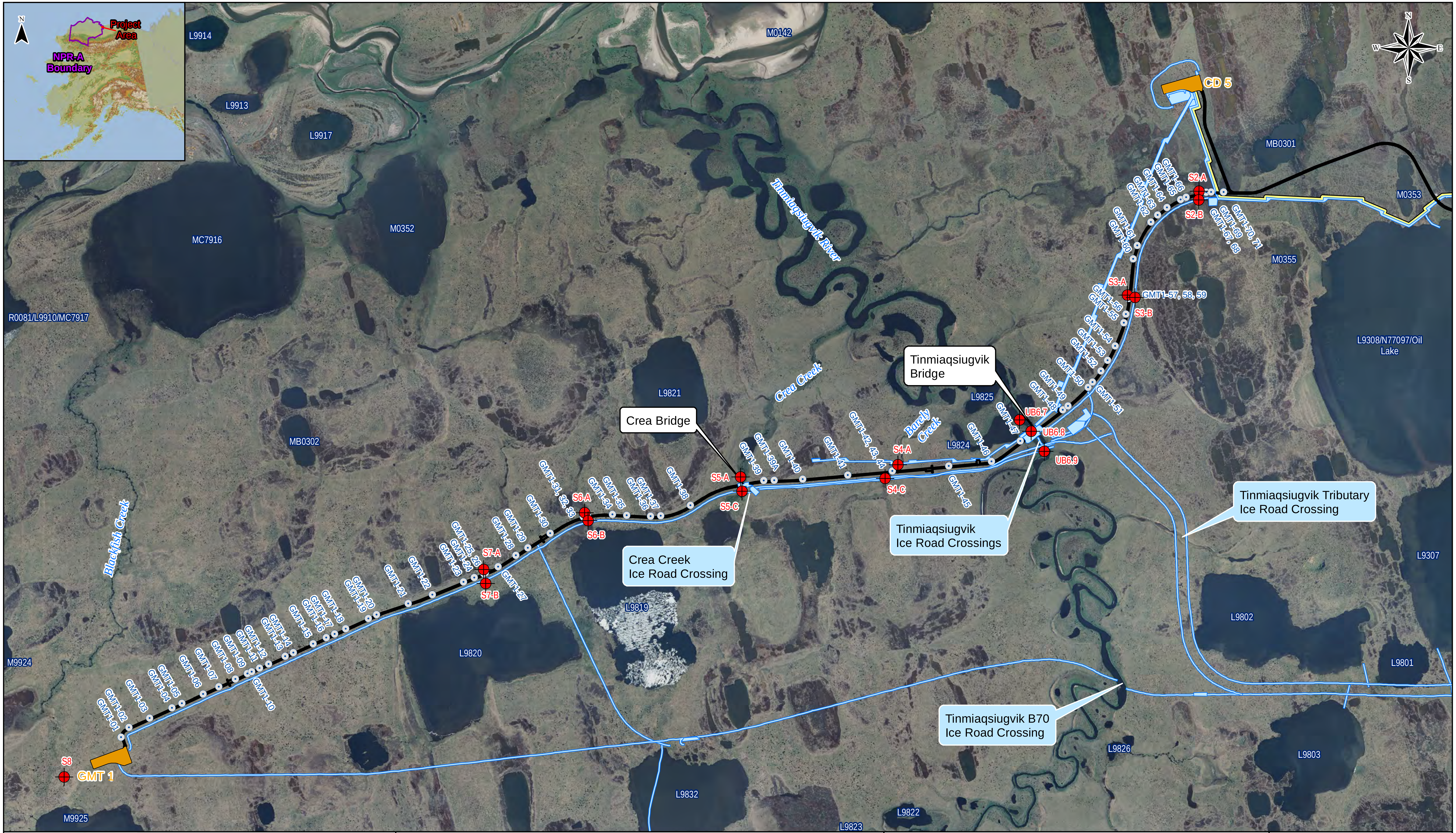
Permit stipulations by USACE permit POA-2013-461, stipulation #6.g requires the following:

- Monitoring the Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek culvert battery for the first three thaw seasons following construction of the crossings:
    - Spring breakup stage and discharge measurements;
    - Continuous stage and discharge monitoring until seasonal flows cease or steady base flows are observed;
    - Documenting highest and lowest stage, velocities, and discharge during seasonal flow;
    - Photo documentation of all bridge abutments at the ground surface, creek culvert inlets and outlets, and channel and bank conditions on each side of the road; and
    - Demonstrating adequate conveyance of surface water flow and maintenance of natural drainage patterns

A GMT1 Spring Breakup Culvert Monitoring Report was transmitted to USACE on July 21, 2017 which detailed spring breakup monitoring results at all GMT1 access road culverts (Michael Baker 2017). Those results are also included in this report.

1.2 GAGE STATIONS

Figure 1.2 shows the GMT1 access road and pad gage stations. Table 1.1 details the gage stations and monitoring tasks per location.



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0 0.25 0.5 1 miles

- ⊙ Culvert
- ⊕ Gage Location
- Ice Road
- Existing Road
- Pipeline
- ▭ Ice Pad
- ▨ Existing Facility

Imagery Source : Conoco Phillips Alaska 2015

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2017 GMT1 Gage Stations

FIGURE: 1.2

(SHEET 1 of 1)

Table 1.1: GMT1 Access Road & Pad Gage Stations and Monitoring Tasks

Monitoring Location Description	Gage Station	Gage Station Description	Monitoring Tasks Per Location						
			Observations	Spring Breakup PT	Summer PT	Spring Breakup Measured Discharge	Summer Measured Discharge	Spring Breakup Real-Time Monitoring	Summer Real-Time Monitoring
Tinmiaqsiugvik Bridge	**UB6.9**	West side of Tinmiaqsiugvik River at river mile 6.9, 650 feet south (upstream) of bridge centerline	X	X	X	X	X	X	X
	UB6.7	West side of Tinmiaqsiugvik River at river mile 6.7, 600 feet north (downstream) of bridge centerline		X	X				
Barely Creek Culvert Battery	**S4-C**	West side of Barely Creek, north (upstream) side of road and culvert battery	X	X	X	X	--	--	--
	S4-A	West side of Barely Creek, south (downstream) side of road and culvert battery, on VSM 626		X	X				
Crea Bridge	**S5-A**	West side of Crea Creek, 260 feet north (downstream) of bridge centerline	X	X	X	X	--	X	X
	S5-C	West side of Crea Creek, 300 feet south (upstream) of bridge centerline		X	X				
Culverts	**S2-A**	North (downstream) side of road, in small swale	X	X	--	X	--	--	--
	S2-B	South (upstream) side of road, in small swale		X	--				
	S3-A	West (downstream) side of road, in small swale	X	X	--	X	--	--	--
	S3-B	East (upstream) side of road, in small swale		X	--				
	S6-A	North (downstream) side of road, between Lake L9819 and Lake L9821	X	X	--	X	--	--	--
	S6-B	South (upstream) side of road, between Lake L9819 and Lake L9821		X	--				
	S7-A	North (downstream) side of road, downstream of Lake L9820	X	X	--	X	--	--	--
	S7-B	South (upstream) side of road, downstream of Lake L9820		X	--				
GMT1 Pad	**S8**	West side of GMT1 pad, downstream of Lake M9925, upstream of Blackfish Creek	X	X	--	--	--	--	--

2. METHODS

Site visits were performed as needed and as conditions allowed. The field methodologies used to collect hydrologic data on the North Slope of Alaska during spring breakup are proven safe, efficient, and accurate for the conditions encountered.

2.1 OBSERVATIONS

Helicopter reconnaissance flights were conducted in the headwaters of the FCB to track the progression of floodwater. Field data collection and observations of breakup progression, ice events, interactions between floodwaters and infrastructure, and summer conditions were recorded in field notebooks. Photographic documentation of spring breakup and summer conditions was collected using digital cameras with integrated global positioning systems. Each photo was geotagged with the latitude and longitude, date, and time. The photo location is referenced to the North American Datum of 1983 horizontal datum (NAD83).

UMIAQ provided Hägglund track vehicle support to access gage stations during setup, before helicopter support was onsite at Alpine. Soloy Helicopters, LLC and Alpine Environmental Coordinators provided helicopter support and a pickup truck, respectively, to access gage stations during spring breakup and summer monitoring.

2.2 STAGE

Stage data was collected using hydrologic staff gages (gages) and pressure transducers (PTs) designed to measure water levels.

HYDROLOGIC STAFF GAGES

Gage stations were established at the GMT1 pad and along the access road adjacent to infrastructure and consist of one or more gage assemblies positioned perpendicular to the waterbody or road. The number of gage assemblies per gage station installed at the Tinmiaqsiugvik Bridge and Crea Bridge was dependent upon site specific conditions: primarily slope of the channel, bank, and overbank. In locations where terrain elevation varied by more than three feet, multiple gages were installed linearly from the edge of the channel up to the overbank. Individual gage assemblies were identified with alphabetical designations beginning with ‘A’ representing the location nearest to the stream. Gage stations were identified with alphabetical designations with ‘U’ or ‘D’ representing the furthest upstream or downstream gage station, respectively. Gage assemblies were installed at elevations overlapping by approximately one foot. Paired gages installed at locations along the access road captured water levels on the upstream and downstream side of drainage structures to determine stage differential and were identified with alphabetical designations with ‘A’ representing the location on the north side of the GMT1 access road. The location of each gage assembly was recorded with a handheld GPS referenced NAD83.

Each gage assembly includes a standard U.S. Geological Survey (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 100th of a foot between 0.00 to 3.33 feet (Photo 2.1). High water marks (HWMs) were measured by applying chalk on the angle iron gage supports or VSMs and measuring the wash line (Photo 2.2).

Gage assemblies were surveyed to their associated vertical control using standard differential leveling techniques relative to a known benchmark elevation to determine a correction in feet (ft) BPMSL. Gage locations and associated vertical control are detailed in Appendix A.

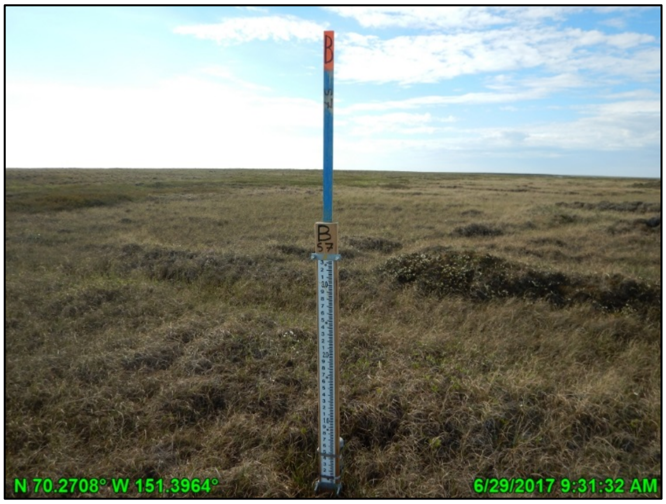


Photo 2.1: Gage S7-B; June 29, 2017

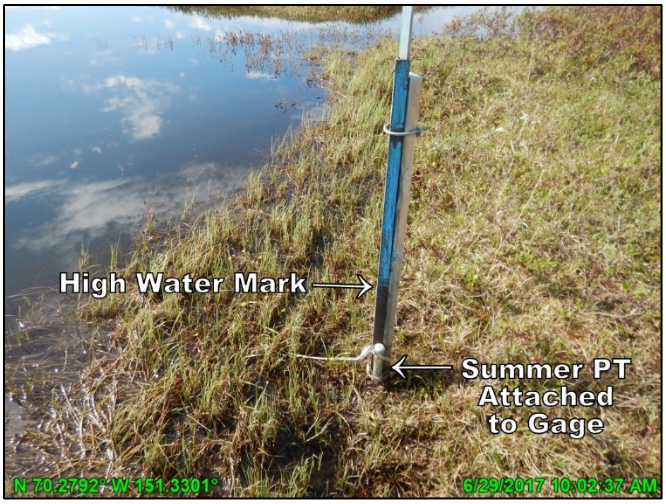


Photo 2.2: Chalked gage S5-C with HWM and PT; June 29, 2017

PRESSURE TRANSDUCERS

Primary PTs were installed at every gage station and supplemented by gage measurements to provide a continuous record of stage. Secondary PTs were installed to validate and backup the primary PT data at locations where discharge was measured and calculated. PTs are designed to collect and store pressure and temperature data at discrete pre-set intervals; all PTs were programmed to collect data at 15-minute intervals. Each PT was housed in a small perforated galvanized steel pipe and secured to the base of the gage assembly. By sensing the absolute pressure of the atmosphere and water column above the PT, the depth of water above the sensor was calculated. Absolute pressure was accounted for using a barometric pressure sensor (Baro PT) attached to the telemetry system at the Tinmiaqsiugvik Bridge. During data processing, the PT measurements were adjusted to WSEs recorded at the gages. PT setup and testing methods are detailed in Appendix B.

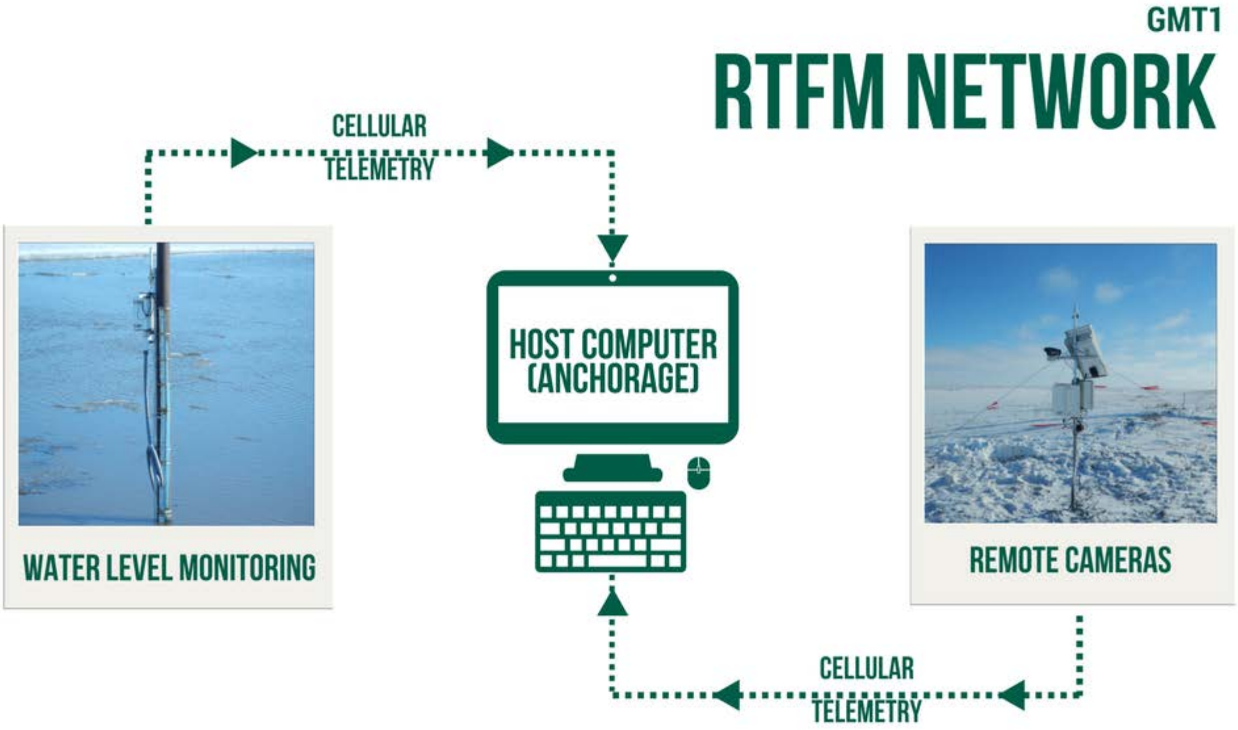
REAL-TIME FLOOD MONITORING NETWORK

Table 2.1 presents the Real-Time Flood Monitoring (RTFM) Network locations. The RTFM Network has the following components: remote cameras to monitor stage and river conditions, sensors to monitor stage and barometric pressure, dataloggers and telemetry systems to collect and transmit data, and a host computer to receive the transmitted data (Figure 2.1). The ability to remotely monitor stage helps reduce helicopter traffic, allows for round-the-clock monitoring of conditions, and allows for remote monitoring when helicopter travel is restricted due to weather or mechanical conditions. In addition, a network of real-time monitoring stations helps hydrologists deploy resources during peak conditions when critical measurements are required.

Table 2.1: RTFM Network Stations

Monitoring Location Description	Real-Time Data
Tinmiaqsiugvik Bridge	• Stage • Barometric pressure • River conditions via remote camera images
Crea Bridge	• Stage • Creek conditions via remote camera images

Figure 2.1: RTFM Network Schematic



Remote Cameras

High resolution digital cameras (Photo 2.3) were programmed to take pictures at 15-minute intervals. Cameras collected photographs to document conditions and to help hydrologists determine when site visits were necessary. Vehicle access for spring breakup monitoring along the newly constructed GMT1 gravel road was not allowed due to the soft and unconsolidated gravel soils from the 2017 winter placement. Summer access and monitoring along the GMT1 road was also restricted due to gravel compaction and re-work by CPAI. Limited road access became available in the fall, but due to continuous construction operations on the GMT1 gravel road, hydrologists utilized helicopters for much of the field work.

Photo 2.3: Remote camera setup at the Tinmiaqsiugvik Bridge, looking southwest (upstream); June 29, 2017

SENSORS

PTs were programmed to read and record water levels and barometric pressure at 15-minute intervals. Data cables linking the PTs and dataloggers were housed in metal conduit.

DATALOGGERS & TELEMETRY

Onsite dataloggers were programmed to interface with the PTs. Data was uploaded to the datalogger via a data cable and stored internally. The dataloggers were programmed to interact with telemetry equipment to transmit data. Data was transmitted using an onsite cellular modem and TCP/IP communication where each cellular modem has a unique static IP address. To conserve power, cellular modems were programmed to power-on every 60 minutes for data transmission. Systems were powered with 12v DC batteries and charged with onsite solar panels.

HOST COMPUTER, DATA ACCESS, & NOTIFICATIONS

A host computer monitored the internet for the cellular modem IP addresses and communicated with the dataloggers once the connection was established. The host computer received the data as an ASCII file and Campbell Scientific Loggernet software was used for data processing. 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 was plotted on graphs and updated in tables as data was received.

2.3 VELOCITY & DISCHARGE

MEASURED VELOCITY & DISCHARGE

Discharge (in cubic feet per second [cfs]) was measured as close to observed spring breakup peak stage as possible at the following drainage structures:

- Tinmiaqsiugvik Bridge

- Crea Bridge
- Barely Creek culvert battery
- Culverts observed conveying flow

Tinmiaqsiugvik Bridge discharge was also measured in the summer (Photo 2.4). Tinmiaqsiugvik Bridge and Crea Bridge discharge were measured using the USGS midsection technique (USGS 1982). Discharge at the Barely Creek culverts and other culverts observed conveying flow were measured using the USGS velocity/area technique (USGS 1968). Flow depths and velocities at the Tinmiaqsiugvik Bridge were measured using a Price AA current meter suspended by cable with a sounding weight. Flow depths and velocities at Crea Bridge and culverts were measured using a flow meter attached to a wading rod. Discharge was calculated based on velocity, flow depth, and channel cross section geometry or culvert geometry. Measured velocity and discharge methods are further detailed in Appendix C.1.1.

Photo 2.4: Measuring summer discharge at the Tinmiaqsiugvik Bridge; September 9, 2017

CALCULATED VELOCITY & DISCHARGE

Velocity and discharge were calculated indirectly and, when possible, calibrated with the respective direct measurement and observed WSEs. Under open channel conditions, peak velocity and discharge typically occur at the same time as peak stage; however, peak velocity and discharge can be affected by ice and snow which can temporarily increase stage and reduce velocity. This in turn yields a lower discharge than an equivalent stage under open water conditions.

Culvert peak velocity and discharge were calculated using the WSE differential between the headwater and tailwater elevation, approximated by WSEs at corresponding gages, and survey data provided by UMIAQ (UMIAQ 2017a).

Continuous velocity and discharge were calculated at the following locations:

- Tinmiaqsiugvik Bridge

- Crea Bridge
- Barely Creek culvert battery

Velocity and discharge results are estimates based on conditions at the time of data collection. In the spring, these 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 velocity and discharge indirectly. In consideration of these conditions, calculations of peak velocity and discharge are presented with quality ratings, as described in Table 2.2. Detailed calculated velocity and discharge methods are presented in Appendix C.1.2.

Table 2.2: Peak Velocity and Discharge Quality Ratings

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

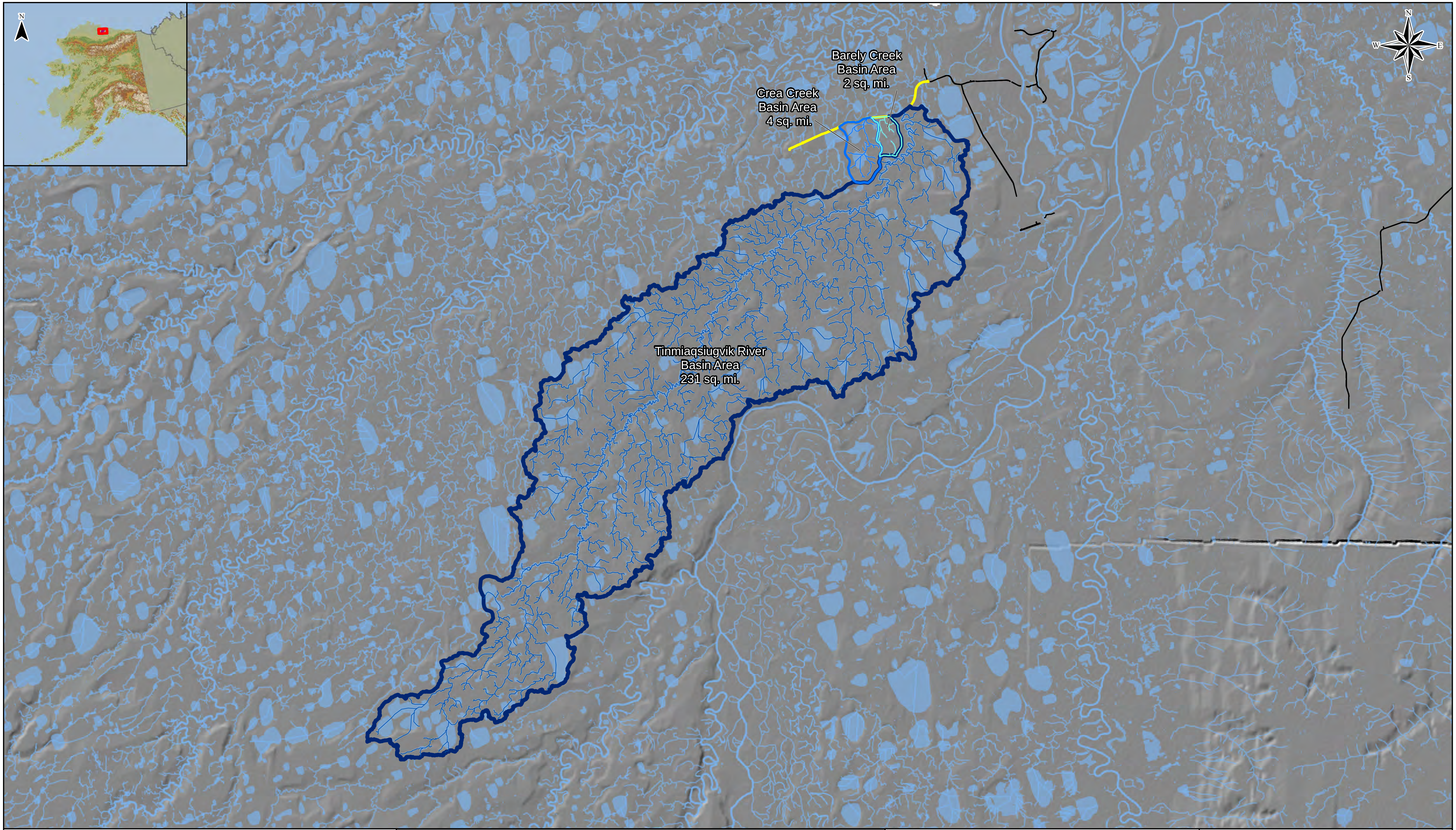
2.4 FLOOD FREQUENCY ANALYSIS

Estimates of the magnitude and frequency of peak discharge at the Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek culvert battery were determined for the 2-, 10-, 25-, 50-, 100-, and 200-year recurrence intervals using the 2003 USGS peak discharge regional regression equations for Region 7 (USGS 2003). In addition, estimates of the magnitude and frequency of peak discharge at Tinmiaqsiugvik Bridge were determined for the 2-, 10-, 25-, 50-, 100-, and 200-year recurrence intervals using the regional regression equations developed and revised by URS in 2002 (URS 2003). A recurrence interval was assigned to the peak discharge value at each location based on the results of the regression analysis. Region 7 USGS regression results tend to over-predict recurrence intervals, particularly for the lower recurrence intervals when ice and snow have more effect on stage and discharge.

Basins areas for each of the three sites were previously delineated and have been updated to reflect the most current USGS National Hydrography Dataset and available Digital Elevation Model data (Michael Baker 2005, 2014). The revised basin areas for Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek culvert battery are presented in Table 2.3 and Figure 2.2.

Table 2.3: Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek Culvert Battery Basin Areas

Basin	Basin Area (square miles)
Tinmiaqsiugvik Bridge (upstream side of bridge)	231
Crea Bridge (upstream side of bridge)	4.0
Barely Creek (upstream side of GMT1 access road)	1.6



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- Road
- GMT1 Access Road
- Stream / River
- Waterbody
- Barely Creek Flowline
- Crea Creek Flowline
- Tinmiaqsiugvik River Flowline
- Barely Creek Basin
- Crea Creek Basin
- Tinmiaqsiugvik River Basin

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Tinmiaqsiugvik Bridge Crea Bridge & Barely Creek Culvert Battery Basins

Coordinate System: NAD 1983 Alaska State Pane Zone 4, US Foot

FIGURE: 2.2

(SHEET 1 of 1)

2.5 DRAINAGE STRUCTURE PERFORMANCE EVALUATION

Culvert performance was evaluated based on observations, stage, and discharge measurements with a focus on maintenance, repair, upgrade, setting adjustments, or replacement. Bridge performance was evaluated based on observations, stage, and discharge measurements with a focus on maintenance of natural drainage patterns.

2.6 POST-BREAKUP CONDITIONS ASSESSMENT

Post-breakup conditions assessment included visual observations and photo documentation of Tinmiaqsiugvik Bridge and Crea Bridge abutments and bank conditions on each side of the GMT1 access road, and culvert inlets and outlets. In addition, the condition of the gravel fill around the bridges and culverts was evaluated to identify areas of erosion.

2.7 ICE ROAD CROSSINGS BREAKUP

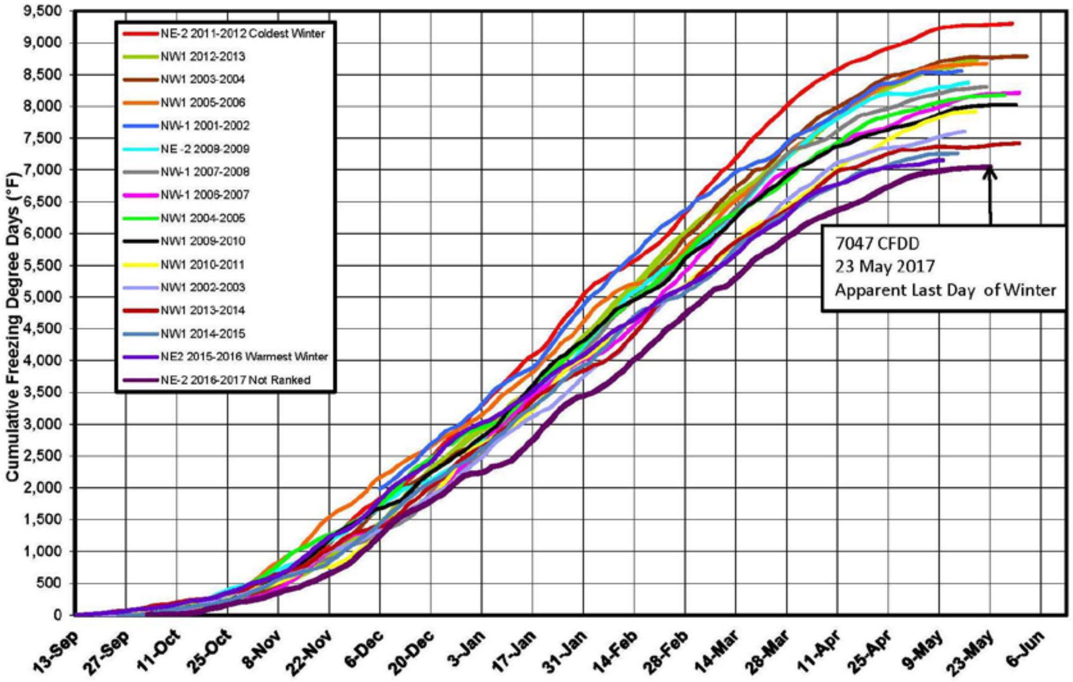
Aerial observations of the hydraulic effects of winter ice road crossings (Figure 1.2) before breakup, during breakup, and post-breakup included:

- Crea Creek, south side of Crea Bridge
- Tinmiaqsiugvik River, north and south side of Tinmiaqsiugvik Bridge
- Tinmiaqsiugvik River B70
- Tinmiaqsiugvik River Tributary

3. OBSERVATIONS

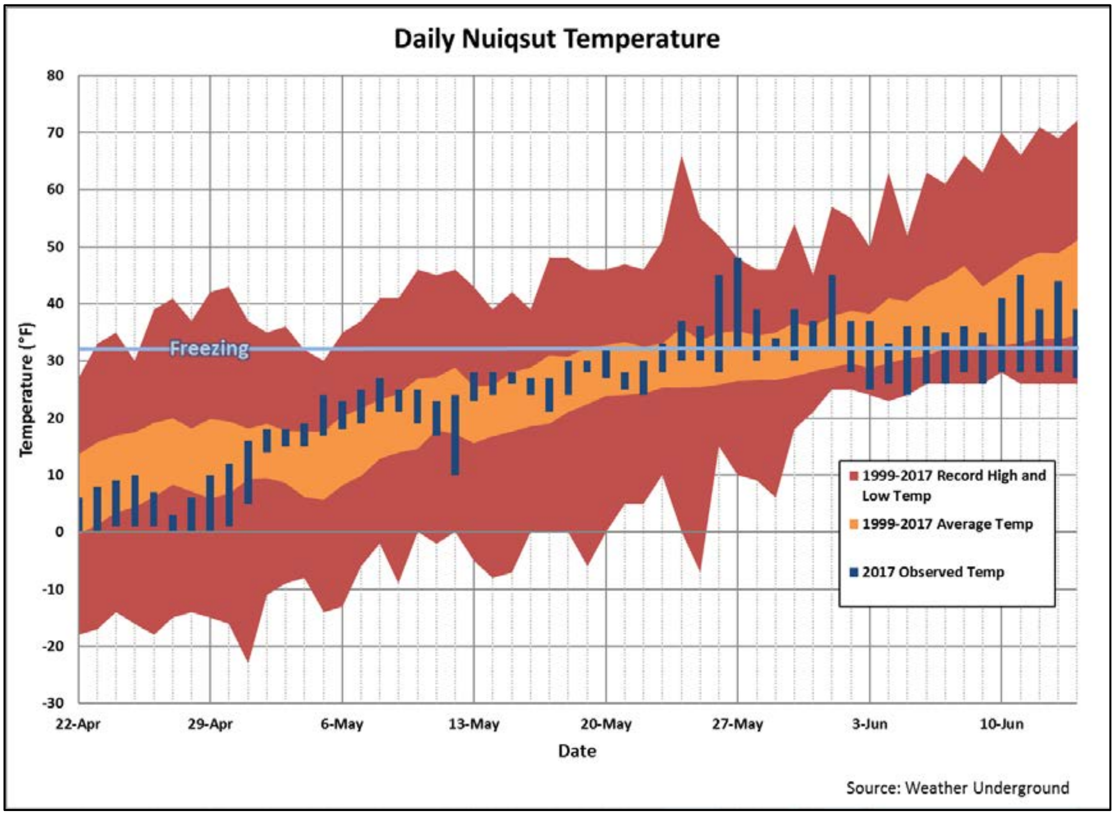
3.1 GENERAL CLIMATIC SUMMARY

According to cumulative freezing degree days (CFDD) measured at the National Petroleum Reserve Alaska (NPR-A) tundra monitoring station, the 2016-2017 (September – May) winter was the warmest on record for the past 16 years, as shown in Graph 3.1 (ICE 2017). As of March 1, 2017, snowpack east of the Colville River was reported as 90-109% of the 1981-2010 median. In April and May 2017, all North Slope snowpack was reported as 90-109% of the 1981-2010 median (Natural Resources Conservation Service 2017).



Graph 3.1: NPRA N. Tundra Monitoring Station, CFDD, Winters 2002-2017 (ICE 2017)

Temperatures for the Alpine area are available from the Nuiqsut weather station, located approximately 8 air miles southeast of the GMT1 access road. Daily low ambient air temperatures remained at or below freezing throughout breakup which slowed local breakup processes. Graph 3.2 illustrates daily high and low ambient air temperatures recorded in Nuiqsut superimposed on the average and record daily highs and lows during the breakup monitoring period (Weather Underground 2017).



Source: Weather Underground

Graph 3.2: Nuiqsut Daily High and Low Ambient Air Temperatures

3.2 GENERAL BREAKUP SUMMARY

Visual inspections from April 27 through May 1 confirmed that snow had been cleared at most culvert inlets and outlets, snow had been cleared at all bridges, and the ice roads were slotted. Some additional snowfall in early May accumulated along the road embankment prior to spring breakup.

On May 17, minimal local melt was observed on top of channel ice in the Tinmiaqsiugvik River near the GMT1 access road (Photo 3.1). No water was observed moving in the drainage. All other drainages were snow covered and frozen. Snow cover along the GMT1 access road was approximately 90%. By May 23, ponded, local melt was accumulating in the slotted sections of the construction ice roads and ice pads upstream and downstream of the Tinmiaqsiugvik Bridge (Photo 3.2), but no flow was observed. On May 24, local melt was observed accumulating in some of the small drainages, on the upstream side of the Crea Bridge (Photo 3.3), and on the upstream and downstream side of the Barely Creek culvert battery. By this time, approximately 50% of the tundra along the GMT1 access road was exposed.

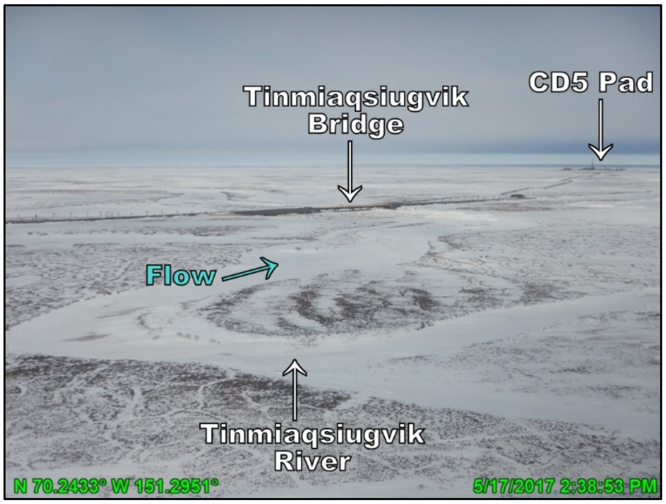


Photo 3.1: Local melt in the Tinmiaqsiugvik River, looking northeast (downstream); May 17, 2017

Photo 3.2: Ponded local melt in the slotted section of the Tinmiaqsiugvik River, looking southeast (upstream); May 23, 2017

Photo 3.3: Local melt around Crea Bridge, looking west; May 24, 2017

By May 26, local melt was observed accumulating at most gage stations and minor flow was observed at the Tinmiaqsiugvik Bridge (Photo 3.4, Photo 3.5, Photo 3.6, and Photo 3.7). On May 28, minimal snow cover remained along the GMT1 access road, flow developed at the Crea Bridge and Barely Creek culvert battery, and flow continued to develop at the Tinmiaqsiugvik Bridge. Integrated meltwater was observed between the upstream and downstream side of the GMT1 road in smaller drainages. Drifted snow remained along the road embankment. Over the next few days, remote camera images at Crea Bridge and Tinmiaqsiugvik Bridge showed continued rising stage and the deterioration of construction ice pads and ice rubble piles. Fully developed flow, confined to the slotted channels, was observed at the Tinmiaqsiugvik Bridge and Crea Bridge on May 29.

Photo 3.4: Minor flow in the Tinmiaqsiugvik River, looking south (upstream); May 26, 2017

Photo 3.5: Ponded local melt in Barely Creek, looking east; May 26, 2017

Photo 3.6: Ponded local melt in Crea Creek, looking east; May 26, 2017

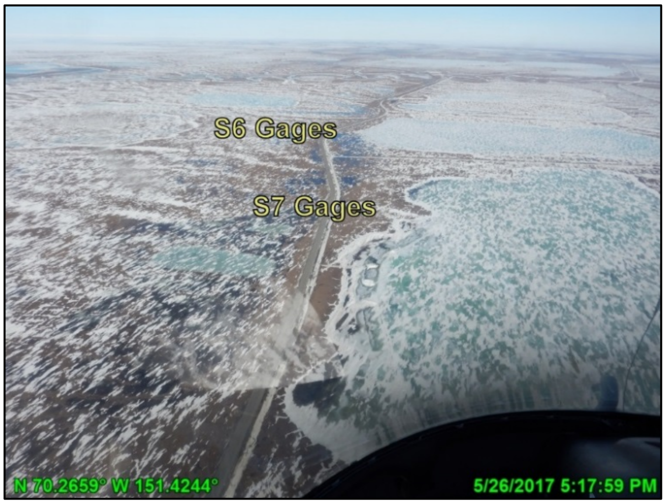


Photo 3.7: Local melt accumulating along GMT1 access road near S6 and S7 gages, looking east; May 26, 2017

By May 30, Tinmiaqsiugvik River flow had expanded beyond the slotted channel, encompassing most of the natural channel within the bridge opening. Culverts in defined drainages along the road were observed conveying flow on May 31. Remaining snow cover along the GMT1 access road was approximately 10-20%. Stage peaked at all gage stations by May 31. Floodwater remained within the channel banks and no contracted flow between the bridge abutments was observed. By June 2, water levels were slowly dropping in drainages along the GMT1 access road (Photo 3.8). On June 3, nearly all snow cover on the tundra along the GMT1 access road had melted and some culverts continued to convey low flow (Photo 3.9). By June 7, water was confined to the main channel at the Tinmiaqsiugvik Bridge (Photo 3.10). Water levels continued to recede trending towards low flow summer conditions.

Photo 3.8: Stage receding in Crea Creek, looking northeast (downstream); June 2, 2017

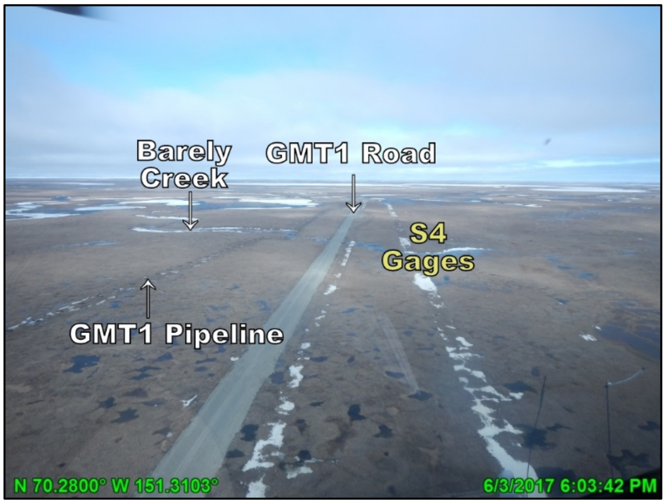
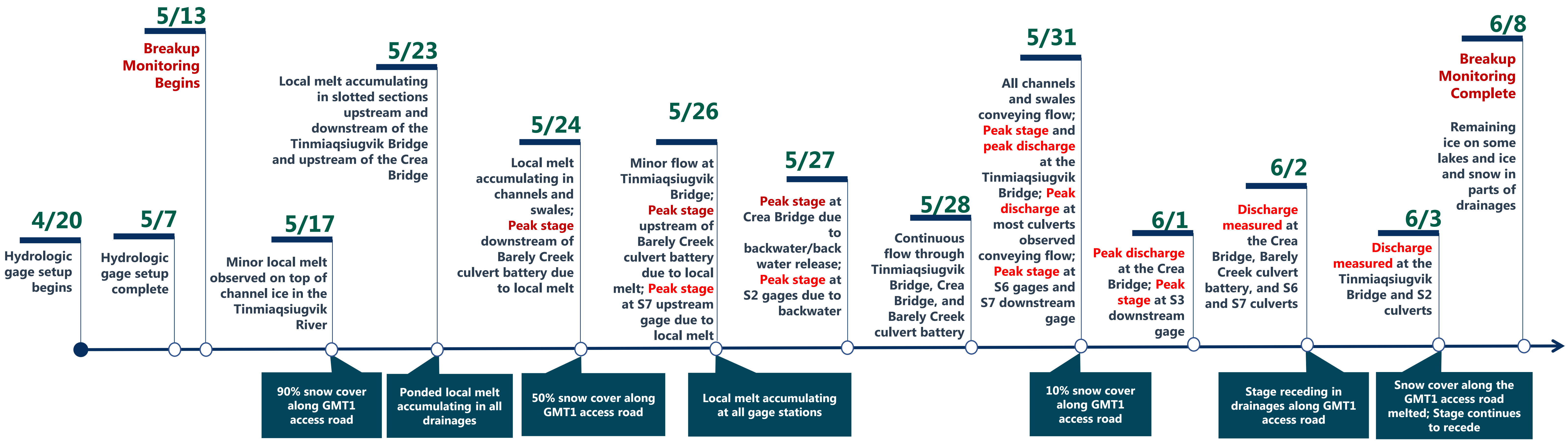


Photo 3.9: Remaining snow cover along GMT1 access road, looking east; June 3, 2017

Photo 3.10: Stage receding at the Tinmiaqsiugvik Bridge, looking southwest; June 7, 2017

Figure 3.1 provides a visual timeline summarizing the major breakup events.

Figure 3.1: Spring Breakup Hydrologic Timeline



4. STAGE, VELOCITY, & DISCHARGE

Table 4.1 presents a summary of spring breakup stage, velocity, and discharge.

Table 4.1: Spring Breakup Stage, Velocity, and Discharge Summary

Monitoring Location Description	Gage Station	Spring Peak Stage		Spring Measured Velocity & Discharge				Spring Peak Average Velocity			Spring Peak Discharge		
		Stage ft BPMSL	Date & Time	Average Velocity fps	Discharge cfs	Stage ft BPMSL	Date & Time	Average Velocity fps	Stage ft BPMSL	Date & Time	Discharge cfs	Stage ft BPMSL	Date & Time
Tinmiaqsiugvik Bridge	**UB6.9**	8.80	5/31, 8:45 AM	3.2 [3]	1,300	8.18	6/3, 11:30 AM	6.4 [3]	8.60	5/30, 8:00 PM	2,800	8.80	5/31, 9:30 AM
	UB6.7	6.83	5/31, 9:30 PM			6.61			5.86			6.60	
Barely Creek Culvert Battery	**S4-C**	16.24 [1]	5/26, 6:30 PM	0.4 [4]	1 [6]	14.58	6/2, 5:45 PM	5.0 [5]	14.67	5/31, 10:45 AM	17 [6]	14.67	5/31, 10:45 AM
	S4-A	13.75 [1]	5/24, 2:00 AM			12.58			12.67			12.67	
Crea Bridge	**S5-C**	18.67 [2]	5/27, 4:45 PM	0.9	50	17.60	6/2, 3:00 PM	1.3	17.84	6/1, 6:15 PM	70	17.84	6/1, 6:15 PM
	S5-A	17.22 [2]	5/27, 6:15 PM			17.02			17.05			17.05	
Culverts	**S2-B**	18.47 [2]	5/27, 6:00 PM	1.2 [4]	7 [6]	18.07	6/3, 4:10 PM	4.3 [5]	18.38	5/25, 6:45 PM	50 [6]	18.38	5/25, 6:45 PM
	S2-A	18.36 [2]	5/27, 3:15 PM			17.90			17.92			17.92	
	S3-B	dry	--	dry	dry	--	--	dry	--	--	dry	--	--
	S3-A	20.79 [2]	6/1, 7:45 AM			--			--			--	
	S6-B	24.47	5/31, 2:30 PM	2.0 [4]	11 [6]	24.29	6/2, 4:35 PM	2.5 [5]	24.42	5/31, 12:45 AM	20 [6]	24.42	5/31, 12:45 AM
	S6-A	24.28	5/31, 5:15 PM			24.23			24.17			24.17	
	S7-B	27.28 [1]	5/26, 8:15 PM	0.3 [4]	0.1 [6]	26.47	6/2, 5:20 PM	5.9 [5]	26.97	5/31, 4:45 PM	11 [6]	26.97	5/31, 4:45 PM
	S7-A	25.86	5/31, 8:15 PM			25.63			25.58			25.58	
GMT1 Pad	**S8**	dry	--	--	--	--	--	--	--	--	--	--	--

Notes:

[1] Peak stage from ponded, local melt

[2] Peak stage from backwater/backwater release

[3] Measured/calculated for flow through the main channel of the spring breakup cross-section

[4] Average through all associated culverts conveying flow

[5] Maximum measured/calculated through a single culvert

[6] Sum of all associated culverts conveying flow

Table 4.2, Table 4.3, and Table 4.4 present summaries of summer stage, velocity, and discharge.

Table 4.2: Summer Peak Stage, Velocity, & Discharge Summary

Monitoring Location Description	Gage Station	Summer Peak Stage		Summer Peak Velocity			Summer Peak Discharge		
		Stage ft BPMSL	Date & Time	Average Velocity fps	Stage ft BPMSL	Date & Time	Discharge cfs	Stage ft BPMSL	Date & Time
Tinmiaqsiugvik Bridge	**UB6.9**	2.95	7/24, 8:45 PM	0.93 [1,2]	0.97	7/11, 7:30 PM	340 [1]	2.40	7/22, 4:30 PM
	UB6.7	2.98			1.07			2.46	
Barely Creek Culvert Battery	**S4-C**	14.54	9/7, 5:00 AM	4.5 [3]	14.36	8/19, 5:30 PM	14 [4]	14.54	9/7, 5:00 AM
	S4-A	12.69			12.48			12.69	
Crea Bridge	**S5-C**	16.90	9/7, 8:15 AM	1.0	16.72	8/31, 3:15 AM	23	16.90	9/7, 8:15 AM
	S5-A	16.39	9/7, 7:30 AM		16.20			16.39	

Notes:

[1] Calculation results in flow moving in the upstream direction; potentially attributable to wind effects or instrument sensitivity

[2] Calculated for flow through the entire summer (open) channel cross-section

[3] Maximum calculated through a single culvert

[4] Sum of all associated culverts conveying flow

Table 4.3: Summer Minimum Stage, Velocity, & Discharge Summary

Monitoring Location Description	Gage Station	Summer Minimum Stage		Summer Minimum Velocity & Discharge			
		Stage ft BPMSL	Date & Time	Average Velocity fps	Discharge cfs	Stage ft BPMSL	Date & Time
Tinmiaqsiugvik Bridge	**UB6.9**	0.39	7/17, 8:00 AM	0.02 [1]	0	0.45	8/5, 9:45 AM
	UB6.7	0.45	8/5, 8:45 AM			0.45	
Barely Creek Culvert Battery	**S4-C**	13.80	7/19, 11:00 PM	0.0 [2]	5 [3]	14.01	7/19, 11:00 PM
	S4-A	11.86	7/17, 1:30 AM			12.05	
Crea Bridge	**S5-C**	15.39	7/19, 7:45 PM	0.5	0.5	15.39	7/19, 7:45 PM
	S5-A	14.85	7/19, 11:00 PM			14.85	

Notes:

[1] Calculated for flow through the entire summer (open) channel cross-section

[2] Minimum calculated through a single culvert

[3] Sum of all associated culverts conveying flow

Table 4.4: Summer Measured Velocity & Discharge

Monitoring Location Description	Gage Station	Summer Measured Velocity & Discharge			
		Average Velocity fps	Discharge cfs	Stage ft BPMSL	Date & Time
Tinmiaqsiugvik Bridge	**UB6.9**	0.94 [1]	330	not recorded	9/9, 2:00 PM
	UB6.7				

Notes:

[1] Measured for flow through the entire summer (open) channel cross-section

4.1 TINMIAQSIUGVIK BRIDGE

The UB gage stations are located in the Tinmiaqsiugvik River at river mile 6.7 (downstream of the Tinmiaqsiugvik Bridge) and at river mile 6.9 (upstream of the Tinmiaqsiugvik Bridge), measured upstream from the confluence with Fish Creek. This river drains an area of 231 square miles at the upstream side of the Tinmiaqsiugvik Bridge and flows northwest into Fish Creek downstream of the bridge. The UB gage stations have been monitored intermittently since 2003.

Spring and summer measured and calculated velocity and discharge data and plan and profile drawings are provided in Appendix C.2.1.

SPRING

Stage and discharge at the Tinmiaqsiugvik Bridge were influenced by channel ice downstream of the bridge (Photo 4.1) and remnant ice roads and pads upstream of and at the bridge (Photo 4.2). Peak discharge coincided with peak stage at the upstream gage station, UB 6.9.

Continuous discharge and velocity was calculated during spring breakup based on conditions measured on June 3, three days after peak. The accuracy of these indirect calculations is dependent on conditions at the time of calculation, particularly the presence of snow, bottomfast ice, and ice jam backwater effects. The presence of snow and bottomfast ice in the channel impact river hydraulics by elevating the riverbed and constricting the banks, which raises stage above snow- and ice-free channel conditions. The snow and ice also affect the size, shape, and roughness of the channel. Bottomfast ice can persist long into the breakup flood. Because the ice and snow are melting during breakup, factors such as channel geometry, slope, and roughness continuously change until the channel is snow- and ice-free. These dynamic characteristics of the channel were documented in 2006 when channel profiles were measured daily during breakup (Michael Baker 2007). This year, in addition to the ablation of naturally occurring snow and ice, channel conditions at the Tinmiaqsiugvik Bridge were influenced by the presence of constructed ice pads and roads as well as the mechanical slotting of a trench along the thalweg through the bridge reach. While the constructed ice pads and roads did not affect bridge performance, indirect calculations, including the estimated peak discharge, were impacted and assigned a poor quality rating (Table 2.2). Calculated discharge is likely overestimated prior to the June 3 measurement when more of the channel was obstructed by ice, however the extent cannot be quantified. Indirect discharge calculated at the time of the direct measurement was 2.6% less than the measured discharge. Calculated peak velocity occurred when flow was confined to the main channel, prior to peak stage and discharge.

Discharge was measured from the upstream side of the Tinmiaqsiugvik Bridge. The discharge measurement was influenced by ice and snow throughout the cross-section, willows in the left overbank, and backwater from an ice jam downstream of the bridge (Photo 4.3). The average velocity was 2.11 fps and the highest depth-averaged velocity was within a particular section

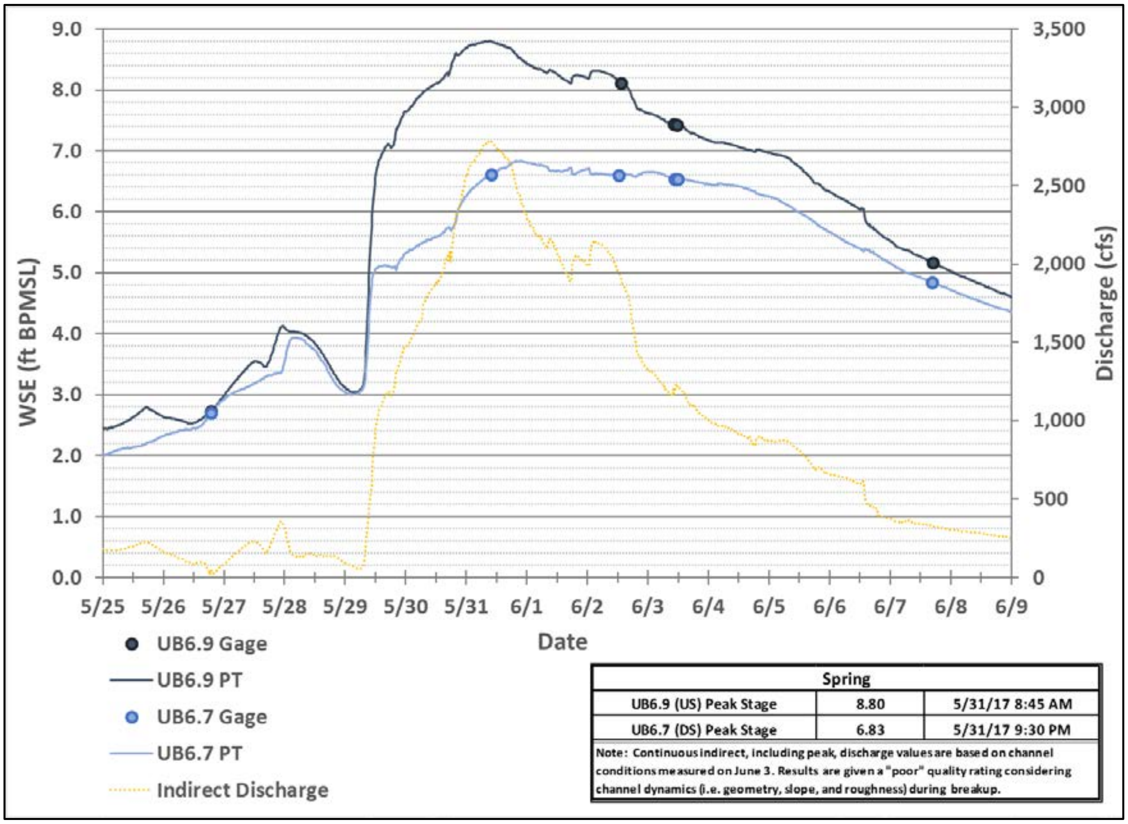
was 4.14 fps. The quality of the measurement was classified as poor based on conditions at the time of measurement.

Tinmiaqsiugvik Bridge spring breakup stage and discharge data is provided in Graph 4.1; discharge and velocity data is provided in Graph 4.2.

Photo 4.1: Conditions at the Tinmiaqsiugvik Bridge the day of spring peak stage and discharge, looking southeast; May 31, 2017

Photo 4.2: Conditions at the Tinmiaqsiugvik Bridge the day of spring peak stage and discharge, looking north; May 31, 2017

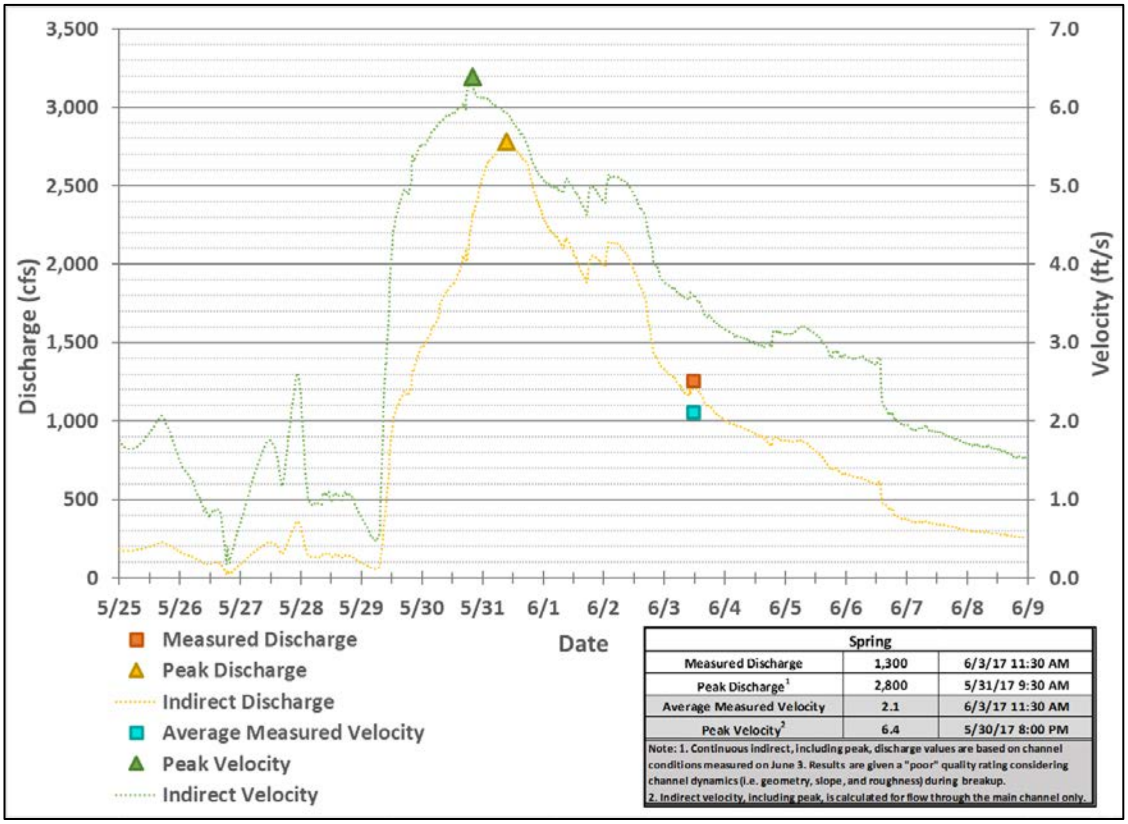
Photo 4.3: Conditions at the Tinmiaqsiugvik Bridge the day of discharge measurement, looking east; June 3, 2017



Spring		
UB6.9 (US) Peak Stage	8.80	5/31/17 8:45 AM
UB6.7 (DS) Peak Stage	6.83	5/31/17 9:30 PM

Note: Continuous indirect, including peak, discharge values are based on channel conditions measured on June 3. Results are given a "poor" quality rating considering channel dynamics (i.e. geometry, slope, and roughness) during breakup.

Graph 4.1: Tinmiaqsiugvik Bridge Spring Breakup Stage & Discharge



Spring		
Measured Discharge	1,300	6/3/17 11:30 AM
Peak Discharge[1]	2,800	5/31/17 9:30 AM
Average Measured Velocity	2.1	6/3/17 11:30 AM
Peak Velocity[2]	6.4	5/30/17 8:00 PM

Note: 1. Continuous indirect, including peak, discharge values are based on channel conditions measured on June 3. Results are given a "poor" quality rating considering channel dynamics (i.e. geometry, slope, and roughness) during breakup.
2. Indirect velocity, including peak, is calculated for flow through the main channel only.

Graph 4.2: Tinmiaqsiugvik Bridge Spring Breakup Velocity & Discharge

SUMMER

The Tinmiaqsiugvik River was ice and snow free and flow was within the main channel by the time field crews returned at the end of June (Photo 4.4). The spring PTs had gone dry and were moved lower in the channel at that time. Summer stage, velocity, and discharge were significantly lower than during spring breakup (Photo 4.5).

Continuous discharge and velocity was calculated based on conditions measured on September 9, when the channel was ice- and snow-free. Discharge and velocity trended in an upstream direction for the beginning of the summer, alternated upstream and downstream during the middle of the summer, and trended downstream for the latter part of the summer. Calculations resulting in upstream velocity and discharge may potentially be attributable to wind effects or errors related to instrument sensitivity. Peak discharge occurred at the same time as the second highest stage (Photo 4.6), two days prior to peak summer stage (Photo 4.7). Peak velocity occurred prior to peak stage and discharge. Indirect summer calculations, including the estimated peak discharge and velocity, were assigned a good quality rating (Table 2.2) based on open-channel conditions.

Summer discharge was measured from the same location as the spring breakup discharge measurement. The average velocity was 0.94 fps and the highest depth-averaged velocity within a particular section was 1.11 fps. The quality of the measurement was classified as good based on open channel and uniform flow conditions at the time of measurement (Photo 4.8).

Tinmiaqsiugvik Bridge summer stage and discharge data is provided in Graph 4.3; discharge and velocity data is provided in Graph 4.4.

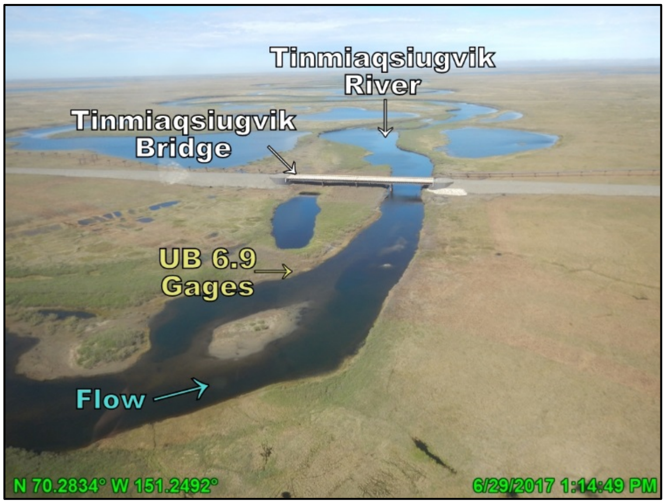


Photo 4.4: Open channel conditions at the Tinmiaqsiugvik Bridge, looking northwest (downstream); June 29, 2017

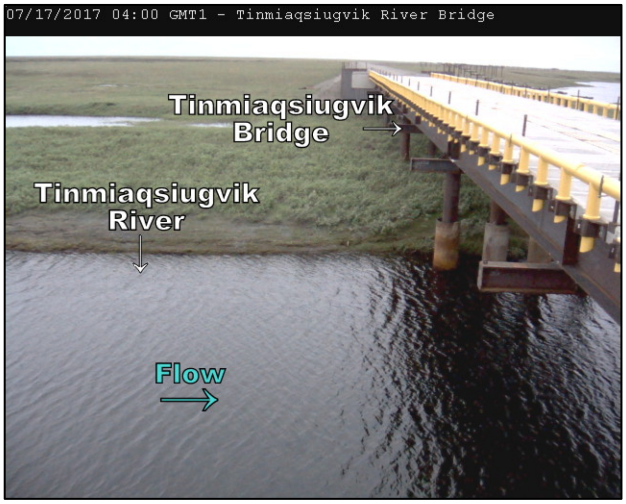


Photo 4.5: Minimum summer stage at the Tinmiaqsiugvik Bridge, looking southwest; July 17, 2017

Photo 4.6: Peak summer discharge (upstream flow direction) at the Tinmiaqsiugvik Bridge, looking southwest; July 22, 2017

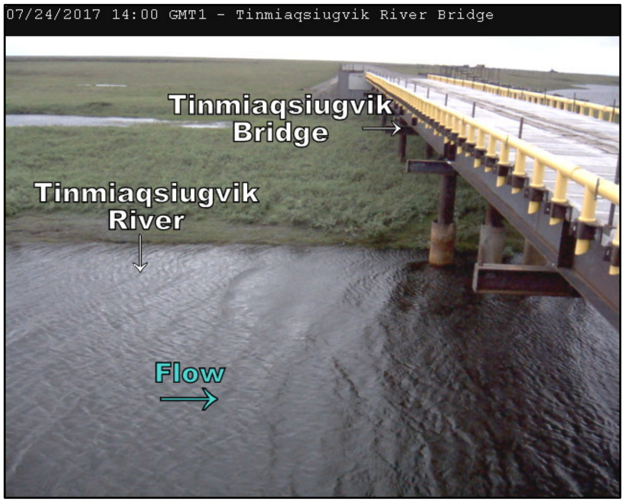
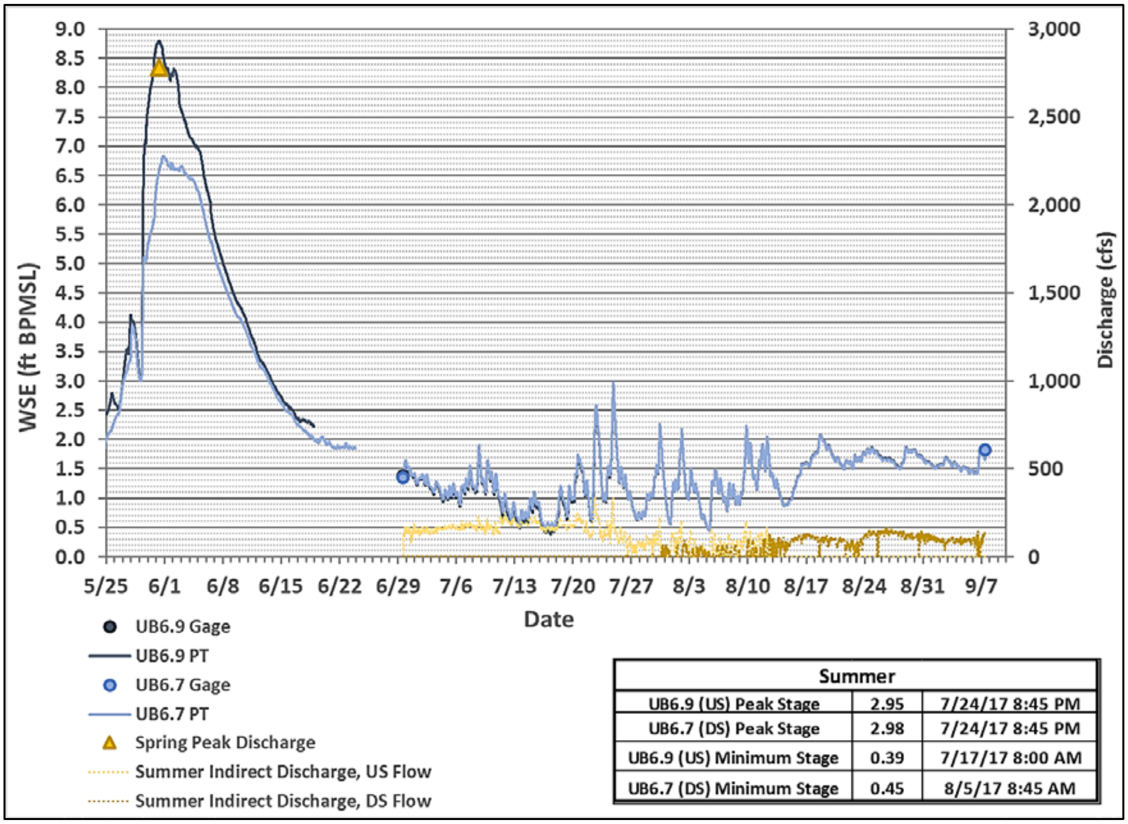


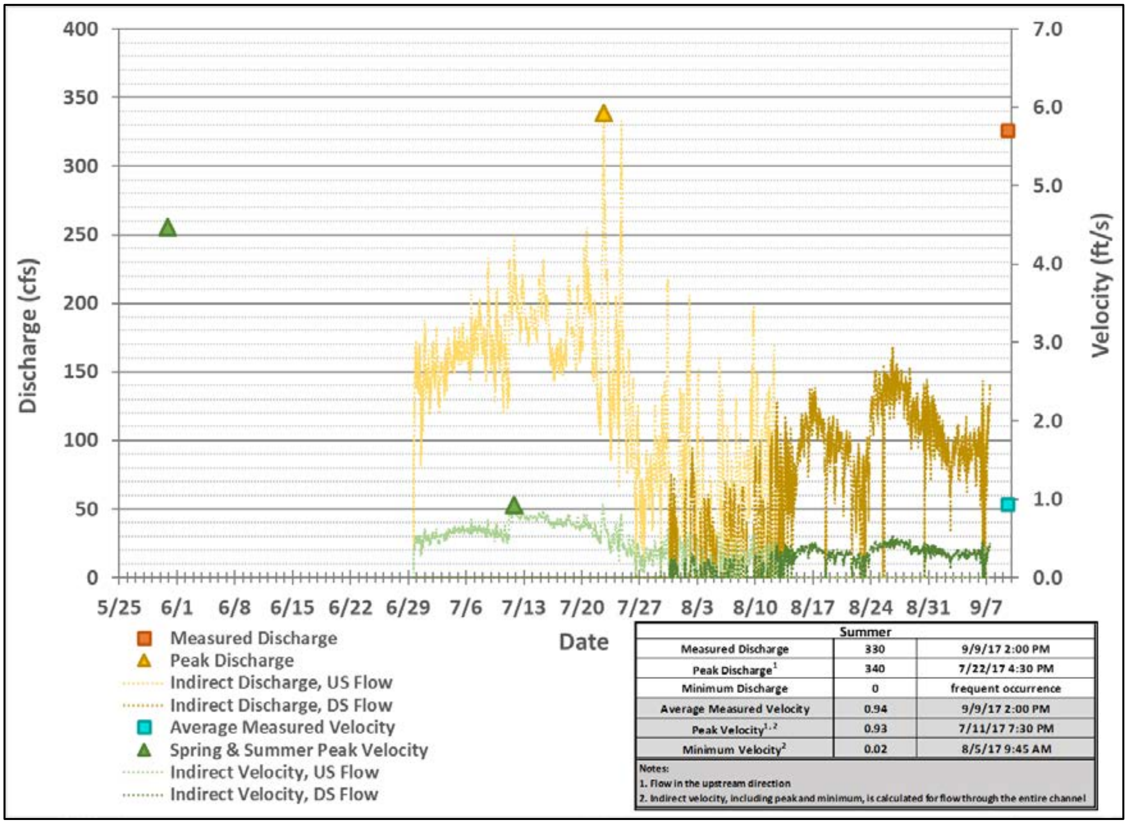
Photo 4.7: Peak summer stage at the Tinmiaqsiugvik Bridge, looking southwest; July 24, 2017

Photo 4.8: Flow confined within the main channel at the Tinmiaqsiugvik Bridge the day of summer discharge measurement, looking northeast; September 9, 2017



Summer		
UB6.9 (US) Peak Stage	2.95	7/24/17 8:45 PM
UB6.7 (DS) Peak Stage	2.98	7/24/17 8:45 PM
UB6.9 (US) Minimum Stage	0.39	7/17/17 8:00 AM
UB6.7 (DS) Minimum Stage	0.45	8/5/17 8:45 AM

Graph 4.3: Tinmiaqsiugvik Bridge Summer Stage & Discharge



Summer		
Measured Discharge	330	9/9/17 2:00 PM
Peak Discharge[1]	340	7/22/17 4:30 PM
Minimum Discharge	0	frequent occurrence
Average Measured Velocity	0.94	9/9/17 2:00 PM
Peak Velocity[1, 2]	0.93	7/11/17 7:30 PM
Minimum Velocity[2]	0.02	8/5/17 9:45 AM

Notes:
1. Flow in the upstream direction
2. Indirect velocity, including peak and minimum, is calculated for flow through the entire channel

Graph 4.4: Tinmiaqsiugvik Bridge Summer Velocity & Discharge

4.2 CREA BRIDGE

The S5 gage stations are located in Crea Creek upstream and downstream of the Crea Bridge. Crea Creek is a beaded stream that drains an area of 4.0 square miles at the upstream side of the Crea Bridge and flows northeast into the Tinmiaqsiugvik River downstream of the Crea Bridge and downstream of the Tinmiaqsiugvik Bridge. The S5 gage stations have been monitored intermittently since 2005.

Spring and summer measured and calculated velocity and discharge data and plan and profile drawings are provided in Appendix C.2.2.

SPRING

Spring breakup peak stage and discharge at the Crea Bridge were significantly influenced by ice and snow. Isolated meltwater was ponded upstream and downstream of the bridge the day prior to peak stage (Photo 4.9). Peak stage was the result of isolated meltwater which released by carving through the snow under the bridge. This caused a rapid fall of the stage hydrograph at the upstream gage, S5-C, and brief and rapid peak and fall of the stage hydrograph at the downstream gage, S5-A (Photo 4.10).

Peak discharge occurred a few days after peak stage (Photo 4.11) and was calculated using the open channel cross-section measured during the direct discharge measurement. The estimated peak discharge was assigned a fair to poor quality rating (Table 2.2) due to the influence of snow and ice observed during peak conditions and the direct measurement against which indirect calculations were calibrated. Indirect discharge calculated at the time of direct measurement was 2.0% greater than the measured discharge. Peak velocity occurred after peak stage and at the same time as peak discharge. Bottomfast ice in channel beads and snow along the banks at the bridge were still in place at the conclusion of breakup monitoring and some overbank flow was still present.

Discharge was measured approximately 10 feet downstream of the Crea Bridge. The channel cross-section was ice- and snow-free. However, discharge was influenced by snow constricting flow through the bridge upstream of the cross-section and by willows on both banks (Photo 4.12). The average velocity was 0.92 fps and the highest depth-averaged velocity within a particular section was 2.79 fps. The quality of the measurement was classified as fair based on conditions at the time of measurement.

Crea Bridge stage and discharge data is provided in Graph 4.5; discharge and velocity data is provided in Graph 4.6.

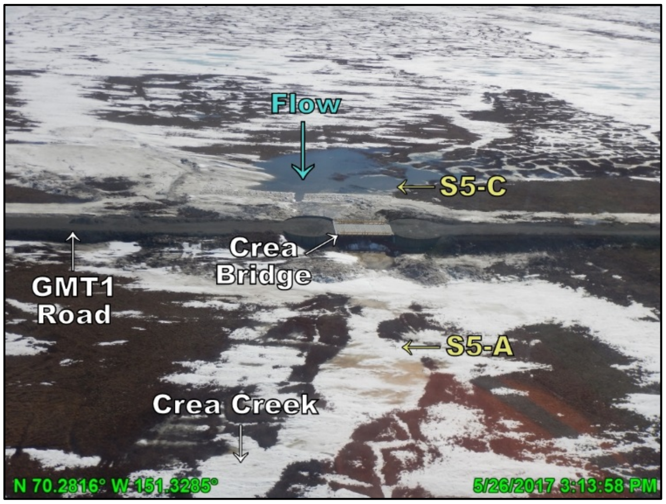


Photo 4.9: Conditions at the Crea Bridge the day before spring peak stage, looking south (upstream); May 26, 2017

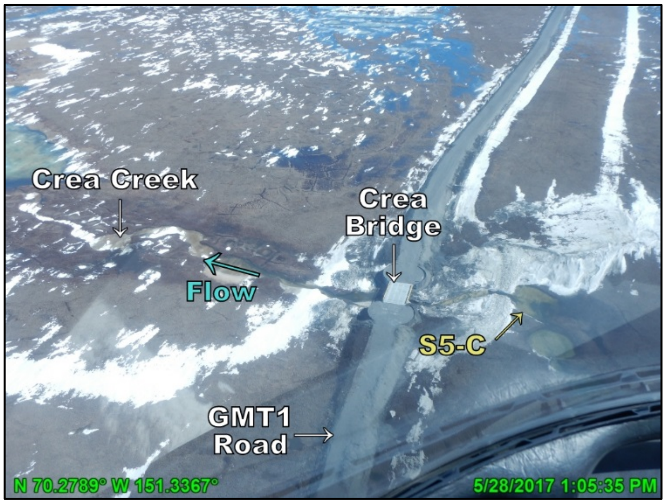
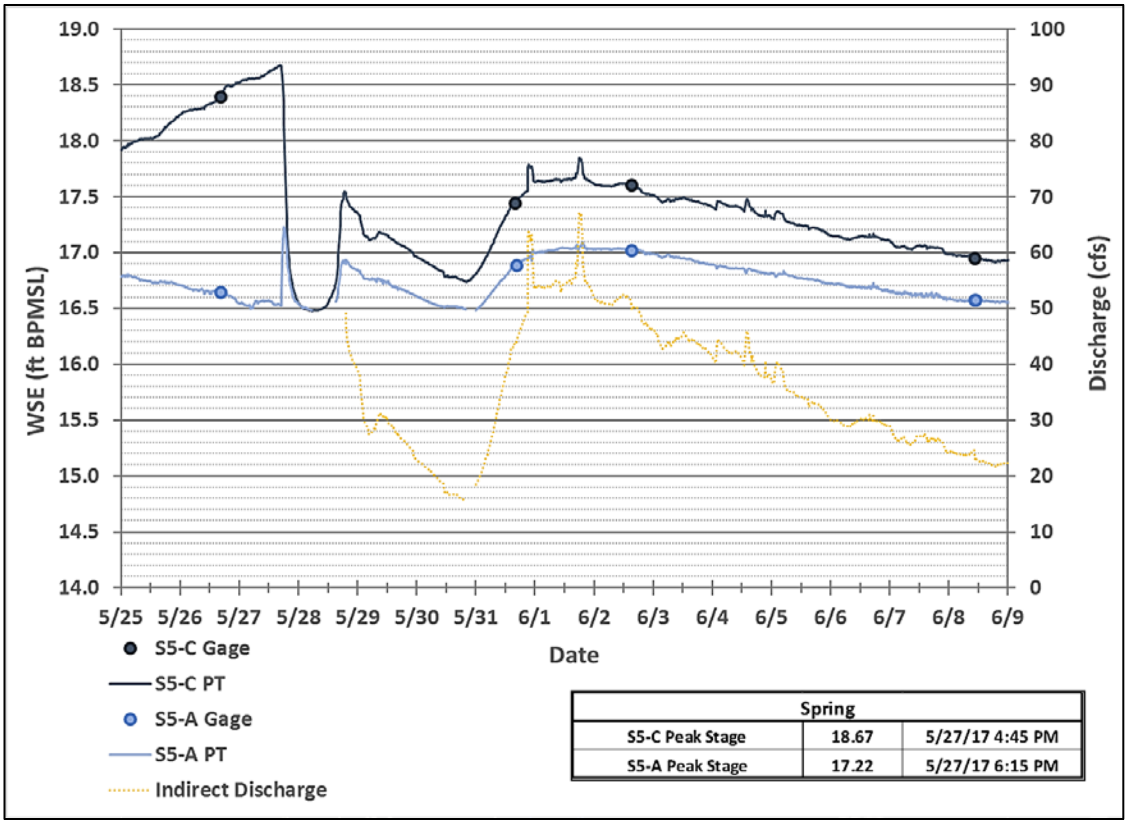


Photo 4.10: Ice and snow influence at the Crea Bridge the day after spring peak stage, looking east; May 28, 2017

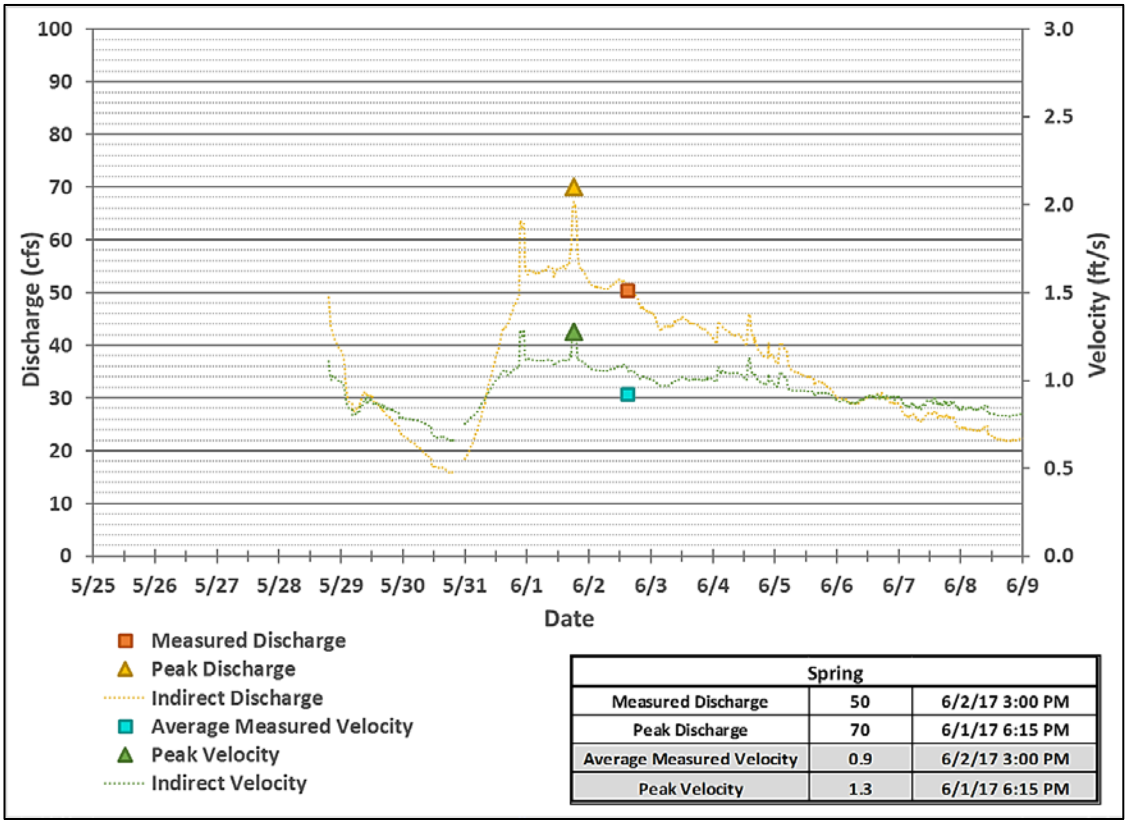
Photo 4.11: Ice and snow influence at the Crea Bridge the day of spring peak discharge, looking southwest; June 1, 2017

Photo 4.12: Conditions at the Crea Bridge the day of spring discharge measurement, looking east; June 2, 2017



Spring		
S5-C Peak Stage	18.67	5/27/17 4:45 PM
S5-A Peak Stage	17.22	5/27/17 6:15 PM

Graph 4.5: Crea Bridge Spring Breakup Stage & Discharge



Spring		
Measured Discharge	50	6/2/17 3:00 PM
Peak Discharge	70	6/1/17 6:15 PM
Average Measured Velocity	0.9	6/2/17 3:00 PM
Peak Velocity	1.3	6/1/17 6:15 PM

Graph 4.6: Crea Bridge Spring Breakup Velocity & Discharge

SUMMER

Crea Creek was generally ice and snow free and flow was conveyed within main channel banks by the time field crews returned to the site at the end of June (Photo 4.13). Summer stage, discharge, and velocities at the Crea Bridge were significantly lower than during spring breakup. The stage hydrographs and calculated discharge indicate that downstream flow was present throughout the summer.

Peak discharge coincided with peak stage (Photo 4.14). It was calculated using the cross-section profiled during the direct discharge measurement, which was ice and snow-free. The estimated peak discharge was assigned a good quality rating (Table 2.2) based on those conditions.

Peak velocity occurred prior to peak stage and discharge. Crea Bridge stage and discharge data is provided in Graph 4.7; discharge and velocity data is provided in Graph 4.8.

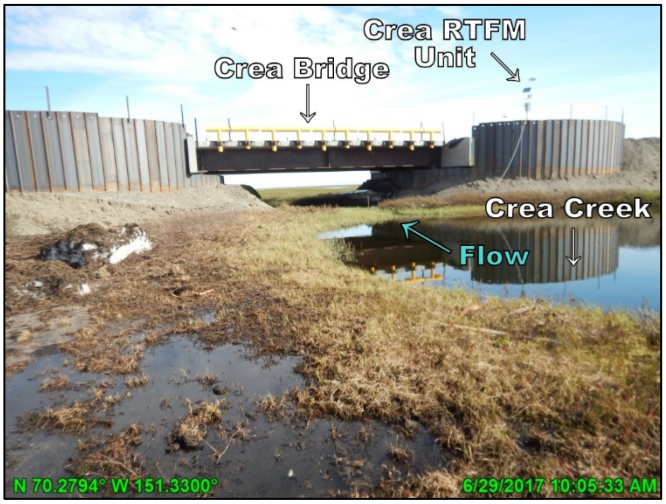


Photo 4.13: Open channel conditions at the Crea Bridge, looking northeast (downstream); June 29, 2017

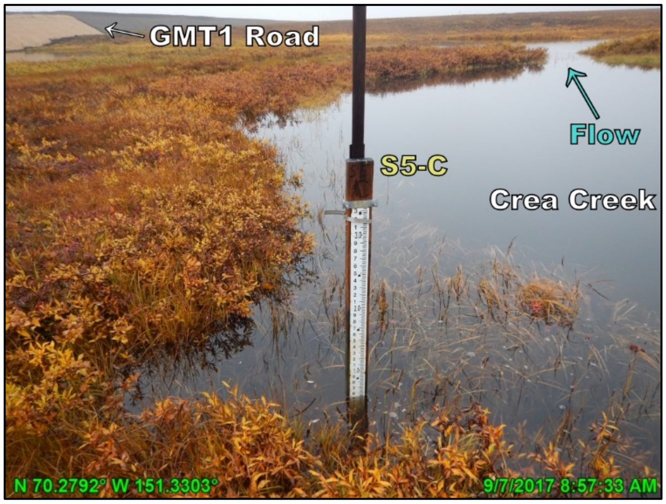
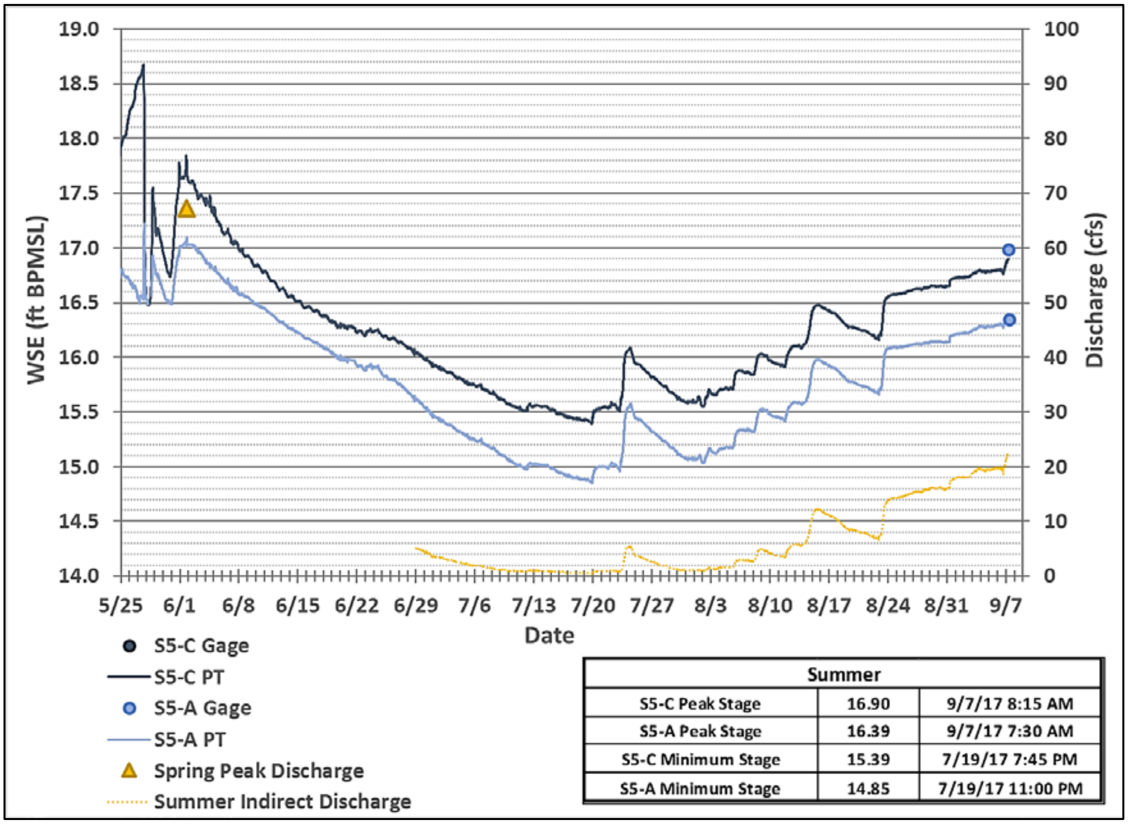
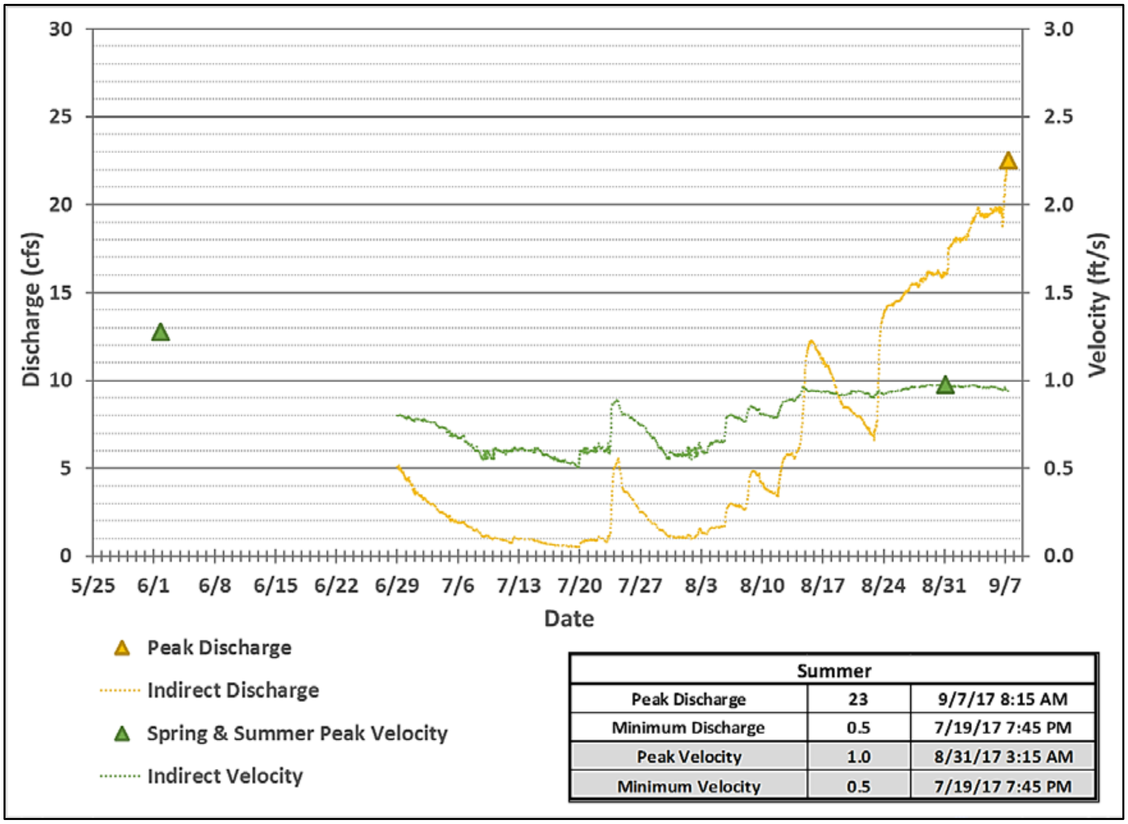


Photo 4.14: Peak summer stage and discharge at the Crea Bridge upstream gage S5-C, looking northeast; September 7, 2017



Summer		
S5-C Peak Stage	16.90	9/7/17 8:15 AM
S5-A Peak Stage	16.39	9/7/17 7:30 AM
S5-C Minimum Stage	15.39	7/19/17 7:45 PM
S5-A Minimum Stage	14.85	7/19/17 11:00 PM

Graph 4.7: Crea Bridge Summer Stage & Discharge



Summer		
Peak Discharge	23	9/7/17 8:15 AM
Minimum Discharge	0.5	7/19/17 7:45 PM
Peak Velocity	1.0	8/31/17 3:15 AM
Minimum Velocity	0.5	7/19/17 7:45 PM

Graph 4.8: Crea Bridge Summer Velocity & Discharge

4.3 BARELY CREEK CULVERT BATTERY

The S4 gage stations and culverts GMT1-42, GMT1-43, and GMT1-44 are located in Barely Creek, a beaded stream that drains an area of 1.6 square miles at the upstream side of the GMT1 access road. Barely Creek flows northeast into the Tinmiaqsiugvik River downstream of the Tinmiaqsiugvik Bridge. Barely Creek has been monitored intermittently since 2005. Culvert GMT1-42 is 60 inches in diameter and culverts GMT1-43 and GMT1-44 are 36 inches in diameter.

Plan and profile drawings and spring and summer measured and calculated velocity and discharge data is provided in Appendix C.2.3 and Appendix C.2.4.

SPRING

Spring breakup peak stage and discharge were significantly influenced by ice and snow. Peak stage at the upstream gage, S4-C, was followed by a sharp drop in stage attributed to a sudden release of ponded water through a channelized section of the ice road parallel to and upstream of the GMT1 access road (Photo 4.15). Flow through the culverts was observed two days after peak stage (Photo 4.16). Barely Creek, in the vicinity of the culvert battery, was flowing under generally open channel conditions by June 2, with flow in the overbanks.

Discharge was measured at each culvert outlet. The average velocity was 0.40 fps and the highest velocity at a single culvert was 0.7 fps. The quality of the measurement was classified as good based on open channel conditions at the time of measurement (Photo 4.19, Photo 4.20, and Photo 4.21).

Peak discharge was calculated when bottomfast ice was still present in the channel beads and flow upstream of the road was conveyed through a narrow channel in the adjacent ice road (Photo 4.17 and Photo 4.18). The estimated peak discharge was assigned a fair quality rating (Table 2.2) due to that influence. Indirect discharge calculated at the time of direct measurement was within the same order of magnitude as the measured discharge. Peak velocity occurred after peak stage and at the same time as peak discharge.

Barely Creek culvert battery spring breakup stage, velocity, and discharge data is provided in Graph 4.9.

Photo 4.15: Conditions at the Barely Creek culvert battery the day of spring peak stage at gage S4-C, looking west; May 26, 2017

Photo 4.16: Flow through the Barely Creek culvert battery, looking east; May 28, 2017

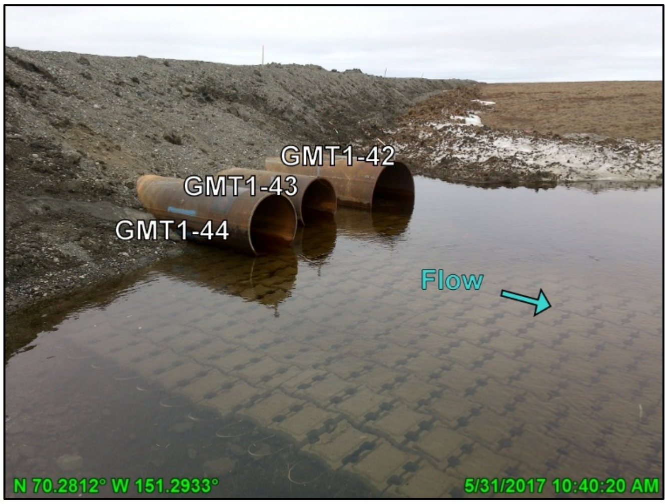


Photo 4.17: Conditions at the Barely Creek culvert battery outlet the day of spring peak discharge, looking west; May 31, 2017

Photo 4.18: Conditions at the Barely Creek culvert battery the day of spring peak discharge, looking northeast (downstream); May 31, 2017

Photo 4.19: Generally open channel conditions at Barely Creek the day of spring measured discharge, looking northeast; June 2, 2017

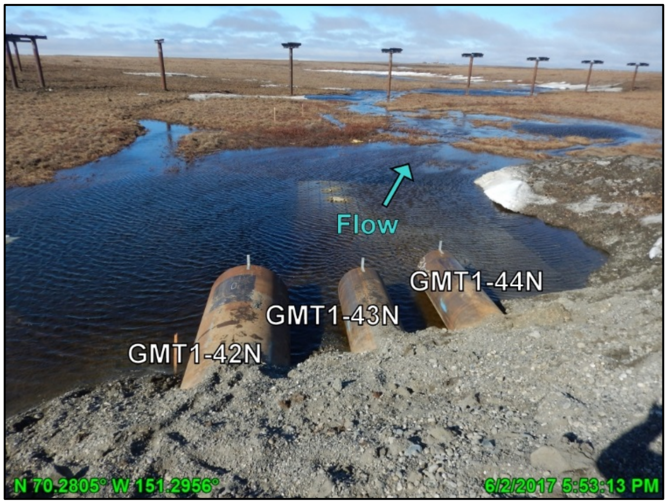
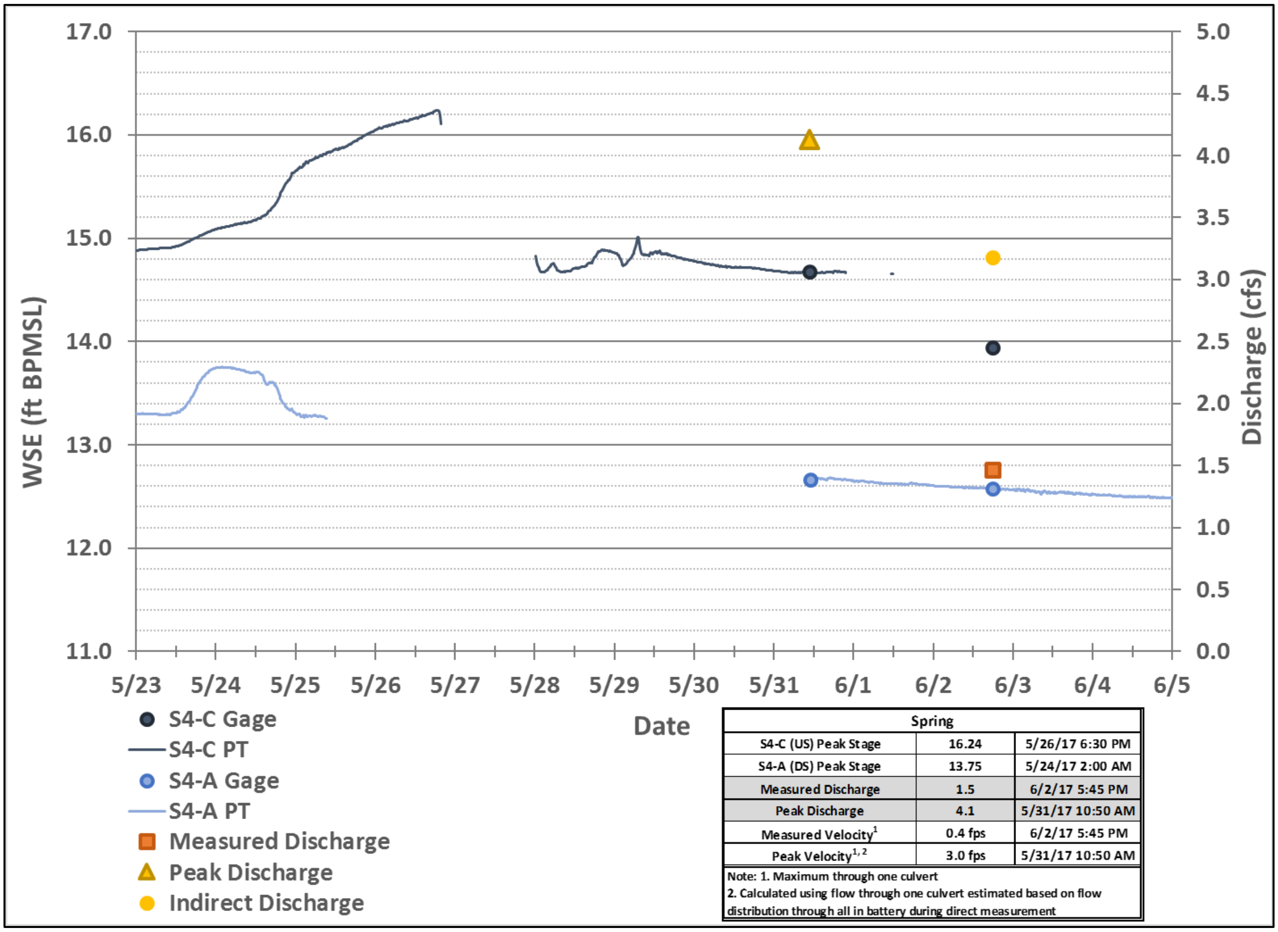


Photo 4.20: Barely Creek culvert battery the day of spring measured discharge, looking northeast (downstream); June 2, 2017

Photo 4.21: Barely Creek culvert battery the day of spring measured discharge, looking southwest (upstream); June 2, 2017



Spring		
S4-C (US) Peak Stage	16.24	5/26/17 6:30 PM
S4-A (DS) Peak Stage	13.75	5/24/17 2:00 AM
Measured Discharge	1.5	6/2/17 5:45 PM
Peak Discharge	4.1	5/31/17 10:50 AM
Measured Velocity[1]	0.4 fps	6/2/17 5:45 PM
Peak Velocity[1, 2]	3.0 fps	5/31/17 10:50 AM

Note: 1. Maximum through one culvert
2. Calculated using flow through one culvert estimated based on flow distribution through all in battery during direct measurement

Graph 4.9: Barely Creek Culvert Battery Spring Breakup Stage, Velocity, & Discharge

SUMMER

Summer stage, discharge, and velocity at the Barely Creek culvert battery were lower than during spring breakup. The upstream and downstream stage hydrographs and observations during site visits suggest that water was present but ponded early in the summer. Flow was passed by one (Photo 4.22) to three culverts (Photo 4.23) in the battery throughout the remainder of the summer.

Peak discharge and peak velocity coincided with peak stage. The estimated discharge was assigned a fair to good quality rating based on open channel conditions.

Barely Creek culvert battery summer stage and discharge data is provided in Graph 4.10; discharge and velocity data is provided in C.2.4.

Photo 4.22: Summer flow through one Barely Creek culvert, looking north; June 29, 2017

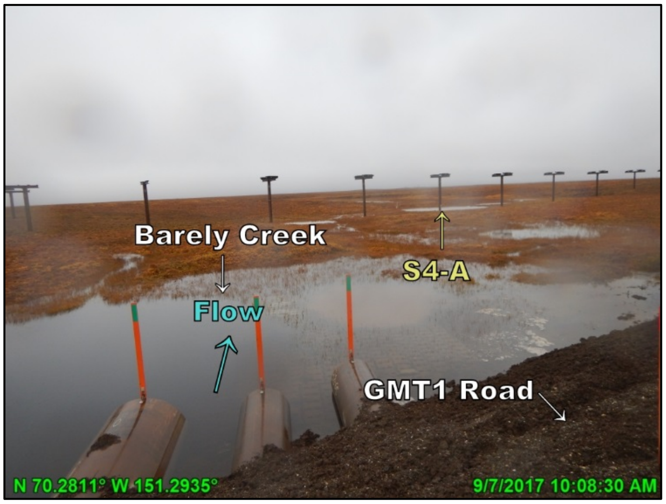
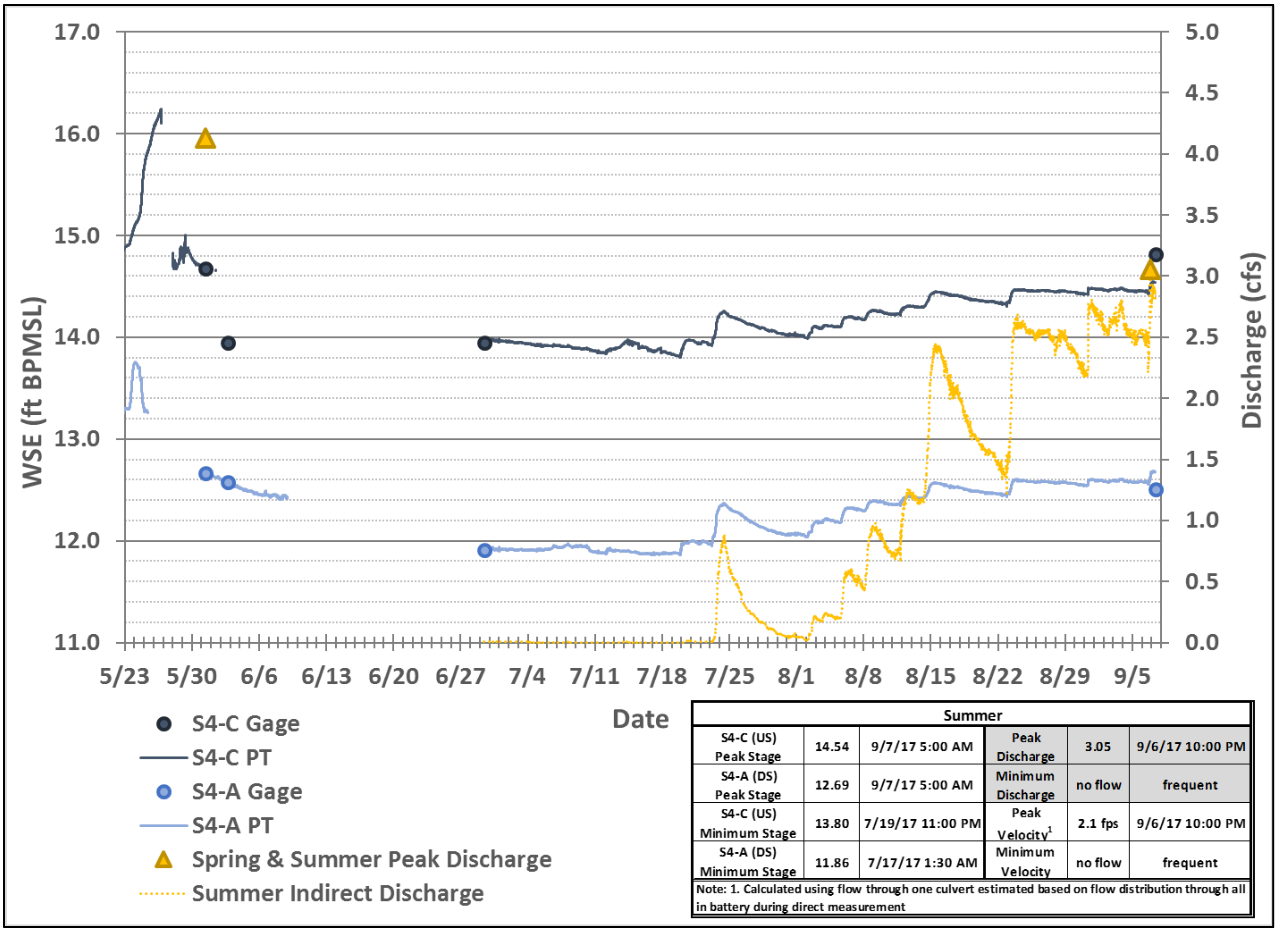


Photo 4.23: Summer flow through all three Barely Creek culverts, looking north; September 7, 2017



Summer					
S4-C (US) Peak Stage	14.54	9/7/17 5:00 AM	Peak Discharge	3.05	9/6/17 10:00 PM
S4-A (DS) Peak Stage	12.69	9/7/17 5:00 AM	Minimum Discharge	no flow	frequent
S4-C (US) Minimum Stage	13.80	7/19/17 11:00 PM	Peak Velocity[1]	2.1 fps	9/6/17 10:00 PM
S4-A (DS) Minimum Stage	11.86	7/17/17 1:30 AM	Minimum Velocity	no flow	frequent

Note: 1. Calculated using flow through one culvert estimated based on flow distribution through all in battery during direct measurement

Graph 4.10: Barely Creek Culvert Battery Summer Stage & Discharge

4.4 CULVERTS

The S2, S3, S6, and S7 gage stations have been monitored intermittently since 2009.

Spring measured and calculated velocity and discharge data is provided in Appendix C.2.3. Summer stage, velocity, and discharge were not measured or calculated at any of these locations.

S2 CULVERTS (GMT1-60 THROUGH GMT1-71)

The S2 gage stations are situated in a natural depression which encompasses the CD5 road intersection and extends into the GMT1 access road. The drainage area at the upstream side of the culverts is approximately 0.01 square miles. On the downstream side of the GMT1 access road, the drainage connects to Lake MB0301 to the northeast and a beaded stream to the northwest which flows into the Tinmiaqsiugvik River downstream of the Tinmiaqsiugvik Bridge. Culverts GMT1-60 through GMT1-71 equalize accumulating meltwater on the north and south side of the GMT1 access road.

On May 26, the ice road and drifted snow on the south (upstream) side of the GMT1 access road had mostly melted and neither were influencing drainage patterns (Photo 4.24). The pipeline construction ice road located north (downstream) of the GMT1 pipeline and north (downstream) of the GMT1 access road north (downstream) of the GMT1 pipeline was still intact and meltwater was accumulating between that and the GMT1 access road. S2 PTs began recording concurrent rising stage on both sides of the access road, suggesting a hydraulic connection was established through the culverts.

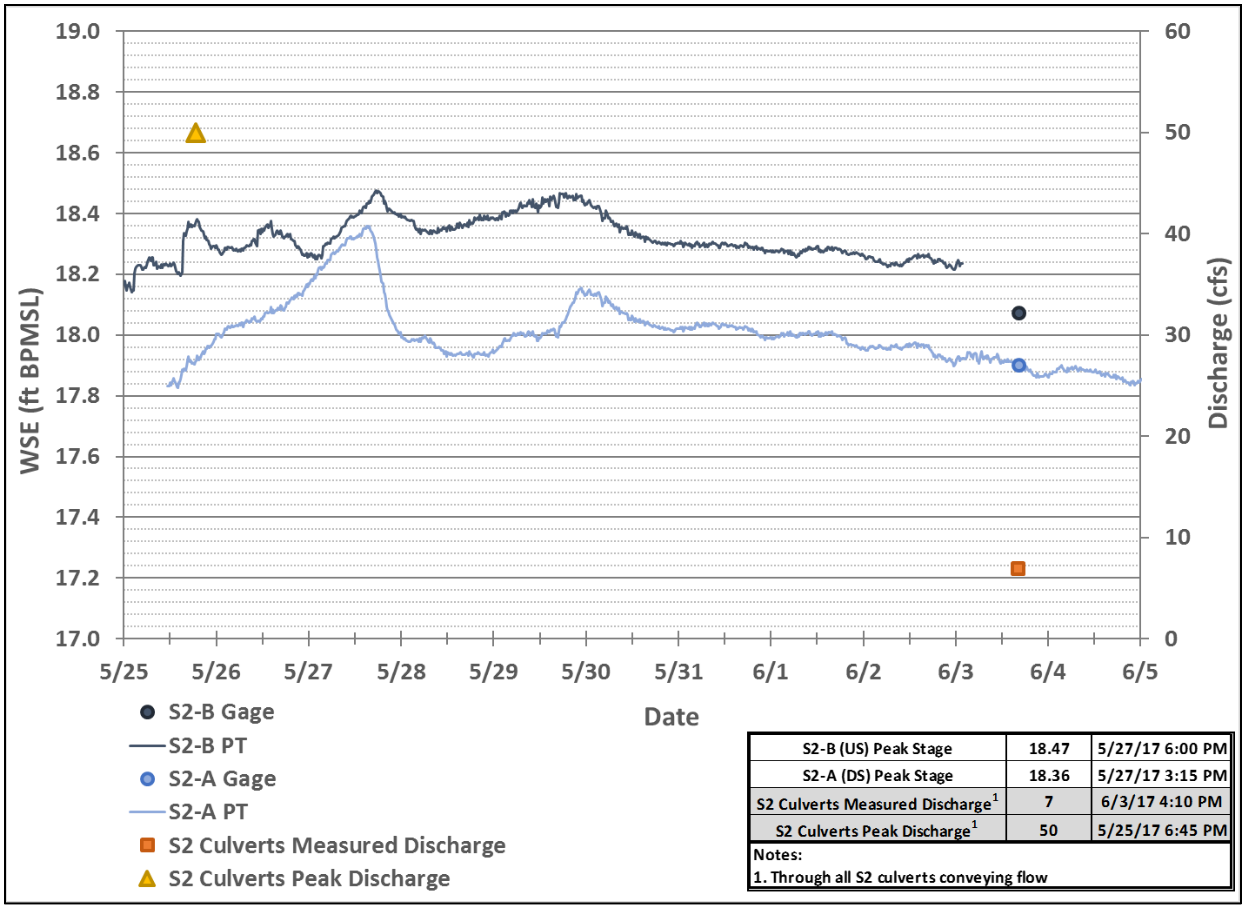
Spring breakup stage was likely temporarily influenced by the pipeline construction ice road north (downstream) of the S2 gage stations. The sharp decline in water levels after peak stage at the downstream gage, S2-A, was likely attributed to meltwater passing through the pipeline construction ice road. Observations on May 28 confirm the presence of hydraulic channels melted through the pipeline construction ice road.

Spring velocity and discharge were measured at the outlets of culverts GMT1-65 through GMT1-69 (Photo 4.25). The average velocity through these culverts was 1.2 fps. The quality of the measurement was classified as good based on open channel conditions at the time of measurement.

S2 spring breakup stage and discharge data are provided in Graph 4.11.

Photo 4.24: S2 gages and culverts the day prior to spring peak stage and the day after spring peak discharge, looking northeast; May 26, 2017

Photo 4.25: Culvert GMT1-68 the day of spring discharge measurement, looking south; June 3, 2017



S2-B (US) Peak Stage	18.47	5/27/17 6:00 PM
S2-A (DS) Peak Stage	18.36	5/27/17 3:15 PM
S2 Culverts Measured Discharge[1]	7	6/3/17 4:10 PM
S2 Culverts Peak Discharge[1]	50	5/25/17 6:45 PM

Notes:
1. Through all S2 culverts conveying flow

Graph 4.11: S2 Spring Breakup Stage & Discharge

S3 CULVERTS (GMT1-50 THROUGH GMT1-59)

The S3 gage stations are situated in a small, poorly defined network of high centered polygon troughs. The S3 drainage is approximately 0.9 square miles upstream of the culverts. The S2 drainage is downstream to the east and the Tinmiaqsiugvik River is downstream to the west. In the past, during periods of high flow, backwater from the Tinmiaqsiugvik River has been observed extending to this area. This was not the case in 2017 when spring breakup flows in the Tinmiaqsiugvik River remained low and confined within the channel banks. Culverts GMT1-57 through GMT1-59 are situated in the drainage depression while culverts GMT1-50 through GMT1-56 are situated on higher ground to the west.

Similar to conditions observed at the S2 gage stations, the pipeline construction ice road north (downstream) of the GMT1 access road remained partially intact during breakup. Similarly, meltwater accumulated between the GMT1 access road and the pipeline construction ice road, influencing water levels at the S3 gage stations. The PT installed on the upstream gage, S3-B, remained dry throughout breakup and aerial observations indicate no meltwater was on the south side of the road embankment. As a result, no hydraulic connections were established through the culverts during breakup (Photo 4.26, Photo 4.27, and Photo 4.28). Observations on June 2 confirmed that there were no visible drainages melted through the snowpack in the vicinity of the culvert inlets and outlets (Photo 4.29).

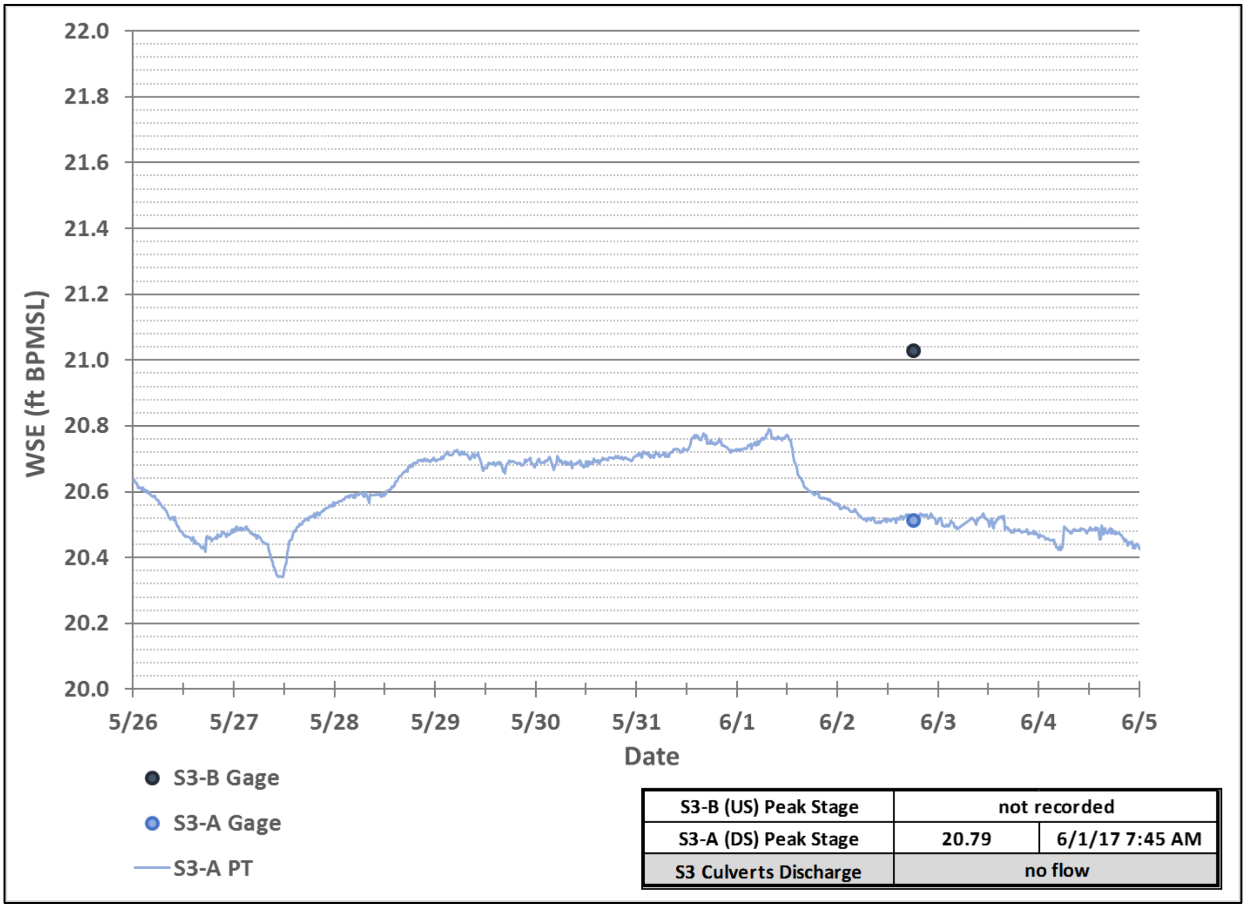
S3 spring breakup stage data is provided in Graph 4.12.

Photo 4.26: Local melt at S3 gages, looking northeast; May 26, 2017

Photo 4.27: S3 gages the day prior to peak stage at gage S3-A, looking south; May 31, 2017

Photo 4.28: S3 gages the day of peak stage at gage S3-A, looking west (downstream); June 1, 2017

Photo 4.29; S3 gages the day after spring peak stage, looking southeast (upstream); June 2, 2017



S3-B (US) Peak Stage	not recorded	
S3-A (DS) Peak Stage	20.79	6/1/17 7:45 AM
S3 Culverts Discharge	no flow	

Graph 4.12: S3 Spring Breakup Stage

S6 CULVERTS (GMT1-31 THROUGH GMT1-33)

The S6 gage stations and culverts GMT1-31 through GMT1-33 are situated in a swale depression that connects Lake L9819 (south of the GMT1 access road) to a smaller lake downstream to the north; Fish Creek is further downstream. The S6 drainage is approximately 0.7 square miles upstream of the culverts, 0.4 square miles of which is Lake L9819.

On the day of peak stage, streamflow in the drainage had melted a path through the remaining ice road and flow through the culverts was unobstructed (Photo 4.30, Photo 4.31, and Photo 4.32). Spring velocity and discharge were measured at the outlets of culverts GMT1-31 through GMT1-33 (Photo 4.33). The average velocity through these culverts was 1.1 fps. The quality of the measurement was classified as good based on open channel conditions at the time of the measurement.

S6 spring breakup stage and discharge is provided in Graph 4.13.

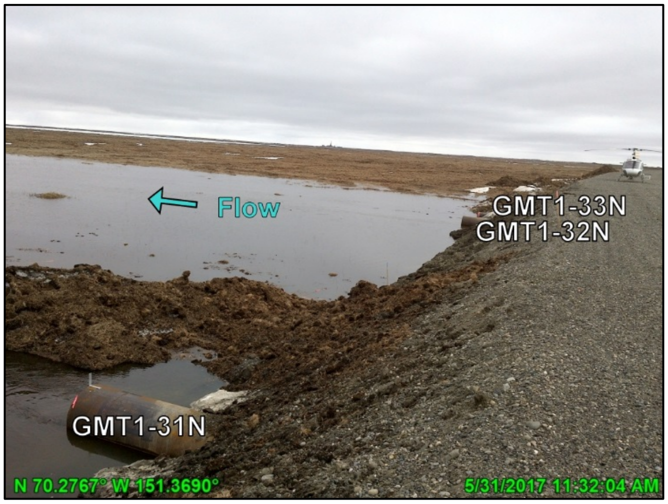


Photo 4.30: S6 culverts GMT1-31 through 33 the day of spring peak stage and discharge, looking northeast; May 31, 2017

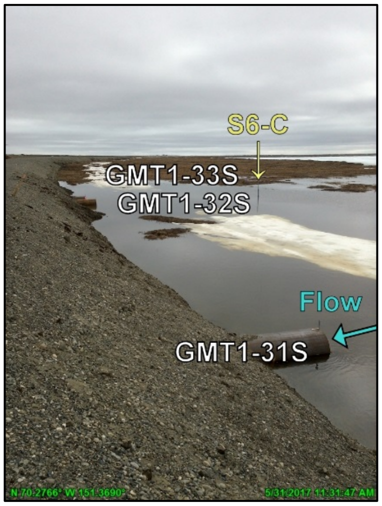


Photo 4.31: S6 culverts GMT1-31S the day of spring peak stage and discharge, looking east; May 31, 2017

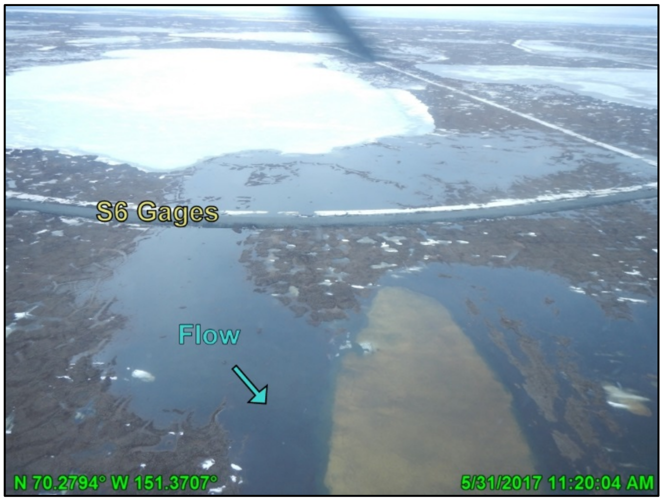
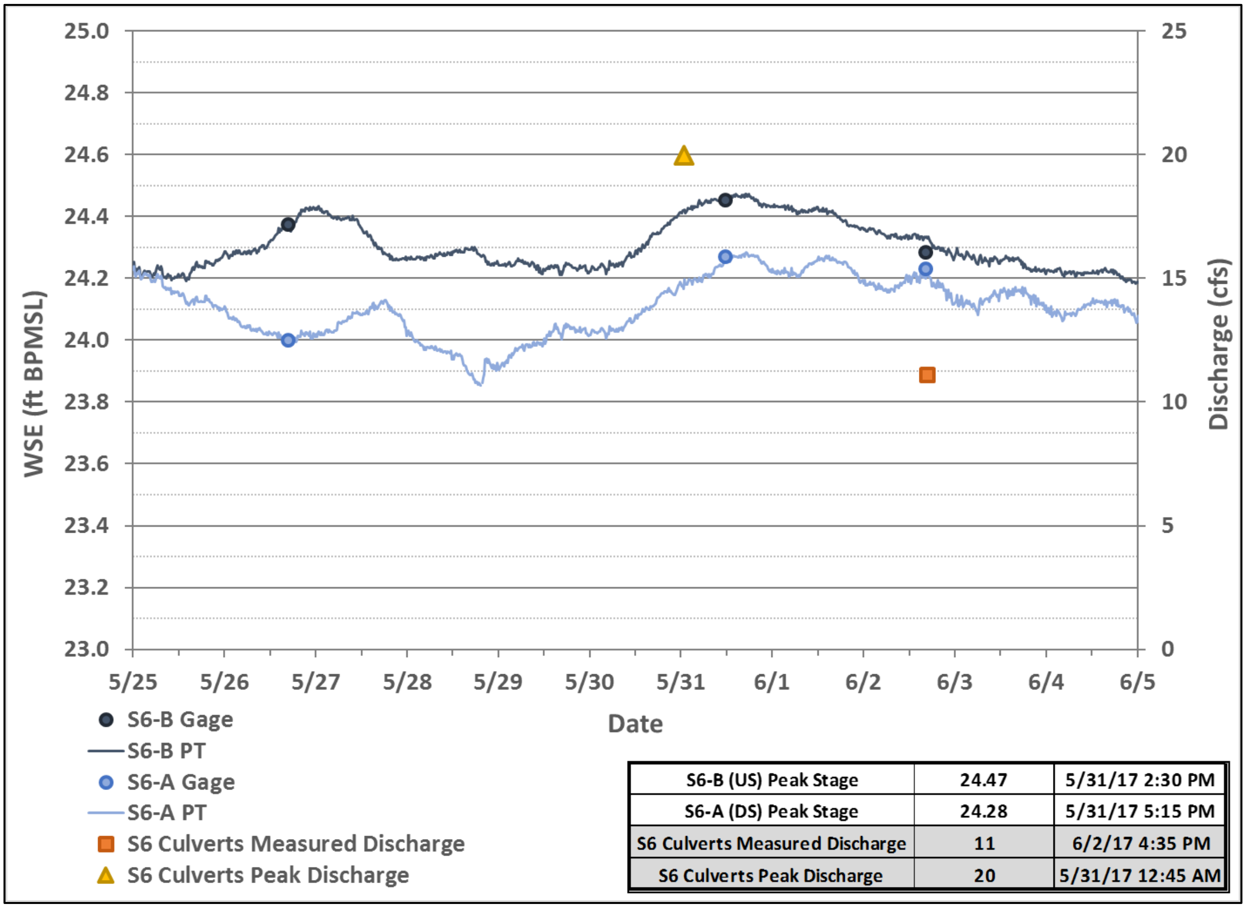


Photo 4.32: S6 gages and culverts the day of spring peak stage and discharge, looking south (upstream); May 31, 2017

Photo 4.33: S6 gages and culverts the day of spring measured discharge, looking northeast; June 2, 2017



S6-B (US) Peak Stage	24.47	5/31/17 2:30 PM
S6-A (DS) Peak Stage	24.28	5/31/17 5:15 PM
S6 Culverts Measured Discharge	11	6/2/17 4:35 PM
S6 Culverts Peak Discharge	20	5/31/17 12:45 AM

Graph 4.13: S6 Spring Breakup Stage and Discharge

S7 CULVERTS (GMT1-21 THROUGH GMT1-29)

The S7 gage stations and culverts are situated in a swale depression that drains approximately 0.9 square miles upstream of the culverts, including Lake L9820. Flow direction is north toward Fish Creek.

On May 26, isolated pockets of meltwater were observed in the drainage and the ice road adjacent to the south side of the GMT1 access road remained intact. Peak stage was recorded at the upstream gage, S7-B (Photo 4.34). Peak stage at S7-B was likely attributed to local meltwater which ponded upstream of the ice road and did not appear to be connected to the culverts. On May 31, peak stage was recorded at the downstream gage, S7-A. The drainage was dry on the north side of the road between the culverts and the downstream gage (Photo 4.35). PT data suggests flow through the culverts began around May 31, when the downstream gage, S7-A, experienced a relatively sharp rise in water levels coinciding with rising stage measured upstream at gage S7-B.

Spring velocity and discharge were measured at the outlets of culverts GMT1-25 (Photo 4.36). All other culverts remained dry. The velocity through this culvert was 0.3 fps. The quality of the measurement was classified as good based on open channel conditions at the time of the measurement.

S7 spring breakup stage and discharge is provided in Graph 4.14.

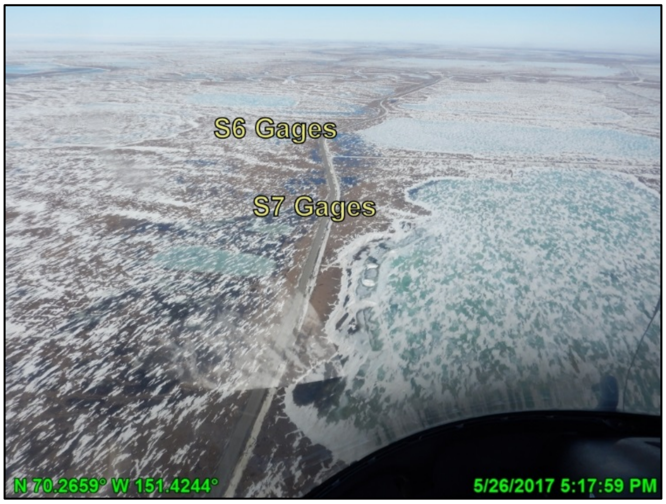


Photo 4.34: S7 gages the day of spring peak stage at gage S7-B, looking east; May 26, 2017

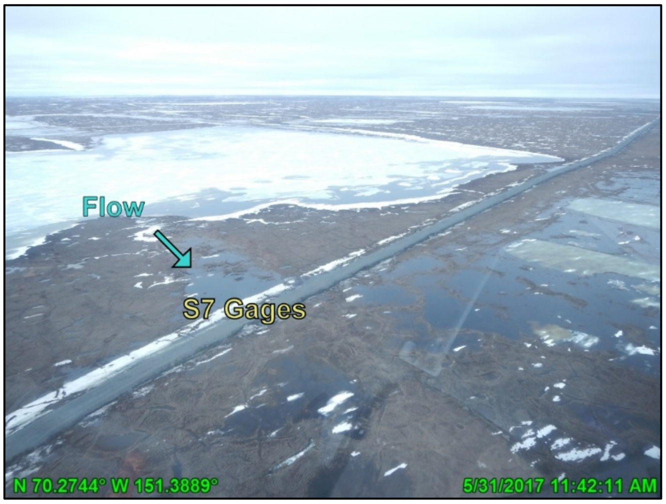
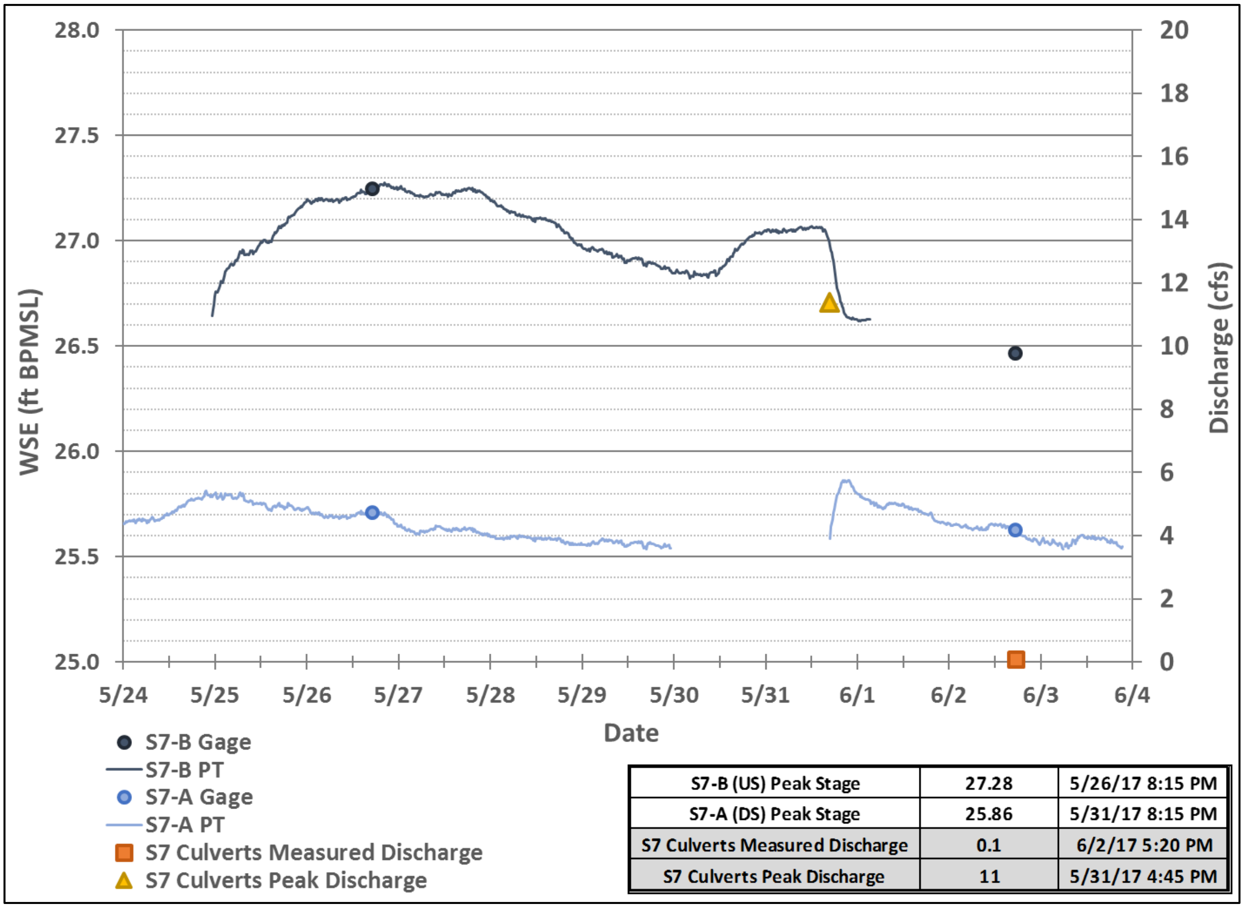


Photo 4.35: S7 gages the day of spring peak stage at gage S7-A and peak discharge, looking southwest (upstream); May 31, 2017

Photo 4.36: S7 gages the day of spring measured discharge, looking north (downstream); June 2, 2017



S7-B (US) Peak Stage	27.28	5/26/17 8:15 PM
S7-A (DS) Peak Stage	25.86	5/31/17 8:15 PM
S7 Culverts Measured Discharge	0.1	6/2/17 5:20 PM
S7 Culverts Peak Discharge	11	5/31/17 4:45 PM

Graph 4.14: S7 Spring Breakup Stage and Discharge

4.5 GMT1 PAD

The S8 gage station is located approximately 900 feet west of GMT1 pad. The gage is located in a swale downstream of Lake M9925 that drains north into Blackfish Creek, a beaded stream that drains generally northeast into Lake MC7916 and into Fish Creek. The S8 gage station has been monitored intermittently since 2009.

No rise in stage was observed at the G8 gage station. Meltwater was present but was not sufficient enough to be recordable by the PT and was related to local melt only (Photo 4.37, Photo 4.38, Photo 4.39, and Photo 4.40).

Photo 4.37: Local melt at gage S8 and GMT1 pad, looking northeast; May 26, 2017

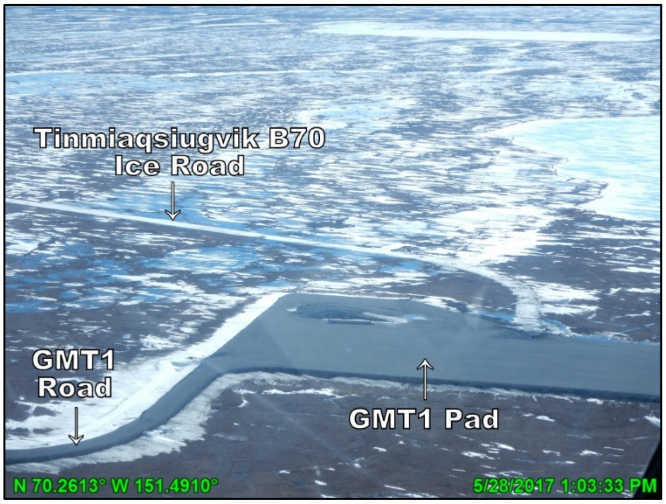


Photo 4.38: Local melt at GMT1 pad, looking south; May 28, 2017

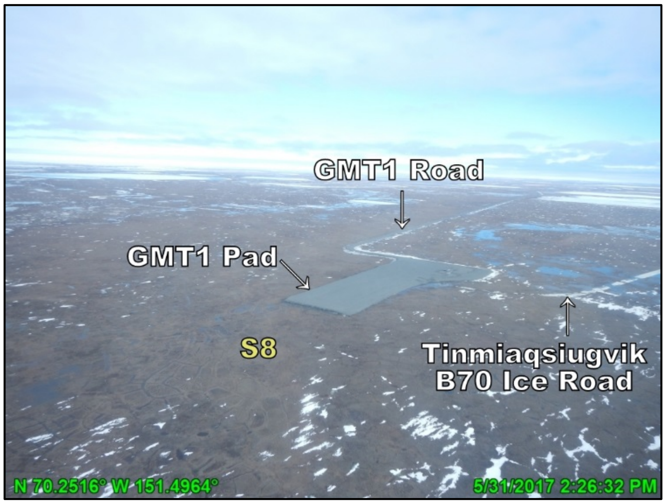


Photo 4.39: Local melt at gage S8 and GMT1 pad, looking northeast; May 31, 2017

Photo 4.40: Local melt at gage S8 and GMT1 pad, looking northeast; June 2, 2017

5. FLOOD FREQUENCY ANALYSIS

Table 5.1 presents the Tinmiaqsiugvik Bridge flood frequency analysis results from the URS peak discharge regional regression analysis (URS 2003) and the USGS peak discharge regional regression analysis (USGS 2003). This year's Tinmiaqsiugvik Bridge peak discharge of 2,800 cfs has a recurrence interval of less than 2 years based on the USGS results and 3-years based on the URS results.

Table 5.1: Tinmiaqsiugvik Bridge Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	URS Peak Discharge [1]	USGS Peak Discharge [2]
%	years	cfs	cfs
50	2	2,300	3,600
20	5	3,700	5,400
10	10	4,800	6,500
4	25	6,200	7,900
2	50	7,500	8,900
1	100	8,800	9,900
0.5	200	10,300	10,900

Notes:
[1] URS 2003
[2] USGS 2003

Table 5.2 presents the Crea Bridge and Barely Creek culvert battery flood frequency analysis results from the USGS peak discharge regional regression analysis (USGS 2003). This year's Crea Bridge peak discharge of 70 cfs and Barely Creek culvert battery peak discharge of 4.1 cfs have recurrence intervals of less than 2 years.

Table 5.2: Crea Bridge and Barely Creek Culvert Battery Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge [1]	
		Crea Bridge	Barely Creek Culvert Battery
%	years	cfs	cfs
50	2	100	40
20	5	160	70
10	10	200	90
4	25	260	120
2	50	290	140
1	100	330	160
0.5	200	370	180

Notes:
[1] USGS 2003

The recurrence intervals should be considered with respect to conditions at the time of peak discharge. Detailed USGS regression analysis results are provided in Appendix E.

6. DRAINAGE STRUCTURE PERFOMANCE EVALUATION

No performance issues were identified at any bridges or culverts conveying flow along the GMT1 access road. Temporary ponded water was present in drainages at several locations along the access road but was attributed to ice roads and snow along the road embankment. Once conveyance paths were established through the ice roads and drifted snow, the bridges and culverts all performed as designed and natural drainage patterns were maintained.

Construction fill was observed at the inlet and outlet of culvert GMT1-26 and should be removed to maintain an open conveyance path. A new culvert east of Crea Creek, GMT1-39A, was installed in the summer. Otherwise, no discernable culvert maintenance, repair, upgrade, setting adjustments, and/or replacements are recommended based on ground assessments and aerial observations.

7. POST-BREAKUP CONDITIONS ASSESSMENT

Post-breakup conditions assessment of Tinmiaqsiugvik Bridge and Crea Bridge abutments and bank conditions on each side of the GMT1 access road, Barely Creek culvert battery inlets and outlets, GMT1 access road culverts, and the GMT1 pad was conducted throughout the summer. No displacement of uncompacted gravel fill attributed with spring breakup flooding was observed along the road embankment, around culvert inlets and outlets, or around bridge abutments. There were no signs of sloughing or undermining at drainage structures and no channel changes were observed at the crossings. Additional photo documentation of post-breakup conditions is provided in Appendix D.1.

Photo 7.1: Crea Bridge right (east) abutment, looking northeast (downstream); June 29, 2017

Photo 7.2: Tinmiaqsiugvik Bridge right (east) abutment and east bank, looking southeast (upstream); June 29, 2017

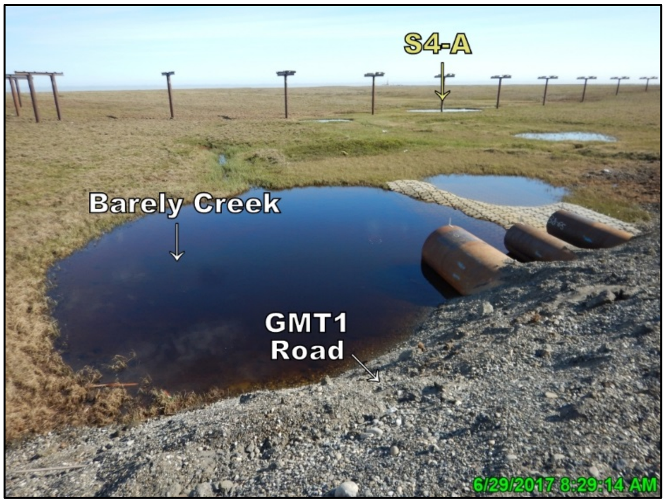


Photo 7.3: Barely Creek culvert battery outlet, looking northeast (downstream); June 29, 2017

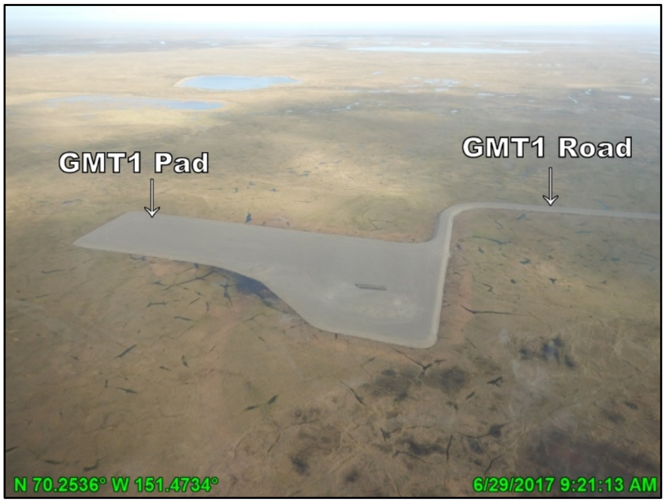


Photo 7.4: GMT1 pad, looking northwest; June 29, 2017

8. ICE ROAD CROSSINGS BREAKUP

Ice roads are constructed annually for ground transportation of supplies and equipment to Alpine facilities. Aerial surveys were conducted during spring breakup to observe and document the progression of melting and degradation of the ice road crossings. To facilitate melt and the progression of breakup flooding, ice road crossings are mechanically slotted at the conclusion of the winter season.

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

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Appendix A GAGE LOCATIONS & VERTICAL CONTROL

Gage Assembly	Gage Assembly Location		Associated Vertical Control	Vertical Control Elevation (ft BPMSL)	Vertical Control Location	
	Latitude (NAD83)	Longitude (NAD83)			Latitude (NAD83)	Longitude (NAD83)
S2-A[1]	70.3048	-151.2198	MON-32	27.546	70.3022	-151.2331
S2-B[1]	70.3041	-151.2199				
S3-A[1]	70.2961	-151.2368				
S3-B[1]	70.2959	-151.2350				
S4-A[1]	70.2817	-151.2922	MON-37	25.395	70.2801	-151.3018
S4-C[1]	70.2804	-151.2955				
S5-A[1]	70.2804	-151.3306	PBM-39	25.247	70.2792	-151.3325
S5-C[1]	70.2792	-151.3302				
S6-A[1]	70.2772	-151.3686	MON-40	28.267	70.2764	-151.3639
S6-B[1]	70.2765	-151.3677				
S7-A[1]	70.2723	-151.3929	MON-41	29.870	70.2709	-151.3948
S7-B[1]	70.2711	-151.3924				
S8-A[1]	70.2543	-151.4943	PBM-11	42.481	70.2559	-151.4896
UB6.7-A[1]	70.2856	-151.2626	PBM-35	15.957	70.2832	-151.2620
UB6.7-B[1]	70.2855	-151.2627				
UB6.7-C	70.2852	-151.2632				
UB6.7-D	70.2852	-151.2633				
UB6.9-A[1]	70.2834	-151.2578				
UB6.9-B[1]	70.2830	-151.2571				

Notes:
*Historical location
[1] Pressure transducer

Appendix B PT SETUP & TESTING METHODS

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

The PTs were tested before field mobilization. The PTs were configured using Win-Situ® LT 5.6.21.0 (for the Level TROLL 500s) or Solinst Levelogger® v4.0.3 (for the Solinst Leveloggers) software prior to placement in the field. Absolute pressure was set to zero. The PT sensor was surveyed during setup to establish a vertical datum using local control.

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

Appendix C VELOCITY & DISCHARGE METHODS, SITE SPECIFIC DATA, PLANS, & PROFILES

C.1 METHODS

C.1.1 MEASURED VELOCITY & DISCHARGE

1) STANDARD USGS MIDSECTION TECHNIQUES

Flow depth and velocity measurements were taken from the upstream side of the Tinmiaqsiugvik Bridge deck 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 counter weight. 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 and summer monitoring in accordance with USGS precise standards. A spin test of the meter was completed prior to and after the 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.

Flow depth and velocity measurements were taken approximately 10 feet downstream of the Crea Bridge using an electromagnetic velocity meter attached to a wading rod. The accuracy of the 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 cross section geometry.

2) USGS VELOCITY/AREA TECHNIQUE

Standard USGS velocity/area techniques (USGS 1968) were used to measure flow depth and velocity to determine discharge at the culvert outlets. Flow depth and velocity were measured using an electromagnetic velocity meter attached to a wading rod. The accuracy of the 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.

C.1.2 INDIRECT VELOCITY & DISCHARGE

1) CULVERTS

Bentley CulvertMaster® software was used to calculate spring and summer velocity through the Barely Creek culvert battery and spring velocity and discharge through the additional GMT1 road culverts. Barely Creek spring and summer discharge was calculated using the normal depth method and a cross section profiled during a 2011 direct discharge measurement performed downstream of the road. Velocities through each Barely Creek culvert were calculated using distributed flow based on the flow distribution at the time of direct measurement. Timing and magnitude of velocity and discharge through the culverts were determined based on recorded stage on both sides of the road prism. Peak velocity and discharge results were evaluated against visual assessment of performance, when available. Velocity and discharge through the culverts assumes ice-free open-water conditions and were estimated based on several variables, including:

- Headwater and tailwater elevations at each culvert (hydraulic gradient)
- Culvert diameter and length from UMIAQ as-built surveys (UMIAQ 2017a)
- Culvert Manning's roughness coefficients (0.013 for smooth steel)
- Culvert invert elevations (surveyed by UMIAQ summer 2017)
- For Barely Creek, spring and summer culvert upstream and downstream invert elevations (surveyed by Michael Baker spring 2017 and UMIAQ summer 2017)

2) NORMAL DEPTH

The Normal Depth method (Chow 1959) was used to calculate peak velocity and discharge at the Tinmiaqsiugvik Bridge and Crea Bridge using channel cross section geometry and stage differential between gage sites as an estimate for the energy gradient. Velocity was calculated as a function of discharge and cross-sectional flow area and represents an average for the cross-section.

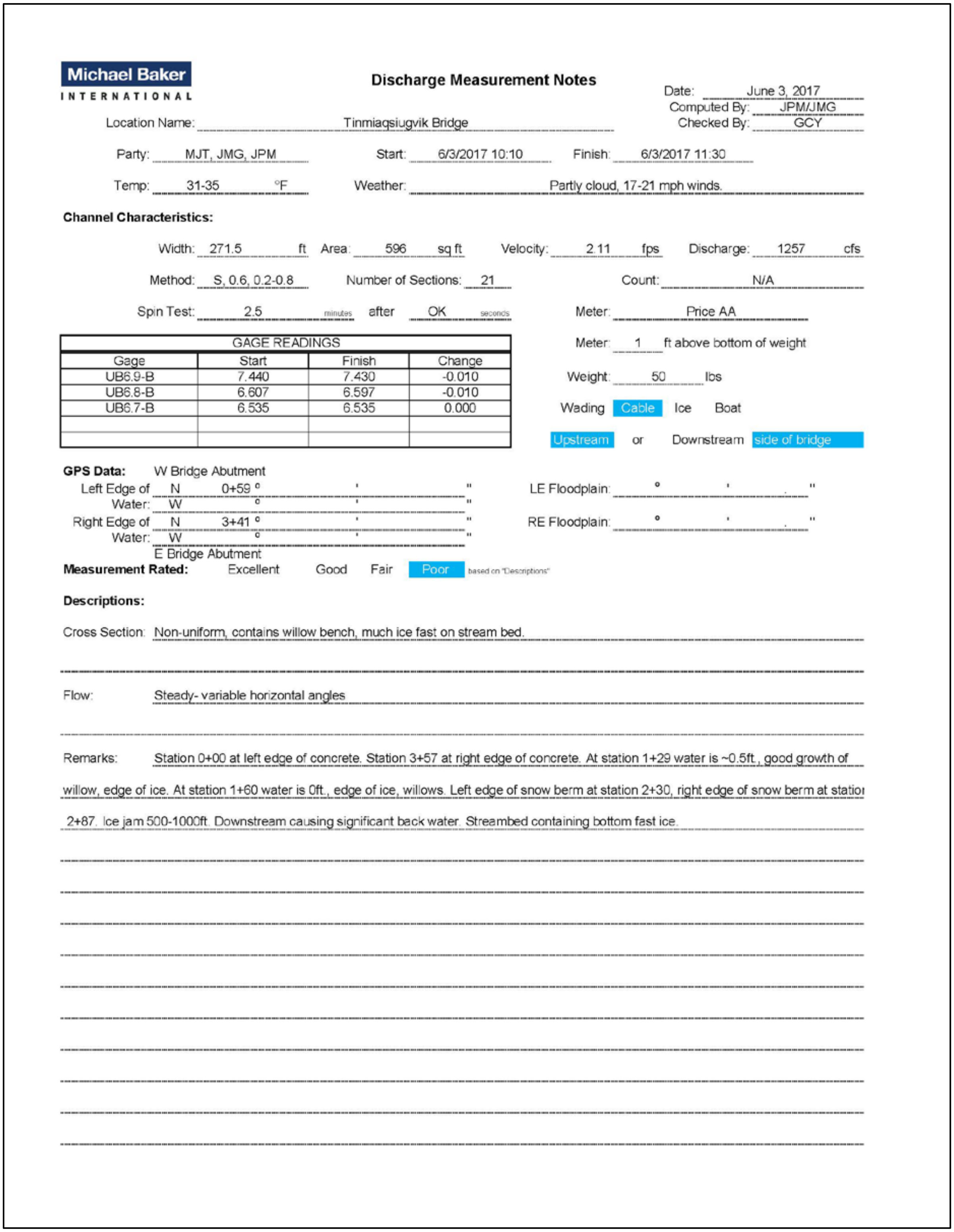
Cross sectional geometry for the Tinmiaqsiugvik Bridge and Crea Bridge was surveyed by Michael Baker during spring breakup and summer 2017. Stage and energy gradient data were obtained from observations, gage data, and PT data.

Different cross-sections were used to calculate flow and velocity at the Tinmiaqsiugvik Bridge. This was done to account for spring (ice-affected) conditions and for summer (open channel) conditions. Cross-sectional area of the main channel was used for spring breakup velocity calculations because it passed the majority of flow, i.e. overbank areas were not included in the cross-section for the purposes of average velocity calculations. Cross-sectional area of the entire channel was used for summer velocity calculations because flow was generally not present in the overbank areas.

C.2 SITE SPECIFIC DATA, PLANS, & PROFILES

C.2.1 TINMIAQSIUGVIK BRIDGE

1) SPRING BREAKUP MEASURED VELOCITY & DISCHARGE



Michael Baker
INTERNATIONAL

Discharge Measurement Notes

Date: June 3, 2017
Computed By: JPM/JMG
Checked By: GCY

Location Name: Tinmiaqsiugvik Bridge

Party: MJT, JMG, JPM   Start: 6/3/2017 10:10   Finish: 6/3/2017 11:30

Temp: 31-35 °F   Weather: Partly cloud, 17-21 mph winds.

Channel Characteristics:

Width: 271.5 ft   Area: 596 sq ft   Velocity: 2.11 fps   Discharge: 1257 cfs

Method: S, 0.6, 0.2-0.8   Number of Sections: 21   Count: N/A

Spin Test: 2.5 minutes after OK seconds   Meter: Price AA

GAGE READINGS			
Gage	Start	Finish	Change
UB6.9-B	7.440	7.430	-0.010
UB6.8-B	6.607	6.597	-0.010
UB6.7-B	6.535	6.535	0.000

Meter: 1 ft above bottom of weight

Weight: 50 lbs

Wading [✓ Cable] Ice Boat

[✓ Upstream] or Downstream side of bridge

GPS Data: W Bridge Abutment
Left Edge of Water: N 0+59 ° ' " W ° ' "
Right Edge of Water: N 3+41 ° ' " W ° ' "
E Bridge Abutment

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

Measurement Rated: Excellent Good Fair [✓ Poor] based on "Descriptions"

Descriptions:

Cross Section: Non-uniform, contains willow bench, much ice fast on stream bed.

Flow: Steady- variable horizontal angles

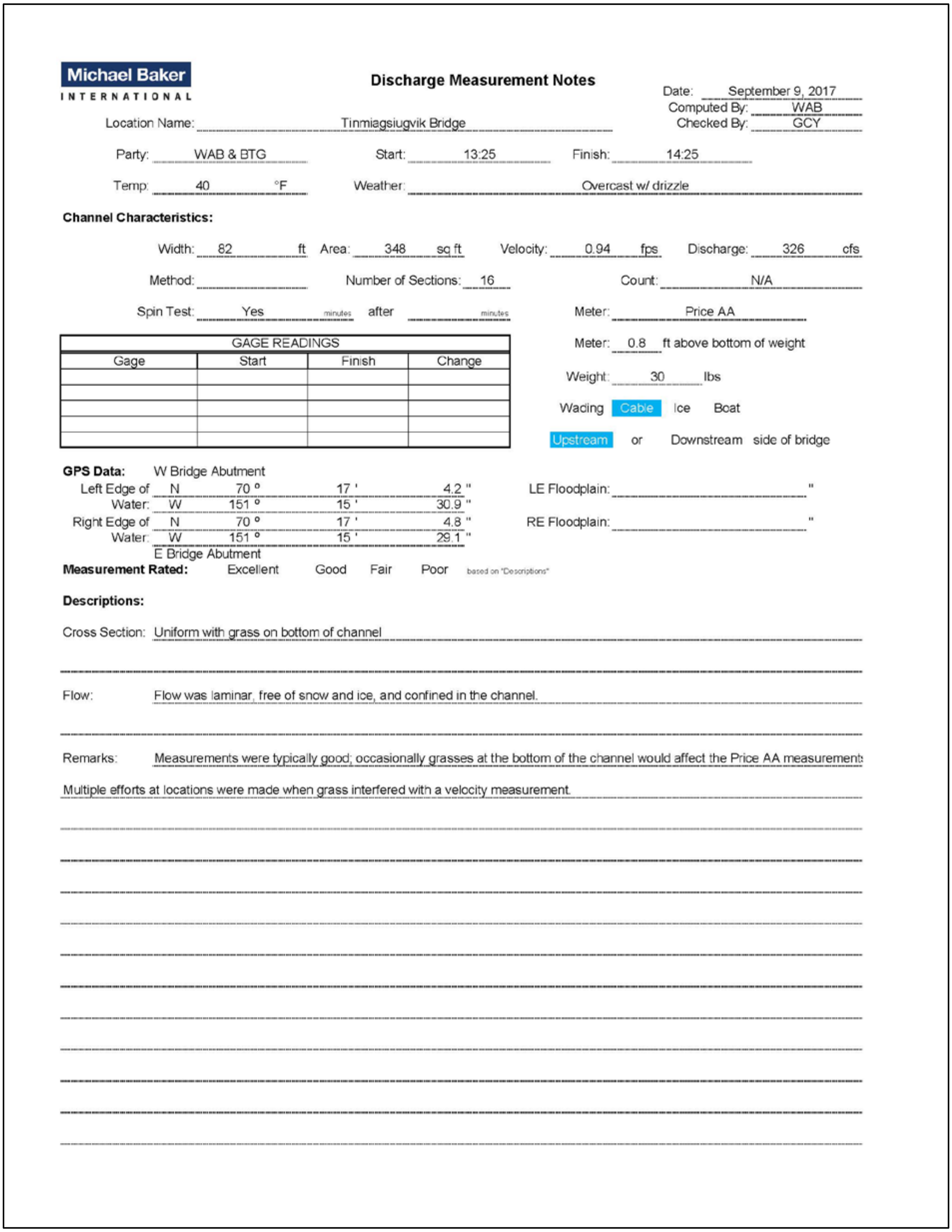
Remarks: Station 0+00 at left edge of concrete. Station 3+57 at right edge of concrete. At station 1+29 water is ~0.5ft., good growth of willow, edge of ice. At station 1+60 water is 0ft., edge of ice, willows. Left edge of snow berm at station 2+30, right edge of snow berm at statio 2+87. Ice jam 500-1000ft. Downstream causing significant back water. Streambed containing bottom fast ice.

Tinmiaqsiugvik Bridge
June 3, 2017

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY			Area (s.f.)	Discharge (cfs)
							At Point (fps)	Mean in Vertical (fps)	Adjusted for Angle Coeff (fps)		
LEW @ 10:10											
	59		0.0								
1	70	18.5	1.3	0	30	44	1.53	1.53	1.53	24.1	36.88
1	85	15.0	1.6	0	25	43	1.31	1.31	1.31	24.0	31.44
1	100	15.0	1.9	0	25	46	1.23	1.23	1.23	28.5	34.94
1	115	42.5	1.5	0	30	41	1.64	1.64	1.64	63.8	104.82
	185	42.5	0.3	0							
0.98	200	17.5	1.0	0	20	51	0.89	0.89	0.87	17.5	15.26
0.7	220	22.5	1.4	0	25	48	1.18	1.18	0.82	31.5	25.92
0.5	245	20.0	2.4	0.6	20	40	1.13	1.13	0.56	48.0	27.10
0.4	260	17.5	2.7	0.6	25	46	1.23	1.23	0.49	47.3	23.17
0.5	280	15.0	2.8	0.6	20	46	0.98	0.98	0.49	42.0	20.67
0.99	290	7.5	2.9	0.6	50	47	2.38	2.38	2.36	21.8	51.30
1	295	5.0	9.7	0.2 0.8	80 60	45 40	3.97 3.35	3.66	3.66	48.5	177.53
1	300	5.0	9.8	0.2 0.8	85 67	41 41	4.63 3.65	4.14	4.14	49.0	202.75
1	305	5.0	9.6	0.2 0.8	80 68	42 42	4.25 3.62	3.93	3.93	48.0	188.82
1	310	5.0	9.6	0.2 0.8	80 74	44 48	4.06 3.44	3.75	3.75	48.0	180.08
1	315	5.0	7.0	0.2 0.8	62 54	45 44	3.08 2.75	2.91	2.91	35.0	101.95
1	320	13.0	1.5	0	33	42	1.76	1.76	1.76	19.5	34.40
	341		0.0								
REW @ 11:30											

Total Discharge: **1257.03** cfs

2) SUMMER MEASURED VELOCITY & DISCHARGE



Michael Baker INTERNATIONAL

Discharge Measurement Notes

Date: September 9, 2017
Computed By: WAB
Checked By: GCY

Location Name: Tinmiagsiugvik Bridge

Party: WAB & BTG Start: 13:25 Finish: 14:25

Temp: 40 °F Weather: Overcast w/ drizzle

Channel Characteristics:

Width: 82 ft Area: 348 sq ft Velocity: 0.94 fps Discharge: 326 cfs

Method: Number of Sections: 16 Count: N/A

Spin Test: Yes minutes after minutes Meter: Price AA

Meter: 0.8 ft above bottom of weight

Weight: 30 lbs

Wading [✓ Cable] Ice Boat

[✓ Upstream] or Downstream side of bridge

GAGE READINGS			
Gage	Start	Finish	Change

GPS Data: W Bridge Abutment

Left Edge of	N	70 °	17 '	4.2 "
Water:	W	151 °	15 '	30.9 "
Right Edge of	N	70 °	17 '	4.8 "
Water:	W	151 °	15 '	29.1 "

E Bridge Abutment

LE Floodplain: "

RE Floodplain: "

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

Descriptions:

Cross Section: Uniform with grass on bottom of channel

Flow: Flow was laminar, free of snow and ice, and confined in the channel.

Remarks: Measurements were typically good; occasionally grasses at the bottom of the channel would affect the Price AA measurements
Multiple efforts at locations were made when grass interfered with a velocity measurement.

Tinmiagsiugvik Bridge
September 9, 2017

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
LEW @ START TIME											
	248	252.0	0.0								
1	256	11.0	2.9	1.74	14	51	0.63	0.63	0.63	31.9	20.04
1	262	5.5	3.6	2.16	15	49	0.70	0.70	0.70	19.8	13.83
1	267	5.0	4.1	0.82 2.46	16 26	62 60	0.59 0.98	0.79	0.79	20.5	16.12
1	272	5.0	4.2	0.84 2.52	13 22	53 49	1.10 1.02	1.06	1.06	21.0	22.25
1	277	5.0	4.4	0.88 2.64	14 23	54 48	0.59 1.08	0.84	0.84	22.0	18.45
0.99	282	5.0	4.7	0.94 2.82	14 25	62 57	1.02 0.99	1.00	0.99	23.5	23.38
1	287	5.0	4.7	0.94 2.82	12 25	57 49	0.95 1.15	1.05	1.05	23.5	24.69
1	292	5.0	4.7	0.94 2.82	14 30	44 48	0.73 1.41	1.07	1.07	23.5	25.05
1	297	5.0	4.5	0.9 2.7	17 30	47 48	0.82 1.41	1.11	1.11	22.5	25.08
1	302	5.0	6.0	1.2 3.6	15 28	48 46	0.71 1.37	1.04	1.04	30.0	31.25
1	307	5.0	6.3	1.26 3.78	14 28	53 50	0.61 1.26	0.93	0.93	31.5	29.42
1	312	5.0	5.0	1 3	13 24	45 41	0.66 1.32	0.99	0.99	25.0	24.74
1	317	5.0	4.5	0.9 2.7	12 22	52 43	1.04 1.16	1.10	1.10	22.5	24.68
1	322	5.0	3.9	2.34	20	52	0.87	0.87	0.87	19.5	17.02
1	327	5.5	2.0	1.2	20	49	0.93	0.93	0.93	11.0	10.18
1	333	5.0	0.0	0 0							
1	337	4.5	+1.2								
1.00	342	6.0	+3.9								
1	349	5.0	+2.2								
1	352	-174.5	+5.3								
REW @ END TIME											

Total Discharge: **326.18** cfs

3) SPRING BREAKUP & SUMMER CALCULATED DISCHARGE

Discharge was calculated using the Normal Depth method. The June 3 direct discharge measurement cross-section was used for spring indirect discharge calculations and the September 9 direct discharge measurement cross-section was used for summer indirect discharge calculations. During spring breakup, flow was split by a large snow berm on the north side of the bridge; this geometry was incorporated into spring indirect calculations. The energy gradient used for both seasons was estimated from WSEs at the UB6.7 and UB6.9 gage stations. The spring indirect calculations Manning’s n values used for indirect calculations were 0.024 for the left overbank related to the presence of bedfast ice, 0.038 for the main channel, and 0.073 for the right overbank related to heavy brush. These values were calibrated based on the direct measurement. The summer indirect discharge Manning’s n values were 0.035 for the right and left portions of the main channel, and 0.03 for the thalweg.

4) PLAN & CROSS SECTION PROFILE

ConocoPhillips Alaska

Feet

0 125 250

Date:	11/01/2017	Project:	158968
Drawn:	BTG	File:	2017_GMT1_8x11L_TINMIAQSIUGVIK.mxd
Checked:	GCY	Scale:	1 in = 250 feet

Legend

● Gage Location	— Road
—+— 2017 Cross Section Alignment	

Imagery Source: ConocoPhillips Alaska, 2015

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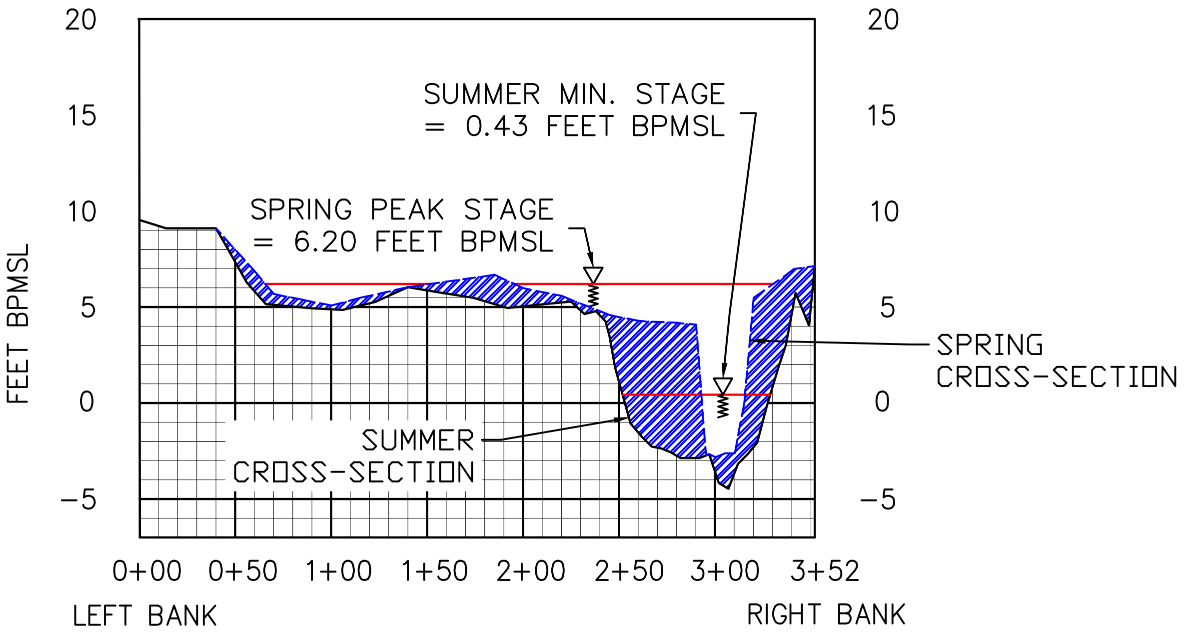
2017 SPRING BREAKUP TINMIAQSIUGVIK RIVER PLAN

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, PBM-35.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2017 BY MICHAEL BAKER INTL.

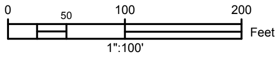


LEGEND

▨ ICE/SNOW

⊞ NATURAL GROUND/CREEK BED

① GMT1 CROSSING – TINMIAQSIUGVIK BRIDGE CROSS-SECTION



ConocoPhillips
Alaska, Inc.

DATE:	10/12/2017	PROJECT:	158968
DRAWN:	DTR	FILE:	TINMIAQSIUGVIK X-SECTION.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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2017 SPRING BREAKUP
TINMIAQSIUGVIK RIVER
PROFILE

(SHEET 2 OF 2)

C.2.2 CREA BRIDGE

1) SPRING BREAKUP MEASURED VELOCITY & DISCHARGE

Date:	6/2/2017	**Time:**	2:00 PM	**Method:**	USGS cross section	**Measurement Rating:**
Loc:	North side of Crea Bridge	**Crew:**	DTR, WAB, & GCY	**Observed Depth:**	Water Surface	Fair
Lat:	N 70.280°	**Long:**	W 151.330°	**Equip:**	Sontek Flow Tracker	

Station (ft)	**Measured Depth (ft)**	**Velocity (ft/s)**	**Section Width (ft)**	**Area (ft²)**	**Discharge (ft³/s)**	**Note**
0+00.0	17.474	-	-	-	-	Left edge of water
0+02.0	16.574	0.05	2	33.15	1.66	
0+04.0	16.124	0.00	2	32.25	0.00	Willow and grass influenced
0+06.0	15.974	0.04	2	31.95	1.28	Willow and grass influenced
0+08.0	15.924	0.10	2	31.85	3.18	Willow and grass influenced
0+10.0	15.774	0.01	2	31.55	0.32	Willow and grass influenced; High Mean signal to noise ratio (SNR)
0+12.0	15.574	0.07	1.5	23.36	1.64	Willow and grass influenced; High velocity angle -30
0+13.0	15.524	0.07	1	15.52	1.09	Willow and grass influenced; High velocity angle -34
0+14.0	15.474	0.62	1	15.47	9.59	Willow and grass influenced; Large signal to noise ratio (SNR)
0+15.0	15.324	1.90	1	15.32	29.12	
0+16.0	15.274	2.06	1.5	22.91	47.20	
0+18.0	14.874	2.48	1.5	22.31	55.33	Thalweg
0+19.0	14.474	2.47	1	14.47	35.75	
0+20.0	14.974	2.51	1	14.97	37.58	
0+21.0	15.224	2.79	1	15.22	42.47	
0+22.0	15.674	2.47	1	15.67	38.71	
0+23.0	15.974	1.28	1	15.97	20.45	
0+24.0	16.274	0.10	1.5	24.41	2.44	Willows
0+26.0	16.374	0.02	3	49.12	0.98	Willows
0+30.0	16.374	0.08	4	65.50	5.24	Willows
0+34.0	16.574	0.24	4	66.30	15.91	Willows
0+38.0	17.124	0.00	3	51.37	0.00	Willows
0+40.0	17.474	-	-	-	-	Right edge of water; Willows

Notes:

1. Measurement performed approximately 10 feet downstream of Crea Bridge.

Total Width (ft)	**Average Depth (ft)**	**Average Velocity (ft/s)**	-	**Total Area (ft²)**	**Total Discharge (ft³/s)**
40.0	15.8	0.92	-	608.7	349.9

2) SPRING BREAKUP & SUMMER CALCULATED DISCHARGE

Discharge was calculated using the Normal Depth method. The June 2 direct discharge measurement was performed during open channel conditions so the spring cross-section was used for spring and summer calculations. The energy gradient used for both seasons was estimated from WSEs at the S5-C and S5-A gage stations. The spring indirect calculations Manning's n values were 0.150 for the left overbank, 0.035 for the main channel, and 0.100 for the right overbank. Overbank values are high because of heavy willows and brush. Roughness values were calibrated based on the spring direct measurement.

3) PLAN & CROSS SECTION PROFILE

ConocoPhillips
Alaska

Feet
0 62.5 125

Date:	11/01/2017	Project:	158968
Drawn:	BTG	File:	2017_GMT1_8x11L_CREA_CREEK.mxd
Checked:	GCY	Scale:	1 in = 125 feet

Legend

● Gage Location

— Road

— 2017 Cross Section Alignment

Imagery Source: ConocoPhillips Alaska, 2015

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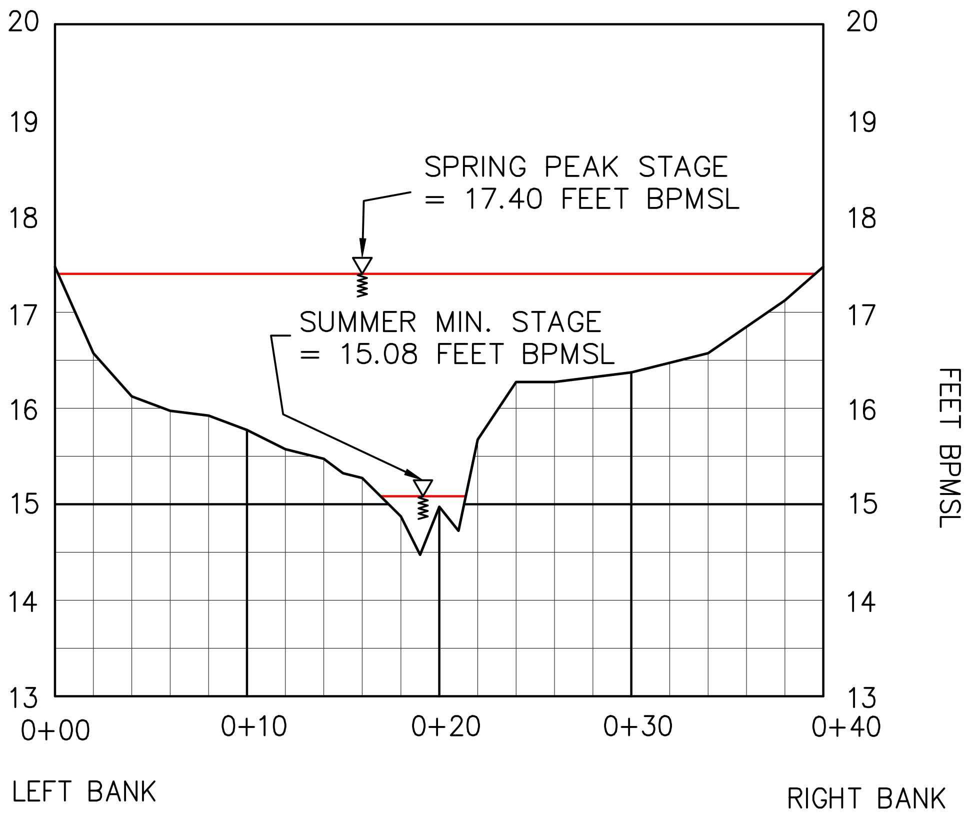
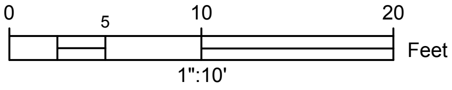
2017 SPRING BREAKUP
CREA CREEK
PLAN

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, PBM–39.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED JUNE 2017 BY MICHAEL BAKER INTL.





① GMT1 CROSSING –CREA BRIDGE CROSS–SECTION

ConocoPhillips
Alaska, Inc.

DATE:	10/12/2017	PROJECT:	158968
DRAWN:	DTR	FILE:	CREA X-SECTION.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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2017 SPRING BREAKUP
CREA CREEK
PROFILE

(SHEET 2 OF 2)

C.2.3 BARELY CREEK CULVERT BATTERY

1) PLAN & CROSS SECTION PROFILE

ConocoPhillips
Alaska

Feet
0 62.5 125

Date: 11/03/2017	Project: 158968
Drawn: BTG	File: 2017_GMT1_8x11L_BARELY_CREEK.mxd
Checked: GCY	Scale: 1 in = 125 feet

Legend

- ● Gage Location
- ▬ Road
- ⊢ 2011 Cross Section Alignment

Imagery Source: ConocoPhillips Alaska, 2015

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INTERNATIONAL

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Fax: (907) 273-1699

2017 SPRING BREAKUP
BARELY CREEK
PLAN

(SHEET 1 of 2)

C.2.4 CULVERTS

1) SPRING BREAKUP MEASURED VELOCITY & DISCHARGE

Gage Station	Culvert	Measurement Date & Time	Total Depth of Flow (ft)	Measured Depth of Flow[1,2] (ft)	Flow Depth	Measured Velocity (ft/s)	Calculated Discharge (cfs)	Total Discharge (cfs)
S7	GMT1-25	6/2/17 5:20 PM	0.30	0.12	Less than Half Full	0.3	0.1	0.1
S6	GMT1-31	6/2/17 4:25 PM	1.30	0.52	Less than Half Full	1.8	5	11
	GMT1-32	6/2/17 4:35 PM	1.15	0.46	More than Half Full	1.9	3	
	GMT1-33	6/2/17 4:45 PM	0.90	0.36	More than Half Full	2.1	3	
S4 (Barely Creek)	GMT1-42	6/2/17 5:40 PM	2.25	0.90	Less than Half Full	0.1	1	1
	GMT1-43	6/2/17 5:45 PM	0.55	0.22	Less than Half Full	0.7	1	
	GMT1-44	6/2/17 5:49 PM	0.30	0.12	Less than Half Full	0.6	0.2	
S2	GMT1-65	6/3/17 4:26 PM	0.60	0.24	Less than Half Full	3.3	3	7
	GMT1-66	6/3/17 4:23 PM	0.55	0.22	Less than Half Full	0.4	0.3	
	GMT1-67	6/3/17 4:10 PM	0.70	0.28	Less than Half Full	1.1	1	
	GMT1-68	6/3/17 4:00 PM	1.15	0.46	Less than Half Full	0.4	1	
	GMT1-69	6/3/17 3:45 PM	1.00	0.40	Less than Half Full	0.6	1	

Notes:

[1] Measurement taken at 0.6 of total depth of flow

2. GMT1-25, GMT1-32, and GMT1-33 are 24” in diameter, GMT1-31, GMT1-43, and GMT1-44 are 36” in diameter, GMT1-42 is 60” in diameter

2) SPRING BREAKUP CALCULATED VELOCITY & DISCHARGE

Gage Station	Culvert	Calculated Date & Time	WSE Differential[1] (ft)	Total Depth of Flow (ft)	Flow Depth	Calculated Velocity (ft/s)	Calculated Discharge (cfs)	Total Discharge (cfs)
S7	GMT1-25	5/31/17 4:45 PM	1.39	1.2	More than Half Full	5.9	11	11
S6	GMT1-31	5/31/17 12:45 AM	0.25	1.3	Less than Half Full	2.9	8	20
	GMT1-32			2.2	More than Half Full	2.3	6	
	GMT1-33			1.7	More than Half Full	2.4	6	
S4 (Barely Creek)	GMT1-42	5/31/17 10:45 AM	2.01	0.4	Less than Half Full	2.9	1.9	4
	GMT1-43			0.4	Less than Half Full	3.0	1.7	
	GMT1-44			0.2	Less than Half Full	2.3	0.6	
	GMT1-42	6/2/17 5:45 PM[2]	1.36	0.7	Less than Half Full	3.87	6	6
	GMT1-43			-	More than Half Full	-	-	
	GMT1-44			-	More than Half Full	-	-	
S2	GMT1-65	5/25/17 6:45 PM	0.46	0.8	Less than Half Full	4.3	6	50
	GMT1-66			0.7	Less than Half Full	2.3	3	
	GMT1-67			1.5	More than Half Full	3.5	12	
	GMT1-68			2.0	More than Half Full	3.3	16	
	GMT1-69			1.6	More than Half Full	3.6	13	

Notes:

[1] Between US and DS gages

[2] Calculated indirectly for conditions at the same time as direct measurement

Appendix D ADDITIONAL PHOTOGRAPHS

D.1 POST-BREAKUP CONDITIONS ASSESSMENT

D.1.1 BARELY CREEK

Photo D.1: Barely Creek culvert battery, looking southwest (upstream); June 28, 2017

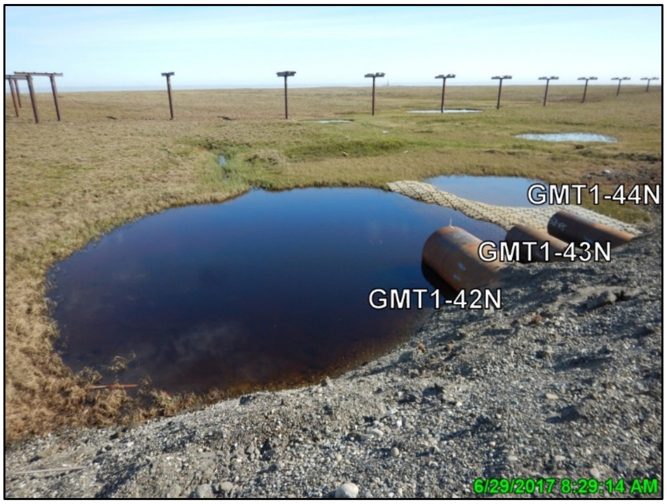

Photo D.2: Barely Creek culvert battery outlet, looking northeast (downstream); June 29, 2017

Photo D.3: Barely Creek culvert battery outlet, looking northwest; September 7, 2017

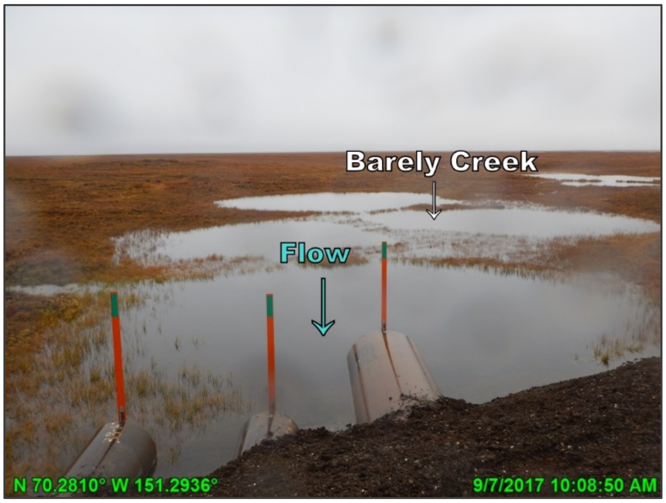

Photo D.4: Barely Creek culvert battery inlet, looking south (upstream); September 7, 2017

D.1.2 CREA CREEK

Photo D.5: Crea Creek at the conclusion of breakup monitoring, looking southeast (upstream); June 8, 2017

Photo D.6: Crea Creek, looking south (upstream); June 28, 2017

Photo D.7: Crea Bridge right (east) abutment, looking northeast (downstream); June 29, 2017

Photo D.8: Flow under Crea Bridge, looking north (downstream); June 29, 2017

Photo D.9: Crea Bridge left (west) abutment, looking northwest (downstream); August 23, 2017

D.1.3 TINMIAQSIUGVIK RIVER

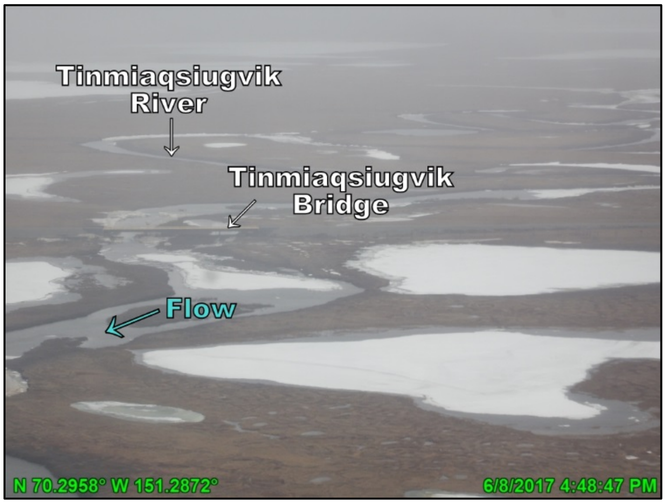

Photo D.10: Tinmiaqsiugvik River at the conclusion of breakup monitoring, looking southeast (upstream); June 8, 2017

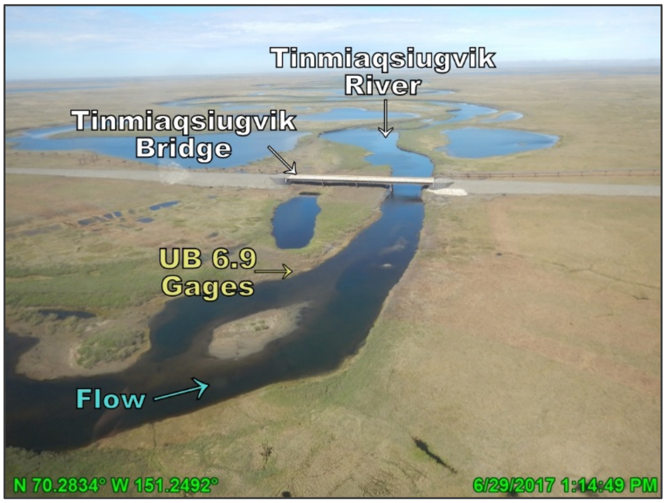

Photo D.11: Tinmiaqsiugvik River, looking northwest (downstream); June 29, 2017

Photo D.12: Tinmiaqsiugvik River, looking southwest (upstream); June 29, 2017

Photo D.13: Tinmiaqsiugvik Bridge right (east) abutment, looking northeast; June 29, 2017

Photo D.14: Tinmiaqsiugvik Bridge left (west) abutment, looking northwest; June 29, 2017

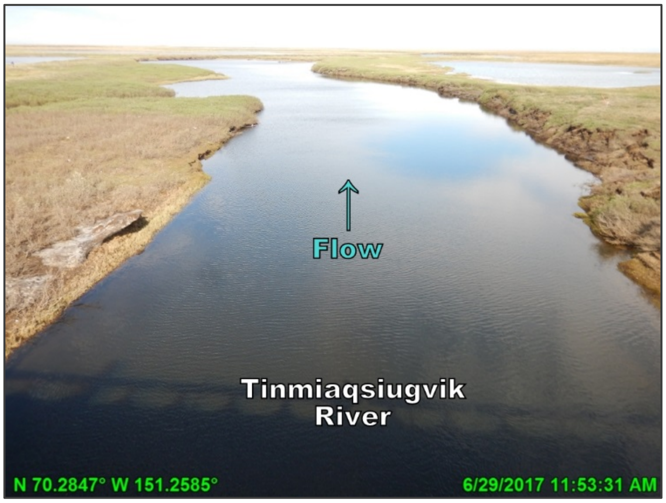

Photo D.15: Tinmiaqsiugvik River from Tinmiaqsiugvik Bridge, looking northwest (downstream); June 29, 2017

Photo D.16: Tinmiaqsiugvik River from Tinmiaqsiugvik Bridge, looking southeast (upstream); June 29, 2017

D.1.4 S2 & S3 CULVERTS

Photo D.17: S3 gages and culverts, looking west; June 3, 2017

Photo D.18: S2 gages and culverts, looking west; June 29, 2017

Photo D.19: S3 gages and culverts, looking west; June 29, 2017

Photo D.20: S3 culverts GMT1-57 through 59, looking east; June 29, 2017

D.1.5 S6 CULVERTS

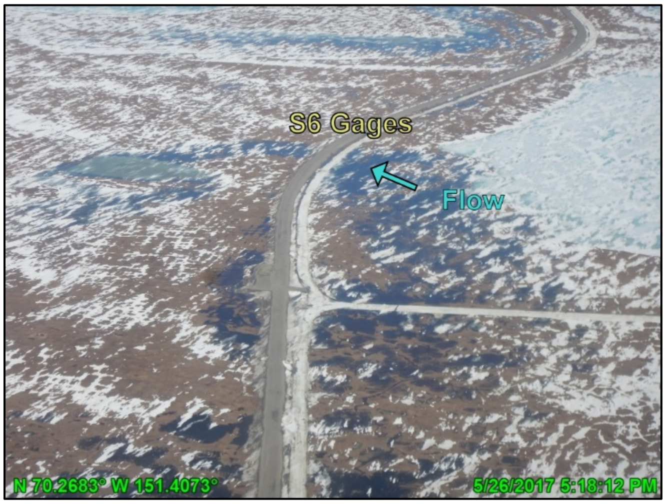

Photo D.21: S6 gages and culverts, looking east; May 26, 2017

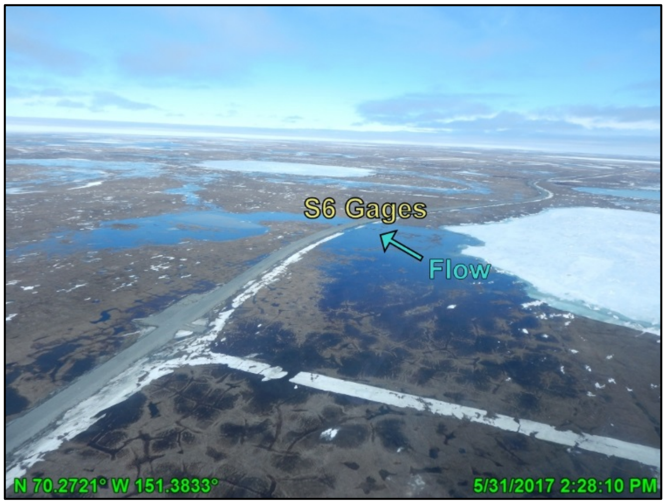

Photo D.22: S6 gages and culverts, looking northeast; May 31, 2017

Photo D.23: S6 and S7 gages and culverts, looking west; June 1, 2017

Photo D.24: S6 gages and culverts, looking west; June 2, 2017

Photo D.25: S6 gages and culverts, looking east; June 2, 2017

Photo D.26: S6 gages and culverts, looking west; June 3, 2017

Photo D.27: S6 gages and culverts, looking east; June 29, 2017

Photo D.28: S6 culverts GMT1-31 through 33, looking east; June 29, 2017

Photo D.29: S6 gages and culverts, looking northwest; June 29, 2017

D.1.6 S7 CULVERTS

Photo D.30: S7 gages and culverts, looking east; May 31, 2017

Photo D.31: S7 gages and culverts, looking west; June 1, 2017

Photo D.32: S7 gage and culverts, looking east; June 2, 2017

Photo D.33: S7 culvert GMT1-25, looking south; June 2, 2017

Photo D.34: S7 gages and culverts, looking northwest; June 29, 2017

Photo D.35: S7 gages and culverts, looking southeast; June 29, 2017

Photo D.36: S7 gages and culverts, looking west; June 29, 2017

D.2 ICE ROAD CROSSINGS BREAKUP

D.2.1 CREA CREEK

Photo D.37: Crea Creek pre-breakup, looking northwest; May 24, 2017

Photo D.38: Crea Creek during breakup, looking southwest; May 31, 2017

Photo D.39: Crea Creek post-breakup, looking north (downstream); June 2, 2017

D.2.2 TINMIAQSIUGVIK RIVER

Photo D.40: Tinmiaqsiugvik River pre-breakup, looking southeast (upstream); May 23, 2017

Photo D.41: Tinmiaqsiugvik River during breakup, looking northeast; May 26, 2017

Photo D.42: Tinmiaqsiugvik River during breakup, looking south (upstream); June 1, 2017

D.2.3 TINMIAQSIUGVIK RIVER TRIBUTARY

Photo D.43: Tinmiaqsiugvik Tributary during breakup, looking west; May 31, 2017

Photo D.44: Tinmiaqsiugvik Tributary and B70 pre-breakup, looking south; May 24, 2017

D.2.4 TINMIAQSIUGVIK RIVER B70

Photo D.45: Tinmiaqsiugvik Tributary and B70 during breakup, looking south; May 26, 2017

Photo D.46: Tinmiaqsiugvik B70 during breakup, looking south; May 31, 2017

Appendix E FLOOD FREQUENCY ANALYSIS

The tables below present the peak discharge magnitude, frequency, standard error of prediction, confidence limits (prediction intervals) on the estimate of peak discharge magnitude, and equivalent years of record for the Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek culvert battery using the USGS computer program that automates site-specific estimates of accuracy (USGS 2003).

Table E.1: Tinmiaqsiugvik Bridge Peak Discharge Regression Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge	Standard Error of Prediction		Confidence Limits		Equivalent Years of Record (EYR)
%	years	cfs	+%	-%	5%	95%	
50	2	3,600	61.5	-38.1	1,610	8,000	1.0
20	5	5,400	58.5	-36.9	2,490	11,600	1.2
10	10	6,500	58.1	-36.8	3,040	14,100	1.5
4	25	7,900	58.7	-37.0	3,670	17,200	1.9
2	50	8,900	59.7	-37.4	4,090	19,500	2.2
1	100	9,900	61.0	-37.9	4,480	22,000	2.5
0.5	200	10,900	62.7	-38.5	4,820	24,500	2.7

Table E.2: Crea Bridge Peak Discharge Regression Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge	Standard Error of Prediction		Confidence Limits		Equivalent Years of Record
%	years	cfs	+%	-%	5%	95%	
50	2	100	63.0	-38.6	43	219	1.6
20	5	160	59.9	-37.5	73	349	1.8
10	10	200	59.7	-37.4	92	440	2.3
4	25	260	60.4	-37.7	116	561	2.9
2	50	290	61.5	-38.1	132	656	3.4
1	100	330	63.0	-38.6	148	755	3.7
0.5	200	370	64.8	-39.3	162	858	4.0

Table E.3: Barely Creek Culvert Battery Peak Discharge Regression Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge	Standard Error of Prediction		Confidence Limits		Equivalent Years of Record
%	years	cfs	+%	-%	5%	95%	
50	2	40	64.1	-39.1	19	100	1.7
20	5	70	61.1	-37.9	33	162	1.9
10	10	90	60.9	-37.8	42	206	2.4
4	25	120	61.7	-38.1	53	266	3.1
2	50	140	62.8	-38.6	61	313	3.6
1	100	160	64.4	-39.2	69	362	4.0
0.5	200	180	66.3	-39.9	76	413	4.3

2017 GMT1 Spring Breakup & Summer Monitoring & Hydrological Assessment