ConocoPhillips Alaska

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2017 GMT1 SPRING BREAKUP CULVERT MONITORING REPORT

Prepared for ConocoPhillips Alaska, Inc.

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ACRONYMS & ABBREVIATIONS

Baro	Barometric
BPMSL	British Petroleum Mean Sea Level
cfs	cubic feet per second
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
DS	Downstream
ft	Feet
fps	Feet per second
GMT1	Greater Moose's Tooth 1
GPS	Global positioning systems
HWM	High water mark(s)
Michael Baker	Michael Baker International
NAD83	North American Datum of 1983
NPR-A	National Petroleum Reserve Alaska
PT	Pressure transducer
UMIAQ	UMIAQ, LLC (formerly LCMF)
USGS	U.S. Geological Survey
US	Upstream
WGS84	World Geodetic System of 1984
WSE	Water surface elevation(s)

1. INTRODUCTION

Greater Moose's Tooth 1 (GMT1) Spring Breakup Culvert Monitoring supports the ConocoPhillips Alaska, Inc. (CPAI) Environmental group in meeting State of Alaska, federal, and local permit stipulations. GMT1 facilities include the GMT1 access road, pad, and pipelines. The GMT1 access road, pad, and a portion of the pipeline were constructed and 71 culverts were installed during the winter of 2016-2017.

The GMT1 access road spring breakup culvert monitoring field program took place during the 2017 GMT1 spring breakup monitoring and hydrologic assessment field program. This program began on April 20 and concluded on June 9. Figure 1 shows the GMT1 access road culvert monitoring locations. Culvert locations and properties are provided in Appendix A and indirect-read hydrologic staff gage (gage) and associated vertical control locations are provided in Appendix B.

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

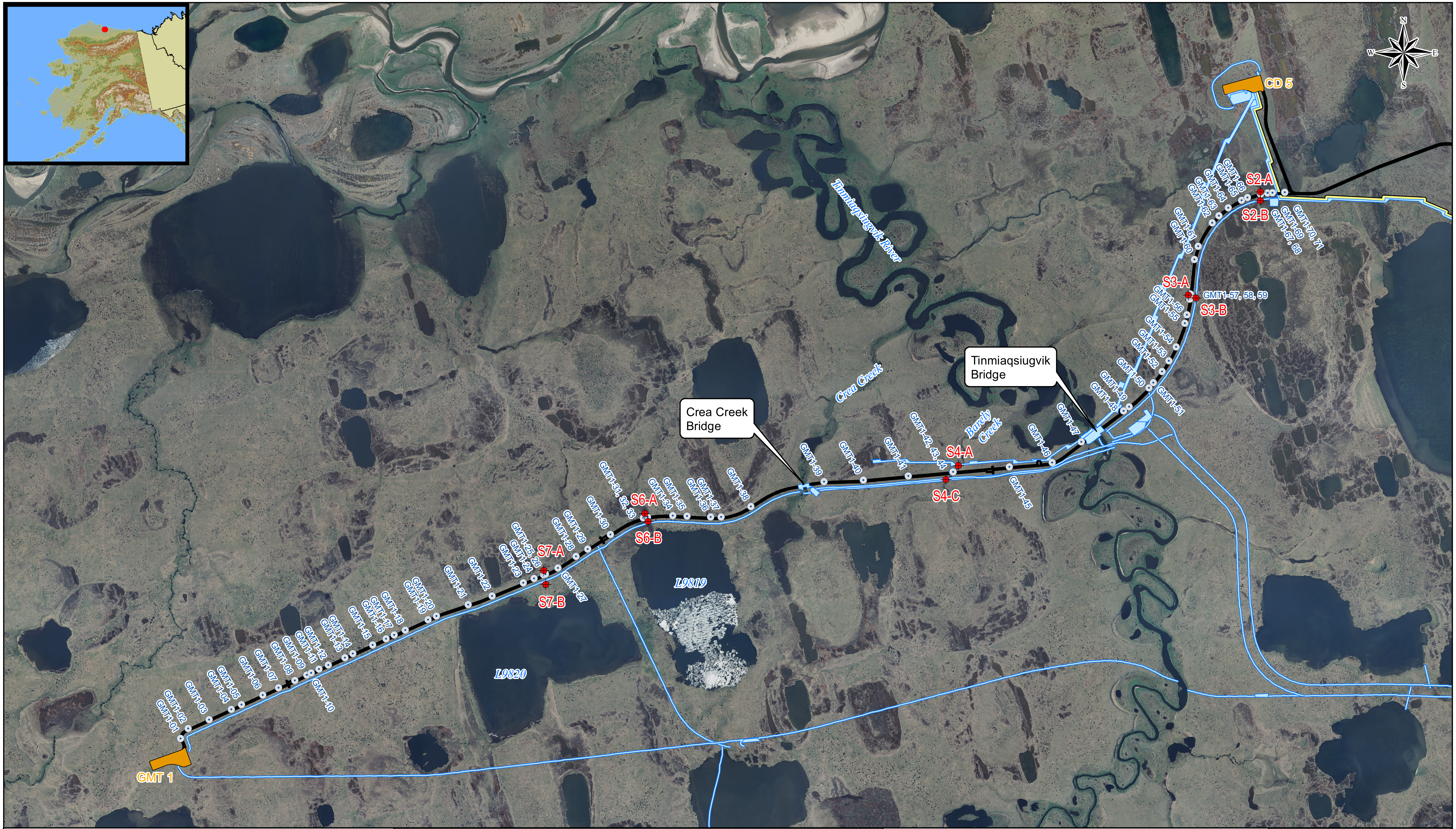
1.1 MONITORING OBJECTIVES

This report addresses culvert performance and evaluation of areas where additional culverts or modifications to existing culverts are necessary to maintain natural drainage. This meets hydrology monitoring requirements set forth in the U.S. Army Corps of Engineers (USACE) permit POA-2013-461. This permit requires annual GMT1 access road culvert monitoring reports to be submitted for three years post-construction. This is the first year of reporting.

The following tasks were conducted to meet the permit requirements:

- Photo documentation of the GMT1 access road and pad to demonstrate hydraulic connections 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
- Evaluation of all areas where culvert maintenance, repair, upgrade, setting adjustments, or replacement are necessary to maintain natural drainage patterns

Pre-construction culvert design data was provided by UMIAQ, LLC (UMIAQ). As-built surveys have not yet been completed. Therefore the culvert locations and properties provided in this report are preliminary and will require updating once as-built data is received.



ConocoPhillips Alaska

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Legend

- Gage Location
- Culvert
- Ice Road
- Existing Road
- Pipeline
- Ice Pad
- Existing Facility

Imagery Source : ConocoPhillips Alaska 2015

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2017 GMT 1
SPRING BREAKUP

Culvert Monitoring Locations

FIGURE: 1

(SHEET 1 of 1)

1.2 DATA COLLECTION

Data was collected at the following locations, as provided in Table 1.1.

Table 1.1: GMT1 Access Road Culvert Data Collection

<table>
<tr><th>Culverts</th><th>Associated Gages</th><th>Location Description</th></tr>
<tr><td>GMT1-01 through GMT1-20</td><td>Ungaged/Visual Observations</td><td>Cross drainage culverts located on high ground between GMT1 pad and Lake L9820</td></tr>
<tr><td>GMT1-21 through GMT1-29</td><td>S7-A/S7-B</td><td>Gages and culverts located upstream and downstream of GMT1 access road in small swale north of Lake L9820</td></tr>
<tr><td>GMT1-30 through GMT1-37</td><td>S6-A/S6-B</td><td>Gages and culverts located upstream and downstream of GMT1 access road in small swale north of Lake L9819</td></tr>
<tr><td>GMT1-38</td><td rowspan="2">Ungaged/Visual Observations</td><td>Cross drainage culvert located on high ground west of Crea Creek Bridge</td></tr>
<tr><td>GMT1-39</td><td>Cross drainage culvert located on high ground east of Crea Creek Bridge</td></tr>
<tr><td>GMT1-40 through GMT1-44</td><td>S4-A/S4-C</td><td>Gages and culverts located upstream and downstream of GMT1 access road at Barley Creek</td></tr>
<tr><td>GMT1-45 through GMT1-47</td><td rowspan="2">Ungaged/Visual Observations</td><td>Cross drainage culverts located on high ground west of the Tinmiaqsiugvik Bridge</td></tr>
<tr><td>GMT1-48 & GMT1-49</td><td>Cross drainage culverts located on high ground east of the Tinmiaqsiugvik Bridge</td></tr>
<tr><td>GMT1-50 through GMT1-61</td><td>S3-A/S3-B</td><td>Gages and culverts located upstream and downstream of GMT1 access road in small swale east of the Tinmiaqsiugvik Bridge</td></tr>
<tr><td>GMT1-62 through GMT1-71</td><td>S2-A/S2-B</td><td>Gages and culverts located upstream and downstream of GMT1 access road in small swale near CD5 intersection</td></tr>
</table>

2. METHODS

2.1 OBSERVATIONS

Gage locations were selected based on topography and hydraulic significance. Field data collection and observations of interactions between floodwaters and infrastructure were recorded in field notebooks and on culvert monitoring field sheets. Photographic documentation of spring breakup conditions were collected using digital cameras with integrated global positioning systems (GPS). The latitude, longitude, data, and time are imprinted on each photo. The photo locations are referenced to the World Geodetic System of 1984 (WGS84) horizontal datum.

UMIAQ provided Hägglunds track vehicle support to access culverts and gage locations during spring breakup setup. CPAI Alpine Field Environmental Coordinators provided a pickup truck and Soloy Helicopters provided helicopter support to access culverts during spring breakup monitoring and post breakup (summer) conditions.

2.2 WATER SURFACE ELEVATIONS

Water surface elevation (WSE) data was collected on both sides of the road prism to document WSE differential for assessing culvert performance. This was completed using a network of gages with pressure transducers (PTs) attached to each gage. For the purposes of this report, stage and WSE are used interchangeably.

HYDROLOGIC STAFF GAGES

Gage assemblies (gage and PT) were installed or rehabilitated prior to breakup. Gage assemblies do not directly correspond to a British Petroleum Mean Sea Level (BPMSL) elevation. Elevations were surveyed relative to a known benchmark elevation using standard differential leveling techniques to determine a correction factor. The correction factor is applied to the gage and PT elevation to obtain the elevation in feet BPMSL (ft BPMSL).

Gage stations consist of one or more gage assemblies positioned on the upstream and downstream sides of the road prism. Each gage assembly includes a standard USGS metal faceplate mounted on a wooden two-by-four. The two-by-four is attached with U-bolts to a 1.5-inch-wide angle iron gage support 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. Gage assemblies were identified with alphabetical designations, with the letter ‘A’ representing the gage assembly located on the north (downstream (DS)) side of the GMT1 access road and the letters ‘B’ and ‘C’ representing gage assemblies located on the south (upstream (US)) side of the GMT1 access road.

High water marks (HWMs) on the gages were recorded by applying chalk on the angle iron posts and measuring the wash line. HWMs were recorded to validate peak stage.

PRESSURE TRANSDUCERS

PTs were attached to all gages to supplement gage readings and provide a continuous record of WSE when the water column is above the PT sensor. PTs were programmed to collect data at 15 minute intervals from May 10 to June 29. 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. During data processing, the PT measurements were adjusted to WSE readings at the gages. PT setup, testing, and processing methods are detailed in Appendix C.

2.3 DISCHARGE MEASUREMENTS

Site visits and direct measurements were performed as near to peak flow conditions as possible. Measurements were collected in all culverts observed conveying flow. Culvert velocity and flow depth were measured directly using a HACH FH950 electromagnetic velocity meter and wading rod. Discharge was calculated using measured velocity, flow depth, and the inside culvert diameter. Inside culvert diameter was determined based on the outside culvert diameter and wall thickness data provided by UMIAQ (UMIAQ 2017). Discharge methods are detailed in Appendix D.

2.4 CULVERT PERFORMANCE EVALUATION

Culvert performance was evaluated based on observations, WSE, and discharge measurements with a focus on maintenance, repair, upgrade, setting adjustments, and/or replacement. In addition, the condition of the road fill around the culverts was evaluated to identify areas of erosion.

3. RESULTS

3.1 GENERAL CLIMATIC SUMMARY

According to cumulative freezing degree days 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 (ICE 2017). As of March 1, 2017, snowpack east of the Colville River was reported as 90-109% of the 1981-2010 median (NRCS 2017). In April and May 2017, all North Slope snowpack was reported as 90-109% of the 1981-2010 median (NRCS 2017). At Nuiqsut, a warming trend began around April 29 (Weather Underground 2017). Daily high air temperatures approached then exceeded freezing on May 23. Daily high air temperatures were between 35 and 45 degrees after May 23 and through the rest of breakup monitoring. Daily low air temperatures were relatively low the entire monitoring period, increasing to freezing between May 27 and June 1.

3.2 GENERAL OBSERVATIONS SUMMARY

Culverts were cleared in April by mechanically removing snow and ice from the inlets and outlets prior to spring breakup flooding. Visual inspections from April 27 through May 1 confirmed that snow and ice had been cleared at most culvert inlets and outlets. Some additional snowfall in early May accumulated along the road embankment prior to spring breakup.

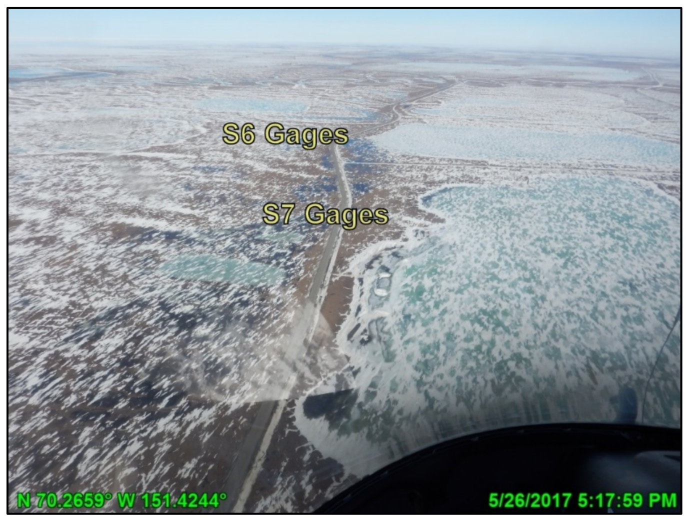


Photo 3.1: Local melt accumulating along GMT1 access road, looking east; May 26, 2017

On May 17, the small drainages along the GMT1 access road were snow covered and frozen. Snow cover on the surrounding tundra was approximately 90%. By May 24, isolated, local melt was accumulating in some of the drainages. On May 26, local melt was observed accumulating at most monitoring locations and large areas of melt were becoming hydraulically connected (Photo 3.1).

By May 28, minimal snow cover remained on the surrounding tundra and meltwater was connecting the upstream and downstream side of the road at most monitoring locations, suggesting culvert conveyance at these locations. Drifted snow and ice roads remained along the road embankment and influenced cross drainage in some locations (Photo 3.2).

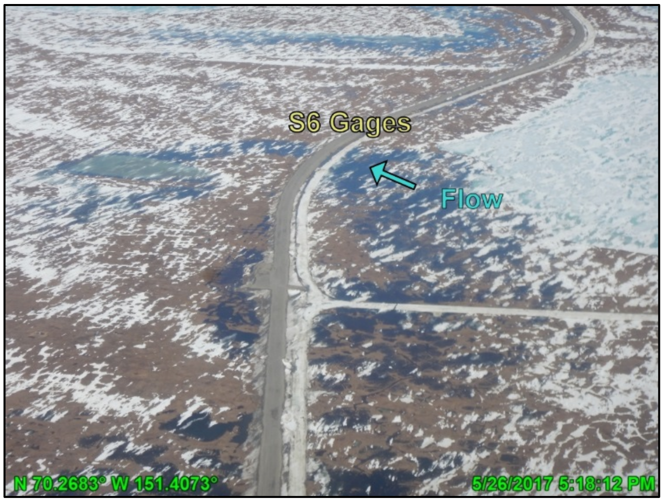


Photo 3.2: Drifted snow and ice road along upstream (south) side of the GMT1 access road, looking east; May 26, 2017

On May 31, only 10-20% snow cover remained on the tundra along the GMT1 access road. Conveyance channels had cut through much of the remaining ice roads and drifted snow. Culverts in defined drainages along the road were observed conveying flow. Cross flow culverts situated on higher ground outside of the defined drainages remained dry during spring breakup monitoring. 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.

3.3 SITE SPECIFIC OBSERVATIONS & WATER SURFACE ELEVATIONS

Summarized observations of flow conditions are tabulated in Appendix E. Additional location specific monitoring photos are provided in Appendix F.

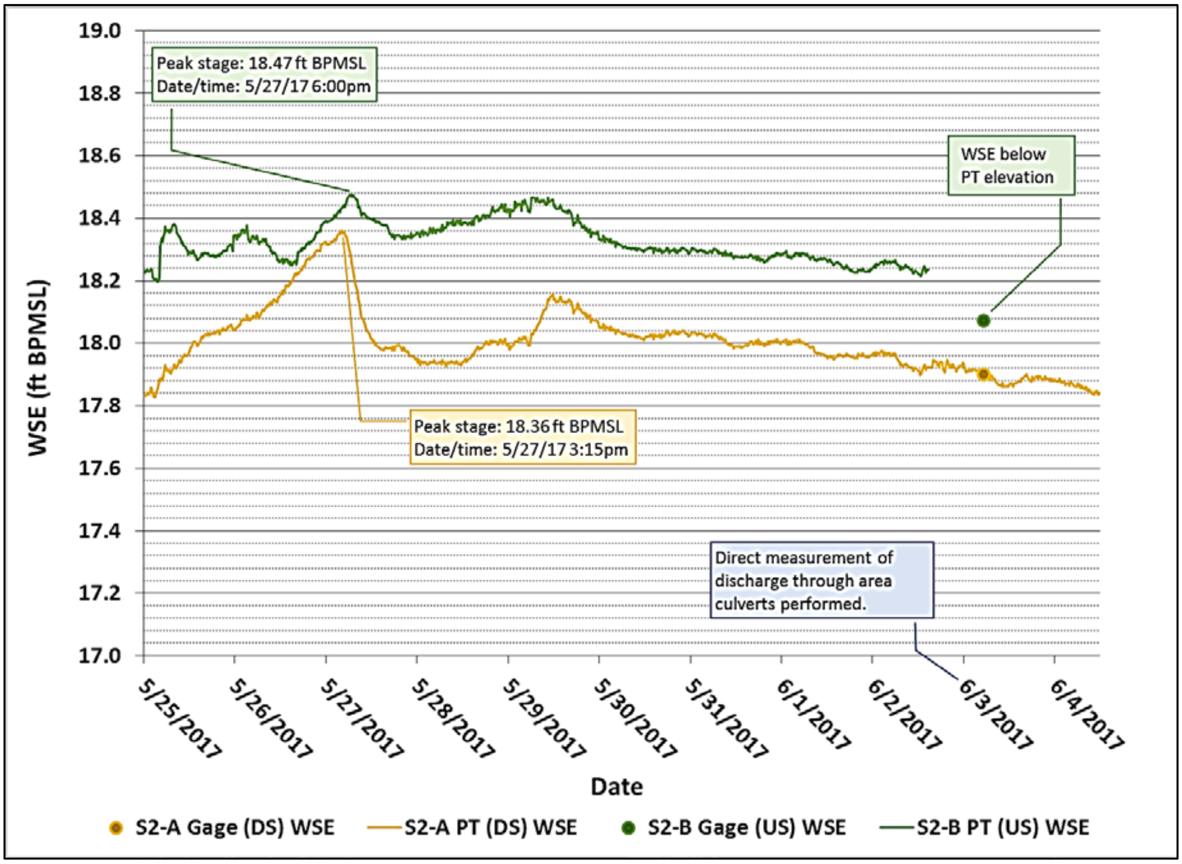
S2 CULVERTS (GMT1-60 THROUGH GMT1-71)

The S2 monitoring location is situated in a large natural depression which encompasses the CD5 road intersection and extends into the GMT1 access road. On the north side of the GMT1 access road, the drainage connects to a beaded stream which flows into the Tinmiaqsiugvik River northwest of the S2 monitoring location. 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 side of the GMT1 access road at the S2 monitoring location had mostly melted and neither were influencing drainage patterns (Photo 3.3). The ice road located north of the GMT1 pipeline north of the GMT1 access road was still intact and meltwater was accumulating between that and the GMT1 access road. PTs recorded concurrent rising water levels on the upstream and downstream side of the road, suggesting a hydraulic connection was established through the culverts.

Photo 3.3: GMT1 access road at S2 gages, looking west; May 31, 2017

Peak stage was recorded at the downstream gage, S2-A, and upstream gage, S2-B, on May 27 at 3:15pm and 6:00pm, cresting at 18.36 feet BPMSL and 18.47 feet BPMSL, respectively (Graph 3.1). WSEs on May 27 were likely temporarily influenced by the pipeline construction ice road downstream of the S2 monitoring location. 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.



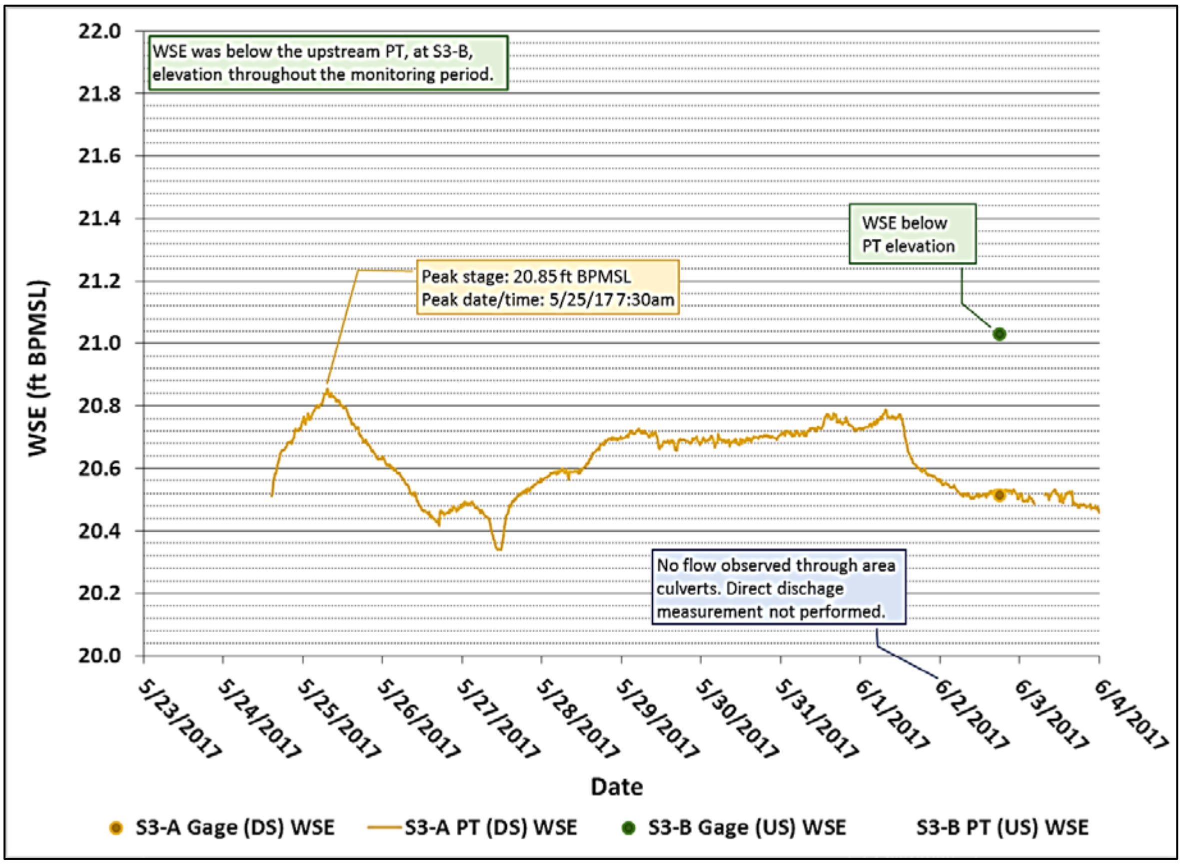
Graph 3.1: S2 Water Surface Elevations

S3 CULVERTS (GMT1-50 THROUGH GMT1-59)

Photo 3.4: Near peak flow conditions at S3 gages, looking southwest; May 31, 2017

The S3 monitoring location is situated in a small, poorly defined network of high centered polygon troughs. The drainage connects the natural depression associated with S2 in the east to the Tinmiaqsiugvik River in the west. In the past, during periods of high flow, backwater from the Tinmiaqsiugvik River has been observed extending to this monitoring location. 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.

The ice road south of the GMT1 access road did not influence area hydraulics aside from providing some meltwater. Similar to conditions observed at the S2 monitoring location, the ice road north of the pipeline north 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 monitoring location. Peak stage was recorded at the downstream gage, S3-A, on May 25 at 7:30am, cresting at 20.85 feet BPMSL (Graph 3.2 and Photo 3.4). 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. Ground observations on June 2 confirmed that there were no visible drainages melted through the snowpack in the vicinity of the culvert inlets and outlets.



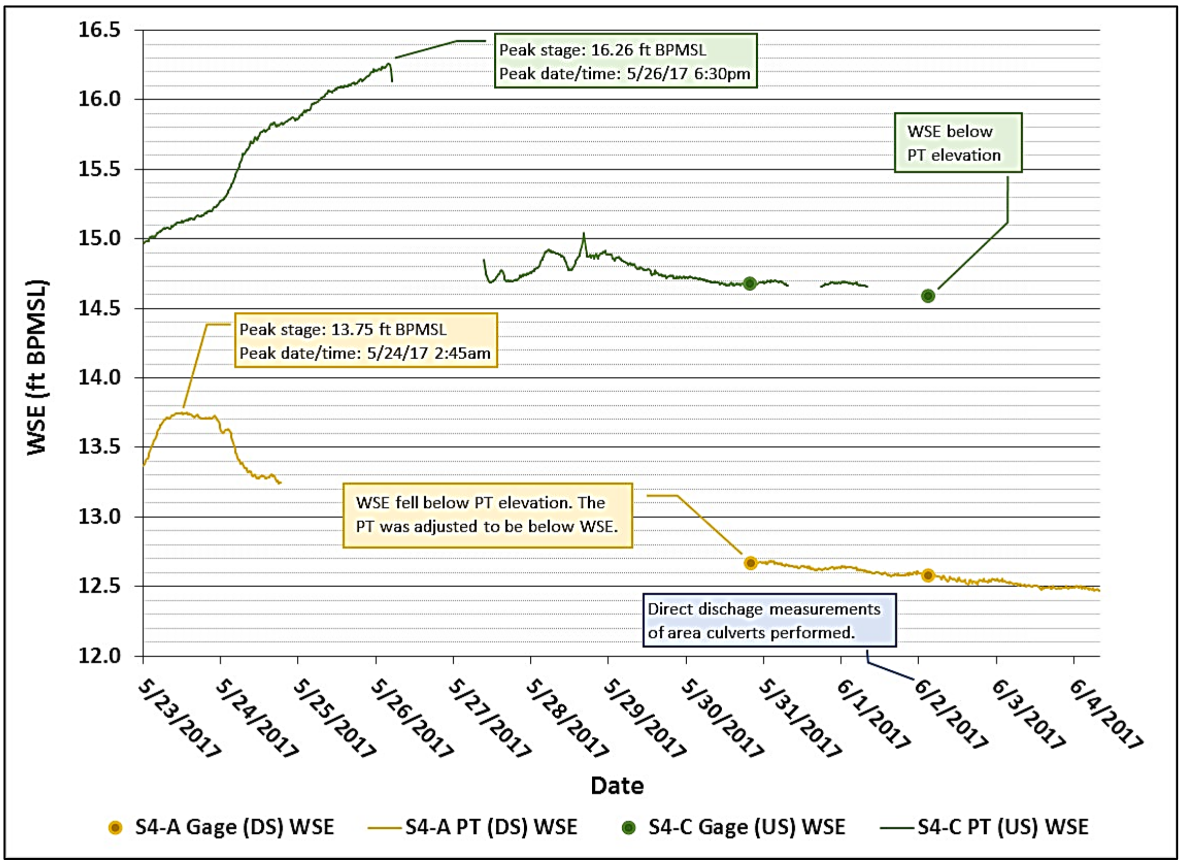
Graph 3.2: S3 Water Surface Elevations

S4 (BARELY CREEK) CULVERTS (GMT1-40 THROUGH GMT1-44)

The S4 monitoring location is located on Barely Creek, a beaded stream that drains north across the GMT1 access road into the Tinmiaqsiugvik River. Culverts GMT1-42, 43, and 44 are located in Barely Creek. Peak stage was observed at the downstream gage, S4-A, on May 24 at 2:45am, cresting at 13.75 feet BPMSL (Graph 3.3). Aerial observations that afternoon show local melt accumulating on the drifted snow but no flow was visible in the drainage.

Photo 3.5: Barely Creek flowing near peak conditions, looking east; May 28, 2017

On May 26, local melt continued to accumulate and ponded water was present between the two ice roads along the south side of the GMT1 access road. Peak stage was recorded at the upstream gage, S4-C, on May 26 at 6:30pm, cresting at 16.26 feet BPMSL (Graph 3.3). This was followed by a sharp drop in stage attributed to a sudden release of ponded water melting through the ice road adjacent to the GMT1 access road. Aerial observations on May 28 confirm that streamflow in the drainage had melted a channel through the remaining ice roads and flow through the culverts was unobstructed (Photo 3.5).



Graph 3.3: S4 Water Surface Elevations

S6 CULVERTS (GMT1-31 THROUGH GMT1-33)

The S6 monitoring location is situated in a swale depression that drains Lake L9819 (south of the GMT1 access road) towards the north. Culverts GMT1-31 through GMT1-33 are located in the swale. On May 26, meltwater in the drainage was accumulating. The ice road adjacent to the south side of the GMT1 access road was still intact.

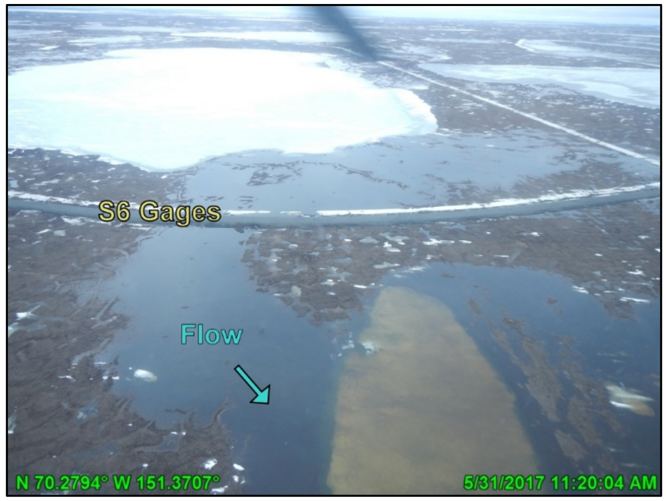
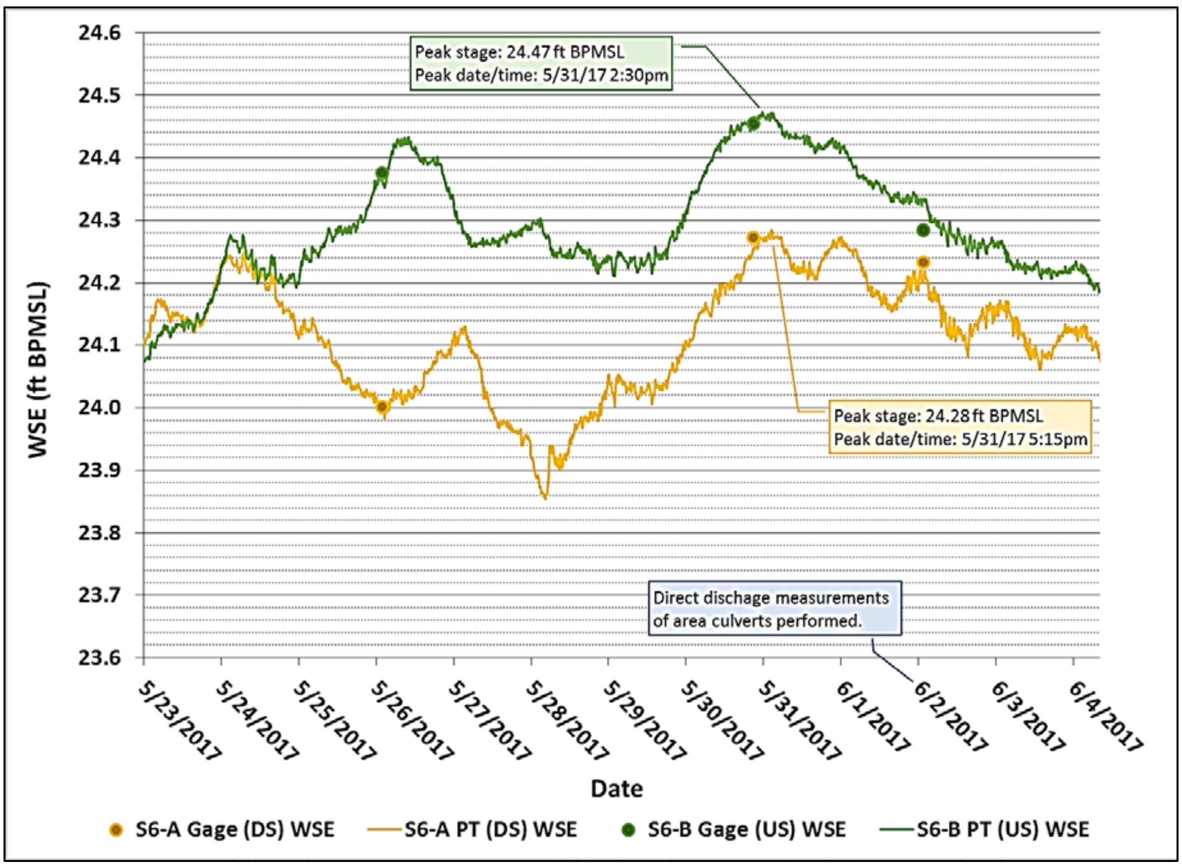


Photo 3.6: Conditions at S6 gages, looking south; May 31, 2017

Peak stage was recorded at the downstream gage, S6-A, and the upstream gage, S6-B, on May 31 at 5:15pm and 2:30pm, respectively; cresting at 24.28 feet BPMSL and 24.47 feet BPMSL, respectively (Graph 3.4). Streamflow in the drainage had melted a path through the remaining ice road and flow through the culverts was unobstructed (Photo 3.6).

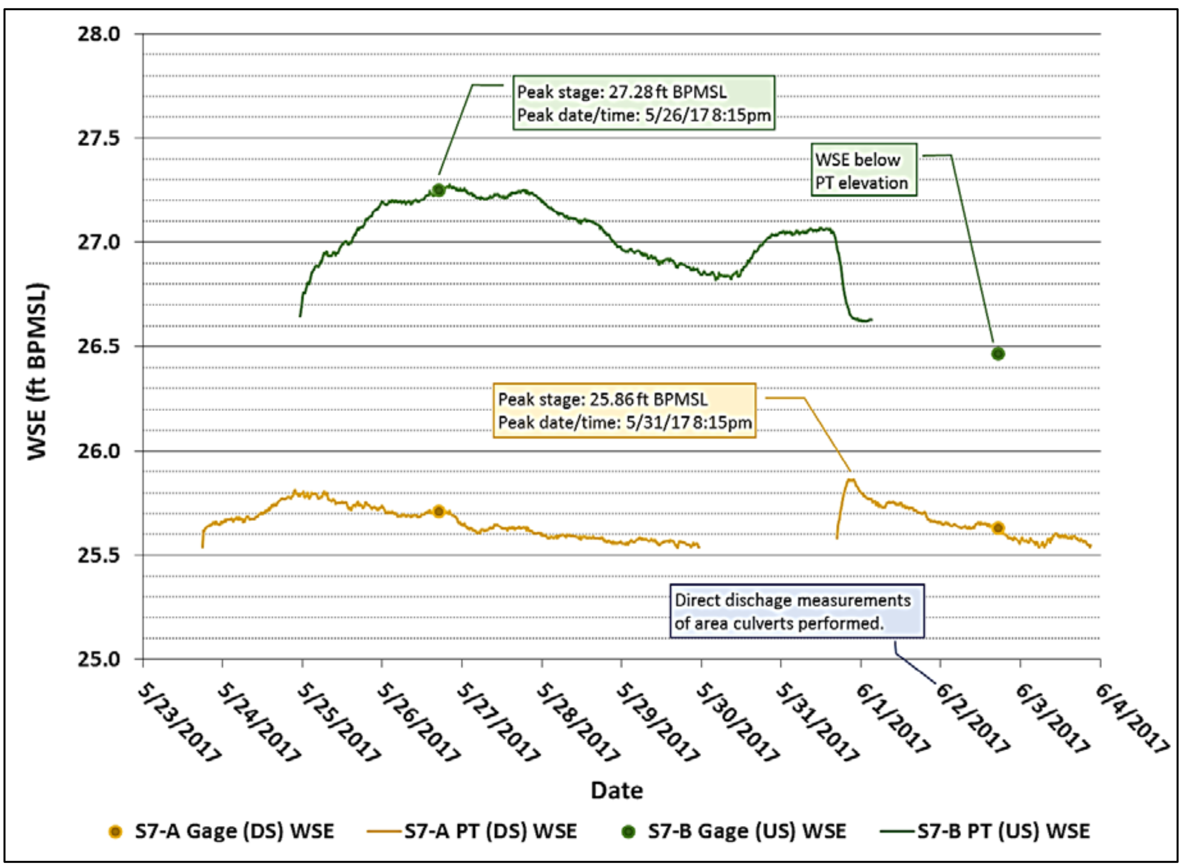


Graph 3.4: S6 Water Surface Elevations

S7 CULVERTS (GMT1-21 THROUGH GMT1-29)

Photo 3.7: GMT1 access road, looking east; May 31, 2017

The S7 monitoring location is situated in a swale depression that drains Lake L9820 (south of the GMT1 access road) towards the north. 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, on May 26 at 8:15pm, cresting at 27.28 feet BPMSL (Graph 3.5). 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, the drainage was dry on the north side of the road between the culverts and the downstream gage, S7-A (Photo 3.7). 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 S7-B. Peak stage was recorded at gage S7-A on May 31 at 8:15pm, cresting at 25.86 feet BPMSL (Graph 3.5). By June 1, the ice road had further deteriorated and no ponded water was present on the upstream side of the road.



Graph 3.5: S7 Water Surface Elevations

Gravel fill near the inlet and outlet of culvert GMT1-26 was identified on June 2 (Photo 3.8). It did not appear to affect spring breakup drainage.

Photo 3.8: Culvert GMT1-26, looking northeast; June 2, 2017

3.4 DISCHARGE MEASUREMENTS

Discharge measurements were collected at culverts GMT1-25, GMT1-31 through GMT1-33, and GMT1-42 through GMT1-44 on the afternoon of June 2. The average measured velocity and total measured discharge through these culverts was 1.1 feet per second (fps) and 12.7 cubic feet per second (cfs), respectively.

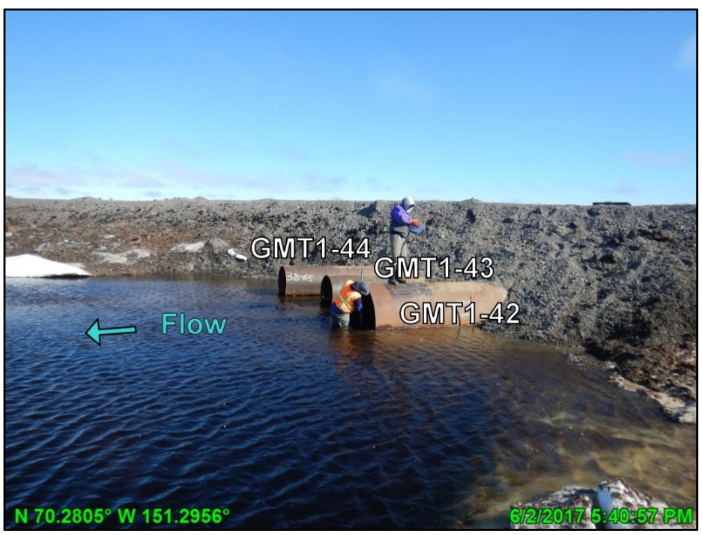


Photo 3.9: Measuring discharge at GMT1-42, looking southeast; June 2, 2017

Discharge measurements were collected at GMT1-65 through GMT1-69 on the afternoon of June 3. The average velocity and total discharge through these culverts was 1.2 fps and 7.0 cfs, respectively.

Total measured discharge through all GMT1 access road culverts was 20 cfs. At the time of direct measurement, culverts GMT1-25, GMT1-31 through GMT1-33, GMT1-42 through GMT1-44, and GMT1-65 through GMT1-69 were conveying 0.5%, 56.5%, 7.5%, and 35.5% of the total discharge, respectively. Culverts GMT1-65 through GMT1-69 had the highest average velocity of 1.2 fps.

Photo 3.10: Measuring discharge at GMT1-68, looking southeast; June 3, 2017

A summary of the discharge measurements collected on June 2 and June 3 is presented in Table 3.1.

Table 3.1: GMT1 Access Road Culvert Discharge

Culvert	Measurement Date & Time	Culvert Inside Diameter (ft)	Flow Area (ft^2)	Measured Depth of Flow (ft)	Measured Velocity (fps)	Discharge (cfs)	Total Discharge (cfs)
GMT1-25	6/2/2017 5:20pm	1.91	0.29	0.30	0.31	0.09	0.1
GMT1-31	6/2/2017 4:25pm	2.80	2.80	1.30	1.84	5.14	11.1
GMT1-32	6/2/2017 4:35pm	1.80	1.72	1.15	1.92	3.30	
GMT1-33	6/2/2017 4:45pm	1.80	1.27	0.90	2.10	2.67	
GMT1-42	6/2/2017 5:40pm	4.80	8.33	2.25	0.08	0.67	1.5
GMT1-43	6/2/2017 5:45pm	2.80	0.85	0.55	0.71	0.60	
GMT1-44	6/2/2017 5:49pm	2.80	0.35	0.30	0.55	0.20	
GMT1-65	6/3/2017 4:26pm	2.80	0.97	0.60	3.33	3.22	7.0
GMT1-66	6/3/2017 4:23pm	2.80	0.85	0.55	0.36	0.31	
GMT1-67	6/3/2017 4:10pm	2.80	1.20	0.70	1.07	1.29	
GMT1-68	6/3/2017 4:00pm	2.80	2.38	1.15	0.42	1.01	
GMT1-69	6/3/2017 3:45pm	2.80	1.97	1.00	0.58	1.15	

3.5 CULVERT PERFORMANCE EVALUATION

No performance issues were identified at any 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 culverts all performed as designed and natural drainage patterns were maintained. No displacement of uncompacted gravel fill attributed with spring breakup flooding was observed along the road embankment or around culvert inlets and outlets. There were no signs of sloughing or undermining at drainage structures and no stream channel changes were observed at access road crossings. Construction fill was observed at the inlet and outlet of culvert GMT1-26 and should be removed to maintain an open conveyance path. Otherwise, no discernable culvert maintenance, repair, upgrade, setting adjustments, and/or replacements are recommended at this time based on ground assessments and aerial observations.

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Appendix A CULVERT LOCATIONS & PROPERTIES

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)	Outside Diameter (in)	Outside Diameter (ft)	Wall Thickness (ft)	Inside Diameter (ft)
GMT1-01N	13+07	70.2577	-151.4806	24	2	0.045	1.910
GMT1-01S		70.2576	-151.4800				
GMT1-02N	16+87	70.2585	-151.4788	24	2	0.045	1.910
GMT1-02S		70.2583	-151.4786				
GMT1-03N	23+93	70.2593	-151.4738	24	2	0.085	1.830
GMT1-03S		70.2592	-151.4733				
GMT1-04N	31+15	70.2602	-151.4684	24	2	0.100	1.800
GMT1-04S		70.2600	-151.4682				
GMT1-05N	34+65	70.2606	-151.4660	24	2	0.045	1.910
GMT1-05S		70.2605	-151.4655				
GMT1-06N	41+61	70.2615	-151.4608	24	2	0.045	1.910
GMT1-06S		70.2613	-151.4606				
GMT1-07N	46+80	70.2621	-151.4570	24	2	0.045	1.910
GMT1-07S		70.2619	-151.4568				
GMT1-08N	52+33	70.2627	-151.4531	24	2	0.100	1.800
GMT1-08S		70.2626	-151.4527				
GMT1-09N	56+29	70.2632	-151.4502	24	2	0.100	1.800
GMT1-09S		70.2630	-151.4498				
GMT1-10N	57+91	70.2634	-151.4491	24	2	0.045	1.910
GMT1-10S		70.2633	-151.4485				
GMT1-11N	60+35	70.2637	-151.4472	24	2	0.045	1.910
GMT1-11S		70.2635	-151.4469				
GMT1-12N	63+36	70.2641	-151.4450	24	2	0.045	1.910
GMT1-12S		70.2639	-151.4447				
GMT1-13N	68+66	70.2647	-151.4410	24	2	0.085	1.830
GMT1-13S		70.2645	-151.4410				
GMT1-14N	71+55	70.2650	-151.4390	24	2	0.085	1.830
GMT1-14S		70.2648	-151.4388				
GMT1-15N	78+14	70.2658	-151.4343	24	2	0.085	1.830
GMT1-15S		70.2657	-151.4339				
GMT1-16N	82+36	70.2663	-151.4311	24	2	0.085	1.830
GMT1-16S		70.2661	-151.4310				
GMT1-17N	85+63	70.2667	-151.4291	36	3	0.045	2.910
GMT1-17S		70.2666	-151.4282				
GMT1-18N	89+03	70.2671	-151.4264	24	2	0.045	1.910
GMT1-18S		70.2669	-151.4260				
GMT1-19N	96+65	70.2680	-151.4209	24	2	0.045	1.910
GMT1-19S		70.2679	-151.4204				
GMT1-20N	99+27	70.2683	-151.4189	24	2	0.045	1.910
GMT1-20S		70.2682	-151.4186				
GMT1-21N	109+04	70.2693	-151.4112	24	2	0.045	1.910
GMT1-21S		70.2691	-151.4115				
GMT1-22N	117+10	70.2701	-151.4054	24	2	0.045	1.910
GMT1-22S		70.2699	-151.4052				
GMT1-23N	127+30	70.2712	-151.3978	24	2	0.045	1.910
GMT1-23S		70.2710	-151.3976				
GMT1-24N	130+95	70.2716	-151.3952	24	2	0.045	1.910
GMT1-24S		70.2714	-151.3948				
GMT1-25N	133+78	70.2719	-151.3929	24	2	0.045	1.910
GMT1-25S		70.2717	-151.3929				
GMT1-26N	134+41	70.2720	-151.3925	24	2	0.045	1.910
GMT1-26S		70.2718	-151.3924				

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)	Outside Diameter (in)	Outside Diameter (ft)	Wall Thickness (ft)	Inside Diameter (ft)
GMT1-27N	138+78	70.2725	-151.3895	24	2	0.045	1.910
GMT1-27S		70.2724	-151.3892				
GMT1-28N	145+38	70.2735	-151.3851	24	2	0.100	1.800
GMT1-28S		70.2734	-151.3846				
GMT1-29N	149+20	70.2741	-151.3823	24	2	0.100	1.800
GMT1-29S		70.2739	-151.3823				
GMT1-30N	157+54	70.2754	-151.3769	24	2	0.100	1.800
GMT1-30S		70.2752	-151.3766				
GMT1-31N	168+63	70.2768	-151.3689	36	3	0.100	2.800
GMT1-31S		70.2766	-151.3688				
GMT1-32N	169+70	70.2769	-151.3681	24	2	0.100	1.800
GMT1-32S		70.2767	-151.3679				
GMT1-33N	169+92	70.2769	-151.3679	24	2	0.100	1.800
GMT1-33S		70.2767	-151.3677				
GMT1-34N	177+38	70.2771	-151.3617	24	2	0.100	1.800
GMT1-34S		70.2769	-151.3619				
GMT1-35N	182+16	70.2770	-151.3582	24	2	0.100	1.800
GMT1-35S		70.2768	-151.3577				
GMT1-36N	189+05	70.2770	-151.3524	24	2	0.100	1.800
GMT1-36S		70.2768	-151.3523				
GMT1-37N	192+11	70.2770	-151.3499	24	2	0.100	1.800
GMT1-37S		70.2768	-151.3499				
GMT1-38N	202+05	70.2779	-151.3427	24	2	0.100	1.800
GMT1-38S		70.2778	-151.3423				
GMT1-39N	225+46	70.2801	-151.3250	24	2	0.100	1.800
GMT1-39S		70.2799	-151.3249				
GMT1-40N	237+46	70.2803	-151.3154	24	2	0.100	1.800
GMT1-40S		70.2801	-151.3151				
GMT1-41N	250+77	70.2807	-151.3044	24	2	0.100	1.800
GMT1-41S		70.2805	-151.3047				
GMT1-42N	264+24	70.2812	-151.2936	60	5	0.100	4.800
GMT1-42S		70.2809	-151.2938				
GMT1-43N	264+32	70.2812	-151.2935	36	3	0.100	2.800
GMT1-43S		70.2809	-151.2937				
GMT1-44N	264+39	70.2812	-151.2935	36	3	0.100	2.800
GMT1-44S		70.2809	-151.2937				
GMT1-45N	281+67	70.2817	-151.2798	24	2	0.100	1.800
GMT1-45S		70.2815	-151.2796				
GMT1-46N	294+82	70.2821	-151.2693	24	2	0.100	1.800
GMT1-46S		70.2819	-151.2690				
GMT1-47N	306+05	70.2838	-151.2623	48	4	0.100	3.800
GMT1-47S		70.2837	-151.2612				
GMT1-48N	321+48	70.2865	-151.2521	24	2	0.100	1.800
GMT1-48S		70.2863	-151.2518				
GMT1-49N	323+41	70.2868	-151.2508	24	2	0.100	1.800
GMT1-49S		70.2866	-151.2507				
GMT1-50N	331+97	70.2884	-151.2460	24	2	0.100	1.800
GMT1-50S		70.2883	-151.2456				
GMT1-51N	334+13	70.2888	-151.2450	24	2	0.100	1.800
GMT1-51S		70.2888	-151.2444				
GMT1-52N	338+32	70.2898	-151.2430	24	2	0.100	1.800
GMT1-52S		70.2897	-151.2425				
GMT1-53N	342+15	70.2907	-151.2414	24	2	0.100	1.800
GMT1-53S		70.2906	-151.2408				

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)	Outside Diameter (in)	Outside Diameter (ft)	Wall Thickness (ft)	Inside Diameter (ft)
GMT1-54N	347+11	70.2919	-151.2396	24	2	0.100	1.800
GMT1-54S		70.2919	-151.2390				
GMT1-55N	354+46	70.2938	-151.2376	24	2	0.100	1.800
GMT1-55S		70.2937	-151.2371				
GMT1-56N	357+20	70.2945	-151.2371	24	2	0.100	1.800
GMT1-56S		70.2945	-151.2366				
GMT1-57N	362+05	70.2958	-151.2366	24	2	0.100	1.800
GMT1-57S		70.2958	-151.2360				
GMT1-58N	363+05	70.2961	-151.2365	36	3	0.100	2.800
GMT1-58S		70.2961	-151.2359				
GMT1-59N	363+57	70.2962	-151.2364	36	3	0.100	2.800
GMT1-59S		70.2962	-151.2358				
GMT1-60N	374+03	70.2991	-151.2356	24	2	0.100	1.800
GMT1-60S		70.2990	-151.2351				
GMT1-61N	378+19	70.3002	-151.2347	24	2	0.100	1.800
GMT1-61S		70.3001	-151.2342				
GMT1-62N	386+46	70.3022	-151.2314	24	2	0.100	1.800
GMT1-62S		70.3020	-151.2310				
GMT1-63N	389+34	70.3028	-151.2298	36	3	0.100	2.800
GMT1-63S		70.3026	-151.2295				
GMT1-64N	392+96	70.3034	-151.2276	36	3	0.100	2.800
GMT1-64S		70.3033	-151.2273				
GMT1-65N	397+59	70.3041	-151.2243	36	3	0.100	2.800
GMT1-65S		70.3039	-151.2241				
GMT1-66N	399+46	70.3043	-151.2229	36	3	0.100	2.800
GMT1-66S		70.3041	-151.2227				
GMT1-67N	403+48	70.3046	-151.2197	36	3	0.100	2.800
GMT1-67S		70.3044	-151.2197				
GMT1-68N	405+62	70.3047	-151.2180	36	3	0.100	2.800
GMT1-68S		70.3045	-151.2180				
GMT1-69N	407+08	70.3047	-151.2168	36	3	0.100	2.800
GMT1-69S		70.3045	-151.2168				
GMT1-70N	410+82	70.3048	-151.2139	36	3	0.100	2.800
GMT1-70S		70.3046	-151.2137				
GMT1-71N	410+58	70.3048	-151.2138	36	3	0.100	2.800
GMT1-71S		70.3046	-151.2137				

Appendix B GAGE & ASSOCIATED VERTICAL CONTROL LOCATIONS

Monitoring Location	Gage ID	Gage Position Relative to Road	Gage Location		Associated Vertical Control	Vertical Control Location	
			Latitude (NAD83)	Longitude (NAD83)		Latitude (NAD83)	Longitude (NAD83)
S2	S2-A	downstream	70.3048	-151.2198	MON-32	70.3022	-151.2331
	S2-B	upstream	70.3041	-151.2199			
S3	S3-A	downstream	70.2961	-151.2368			
	S3-B	upstream	70.2959	-151.235			
S4	S4-A	downstream	70.2817	-151.2922	MON-37	70.2801	-151.3018
	S4-C	upstream	70.2804	-151.2955			
S6	S6-A	downstream	70.2772	-151.3686	MON-40	70.2764	-151.3639
	S6-B	upstream	70.2765	-151.3677			
S7	S7-A	downstream	70.2723	-151.3929	MON-41	70.2709	-151.3948
	S7-B	upstream	70.2711	-151.3924			

Appendix C PT SETUP, TESTING & PROCESSING 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 water levels. The reported pressure is the sum of the forces imparted by the water column and atmospheric conditions. Variations in local barometric pressure are taken into account, using two independent barometric pressure loggers: In-Situ BaroTROLL® and Solinst Barologger®. A correction of barometric pressure was obtained from the Barologger installed at the Colville River East Channel horizontal directionally drilled pipeline crossing. The PT sensors were surveyed during spring breakup setup to establish a vertical datum using local control.

All PTs were tested before field mobilization and 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.

PT-based water level 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 D DISCHARGE METHODS

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

Appendix E GMT1 ROAD CULVERT VISUAL OBSERVATION SUMMARY, JUNE 2 & 3, 2017

Observation Date	Time	Culvert ID	Flow Conditions	Flow Direction	Notes
6/2/2017	16:00	GMT1-01	Dry	-	-
6/2/2017	16:00	GMT1-02	Dry	-	-
6/2/2017	16:00	GMT1-03	Dry	-	-
6/2/2017	16:00	GMT1-04	Dry	-	-
6/2/2017	16:00	GMT1-05	Dry	-	-
6/2/2017	16:00	GMT1-06	Dry	-	-
6/2/2017	16:00	GMT1-07	Dry	-	-
6/2/2017	16:00	GMT1-08	Dry	-	-
6/2/2017	16:00	GMT1-09	Dry	-	-
6/2/2017	16:00	GMT1-10	Dry	-	-
6/2/2017	16:00	GMT1-11	Dry	-	-
6/2/2017	16:00	GMT1-12	Dry	-	-
6/2/2017	16:00	GMT1-13	Dry	-	-
6/2/2017	16:00	GMT1-14	Dry	-	-
6/2/2017	16:00	GMT1-15	Dry	-	-
6/2/2017	16:00	GMT1-16	Dry	-	-
6/2/2017	16:00	GMT1-17	Dry	-	-
6/2/2017	16:00	GMT1-18	Dry	-	-
6/2/2017	16:00	GMT1-19	Dry	-	-
6/2/2017	16:00	GMT1-20	Dry	-	-
6/2/2017	17:15	GMT1-21	Dry	-	-
6/2/2017	17:15	GMT1-22	Dry	-	-
6/2/2017	17:15	GMT1-23	Dry	-	-
6/2/2017	17:15	GMT1-24	Dry	-	-
6/2/2017	17:20	GMT1-25	Flowing	South to North	Grass pushed down suggesting greater flow earlier
6/2/2017	17:25	GMT1-26	Ponded	N/A	Construction fill around inlet and outlet (not in drainage)
6/2/2017	17:15	GMT1-27	Dry	-	-
6/2/2017	17:15	GMT1-28	Dry	-	-
6/2/2017	17:15	GMT1-29	Dry	-	-
6/2/2017	16:00	GMT1-30	Dry	-	-
6/2/2017	16:25	GMT1-31	Flowing	South to North	-
6/2/2017	16:35	GMT1-32	Flowing	South to North	-
6/2/2017	16:45	GMT1-33	Flowing	South to North	-
6/2/2017	16:00	GMT1-34	Dry	-	-
6/2/2017	16:00	GMT1-35	Dry	-	-
6/2/2017	16:00	GMT1-36	Dry	-	-
6/2/2017	16:00	GMT1-37	Dry	-	-
6/2/2017	15:00	GMT1-38	Dry	-	-
6/2/2017	15:00	GMT1-39	Dry	-	-
6/2/2017	16:00	GMT1-40	Dry	-	-
6/2/2017	16:00	GMT1-41	Dry	-	-
6/2/2017	17:40	GMT1-42	Flowing	South to North	-
6/2/2017	17:45	GMT1-43	Flowing	South to North	-
6/2/2017	17:49	GMT1-44	Flowing	South to North	-
6/2/2017	16:00	GMT1-45	Dry	-	-
6/2/2017	16:00	GMT1-46	Dry	-	-
6/2/2017	16:00	GMT1-47	Dry	-	-
6/2/2017	16:00	GMT1-48	Dry	-	-
6/2/2017	16:00	GMT1-49	Dry	-	-
6/2/2017	18:00	GMT1-50	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/2/2017	18:00	GMT1-51	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit

Observation Date	Time	Culvert ID	Flow Conditions	Flow Direction	Notes
6/2/2017	18:00	GMT1-52	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/2/2017	18:00	GMT1-53	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/2/2017	18:00	GMT1-54	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/2/2017	18:00	GMT1-55	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/2/2017	18:00	GMT1-56	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/2/2017	18:00	GMT1-57	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/2/2017	18:00	GMT1-58	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/2/2017	18:00	GMT1-59	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/2/2017	18:00	GMT1-60	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/2/2017	18:00	GMT1-61	Buried	N/A	No flow through S3 culverts, blocked by snow at entrance & exit
6/3/2017	16:40	GMT1-62	Dry		-
6/3/2017	16:40	GMT1-63	Buried	N/A	Snow filling north side of culvert
6/3/2017	16:36	GMT1-64	Isolated Meltwater/ No Flow	N/A	-
6/3/2017	16:26	GMT1-65	Flowing	South to North	-
6/3/2017	16:23	GMT1-66	Flowing	South to North	-
6/3/2017	16:10	GMT1-67	Flowing	South to North	-
6/3/2017	16:00	GMT1-68	Flowing	South to North	-
6/3/2017	15:45	GMT1-69	Flowing	South to North	-
6/3/2017	15:39	GMT1-70	Dry	-	-
6/3/2017	15:39	GMT1-71	Dry	-	-

Appendix F MONITORING LOCATION PHOTOS

F.1 S2 & S3 MONITORING LOCATIONS

Photo A.1: GMT1 access road, looking northeast; May 26, 2017

Photo A.2: GMT1 access road, looking southwest; May 31, 2017

Photo A.3: Tinmiaqsiugvik River crossing under GMT1 access road, looking southwest; June 1, 2017

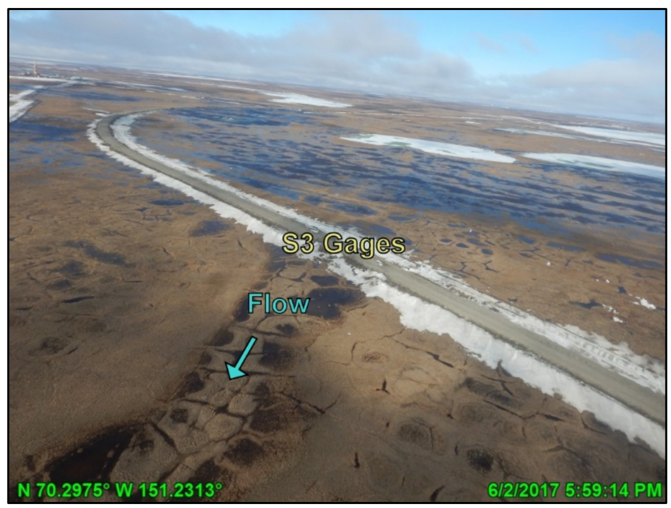

Photo A.4: S3 gages, looking east; June 2, 2017

Photo A.5: GMT1-59N culvert, looking north; June 2, 2017

Photo A.6: GMT1-58N culvert, looking west; June 2, 2017

Photo A.7: GMT1 access road, looking west; June 3, 2017

Photo A.8: GMT1 access road at intersection with CD5 road near S2 monitoring location, looking west; June 29, 2017

Photo A.9: GMT1 access road near S3 monitoring location, looking southwest; June 29, 2017

Photo A.10: GMT1 culverts 57, 58, and 59, looking southeast; June 29, 2017

Photo A.11: GMT1 access road, looking east; June 29, 2017

F.2 S4 (BARELY CREEK) MONITORING LOCATION

Photo A.12: Conditions along GMT1 access road, looking southwest; May 26, 2017

Photo A.13: S4 gage location at Barely Creek, looking northwest; May 26, 2017

Photo A.14: Culverts GMT1-42 through 44, looking east; May 31, 2017

Photo A.15: Conditions near peak stage at S4 gages, looking northeast; May 31, 2017

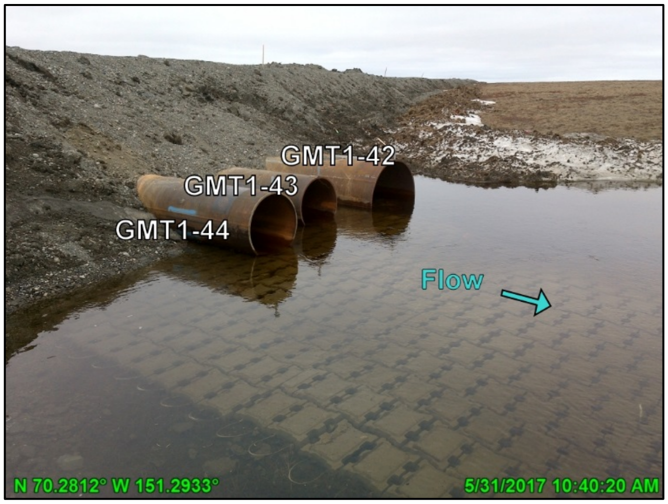

Photo A.16: Culverts GMT1-42 through 44, looking west; May 31, 2017

Photo A.17: Barely Creek, looking east; June 2, 2017

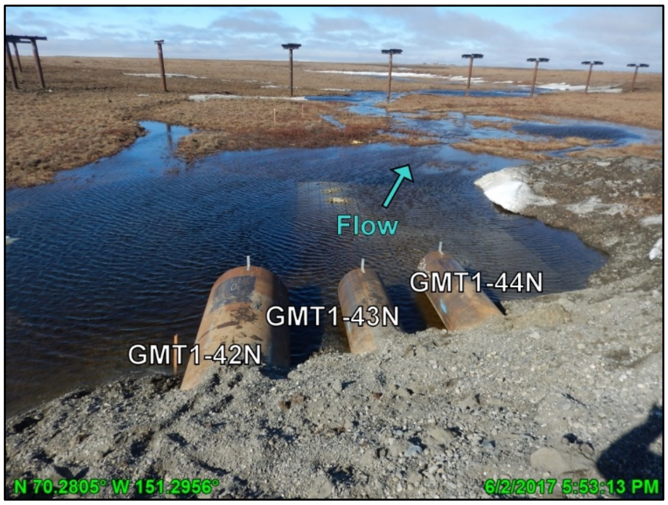

Photo A.18: Culverts GMT1-42 through 44, looking northeast; June 2, 2017

Photo A.19: Culverts GMT1-42 through 44, looking southwest; June 2, 2017

Photo A.20: Post-breakup conditions, looking southwest; June 28, 2017

Photo A.21: Post-breakup conditions, looking northeast; June 29, 2017

F.3 S6 MONITORING LOCATION

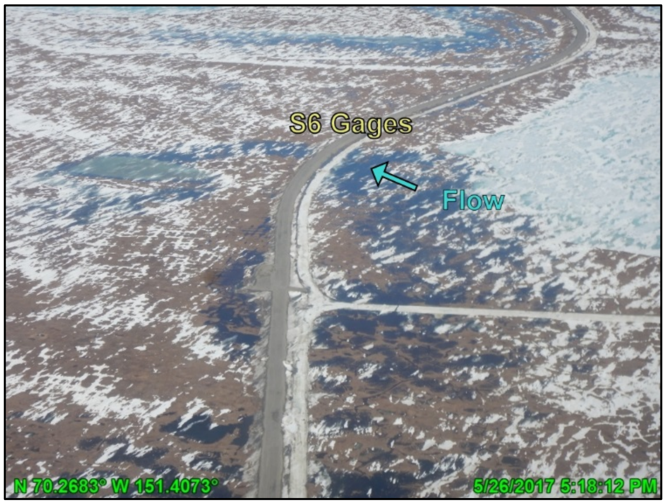

Photo A.22: GMT1 access road conditions, looking northeast; May 26, 2017

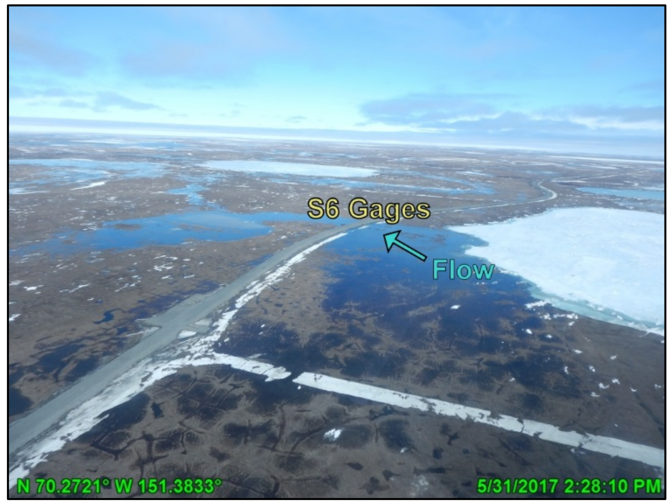

Photo A.23: S6 gage location, looking northeast; May 31, 2017

Photo A.24: Culverts GMT1-31 through 33, looking northeast; May 31, 2017

Photo A.25: GMT1-31S, looking east; May 31, 2017

Photo A.26: Overview of GMT1 access road near S6 and S7 gage locations, looking west; June 1, 2017

Photo A.27: GMT1 access road, looking west; June 2, 2017

Photo A.28: GMT1 access road, looking east; June 2, 2017

Photo A.29: GMT1 access road, looking west; June 3, 2017

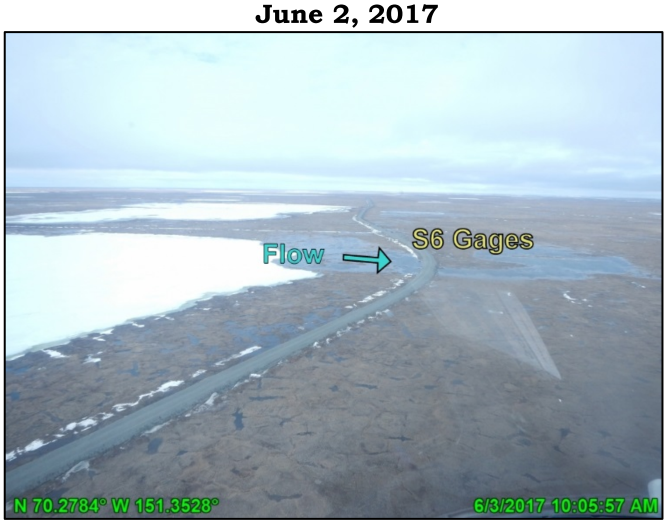

Photo A.30: GMT1 access road, looking west; June 3, 2017

Photo A.31: Post-breakup conditions at S6 gages, looking east; June 29, 2017

Photo A.32: Post-breakup conditions at culverts GMT1-31 through 33, looking east; June 29, 2017

Photo A. 33: GMT1 access road near S6 monitoring location, looking northwest; June 29, 2017

F.4 S7 MONITORING LOCATION

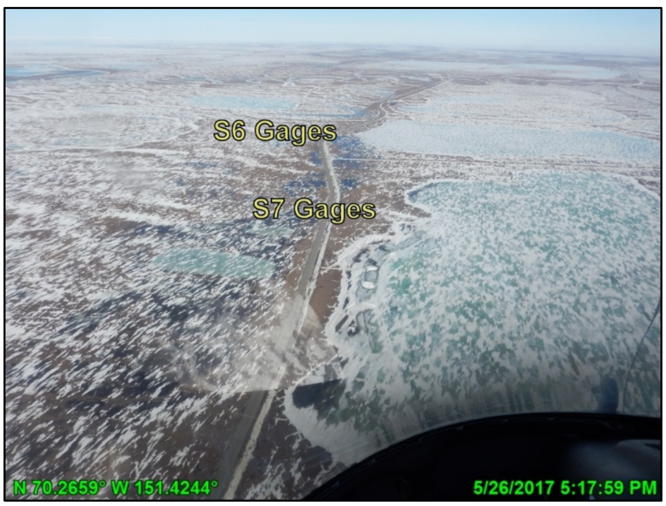

Photo A.34: Breakup monitoring near S7 gages, looking east; May 26, 2017

Photo A.35: Breakup monitoring, looking southwest; May 31, 2017

Photo A.36: GMT1 access road, looking east; May 31, 2017

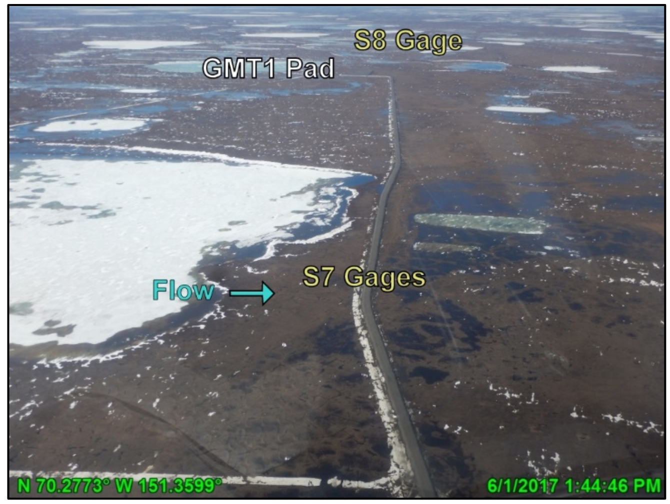

Photo A.37: GMT1 access road, looking west; June 1, 2017

Photo A.38: GMT1 access road, looking east; June 2, 2017

Photo A.39: S7 gage location, looking northeast; June 2, 2017

Photo A.40: Culvert GMT1-25, looking south; June 2, 2017

Photo A.41: GMT1 access road, looking northwest; June 29, 2017

Photo A.42: Post-breakup conditions at S7 gages, looking southeast; June 29, 2017

Photo A. 43: GMT1 access road near S7 monitoring location, looking west; June 29, 2017