Greater Moose's Tooth 1 (GMT1) Alpine Satellite Project

2009 Spring Breakup Hydrologic Assessment

Submitted to

ConocoPhillips Alaska

Submitted by

Baker

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December 2009
117216-MBJ-RPT-001-REV1

GREATER MOOSE'S TOOTH 1 (GMT1) ALPINE SATELLITE PROJECT

2009 SPRING BREAKUP HYDROLGOIC ASSESSMENT

REVISION HISTORY

Revision 0	Initial Issue	September 2009
Revision 1	Reissue of the following Figures: Revision History (place behind cover) Figure 1.1 - 2009 Existing and Proposed Facilities Figure 1.3 - Ublutuoch Drainage Basin Delineation Figure 1.4 - Gage Locations Figure 2.1 - Ublutuoch River Gage Locations Figure 2.2 – S1 Gage Locations Figure 2.3 – S1, S2 & S3 Drainage Basin Delineations Figure 2.4 – S2 Gage Location Figure 2.5 – S3 Gage Location Figure 2.6 – S4 Gage Location Figure 2.7 – S4, S5, & S6 Drainage Basin Delineation Figure 2.8 – S5 Gage Location Figure 2.9 – S6 Gage Location Figure 2.10 – S7 Gage Location Figure 2.11 – S7 & S8 Drainage Basin Delineation Figure 2.12 – S8 (GMT1 Pad) Gage Location	December 2009

EXECUTIVE SUMMARY

This report presents observations and findings of the 2009 Greater Moose's Tooth 1 (GMT1) Alpine Satellite Project Spring Breakup and Hydrologic Assessment conducted by Michael Baker Jr., Inc. at the request of ConocoPhillips Alaska. The assessment supports the Alpine Development Project and Alpine Satellite Development Plan, and is the fifth year of study in the Fish Creek Basin.

Observations and measurements of water surface elevation were recorded at nine locations associated with the proposed GMT1 pad and access road. Both the proposed pad and access road lie within the Fish Creek Drainage Basin (FCB) of the National Petroleum Reserve, Alaska (NPR-A). The nine monitoring locations included seven small drainages along the access road corridor, the proposed pad site, and the Ublutuoch River at the proposed road crossing.

The 2009 GMT1 breakup was characterized by relatively low water surface elevations throughout the monitoring area, with small stream flooding conditions primarily due to local melt. The timing of the 2009 breakup of the Ublutuoch River and area small streams was earlier than the historical average by approximately four days. The 2009 Ublutuoch River peak water surface elevation was slightly below average and peak discharge was slightly above average compared to those on record since observations began in 2001.

The peak water surface elevation at the Ublutuoch River crossing occurred on May 29 and was measured at 8.45 feet British Petroleum Mean Sea Level (BPMSL) at river mile (RM) 6.8. The 2009 peak water surface elevation was approximately two feet lower than the maximum peak observed over the historic record. The peak water surface elevation recurrence interval is 1.5 years, based on stage frequency analysis calculations.

The Ublutuoch peak discharge occurred shortly after peak stage, early on May 30, and was estimated to be 1,990 cfs with a WSE of 8.45 feet BPMSL. The 2009 peak discharge has a recurrence interval of 4 years, based on the Ublutuoch River flood frequency analysis.

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1.0 INTRODUCTION

This report presents the results of the 2009 spring breakup monitoring activities conducted in the eastern portion of the Fish Creek Drainage Basin (FCB) in the vicinity of the proposed Greater Moose's Tooth 1 (GMT1) pad and access road. Figure 1.1 identifies the location of the GMT1 pad and access road in relation to the Colville River Delta (CRD) and existing Alpine facilities.

The Alpine facilities are owned by ConocoPhillips, Alaska (CPAI), in conjunction with Anadarko Petroleum Company, and are operated by CPAI. "Alpine facilities" refers to the existing facilities, including the CD1 processing facility (Alpine); CD2, CD3, and CD4 drilling pads; access roads; and associated pipelines.

Spring breakup flooding is the largest annual flooding event in the North Slope region and monitoring of this event is integral to understanding regional hydrology and maintaining the continued safety of the environment, oilfield personnel, and facilities during the annual flooding event. Flow generally declines over the summer months, with occasional temporary minor flow increases resulting from rainfall events.

Spring breakup monitoring activities have been conducted specifically for the Alpine Development Project (ADP) since 1992, making the 2009 hydrologic field program the 18th consecutive year of CRD breakup investigations. Preliminary hydrologic and hydraulic assessments were conducted in the FCB between 2001 and 2003. Spring breakup monitoring at proposed small stream crossings in the FCB was initially conducted in 2003. This monitoring effort was continued in 2005 and 2006, and then resumed in 2009 in conjunction with the CRD Spring Breakup and Hydrologic Assessment by Baker.

The proposed GMT1 drilling pad and access road is in the eastern portion of the FCB within the National Petroleum Reserve, Alaska (NPR-A). The proposed facilities are part of the Alpine Satellite Development Plan (ASDP). Figure 1.2 illustrates the drainage basins within the CRD and NPR-A. Figure 1.3 shows the Ublutuoch River Drainage Basin.

As shown on Figure 1.1, the proposed GMT1 drilling pad will be accessed by a gravel road that will begin from the west end of the proposed CD5 access road and travel a distance of approximately 7.8 miles west. The proposed road alignment crosses the Ublutuoch River as well as several small drainages.

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2009 EXISTING AND PROPOSED FACILITIES
CRD & NPR-A

FIGURE 1.1 - REV. 1
(SHEET 1 OF 1)

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COLVILLE RIVER AND FISH CREEK BASINS

FIGURE 1.2 (SHEET 1 OF 1)

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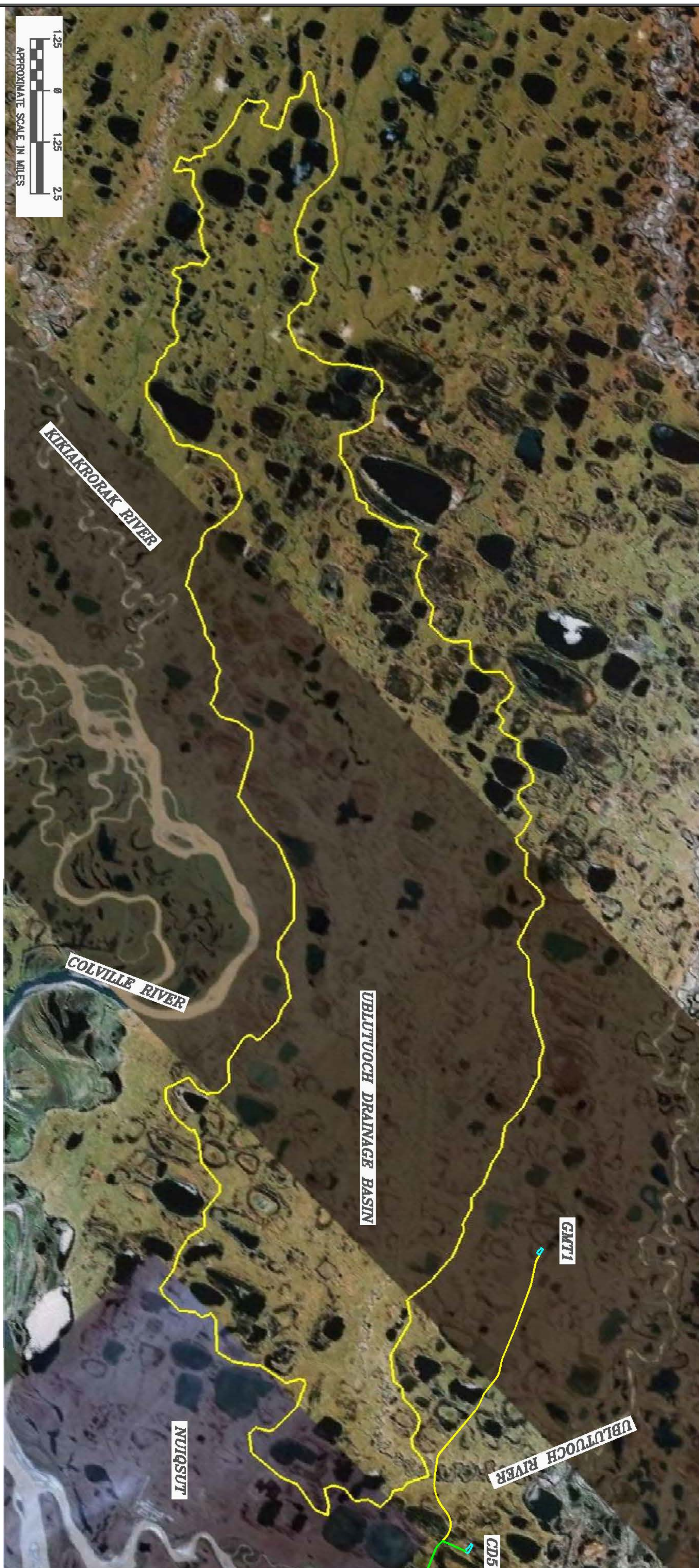

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2009 GMT1 BREAKUP
UBLUTUOCH DRAINAGE
BASIN DELINEATION

FIGURE 1.3 - REV. 1
(SHEET 1 OF 1)

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Preliminary hydrologic and hydraulic assessments were conducted in the FCB between 2001 and 2003; specific spring breakup monitoring at proposed FCB small stream crossings was initially conducted in 2003. Breakup monitoring continued in 2005 and 2006, and then resumed in 2009 in conjunction with the CRD spring breakup field program.

Observations and measurements for the 2009 GMT1 hydrologic assessment were recorded at nine locations along the proposed access road and in the vicinity of the proposed GMT1 pad. This included monitoring and discharge measurements at the Ublutuoch River and at two well-defined small streams. Fieldwork began on May 16 and was completed on June 5. Figure 1.4 illustrates the 2009 GMT1 monitoring locations.

This report presents the results of the 2009 GMT1 spring breakup monitoring program.

- **Section 1, Introduction:** discusses the objectives of the monitoring program and presents climatic information.
- **Section 2, Monitoring Locations**: outlines and discusses the 2009 monitoring sites.
- **Section 3, Methods**: describes the methods used to collect and analyze the data.
- **Section 4, 2009 GMT1 Spring Breakup**: presents summaries of observations, stage, and discharge results for the GMT1 assessment.
- **Section 5, GMT1 Flood and Stage Frequency Analysis**: presents the results of the flood frequency analysis for the proposed GMT1 facility and access road monitoring locations and the stage frequency analysis for the Ublutuoch River.
- **Section 6, References**: contains the references used in the development of this report. A list of Acronyms and a Glossary are also included to assist the reader.

We would like to thank Alaska Kuukpik/LCMF, Inc., and AirLogistics Helicopters for their assistance with the GMT1 water resources field work. Their support and diligence contributed to a safe and productive breakup monitoring season and is greatly appreciated. We would also to express our appreciation to CPAI for their continued trust in Baker to perform this work.

1.1 MONITORING OBJECTIVES

The primary objective of the 2009 GMT1 spring breakup program was to monitor and estimate the magnitude of breakup flooding. This was completed by observation of breakup events, documentation of the distribution of floodwater, measurement of water levels at distinct drainages crossed by the proposed GMT1 facilities, and direct measurement of discharge at the Ublutuoch River and two well-defined channels along the proposed access road. Additionally, indirect discharge calculations were performed at those locations where direct measurements were taken.

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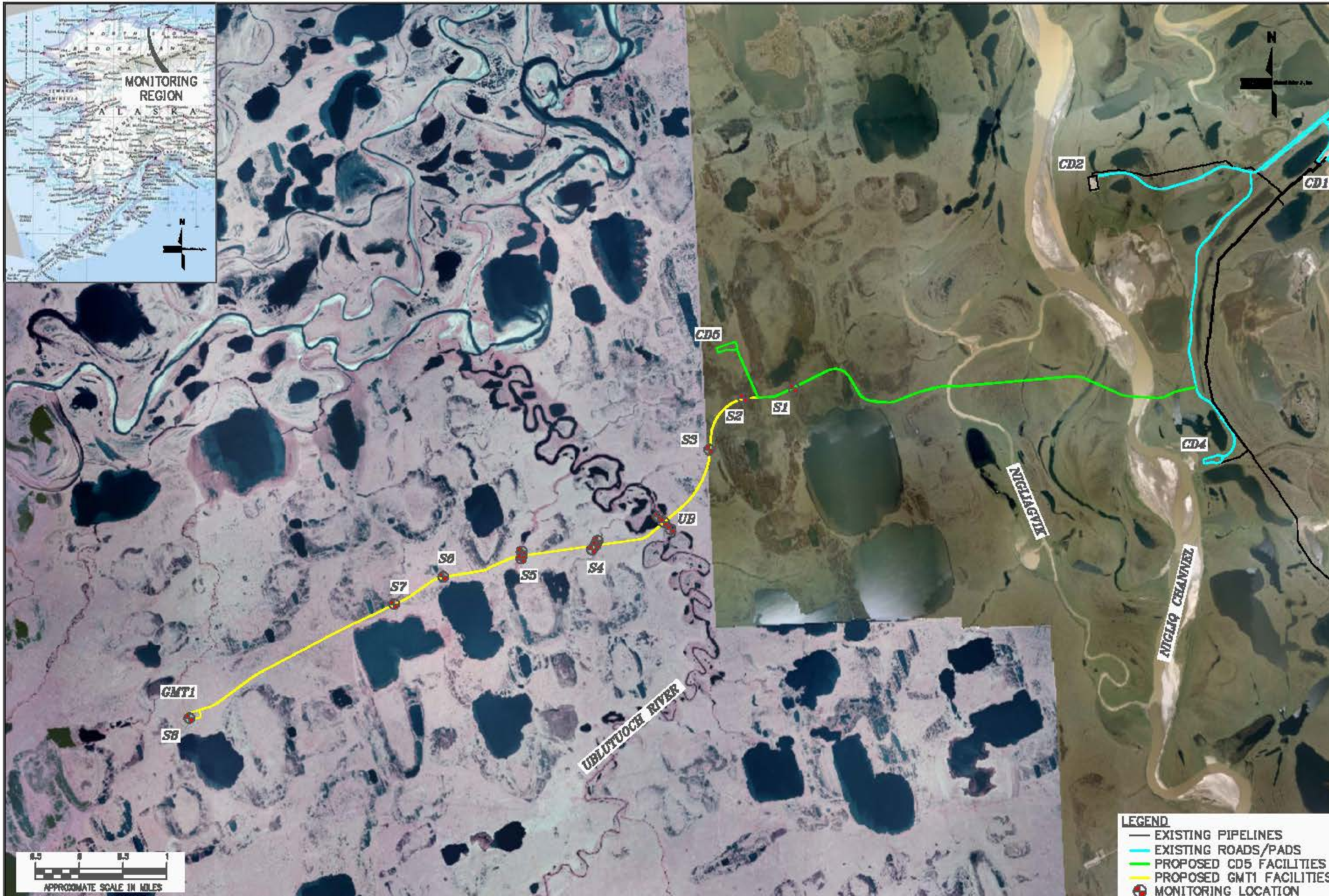

2009 GMT1 BREAKUP GAGE LOCATIONS

FIGURE 1.4 - REV. 1 (SHEET 1 OF 1)

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1.2 CLIMATIC REVIEW

Spring on the North Slope of Alaska is dominated by flooding. The open water season for the area, including the FCB, is generally limited to a four month period from June through September. Snow pack, sustained cold or warm temperatures, ice thickness, wind speed and direction, precipitation, and solar radiation contribute to the breakup cycle.

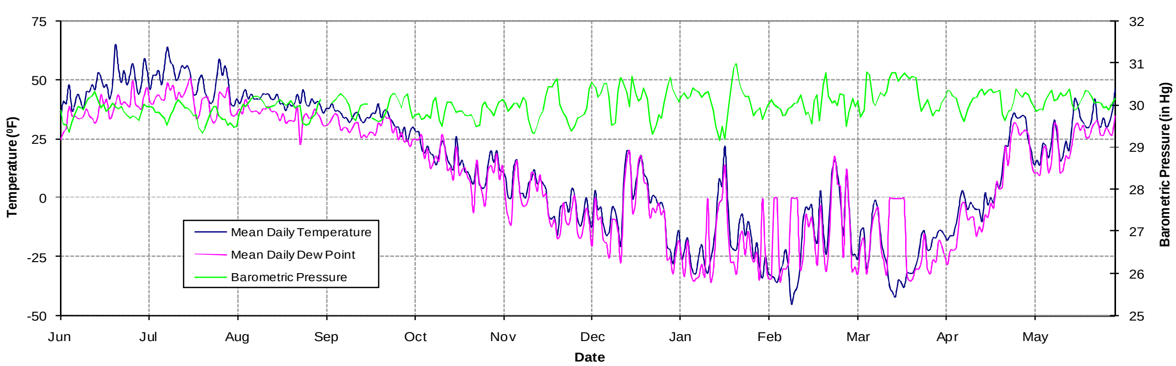
Consistent historical climatic data is generally limited to a record of daily average temperatures, barometric pressure, humidity, and wind speeds. Daily mean air temperatures, from 2003 to 2009, were compiled from weather stations at Nuiqsut, Alpine, Kuparuk, and Deadhorse.

Record temperatures from 2003 through 2009 ranged from -8°F to 70°F during the May 11 to June 17 spring breakup period at these monitoring locations. During the May 11 to June 17 time period in 2009, daily temperatures ranged from 12°F to 61°F.

Reviewing daily temperatures and wind speed can be useful when evaluating the magnitude and timing of breakup. Unseasonably warm weather in late April, with temperatures close to freezing at night, appears to have affected the 2009 breakup cycle, and may be considered as a contributing factor to the early arrival of flow. This is further discussed in section 4.1.

Climatic records for 2009 are available from a monitoring location at Nuiqsut, approximately 12 air miles east-southeast of the proposed GMT1 pad location. Graph 1.1 provides average temperatures for Nuiqsut June 1, 2008 to June 1, 2009, in addition to dew point and barometric pressure.

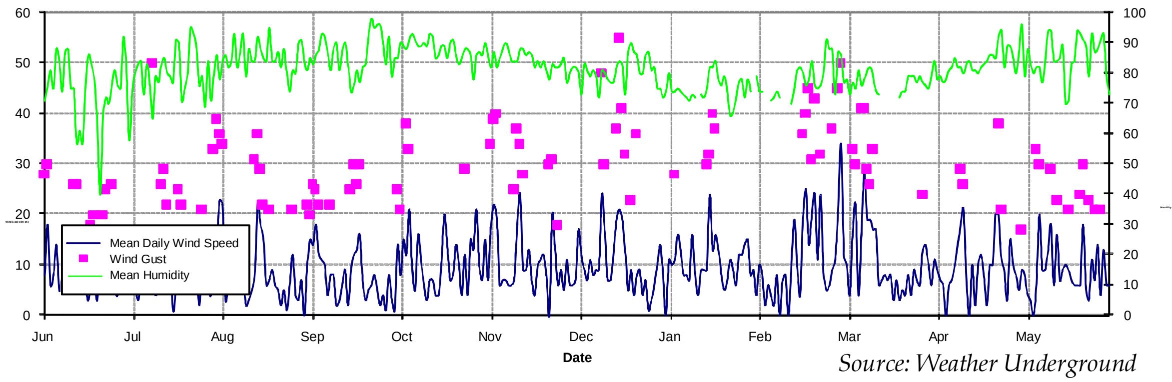
GRAPH 1.1: NUIQSUT MEAN DAILY TEMPERATURE, DEW POINT, AND BAROMETRIC PRESSURE (JUNE 1, 2008 – JUNE 1, 2009)



Source: Weather Underground

The quantity of pre-breakup snow pack and its associated snow water equivalence are largely impacted by wind and relative humidity. Snow density, depth, and ultimately snow water equivalence and snowmelt runoff can increase as wind deposits snow across topographic irregularities and simultaneously reduces particle size via ablation. Increased winds in conjunction with reduced relative humidity can also produce the opposite effect, by accelerating sublimation (similar to evaporation), which reduces both snow water equivalence and available snowmelt runoff. Wind speed data for Nuiqsut between June 1, 2008 and June 1, 2009 may be seen in Graph 1.2, in addition to maximum daily wind gust and mean humidity.

GRAPH 1.2: NUIQSUT MEAN WIND SPEED, MAXIMUM DAILY WIND GUST, AND MEAN HUMIDITY (JUNE 1, 2008 – JUNE 1, 2009)



Source: Weather Underground

1.3 UBLUTUOCH HISTORICAL BREAKUP OVERVIEW

Breakup monitoring data for the FCB has been collected at various locations sporadically since 2001. The most consistent historical record of breakup peak stage and discharge observations available is from the Ublutuoch River, the largest contributing stream within the area of interest. Table 1.1 presents the annual peak discharge, peak stage, and their respective dates for the seven years data is available.

Based on this limited seven-year data record, the average date of peak discharge is June 4. Peak discharge was estimated to have occurred on May 30 in 2009, which comparison shows is five days earlier than average. The average date of peak stage is June 3; in 2009, peak stage occurred on May 29, approximately four days earlier than average.

TABLE 1.1: UBLUTUOCH RIVER HISTORICAL PEAK DISCHARGE, STAGE & DATE

Year	Location (RM)	Discharge		Stage		Reference
		Peak Discharge (cfs)	Date	Peak Stage (feet BPMSL)	Date	
2009	6.8	1,990	30-May	8.45	29-May	This Report
2006	6.8	1,290	6-Jun	6.19	7-Jun	Baker 2006
2005	6.8	1,680	9-Jun	10.01	7-Jun	Baker 2005c
2004	6.8	2,800	5-Jun	10.50	6-Jun	Baker 2005a
2003	6.8	1,300	9-Jun	10.14	6-Jun	Baker 2003a
2002	8.0	1,900	22-May	8.34	22-May	URS 2002
2001	13.7	1,440	10-Jun	18.09	10-Jun	URS 2001

2.0 2009 GMT1 Monitoring Locations

Monitoring locations were selected based on aerial imagery and topography in relation to historic hydrologic and hydraulic observations in the region and proximity of proposed facilities to relevant terrain features.

Many areas on the North Slope of Alaska, including the CRD and the FCB, share similar hydrologic and hydraulic characteristics common to the arctic climate and to the continuous presence of regional permafrost. Shallow groundwater is generally restricted to isolated zones beneath deep lakes and river channels. Groundwater influx is largely nonexistent. For much of the year, many small streams and tributaries in the FCB are completely frozen.

Based on past observations, the majority of annual flow seen in the small streams and tributaries of the FCB is attributed to the spring snowmelt. Annual peak stage for the FCB occurs during the spring breakup. Flow generally declines over the summer months, with occasional temporary minor flow increases resulting from rainfall events.

2.1 Gage Locations and Selection

The 2009 GMT1 monitoring locations listed in Table 2.1 were selected in areas of surface flow or surface water concentration occurring along the proposed GMT1 access road provided by PND Engineers, Inc., and at the proposed pad location. Coordinates for each monitoring site are located in Appendix A. The 2009 monitoring was conducted at the proposed Ublutuoch River Crossing, at seven small stream locations, as well as at a location adjacent to the proposed GMT1 pad. Several of these sites were evaluated in 2006, but the name designations for these sites have been revised to reflect their relative location in 2009. The proposed GMT1 access road corridor remains largely unchanged from the 2006 route. Figure 1.4 illustrates the gage locations as related to the proposed route and pad.

TABLE 2.1: 2009 GREATER MOOSE'S TOOTH 1 (GMT1) MONITORING PROGRAM

Location	Designated Name	Number of Gage Assemblies
Small Streams	S1	1
	S2	1
	S3	1
	S4	3
	S5	3
	S6	1
	S7	1
Proposed GMT1 Pad	S8	1
Ublutuoch River	RM 6.7	4
	RM 6.8	4
	RM 6.9	3
Total		**23**

2.1.1 UBLUTUOCH RIVER

The Ublutuoch River lies in the southeast portion of the FCB. The creek is sinuous with a low gradient, flowing north into Fish Creek at a location approximately 10 river miles (RM) upstream of Harrison Bay. The channel is characterized by numerous meander bends, often with undercut banks and associated bank sloughing along the outer edges.

The Ublutuoch River monitoring sites included sets of three to four gages installed at RM 6.7, 6.8, and 6.9, as shown in Figure 2.1. The RM location designations, UB 6.7, UB 6.8, and UB 6.9, refer to the distance in river miles from the confluence of the Ublutuoch River and Fish Creek. The gages are located on the west bank of the Ublutuoch River. The gage locations were selected to monitor and document local breakup conditions at the proposed bridge location as well as upstream and downstream from the crossing.

The proposed Ublutuoch bridge location at UB 6.8 remains the same as it was in 2005 and 2006. An aerial view of the proposed bridge location is provided in Photo 2.1. At the proposed bridge site, the Ublutuoch River has a drainage area equal to approximately 228 square miles.

PHOTO 2.1: UBLUTUOCH RIVER PROPOSED GMT1 ACCESS ROAD CROSSING SITE, UB 6.8, MAY 31, 2009

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2009 GMT1 BREAKUP
UBLUTUOCH RIVER
GAGE LOCATIONS

FIGURE 2.1 - REV. 1
(SHEET 1 OF 1)

2.1.2 SMALL STREAM SITES

Eight locations were identified as monitoring sites in 2009, and are referred to as small stream sites S1 through S8, increasing in number from east to west, as shown in Figure 1.4. Sites S1 through S7 were selected, based on topography and aerial imagery, as locations where a drainage structure would potentially be required to preserve the integrity of the proposed road, or at areas where flow would likely be affected by the proposed access road. Depending on anticipated flow at each site, one to three gages were installed. Gage S8 was installed in the vicinity of the proposed GMT1 pad to monitor water surface elevations near the proposed facility.

As indicated previously, some of the 2009 monitoring locations differ from the 2006 monitoring locations. This was due either to adjustments to the proposed alignment, which changed the areas of each drainage basin contributing to flow at that location, or because a 2006 monitoring location was determined to have negligible impact to potential infrastructure. For comparison purposes, Table 2.2 compares the 2009 gage locations identifiers with the gage locations identified in the 2006 report.

TABLE 2.2: COMPARISON OF 2009 AND 2006 GAGE LOCATIONS

2009 Gage Identifier	2006 Gage Identifier	Notes
	Site S1	This site was along northern CD5 route location. No longer along proposed CD5 route.
	Site S2	This site was along northern CD5 route location. No longer along proposed CD5 route.
Site S1	Site S3	
Site S2		Location selected to monitor breakup overland flow in this vicinity.
Site S3		Location selected to monitor breakup overland flow in this vicinity.
Ublutuoch 6.7,6.8,6.9	Ublutuoch 6.8	Proposed Bridge Crossing location remains the same.
Site S4	Site S5	
Site S5	Site S6	
Site S6	Site S7	
Site S7		Location selected to monitor breakup overland flow in this vicinity.
Site S8		GMT1 Pad location
	Site S8	Located north of the 2009 proposed facilities.
	Site 9	Located west of the 2009 proposed GMT1 pad site.
	Site S10	Located west of the 2009 proposed GMT1 pad site.
	Site S11	Located north the 2009 proposed facilities.
	Site S12	Located north of the 2009 proposed facilities.
	Site S13	Located west of the 2009 proposed GMT1 pad site.

2.1.2.1 SITE S1

The drainage basin area of Site S1 is approximately 2.4 square miles and includes approximately 1.3 square miles that is Lake L9308. Tussocks were most abundant along the toe of the slope defining the west side of the drainage channel. Figure 2.2 shows the location of the S1 gage. Figure 2.3 illustrates the drainage basin delineation.

2.1.2.2 SITE S2

Site S2 is located within a relatively flat, shallow basin approximately 4.1 square miles in size and includes Lake MB0301 and some small ponded areas. A channel drains the basin toward the Ublutuoch River, located approximately 0.4 miles to the west. Ground cover is mostly comprised of native grass, with some tussocks and dwarf willows. Figure 2.4 shows the S2 gage location and Figure 2.3 shows the S2 drainage basin delineation.

2.1.2.3 SITE S3

A small channel drains the approximately 0.9 square mile drainage basin associated with Site S3 directly into the Ublutuoch River, over a distance of approximately 0.27 miles. Site S3 is near the head of the small channel, which serves some small nearby ponds. Tussocks are abundant in the area. See Figure 2.5 for the S3 gage location and Figure 2.3 for the S3 drainage basin delineation.

2.1.2.4 SITE S4

Site S4 bisects a channel of connected pools draining a small sub-basin composed of approximately 0.7 square mile of ponds and marshes. Grassy swales of fairly uniform topography define the channel of connected pools draining northwest into the Ublutuoch River. Native grass dominates the area with the presence of tussocks limited to regions bordering the channel reach. Figure 2.6 shows the S4 gage location and Figure 2.7 delineates the S4 drainage basin.

2.1.2.5 SITE S5

The 3.6 square mile drainage basin of Site S5 encompasses the Site S6 basin and flows into the Ublutuoch River via connected pools, small ponds, and lakes. The drainage at Site S5 connects two smaller lakes and is uniform in cross-section, having a firm channel bed with underlying sedge and banks dominated by willows. The S5 gage location is identified in Figure 2.8, and the S5 basin delineation is illustrated on Figure 2.7.

2.1.2.6 SITE S6

Site S6 is located in a shallow recession of pooled marshland dominated by grasses and tussocks. The channel is oriented north-south connecting two lakes of varied size. The southern lake (L9819) is approximately 0.4 square miles defining much of the drainage basin of Site S6, while the northern lake is considerably smaller. The drainage area is approximately 0.9 square miles. Figure 2.9 shows the S6 gage location. The S6 drainage basin delineation is shown on Figure 2.7.

2.1.2.7 SITE S7

Lake L9820, with an area of approximately 0.46 square miles, lies upstream and south of Site S7. The S7 drainage basin encompasses approximately 0.9 square mile. No defined channel connects the site directly to the lake. The terrain north of Site S7 slopes downstream, and contains some marshy areas. Native grass and tussocks cover the ground around the site. The S7 gage location is shown in Figure 2.10. The S7 drainage basin delineation is illustrated in Figure 2.11.

2.1.2.8 GMT1 PAD (SITE S8)

Site S8 is located at the proposed GMT1 pad and lies north of Lake M9925. The S8 drainage basin encompasses the Site S7 basin and has an area of approximately 1.1 square miles. No drainage channels were identified. Foliage includes native grass and tussocks. Figure 2.12 shows the S8 gage location while the basin delineation is shown on Figure 2.11.

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2009 GMT1 BREAKUP

S1

GAGE LOCATION

FIGURE 2.2 - REV. 1

(SHEET 1 OF 1)

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2009 GMT1 BREAKUP
S1, S2, & S3 DRAINAGE BASIN DELINEATIONS
FIGURE 2.3 - REV. 1
(SHEET 1 OF 1)

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2009 GMT1 BREAKUP

S2

GAGE LOCATION

FIGURE 2.4 - REV. 1

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2009 GMT1 BREAKUP
S3
GAGE LOCATION

FIGURE 2.5 - REV. 1
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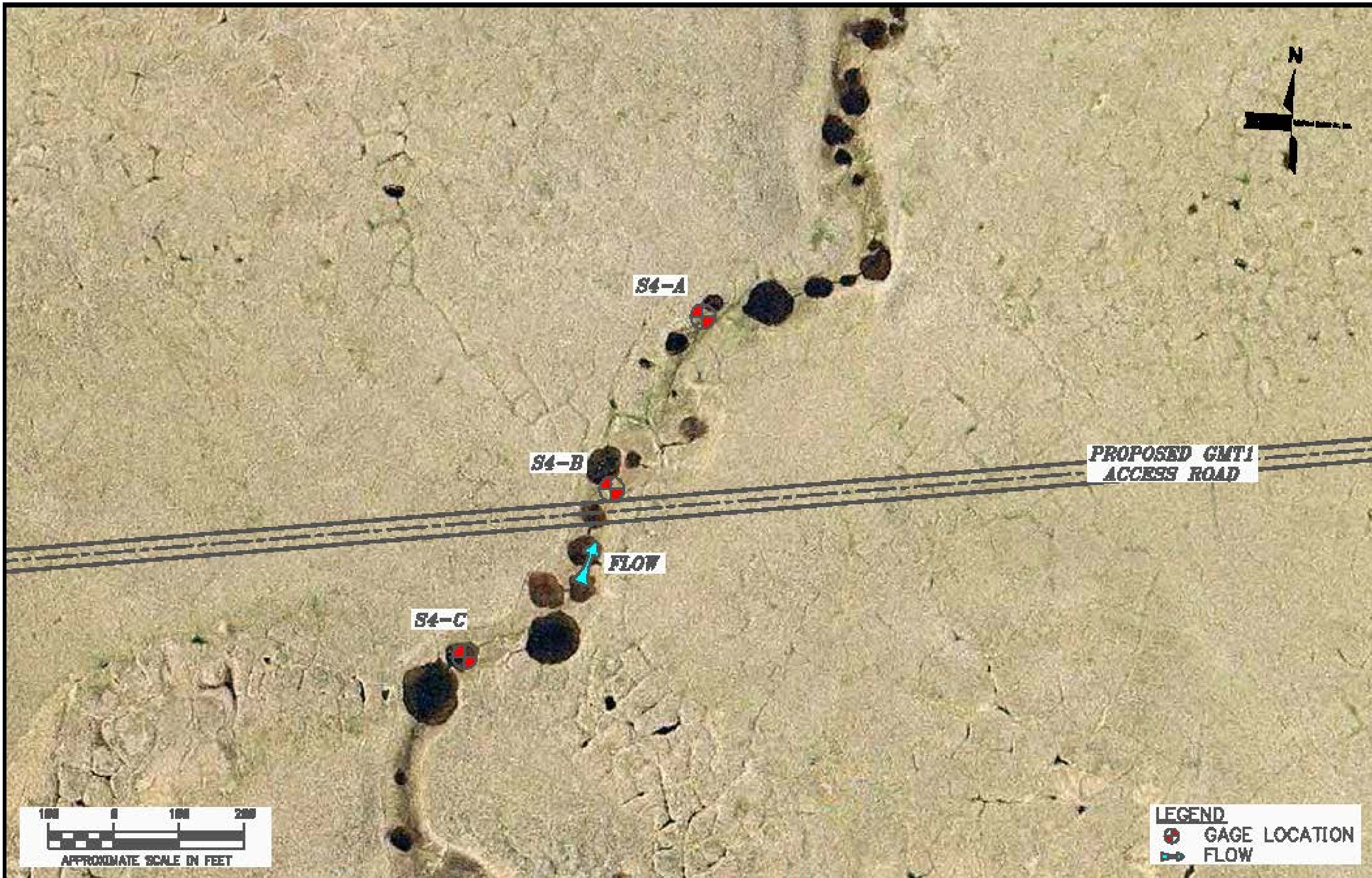

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2009 GMT1 BREAKUP

S4

GAGE LOCATION

FIGURE 2.6 - REV. 1

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2009 GMT1 BREAKUP
S4, S5, & S6 DRAINAGE BASIN DELINEATIONS
FIGURE 2.7 - REV. 1
(SHEET 1 OF 1)

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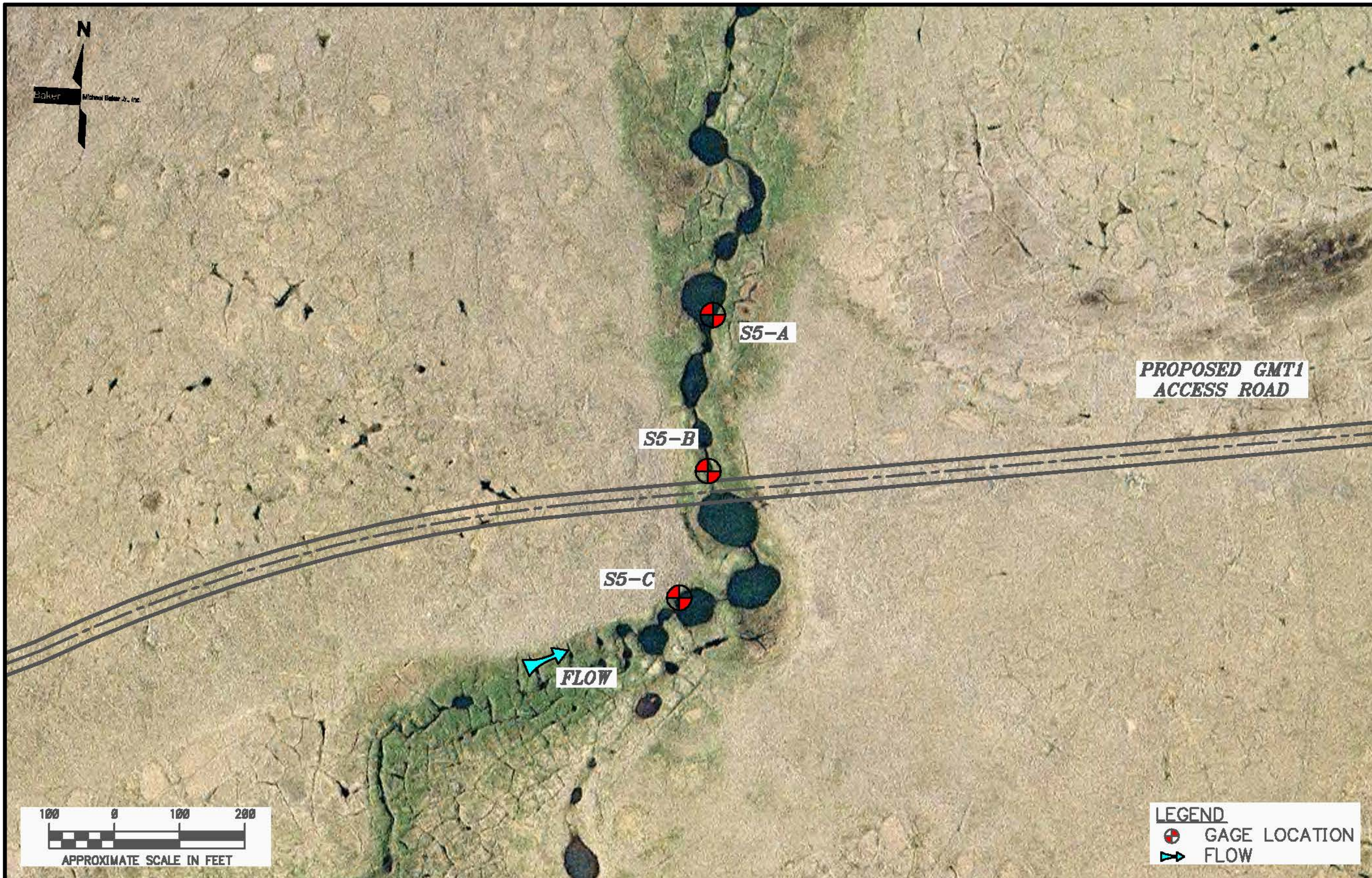

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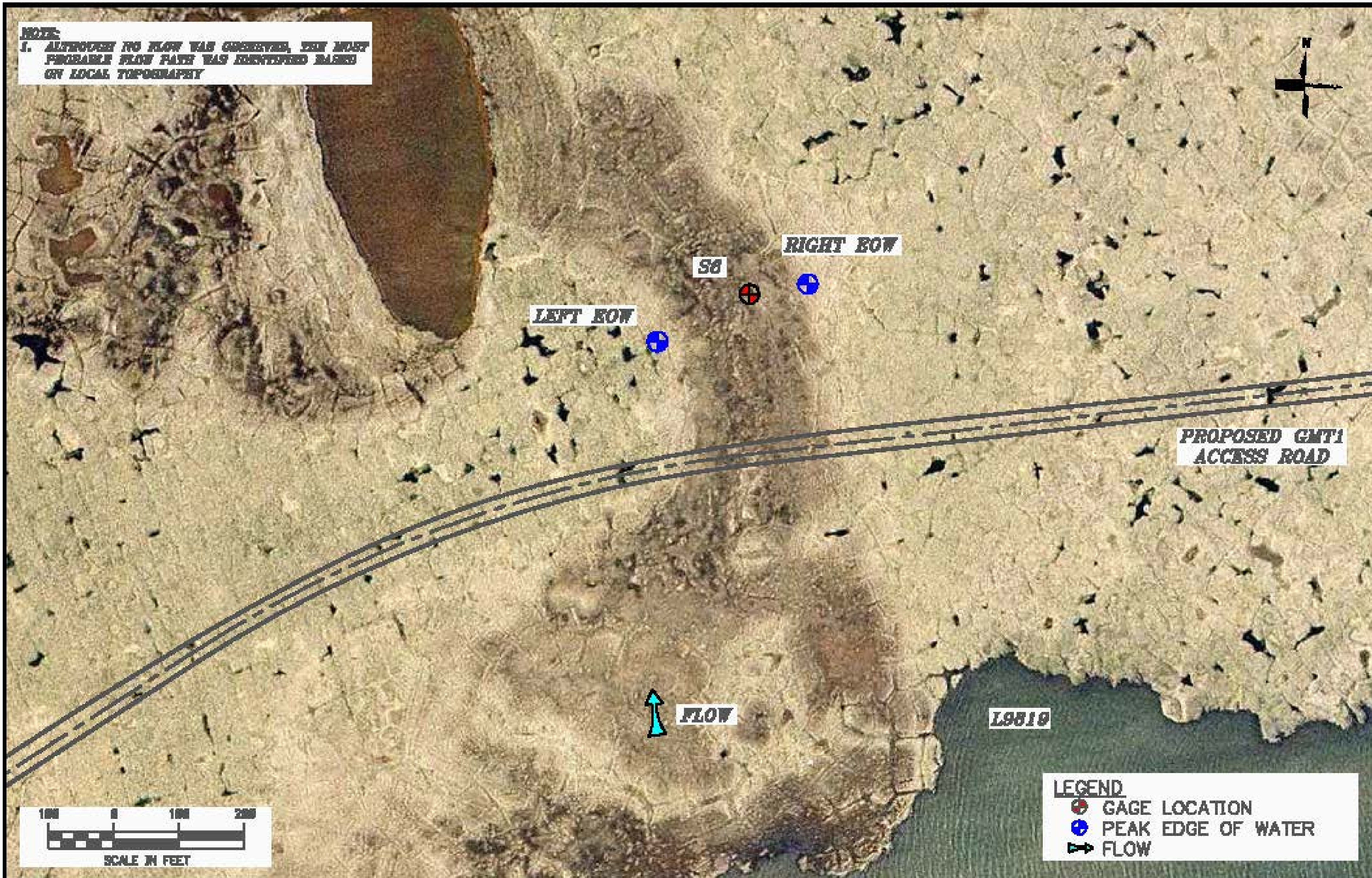
2009 GMT1 BREAKUP

S5

GAGE LOCATION

FIGURE 2.8 - REV. 1

(SHEET 1 OF 1)



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DATE:	12/18/09	PROJECT:	117216
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CHECKED:	HLR	SCALE:	APPROXIMATE

Baker

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2009 GMT1 BREAKUP

S6

GAGE LOCATION

FIGURE 2.9 - REV. 1

(SHEET 1 OF 1)

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DATE:	12/18/09	PROJECT:	117216
DRAWN:	SMC	FILE:	FIGURE 2.10 (S7)
CHECKED:	HLR	SCALE:	APPROXIMATE

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2009 GMT1 BREAKUP
S7
GAGE LOCATION
FIGURE 2.10 - REV. 1
(SHEET 1 OF 1)

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ConocoPhillips Alaska, Inc.

DATE:	12/18/09	PROJECT:	117216
DRAWN:	SMC	FILE:	FIGURE 2.11
CHECKED:	HLR	SCALE:	APPROXIMATE

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2009 GMT1 BREAKUP

S7 & S8 DRAINAGE BASIN DELINEATIONS

FIGURE 2.11 - REV. 1

(SHEET 1 OF 1)

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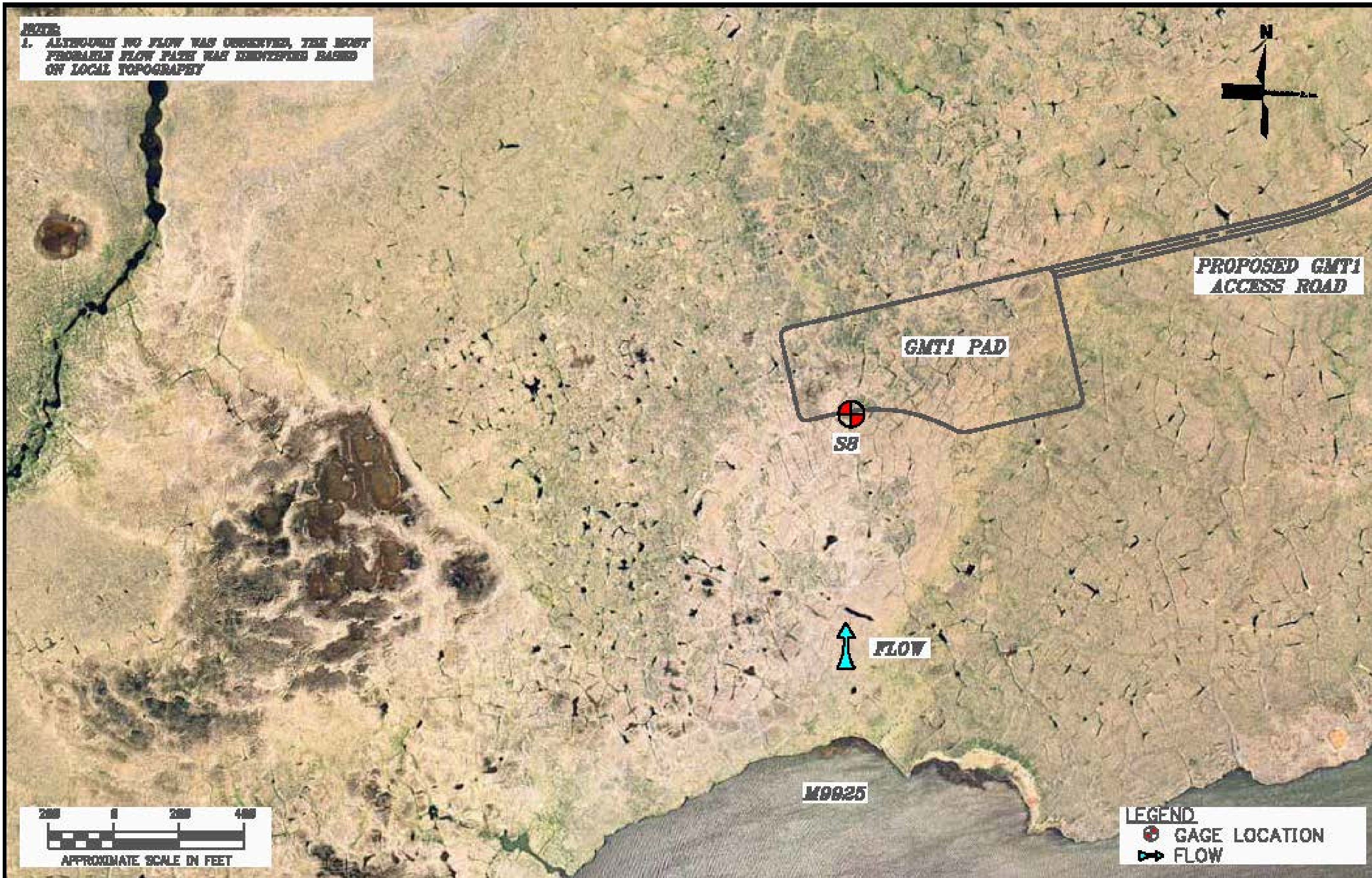

ConocoPhillips Alaska, Inc.

DATE:	12/18/09	PROJECT:	117216
DRAWN:	SMC	FILE:	FIGURE 2.12 (S8)
CHECKED:	HLR	SCALE:	APPROXIMATE

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2009 GMT1 BREAKUP

S8 (GMT1 PAD)

GAGE LOCATION

FIGURE 2.12 - REV. 1

(SHEET 1 OF 1)

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3.0 METHODS

The primary methods used during the 2009 GMT1 spring breakup assessment were visual observations of the distribution of flow, measurement of water surface elevation, and measurement of discharge. Field methods were based on standard techniques proven to be safe, reliable, efficient, and accurate for the conditions found in the FCB during spring breakup.

3.1 VISUAL OBSERVATIONS

An initial reconnaissance flight was conducted on May 16, with attention focused on pre-breakup conditions in the Ublutuoch River area. Visual inspections of the gage sites were conducted daily on the ground or via helicopter between May 27 and June 4, and observations were recorded in field books. Additionally, digital photographs were collected to document the progression of spring breakup prior to, during, and after peak flooding events. The geographic position of the camera, date, and time were automatically imprinted onto each photo. Additional photographs were taken and manually geographically referenced to document the location of each image.

3.2 WATER SURFACE ELEVATION

Water surface elevation (WSE) was measured by visual observation of staff gages at each site, or by survey level loop techniques if the WSE was too low to be read directly off the gages. Pressure transducers (PT) were also employed at the proposed Ublutuoch bridge crossing to measure water depth at 15 minute intervals.

3.2.1 STAFF GAGES

Temporary staff gages set in the GMT1 monitoring locations consisted of one to four gage assemblies per site. Each gage assembly consisted of a metal gage faceplate mounted on a two-by-four timber attached with U-bolts to a 6-foot long 1.5-inch angle iron post driven 2 feet into the ground. The horizontal position of each gage was recorded using a handheld Garmin GPSMAP 60CS in North American Datum of 1983 (NAD83). Photo 3.1 shows an example of a staff gage after installation.

PHOTO 3.1: STAFF GAGE INSTALLED AT SITE S1, MAY 20, 2009

The elevation of each gage was surveyed from a local benchmark tied to British Petroleum Mean Sea Level (BPMSL) using standard level loop techniques. The basis of elevation for each gage and the horizontal position of respective benchmarks and gages are presented in Appendix A. The most recent (as of spring 2009) basis of elevation of vertical control was used. Gage surveys along the GMT1 route commenced on May 25 and were completed on May 31, 2009.

Gages were named based on the site location identification (S1 through S8). In those locations where terrain elevation varied more than three feet, more than one gage was installed. This occurred at sites S4, S5, and at each site along the Ublutuoch River. These gages were further identified with alphabetical designations A, B, C, or D, with A being closest to the water's edge (e.g., S5-A, S5-B, and S5-C).

3.2.2 PRESSURE TRANSDUCERS (PT)

Two PT were installed at the Ublutuoch River to collect WSE data. PT measure the pressure imparted by water at the sensor, allowing the depth of water above the sensor to be calculated. Variations in barometric pressure were taken into account using an independent barometric pressure logger, installed nearby. Resulting data yielded a more accurate and complete record of the fluctuations in WSE than could be captured by visual measurements.

In-Situ, Inc. Level TROLL® 500 sensors were used. The instrument is a non-vented pressure sensor that collects and stores pressure data points and temperature. The factory-calibrated transducers were set to collect absolute pressure and water temperature at 15-minute intervals at gages UB 6.7-B and UB 6.9-A. The measured pressure datum is the sum of the forces imparted by both the water column and atmospheric conditions. As a result, a correction of local barometric pressure was required and obtained from an In-Situ, Inc. BaroTROLL® sensor located on the overbank of UB 6.9.

Prior to deployment, each PT was configured using Win-Situ LT 5.1.1.0®. Absolute pressure was set to zero. Transducers were housed in a segment of perforated galvanized steel pipe and clamped to angle iron in the active channel near the channel bottom surface. The sensor of each transducer was surveyed to establish a vertical datum using local control. Water depth was determined based on the recorded absolute pressure and barometric pressure data.

Water surface elevations were determined by summing the calculated water depth and the surveyed sensor elevation. A standard conversion using the density of water at 0°C was used to calculate all water depths from adjusted gage pressure. Fluctuations in water temperature during the sampling period were not significant enough to impact WSE calculations due to the limited range in temperature and observed water depths. See Table 3.1 for a comparison of sample temperatures and the resultant differences.

TABLE 3.1: COMPARISON OF TEMPERATURE FLUCTUATION ON WSE CALCULATION

Temp (°C)	Temp (°F)	Specific Volume (ft^3/lb)	Density (lb/ft^3)	PSI/1ft Depth	Calculated Depth (ft)*	Difference
-18	0	0.01743	57.3723	0.39842	0.9191	
-1	30	0.01747	57.2410	0.43349	1.0000	-0.0809
0.01	32.018	0.01602	62.4220	0.43349	1.0000	0.0000
2	35	0.01602	62.4220	0.43311	0.9991	0.0009
18	65	0.01604	62.3441	0.43133	0.9950	0.0041
*Calculated using the density at 0.01˚C (32.018°F)						

3.3 Discharge Measurements

Discharge was both directly measured and indirectly calculated at three locations. Standard United States Geological Survey (USGS) midsection methods were used to directly measure discharge. Velocity and discharge measurements were taken as close to the observed peak stage as possible to determine the peak direct discharge. Indirect discharge was calculated based on observed data.

3.3.1 USGS Midsection Techniques

PHOTO 3.2: UBLUTUOCH RIVER BOAT DISCHARGE MEASUREMENT INSTRUMENTATION, MAY 29, 2009

Standard USGS midsection techniques (Rantz 1982) were used to determine discharge at the Ublutuoch River (UB 6.8) as well as at Site S4 and Site S5.

A Price AA velocity meter was used to measure velocities and discharge at UB 6.8. Measurements were taken using a sounding reel connected to a boat-mounted boom with a 30-pound Columbus-type lead sounding weight. A tag line was used to define the cross section and to delineate measurement subsections within the channel. The velocity meter was calibrated by the USGS at the Office of Surface Water (OSW) Hydraulic Laboratory in 2006. To ensure accurate performance of meters, procedures outlined in OSW Technical Memorandum No. 99.06 were followed. Photo 3.2 shows the velocity meter and sounding weight used for the Ublutuoch River UB 6.8 discharge measurement.

Photo 3.3 shows the tagline and boat used for the measurement.

A Marsh-McBirney Flo-Mate 2000 portable velocity meter and USGS wading rod were used to determine discharge at Site S4 and Site S5. A tag line was used to define the cross section and delineate measurement subsections within the channel. Photo 3.4 shows the small stream discharge measurement at Site S4.

PHOTO 3.3: UBLUTUOCH RIVER BOAT DISCHARGE MEASUREMENT PREPARATION, MAY 29, 2009

PHOTO 3.4: SMALL STREAM WADING DISCHARGE MEASUREMENT AT S4, MAY 30, 2009

3.3.2 Indirect Discharge Calculations

The indirect discharge calculations used physical characteristics, such as WSE slope, as input variables. Indirect discharge calculations were performed for the Ublutuoch River, Site S4, and Site S5.

Indirect calculations of peak discharge for the Ublutuoch River were performed by correlating hydraulic depths observed during the direct discharge measurement and during peak discharge conditions. This indirect method assumes that the average measured velocity varies little between the time of direct measurements and actual peak discharge. The assumption is valid if the observed increase in stage, as well as the differential stage between upstream and downstream, is relatively low. For this reason, direct discharge measurements are collected as near to peak discharge as possible.

Indirect calculations of peak discharge for the Ublutuoch River, Site S4 and Site S5 were also performed using the slope-area method for a uniform channel (Benson and Dalrymple 1967). Water surface elevation and slope data were obtained from observations made at gages.

Cross-section geometry for S4, S5, and the Ublutuoch River were based on cross sections surveyed by Kuukpik/LCMF in 2005 on the Ublutuoch River.

3.4 FLOOD AND STAGE FREQUENCY ANALYSIS METHODS

A flood frequency analysis was performed on the small stream sites using delineated drainage basins and USGS regional regression equations for Region 7 (Curran, Meyer, and Tasker 2003). A flood frequency analysis was performed on the Ublutuoch River using three methods: 1) USGS regional regression equations, 2) a station-specific frequency analysis using historic peak discharge, and 3) weighted estimates based on results from the station-specific and regional regression analyses. USGS regression equations and weighted estimates were calculated using methods presented in Curran, Meyer, and Tasker (2003). The program PeakFQ Version 5.2 (USGS 2007) was used to perform the station-specific flood frequency analysis. Additionally, a stage frequency analysis was conducted for the Ublutuoch River using historic peak stage data and HYFRAN hydrologic frequency analysis software (INRS-ETE 2002).

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4.0 2009 GMT1 Spring Breakup

This section presents the images, data, observations and analyses results for the GMT1 Alpine Satellite Project 2009 Hydrologic Assessment. Hydrologic data and observations were documented between May 16 and June 5, 2009, and are described in the following sections. Figure 4.1 presents a visual timeline of the major 2009 breakup events.

4.1 Hydrologic Observations Summary

The 2009 spring breakup event on the North Slope was affected by a period of unseasonably warm weather in late April and early May. Air temperatures for approximately 5 to 7 days spiked into the 30s and even low 40s (see Graph 1.1 in Section 1.2). An early warming trend can "set the stage" for breakup by pre-softening snow and ice such that when the main melt does occur, it occurs more rapidly and efficiently than if the early warming period had not occurred. The timing of breakup in the NPR-A and FCB was likely affected to some degree by the warm weather. The 2009 peak stage in the Ublutuoch River occurred on May 29, approximately four days earlier than the historic average based on a seven year data record (Table 1.1).

4.1.1 GMT1

Incidental aerial observations started May 20 in conjunction with CRD monitoring flights and during gage installation. An aerial photography reconnaissance flight of the proposed GMT1 road right-of-way was also conducted on May 20. During the flight, each gage location along the proposed GMT1 road right-of-way was visited. Water was first observed in the area on May 22 at the Ublutuoch River. Daily monitoring began with observations of flow in the Ublutuoch River on May 27 and continued through June 5.

4.1.2 GMT1 Pad Area

The proposed GMT1 access road terminates at the proposed GMT1 pad. The pad location marks the western-most extent of the study area. An aerial reconnaissance flight of the pad location was conducted on May 20. Gage S8 was installed at the southwest corner of the proposed pad location on May 26. No clear channel was identified; therefore, the location of the single gage was selected to monitor breakup-related overland flows in the vicinity of the proposed pad. This location has no defined drainage channel, and only stagnant local melt was observed throughout the data collection period.

FIGURE 4.1: 2009 GMT1 SPRING BREAKUP HYDROLOGICAL TIMELINE

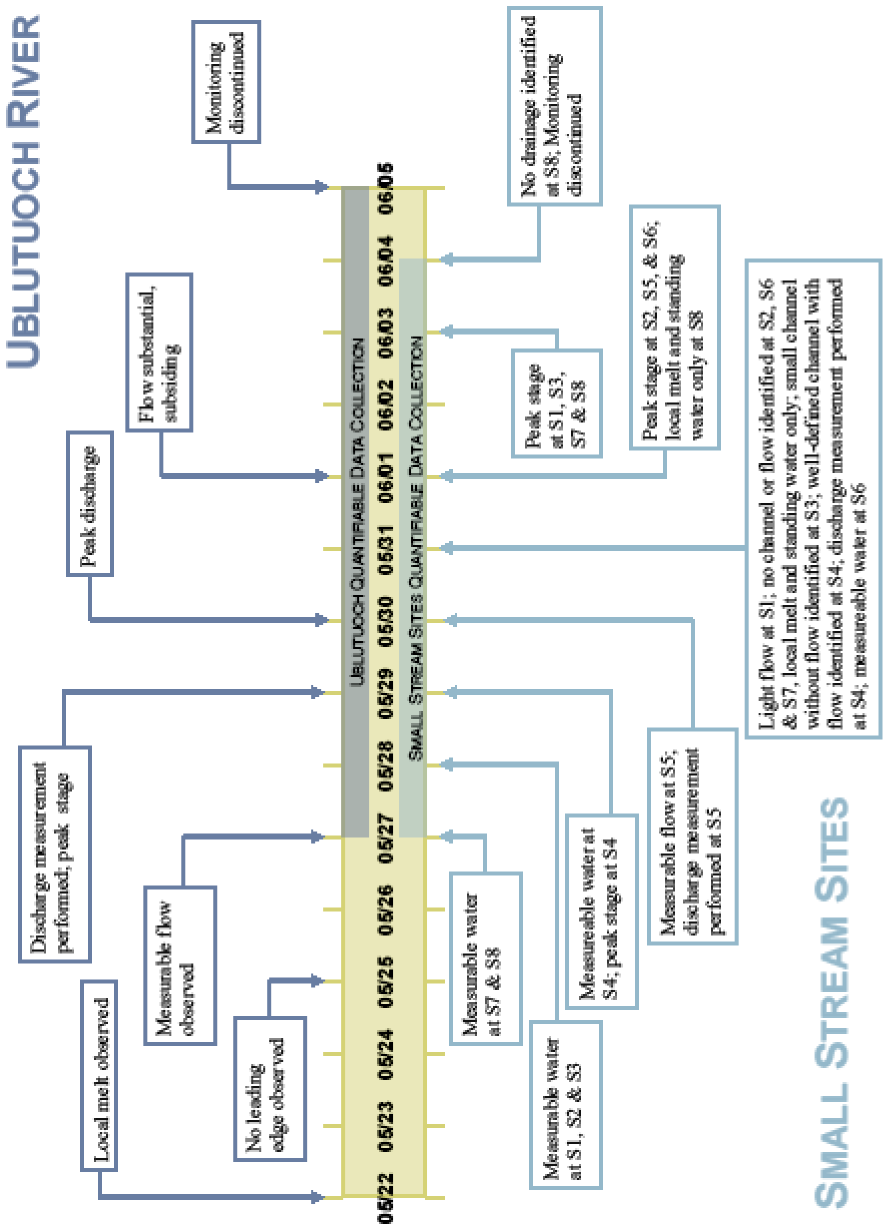


PHOTO 4.1: GMT1 PAD LOCATION, JUNE 1, 2009

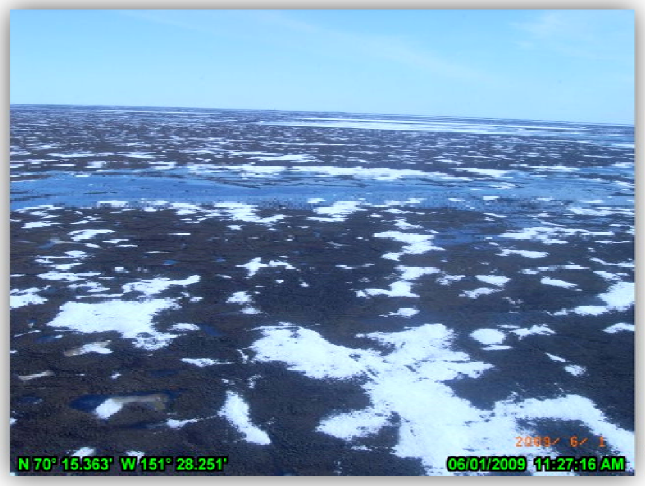


PHOTO 4.2: UNIDENTIFIED FLOW PATH MIDWAY BETWEEN PROPOSED GMT1 PAD AND S7, JUNE 1, 2009

Water was first noted in the proposed pad area on May 27 and determined to be the result of local melt, having no velocity and occurring only in isolated troughs and depressions in the terrain. Measurements made at S8 on subsequent days showed an increase in WSE. All increases were determined to be a result of local melt with no velocity or hydraulic connection to any flow. The peak water surface elevation at S8 occurred midday on June 3. Subsidence of water was noted on the afternoon of June 3 and WSE measurements were discontinued. Photo 4.1 shows the proposed GMT1 pad location and flooding extent on June 1, prior to peak WSE.

On June 1, an unidentified active flow path was observed crossing the alignment approximately halfway between the proposed GMT1 pad and gage S7, as shown in Photo 4.2. The flow was aligned north-south and appeared to be less than one half-foot deep with sustained low velocity flow. This flow path should be considered for quantitative investigation during the 2010 breakup program.

4.1.3 GMT1 ACCESS ROAD

The GMT1 access road extends from the western portion of the proposed CD5 access road. Eight drainage areas are crossed along the route, the largest of which is the Ublutuoch River. As previously discussed, the proposed GMT1 right-of-way was gaged at locations where the proposed road alignment crossed an active flow path or where flow may be impeded by the future road embankment.

Existing 2006 study gages (S5, S6, S7) were deemed appropriate for use in 2009 (re-designated as S4, S5, and S6). Installation of gages at the remaining GMT1 sites and survey of all GMT1 gages was completed on May 27.

4.1.3.1 UBLUTUOCH RIVER

The Ublutuoch River is the only perennial stream along the proposed GMT1 right-of-way. On May 22, localized melt and standing water along the Ublutuoch were noted during a reconnaissance flight to the area. Gage installation and survey was completed on May 25. Gage installation consisted of straightening and repairing gages used in previous years, as well as installing new gages at those locations where gages had been destroyed or were no longer usable. Areas of limited local melt within the channel were present during installation. A May 25 flight upstream from the monitoring site revealed no leading edge of saturated snow or other flooding indications.

PHOTO 4.3: UBLUTUOCH RIVER PROPOSED GMT1 CROSSING, MAY 31, 2009

Daily monitoring began with observations of flow on the Ublutuoch River on May 27. On this day, water was observed at UB 6.9. Floodwater continued to rise until peak stage was reached late in the evening on May 29. Peak discharge was estimated to have occurred shortly after peak stage. Flow steadily abated for the remainder of the observation period. No ice jams were observed in the proximity of the monitoring area.

4.1.3.2 SMALL STREAMS

Small stream sites S4 and S5 were selected as gaging stations at well-defined channels where moderate flow velocity was expected. Little to no flow velocity was expected at sites S1, S2, S3, S6, and S7. These gage locations were selected to quantify water depth for future drainage structure design to mitigate floodwater encroachment on the future road embankment. At those sites where flow velocity was observed, discharge measurements were performed close to peak stage. Maximum depth, average depth, and width of standing water were recorded at those sites where no measureable flow velocity was observed.

Breakup monitoring at the seven FCB small steam sites began on May 27. Gage installation and survey at all sites occurred during the week of May 25. Moderate flow was observed at sites S4 and S5; very little to no flow was observed at the remainder of the sites. All locations at minimum experienced a gradual accumulation then subsidence of standing water; peak stage for all occurred between June 1 and June 3, except S4, which occurred on May 28. Discharge at S4 and S5 was measured on May 31 and May 30, respectively. Small stream WSE monitoring was discontinued on June 4.

4.1.4 Clover Mine Vicinity

The proposed Clover Mine area is located approximately 2.3 miles south of the UB 6.8 gage location. The area is generally bounded on the north by the Ublutuoch River and on the west, east, and south by drainage channels that only experience flow during breakup (ephemeral channels).

2009 breakup conditions in the Clover Mine area were similar to those observed throughout the FCB, characterized by local melt resulting in little to no overland flow. Meltwater in the only significant drainage investigated remained within the defined channel during the observation period. Figure 4.2 and Photo 4.4 show the Clover Mine Site.

FIGURE 4.2: CLOVER MINE SITE

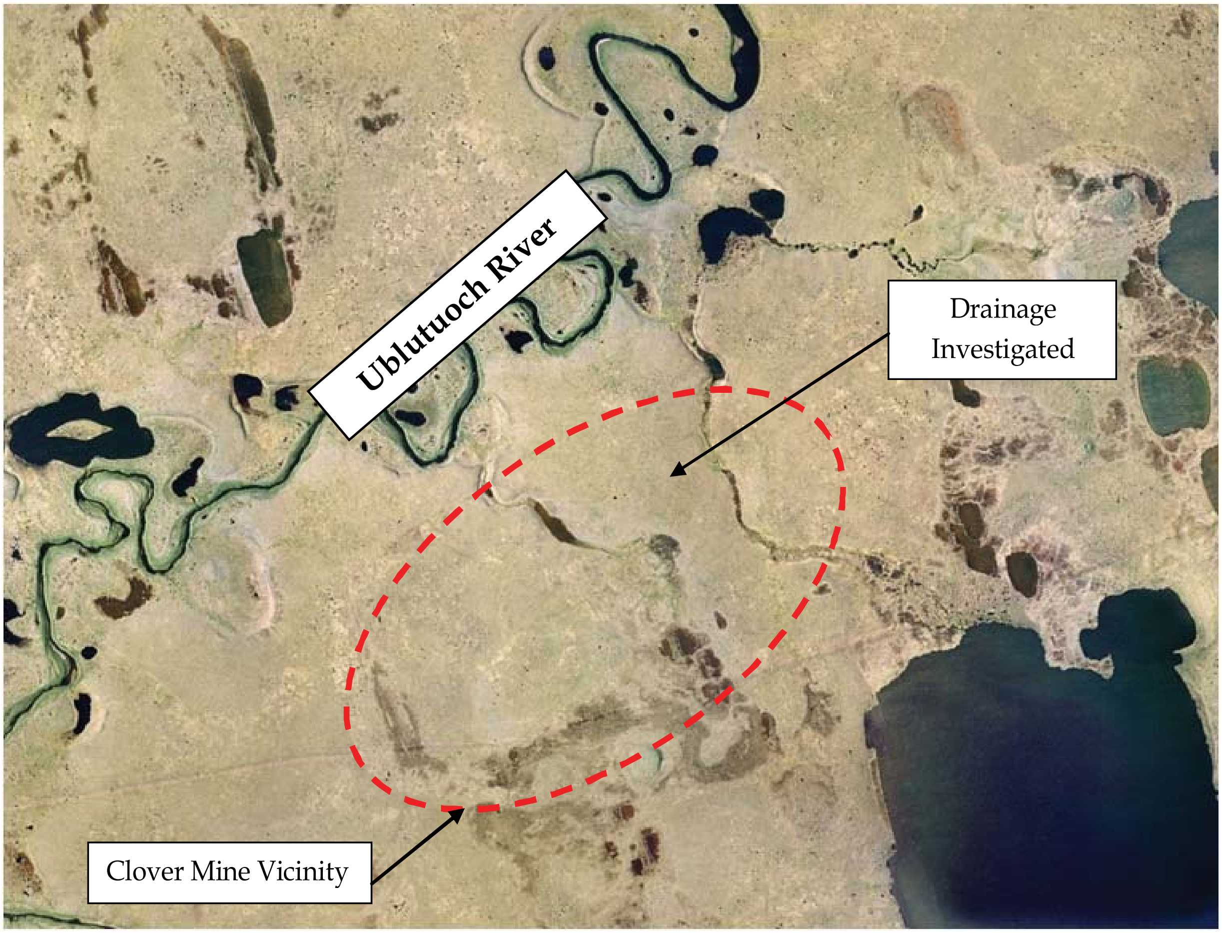


PHOTO 4.4: CLOVER MINE SITE JUNE 2, 2009 (2 VIEWS)

4.2 WATER SURFACE ELEVATION AND DISCHARGE

This section includes a summary of hydrological data collected from the Ublutuoch River, all seven small stream sites, and the GMT1 pad area.

4.2.1 UBLUTUOCH RIVER

Water surface elevation measurements at Ublutuoch River gages UB 6.8 and UB 6.9 began on May 27 and continued until June 3. The gages at UB 6.7 were installed at a slightly higher elevation and water was not observed at that location until May 29. WSE measurement at all Ublutuoch River locations continued until June 3. Monitoring continued until June 5.

PHOTO 4.5: UBLUTUOCH RIVER UB 6.7, MAY 29, 2009

Measured WSE increased gradually from initial observations until peak stage occurred. Peak WSE at UB 6.9 was 8.76 feet BPMSL, as recorded by the PT, and occurred on May 29.

The direct discharge reading on the Ublutuoch River at UB 6.8 was completed on the afternoon of May 29, and was measured as 1,930 cfs. WSE data were collected at all UB gaging locations both before and after the discharge measurement. Peak discharge was estimated to have occurred shortly after peak stage in the early hours of May 30. Indirect discharge calculations yield an estimated peak discharge of 1,990 cfs at UB 6.8.

PHOTO 4.6: UBLUTUOCH RIVER UB 6.8, MAY 31, 2009

During the measurement procedure the right bank was snow-covered and intact snow and ice in the channel encroached on the flow. The left bank was ice- and snow-free. The bottom was generally ice-covered with the exception of the far left portion of the channel.

PHOTO 4.7 UBLUTUOCH RIVER UB 6.9, JUNE 1, 2009

Table 4.1 presents the summary of the direct discharge measurement recorded at UB 6.8.

Table 4.2 presents the observations and WSE measurements.

Photo 4.5 shows the conditions of the Ublutuoch River at UB 6.7 on May 29. Photo 4.6 shows the conditions of the Ublutuoch River at UB 6.8 on May 31. Photo 4.7 shows the conditions of the Ublutuoch River at UB 6.9 on June 1.

Complete discharge notes are located in Appendix B.

TABLE 4.1: UBLUTUOCH RIVER UB 6.8 DIRECT DISCHARGE MEASUREMENT SUMMARY

Date & Time	WSE (ft BPMSL)	Width (ft)	Area (ft^2)	Mean Velocity (ft/s)	Discharge (cfs)	Measurement Rated*	Meter Type	Number of Sections	Measurement Type
5/29/2009 12:30	8.34	281	1,106	1.75	**1,932**	F	Price AA	21	Boat

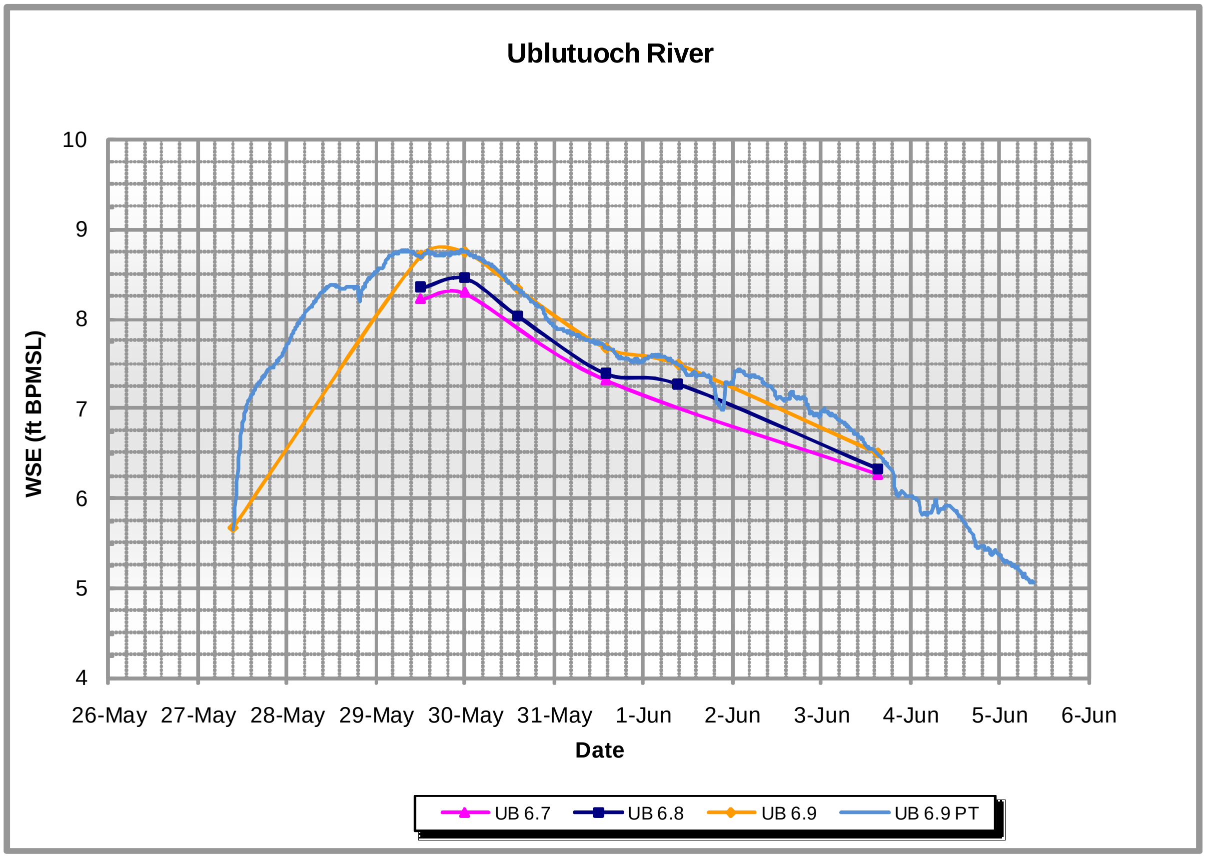
*Measurement Rating
E - Excellent: Point plots nearly on the rating curve; within 2% of true value
G - Good: Within 5% of true value
F - Fair: Within 7-10% of true value
P - Poor: Velocity < 0.70 ft/s; Shallow depth for measurement; less than 15% of true value

TABLE 4.2: UBLUTUOCH RIVER WSE

	WSE (feet BPMSL)			
Date and Time	UB 6.7	UB 6.8	UB 6.9	Observations
5/27/09 9:30 AM		6.20	5.67	First recordable flow.
5/29/09 12:00 PM	8.21	8.34	8.70	
5/29/09 11:59 PM	8.28	8.45	8.74	High water observed the evening of May 29.
5/30/09 2:11 PM		8.03	8.33	
5/31/09 2:02 PM	7.31	7.38	7.67	
6/1/09 9:27 AM		7.27	7.49	
6/3/09 3:15 PM	6.26	6.32	6.50	

Notes:

1. Elevations are based on Mon Char at 24.248, and Mon Coal at 20.524 feet BPMSL, established by LCMF in 2009.
2. One discharge measurement was taken at UB 6.8 of 1,932 cfs on 5/29/2009 at 12:30.



4.2.2 SMALL STREAMS

Water surface elevation monitoring at the seven small stream sites along the proposed GMT1 access road began on May 27 and continued until June 4. Peak stage at site S4 occurred on May 29; peak stage at sites S2, S5, and S6 occurred on June 1; peak stage at sites S1, S3, S7, and S8 occurred on June 3. Moderate flow was observed at sites S4 and S5; slight flow was observed at sites S1, S2 and S7; the remaining locations experienced wide, shallow, slow sheet flow. Discharge measurements were performed at S4 on May 31, and S5 on May 30.

4.2.2.1 SITE S1

The Site S1 peak stage is estimated to have occurred during the morning of June 3, at an elevation of 20.05 feet BPMSL. Throughout breakup, WSE fluctuated by approximately 0.46 feet with no measurable velocity.

The S1 site was typically characterized by accumulated local melt. A possible channel was identified, however the channel dimensions were too small and flow so minor that a discharge measurement was not practical. On June 4 the extents of accumulated water were marked with GPS. The width of the water perpendicular to the proposed alignment was approximately 1,056 feet with a maximum depth of 0.9 feet.

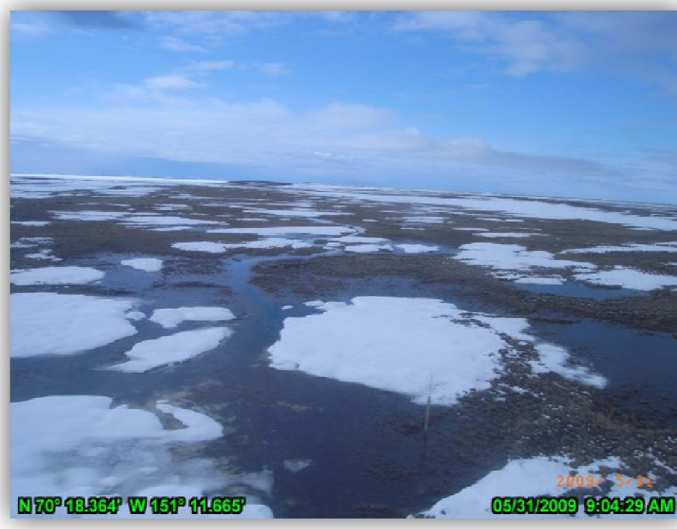


PHOTO 4.8: SITE S1, MAY 31, 2009

Table 4.3 presents the observations and water surface elevations recorded for Site S1.

The May 31 conditions of Site S1 are shown in Photo 4.8.

TABLE 4.3: SITE S1 WSE

Date and Time	WSE (feet BPMSL) S1	Observations
5/28/09 10:15 AM	19.99	
5/31/09 12:00 AM	20.01	
5/31/09 9:05 AM	19.69	
6/1/09 8:58 AM	19.59	
6/3/09 12:00 AM	20.05	High water observed the morning of June 3.
6/3/09 3:46 PM	19.60	
6/4/09 4:45 PM	19.63	

Notes:

1. Elevations are based on Monument CP08-18-27C at 20.414 feet BPMSL, established by LCMF in 2008.
2. No discharge measurements w ere taken at this location.

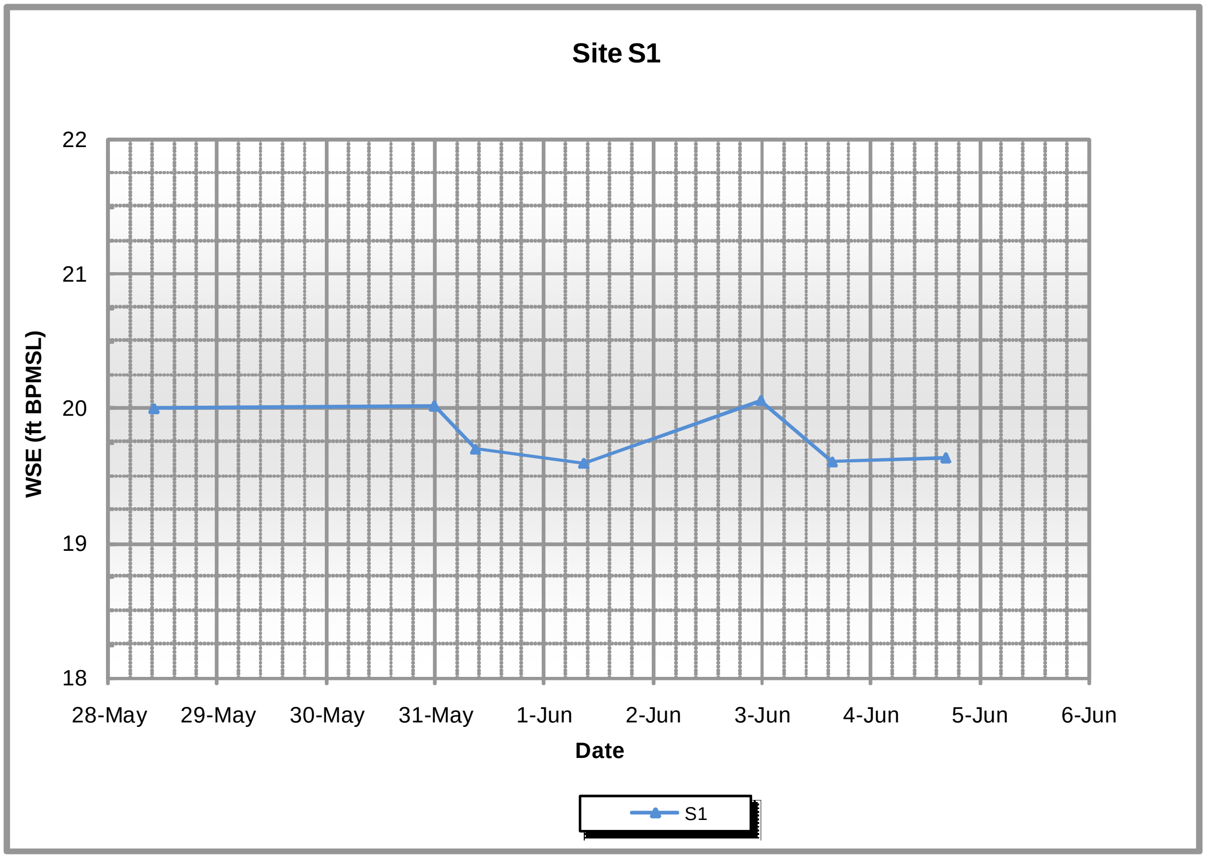


PHOTO 4.9: SITE S2, MAY 31, 2009

4.2.2.2 SITE S2

The Site S2 peak stage is estimated to have occurred during the morning of June 1 at an elevation of 18.20 feet BPMSL. Throughout breakup, WSE fluctuated by approximately 0.06 feet with no measureable velocity.

The S2 site was generally characterized by accumulated local melt; no direct discharge measurement was made. Areas of very low velocity sheet flow with minimal depth were observed in the vicinity of the proposed crossing. On June 4, the extents of accumulated water were marked with GPS. The width of the water perpendicular to the proposed alignment was approximately 2,640 feet with a maximum depth of 1.0 feet.

Table 4.4 presents the observations and water surface elevations recorded for Site S2. The May 31 conditions observed at Site S2 are shown in Photo 4.9.

4.2.2.3 SITE S3

The Site S3 peak stage is estimated to have occurred during the morning of June 3 at an elevation of 20.87 feet BPMSL. Throughout breakup, WSE fluctuated by approximately 0.21 feet with no measureable velocity.

The S3 site was characterized by accumulated local melt; no direct discharge measurement was made. No measureable flow was observed. On June 4, the extents of accumulated water were marked with GPS. The width of the water perpendicular to the proposed alignment was approximately 80 feet with a maximum depth of 0.8 feet.

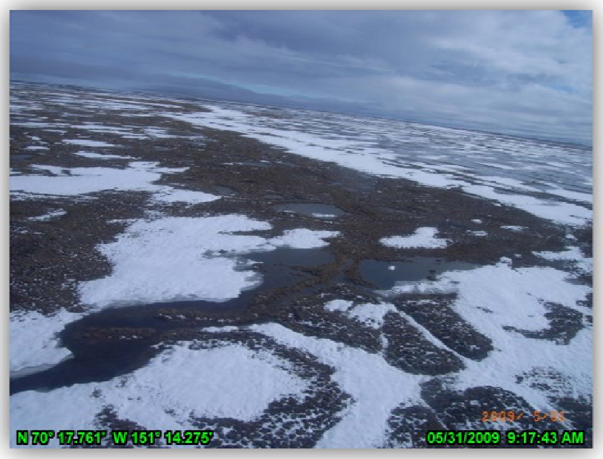


PHOTO 4.10: SITE S3, MAY 31, 2009

Table 4.5 presents the observations and water surface elevations recorded for Site S3. Photo 4.10 shows the conditions of Site S3 on May 31.

TABLE 4.4: SITE S2 WSE

Date and Time	WSE (feet BPMSL) S2	Observations
5/28/09 12:00 PM	18.15	
5/31/09 12:00 AM	18.17	
5/31/09 9:15 AM	18.14	
6/1/09 9:05 AM	18.20	High water observed the morning of June 1.
6/3/09 3:42 PM	18.19	

Notes:

1. Elevations are based on Monument CP08-18-29B at 18.840 feet BPMSL, established by LCMF in 2008.
2. No discharge measurements were taken at this location.

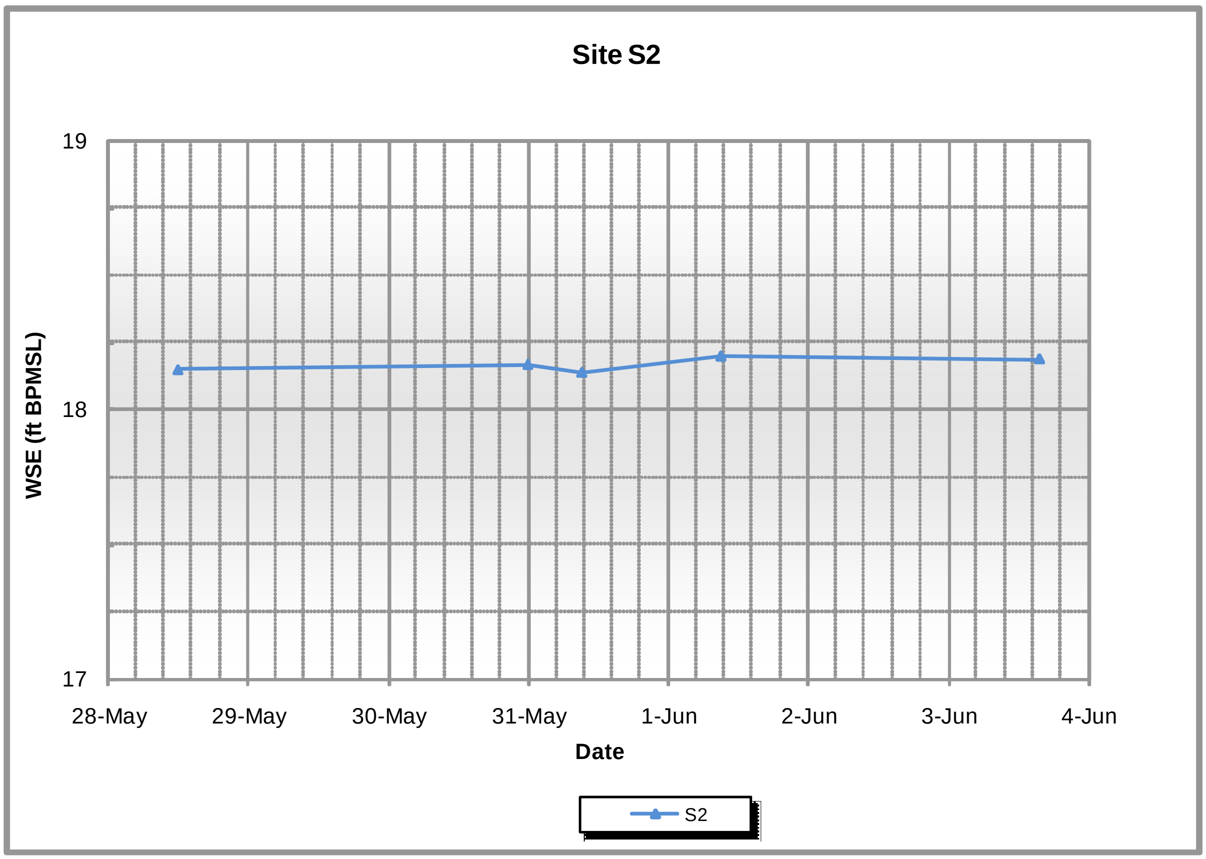
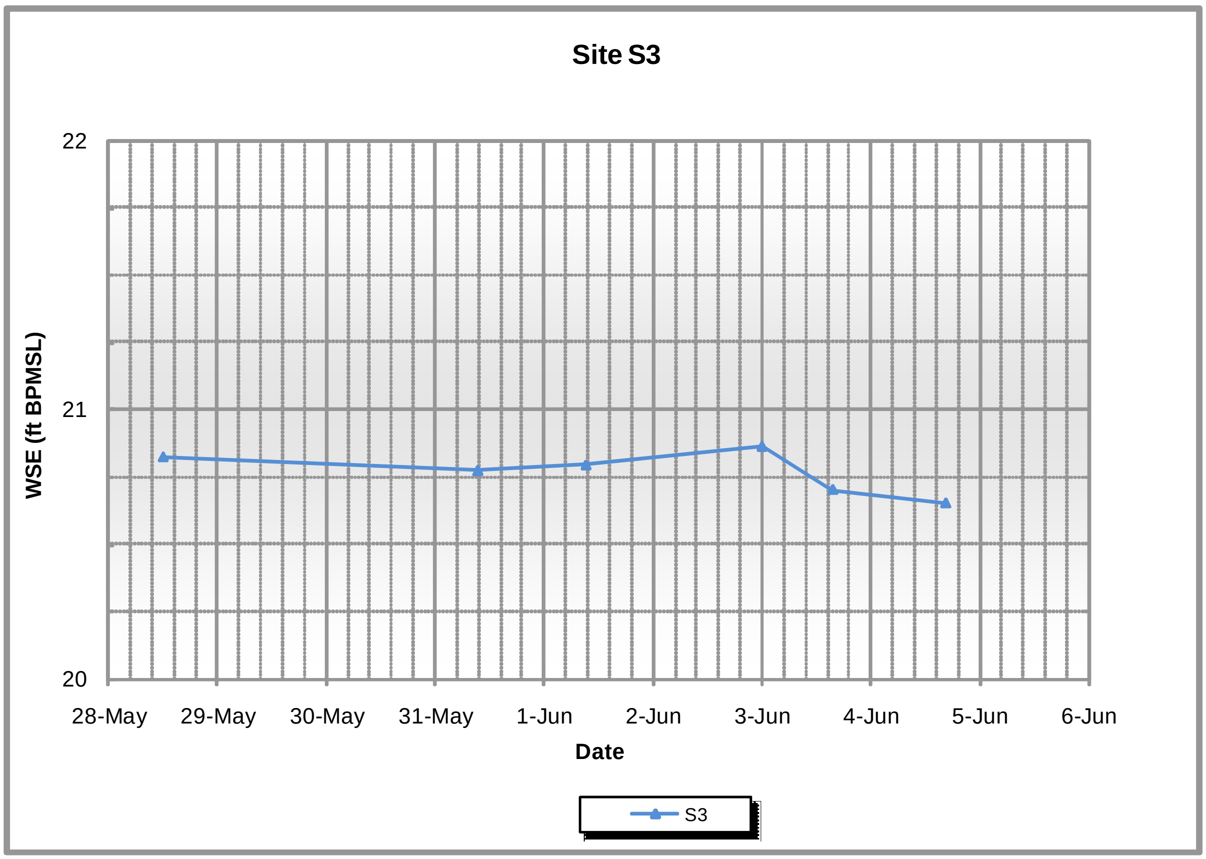


TABLE 4.5: SITE S3 WSE

	WSE (feet BPMSL)	
Date and Time	**S3**	**Observations**
5/28/09 12:00 PM	20.83	
5/31/09 9:20 AM	20.78	
6/1/09 9:11 AM	20.80	
6/3/09 12:00 AM	20.87	High water observed the morning of June 3.
6/3/09 3:35 PM	20.71	
6/4/09 4:30 PM	20.66	

Notes:

1. Elevations are based on Monument CP08-18-29C at 19.560 feet BPMSL, established by LCMF in 2008.
2. No discharge measurements were taken at this location.



4.2.2.4 SITE S4

Meltwater flow was observed visually a few days before water surface elevation data monitoring began at this location. The peak stage at S4-B and S4-C are estimated to have occurred May 29 with elevations of 14.48 and 14.87 BPMSL feet respectively. The peak observed stage at S4-A was 14.79 feet BPMSL measured on the morning of June 3. Throughout breakup, maximum WSE fluctuation at S5 was approximately 0.19 feet, occurring at gage S4-B.

PHOTO 4.11: SITE S4, JUNE 1, 2009

At Site S4, floodwaters were mainly confined to a single, well-defined channel with good flow. A direct discharge measurement was completed at S4-B on May 31 and was measured as 5.6 cfs. Indirect discharge calculations yield an estimated peak discharge of 7 cfs at S4-B.

During the discharge measurement, the reach had discontinuous snow and ice on both banks, with minimal flow occurring under the snow. The discharge cross section was selected at a location where both the left and right banks were ice- and snow-free, and where the channel narrowed relative to upstream and downstream reaches. The channel bottom was entirely ice- and snow-free on the day of the measurement. The cross section width measured 25 feet, with a maximum depth of 0.7 feet.

Table 4.6 presents the discharge measurements recorded for Site S4. Table 4.7 presents the observations and water surface elevations. Photo 4.11 shows the conditions at Site S4 on June 1.

TABLE 4.6: S4 DISCHARGE SUMMARY

Date & Time	WSE (ft BPMSL)	Width (ft)	Area (ft^2)	Mean Velocity (ft/s)	Discharge (cfs)	Measurement Rated*	Meter Type	Measurement Type
5/31/2009 12:57	14.34	25	12.3	0.43	**5.6**	F	Marsh McBirney	Wading

* Measurement Rating

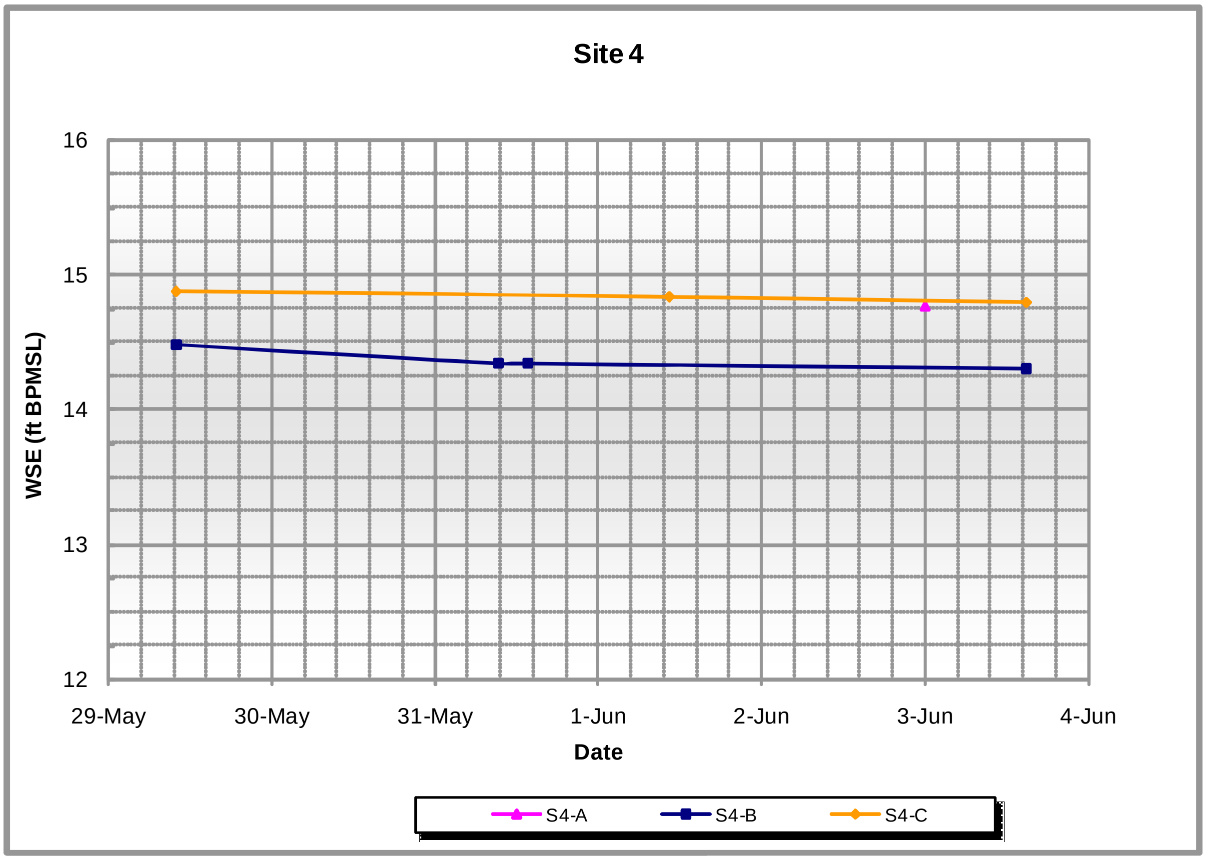
E - Excellent:	Point plots nearly on the rating curve; within 2% of true value
G - Good:	Within 5% of true value
F - Fair:	Within 7-10% of true value
P - Poor:	Velocity < 0.70 ft/s; Shallow depth for measurement; less than 15% of true value

TABLE 4.7: SITE S4 WSE

Date and Time	WSE (feet BPMSL) S4-A	S4-B	S4-C	Observations
5/29/09 10:05 AM		14.48	14.87	High water observed at S4-C the morning of May 29.
5/31/09 9:30 AM		14.33		
5/31/09 1:38 PM		14.33		
6/1/09 10:32 AM			14.83	
6/3/09 12:00 AM	14.76			
6/3/09 3:00 PM		14.29	14.79	

Notes:

1. Elevations are based on Mon Char at 24.248, and Mon Coal at 20.524 feet BPMSL, both established by LCMF in 2009.
2. One discharge measurement was taken of S4 as 5.6 cfs on 5/31/2009 at 12:57.



4.2.2.5 SITE S5

Visual observations of meltwater flow were recorded a few days before water surface elevation data monitoring began at this location. The Site S5 centerline (gage S5-B) peak stage is estimated to have occurred during the morning of June 1 at an elevation of 18.28 feet BPMSL. Throughout breakup, maximum WSE fluctuation at S5 was approximately 0.81 feet, occurring at gage S5-A.

PHOTO 4.12: SITE S5, JUNE 1, 2009

While the stream was characterized by braids and is willow-choked both upstream and downstream of the monitoring location, there was a short reach at Site S5 where floodwaters were confined to a single, well-defined channel.

A direct discharge measurement was completed at Site S5 on May 30, and was measured as 6.8 cfs. Indirect calculations yield an estimated peak discharge of 9 cfs. During the discharge measurement the reach was narrowed by snow and ice on both banks, with some flow occurring under the snow. The channel bottom was primarily slush except for the thalweg where bottomfast ice defining the low water channel was still intact. There was thin ice in place across much of the cross section prior to the discharge measurement. This ice was broken up and floated away before beginning. The width at the measured cross section was 40 feet, with a maximum depth of 1.7 feet.

Table 4.8 presents a summary of the discharge measurement recorded for S5-B. Table 4.9 presents the observations and water surface elevations. Photo 4.12 shows the conditions on June 1. On the left side of the image (downstream of the discharge site), heavy willow growth may be seen.

TABLE 4.8: S5 DISCHARGE SUMMARY

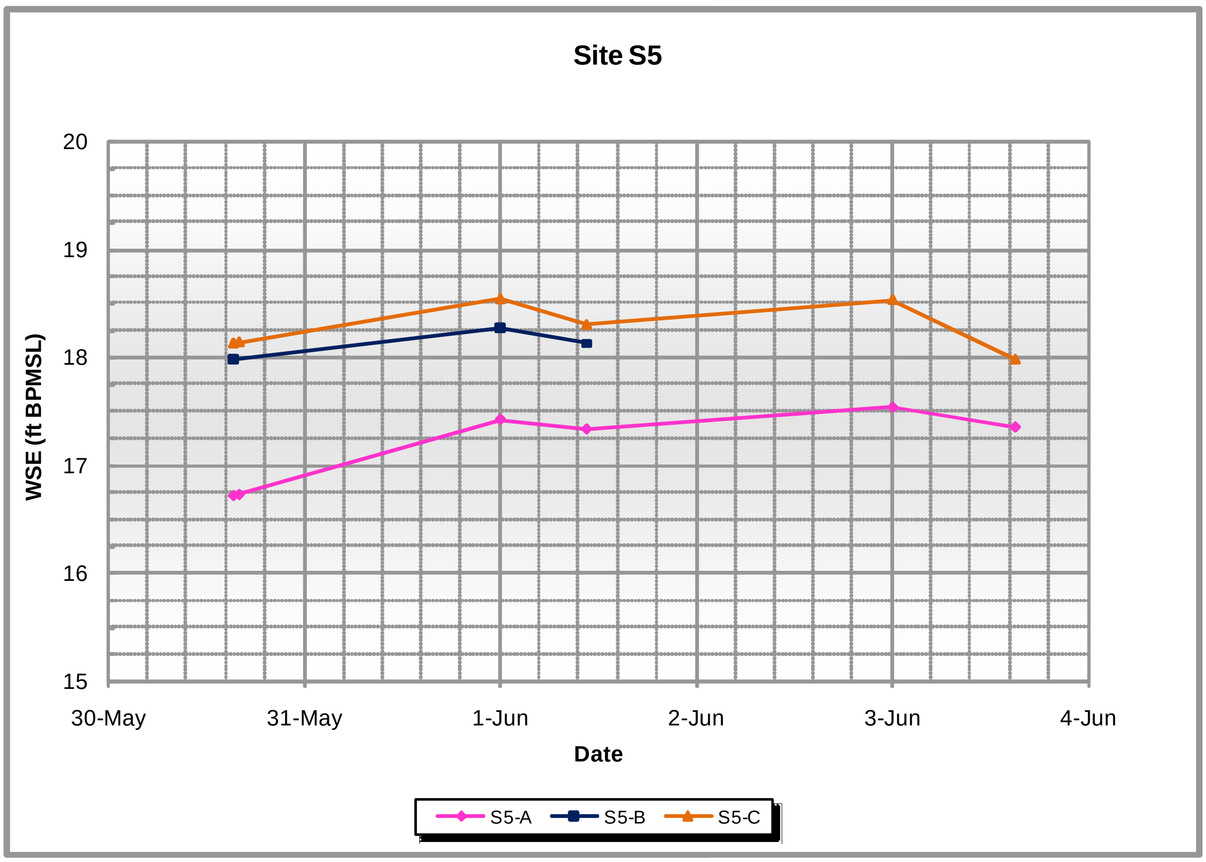
Date & Time	WSE (ft BPMSL)	Width (ft)	Area (ft^2)	Mean Velocity (ft/s)	Discharge (cfs)	Measurement Rated*	Meter Type	Measurement Type
5/30/2009 15:08	18.00	40	48.15	0.15	**6.8**	P	Marsh McBirney	Wading
*Measured Rating								
E - Excellent:	Point plots nearly on the rating curve; within 2% of true value							
G - Good:	Within 5% of true value							
F - Fair:	Within 7-10% of true value							
P - Poor:	Velocity < 0.70 ft/s; Shallow depth for measurement; less than 15% of true value							

TABLE 4.9: SITE S5 WSE

Date and Time	WSE (feet BPMSL) S5-A	S5-B	S5-C	Observations
5/30/09 3:20 PM	16.72	17.98	18.14	S5-B in snow pack, reading likely snow effected.
5/30/09 4:03 PM	16.73		18.15	
6/1/09 12:00 AM	17.42	18.28	18.55	High water observed at S5-C the morning of June 1.
6/1/09 10:32 AM	17.33	18.13	18.31	
6/3/09 12:00 AM	17.53		18.54	
6/3/09 3:00 PM	17.35		17.99	

Notes:

1. Elevations are based on Mon Alma at 25.263, and Mon Clara at 23.228 feet BPMSL, both established by LCMF in 2009.
2. One discharge measurement was taken at S5 of 6.8 cfs on 5/30/2009 at 15:08.



4.2.2.6 SITE S6

The Site S6 peak stage is estimated to have occurred during the morning of June 1 at an elevation of 24.09 feet BPMSL. Throughout breakup, WSE fluctuated by approximately 0.24 feet with no measureable flow.

The S6 site was characterized by accumulated local melt; no direct discharge measurement was made. No measureable flow was observed. On June 4, the extents of accumulated water were marked with GPS. The width of the water perpendicular to the proposed alignment was approximately 248 feet with a maximum depth of 1.0 feet.

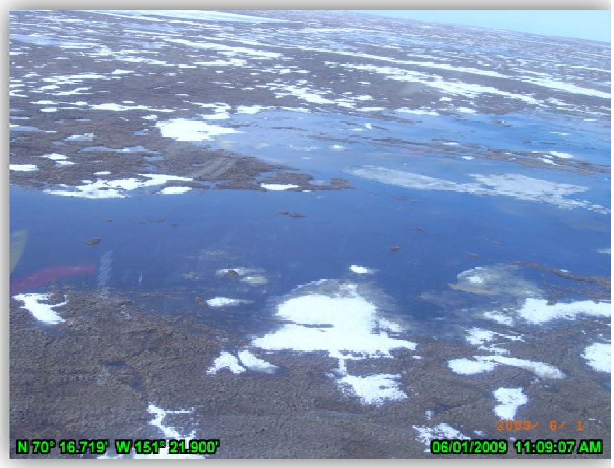


PHOTO 4.13: SITE S6, JUNE 1, 2009

Table 4.10 presents the observations and water surface elevations recorded for Site S6. Photo 4.13 shows the conditions of Site S6 on June 1.

PHOTO 4.14: SITE S7, JUNE 1, 2009

4.2.2.7 SITE S7

The Site S7 peak stage is estimated to have occurred during the morning of June 3 at an elevation of 25.67 feet BPMSL. Throughout breakup, WSE fluctuated by approximately 0.20 feet with no measureable flow.

The S7 site was characterized by accumulated local melt; no direct discharge measurement was made. Measureable flow was observed, but was so slight and shallow that a discharge measurement was not practical. On June 4, the extents of accumulated water were marked with GPS. The width of the water perpendicular to the proposed alignment was approximately 138 feet with a maximum depth of 0.8 feet. Table 4.11 presents the observations and water surface elevations recorded for Site S7. Photo 4.14 shows the conditions of Site S7 on June 1.

TABLE 4.10: SITE S6 WSE

	WSE (feet BPMSL)	
Date and Time	**S6**	**Observations**
5/31/09 1:00 PM	24.07	No Flow Observed
6/1/09 12:00 AM	24.09	High water observed the morning of June 1.
6/1/09 11:13 AM	23.97	
6/3/09 2:42 PM	23.86	
6/4/09 3:40 PM	23.85	

Notes:

1. Elevations are based on Mon Brad at 25.780, and Mon Caid at 25.420 feet BPMSL, established by LCMF in 2005.
2. Monument Brad is 0.76 feet above ground level in 2009.
3. No discharge measurements w ere taken at this location.

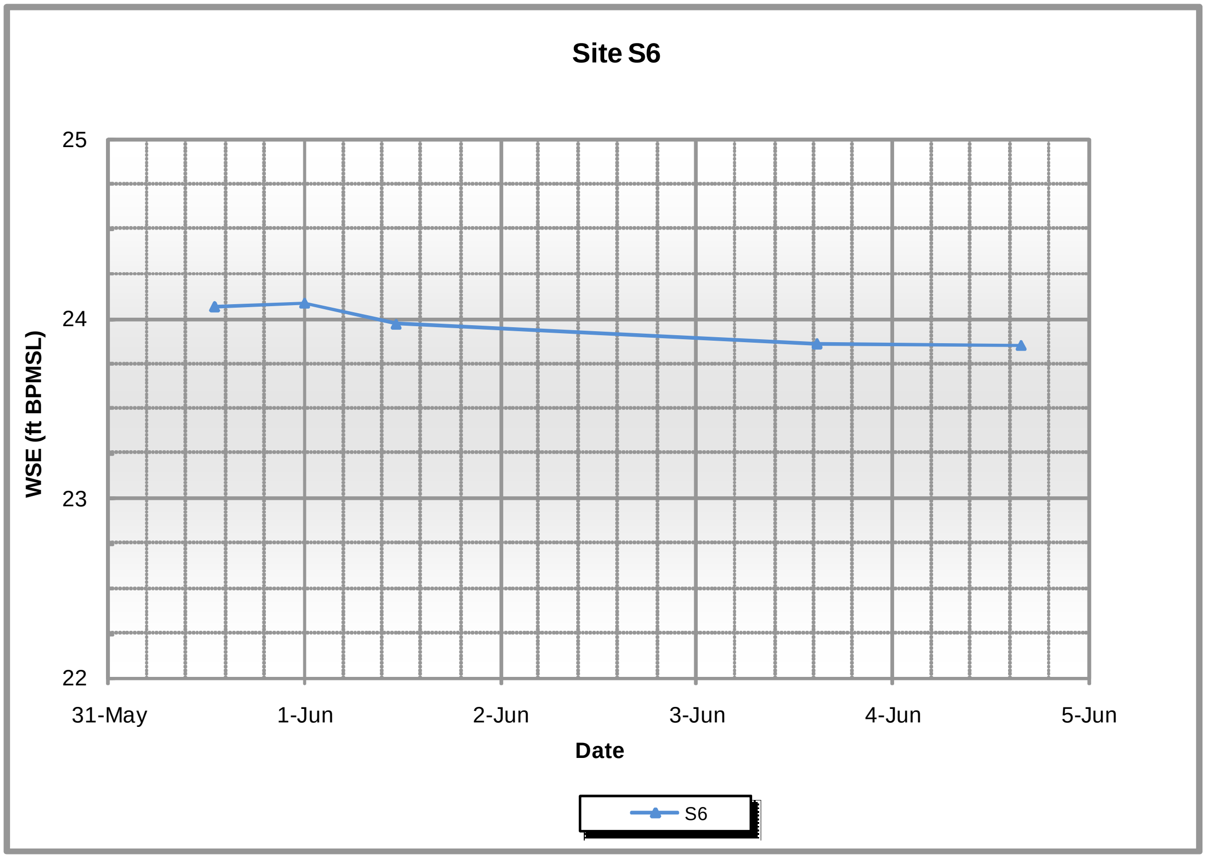
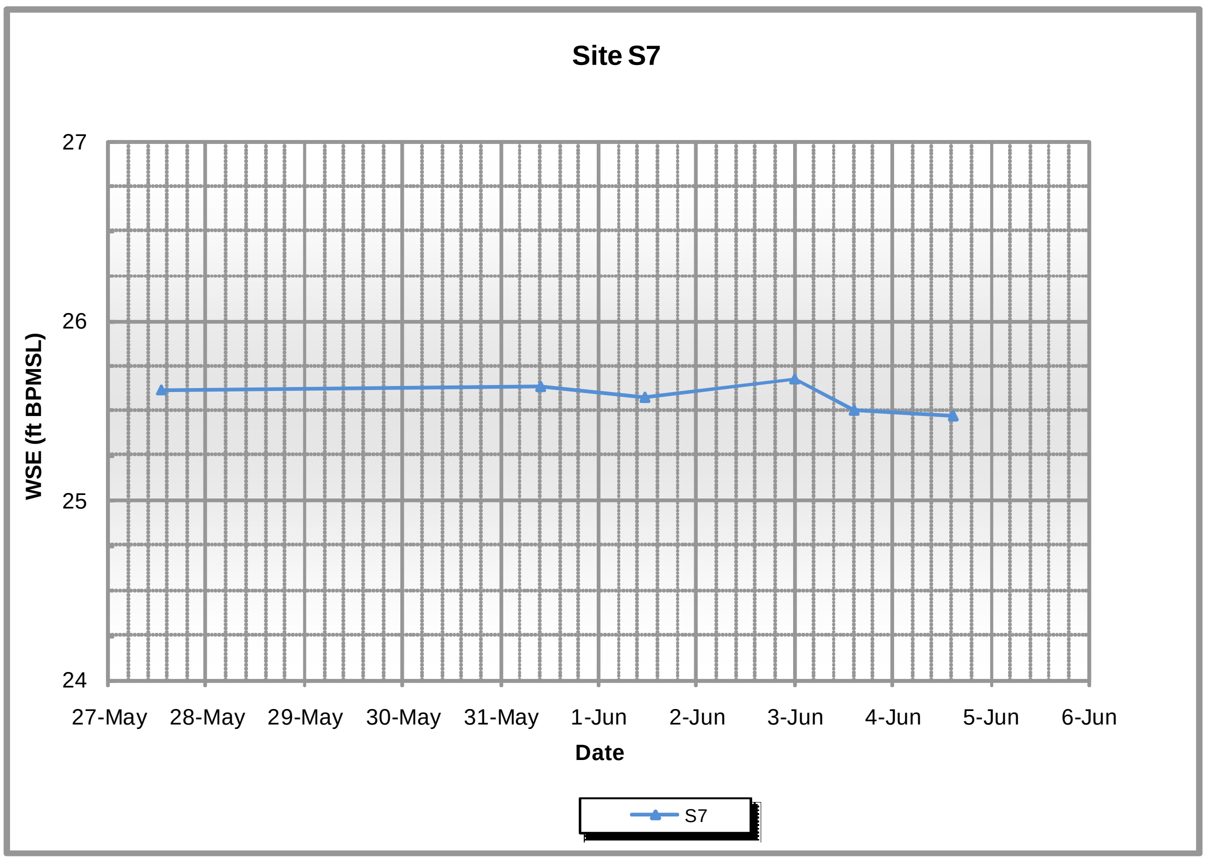


TABLE 4.11: SITE S7 WSE

Date and Time	WSE (feet BPMSL) S7	Observations
5/27/09 12:50 PM	25.61	Local melt only, no flow observed
5/31/09 9:45 AM	25.63	No flow observed
6/1/09 11:19 AM	25.57	
6/3/09 12:00 AM	25.67	High water observed the morning of June 3.
6/3/09 2:34 PM	25.50	
6/4/09 2:50 PM	25.47	

Notes:

1. Elevations are based on Mon Brad at 25.780 feet BPMSL, established by LCMF in 2005.
2. Monument Brad is 0.76 feet above ground level in 2009.
3. No discharge measurements w ere taken at this location.



4.2.2.8 SITE S8 (GMT1 PAD AREA)

The Site S8 peak stage is estimated to have occurred during the morning of June 3rd at an elevation of 41.28 feet BPMSL. Throughout breakup, WSE fluctuated by approximately 0.16 feet with no measureable flow.

The S8 site was characterized by accumulated local melt; no direct discharge measurement was made. No measureable flow was observed.

On June 4, an attempt was made to mark the extent of accumulated water. The width of the water in the vicinity of the proposed pad could not be determined because there was no defined area of continuous accumulated melt. The meltwater was instead contained in many discontinuous and separate potholes and within polygon troughs.

PHOTO 4.15: SITE S8 (GMT1 PAD), JUNE 1, 2009

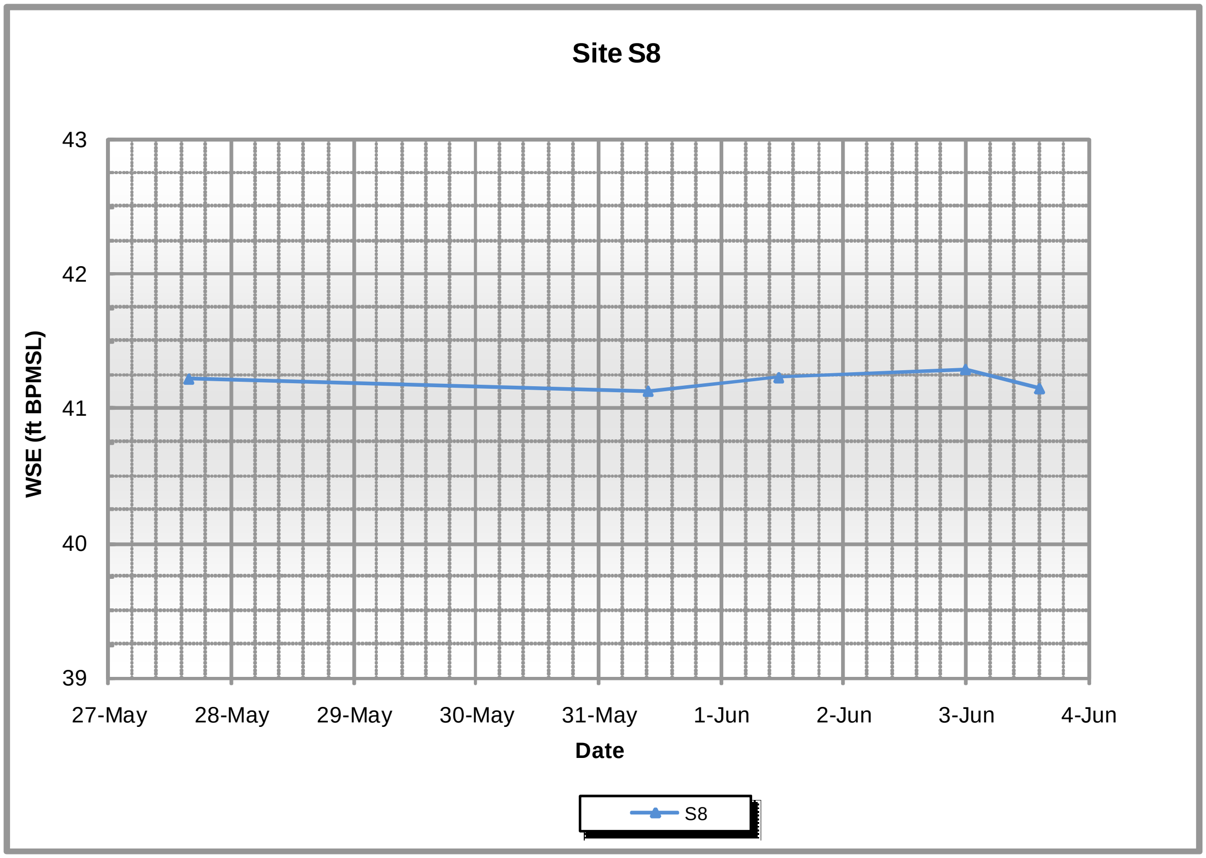
Table 4.12 presents the observations and water surface elevations recorded for Site S8. Photo 4.15 shows the conditions of Site S8 on June 1.

TABLE 4.12: SITE S8 WSE

Date and Time	WSE (feet BPMSL) S8	Observations
5/27/09 3:55 PM	41.21	
5/31/09 9:50 AM	41.12	No Flow Observed
6/1/09 11:26 AM	41.22	
6/3/09 12:00 AM	41.28	High water observed the morning of June 3.
6/3/09 2:29 PM	41.14	

Notes:

1. Elevations are based on Monument Gypsy at 29.330 feet BPMSL, established by LCMF in 2005.
2. No discharge measurements w ere taken at this location.



5.0 Flood and Stage Frequency Analysis

This section discusses the updated Ublutuoch River and small stream sites flood and stage frequency analysis and provides recommendations for use in developing design criteria for the proposed Ublutuoch River Bridge and GMT1 access road drainage structures.

5.1 Ublutuoch River

The proposed GMT1 access road bridge crossing at the Ublutuoch River will be the largest drainage structure between the CD5 and GMT1 facilities. The Ublutuoch River flood frequency and stage frequency analyses discussed in this section will aid in the development of design criteria for the proposed bridge.

5.1.1 Flood Frequency

The earliest available flood frequency analyses of the Ublutuoch River near the proposed GMT1 bridge site were developed in 2002 at Ublutuoch RM 13.7 using a drainage basin area of 222 square miles, and at Ublutuoch RM 8.0 using a drainage area of 233 square miles. The regression equations used in these analyses were based on regional gaged rivers, calibrated for 2001 and 2002 observations, and on the assumption that the 2001 and 2002 breakup events were each mean annual discharges (URS 2002). These data are presented in Table 5.1.

The flood frequency estimates for the Ublutuoch River at Mile 6.8 were updated with the most recent available information. Three methods were evaluated to estimate the flood frequency magnitude: USGS Regional Regression Equations, a Station Specific Frequency Analysis, and a Weight USGS approach.

USGS regional regression equations specific to Region 7 (Curran, Meyer, and Tasker 2003) were used to estimate flood frequency recurrence intervals. In 2005, the area of the drainage basin contributing to flow at Ublutuoch RM 6.8 was estimated to be 228 square miles (Baker 2005b).The drainage basin delineated in 2005 was used as the sole input value for estimating peak discharge values. Estimates are presented in Table 5.1 and Graph 5.1.

Historically, direct discharge measurements have been performed on the Ublutuoch River during spring breakup at RM 6.8 and RM 13.7. The timing of historical discharge measurements relative to seasonal stage records suggests a peak annual discharge has not been captured by direct measurement.

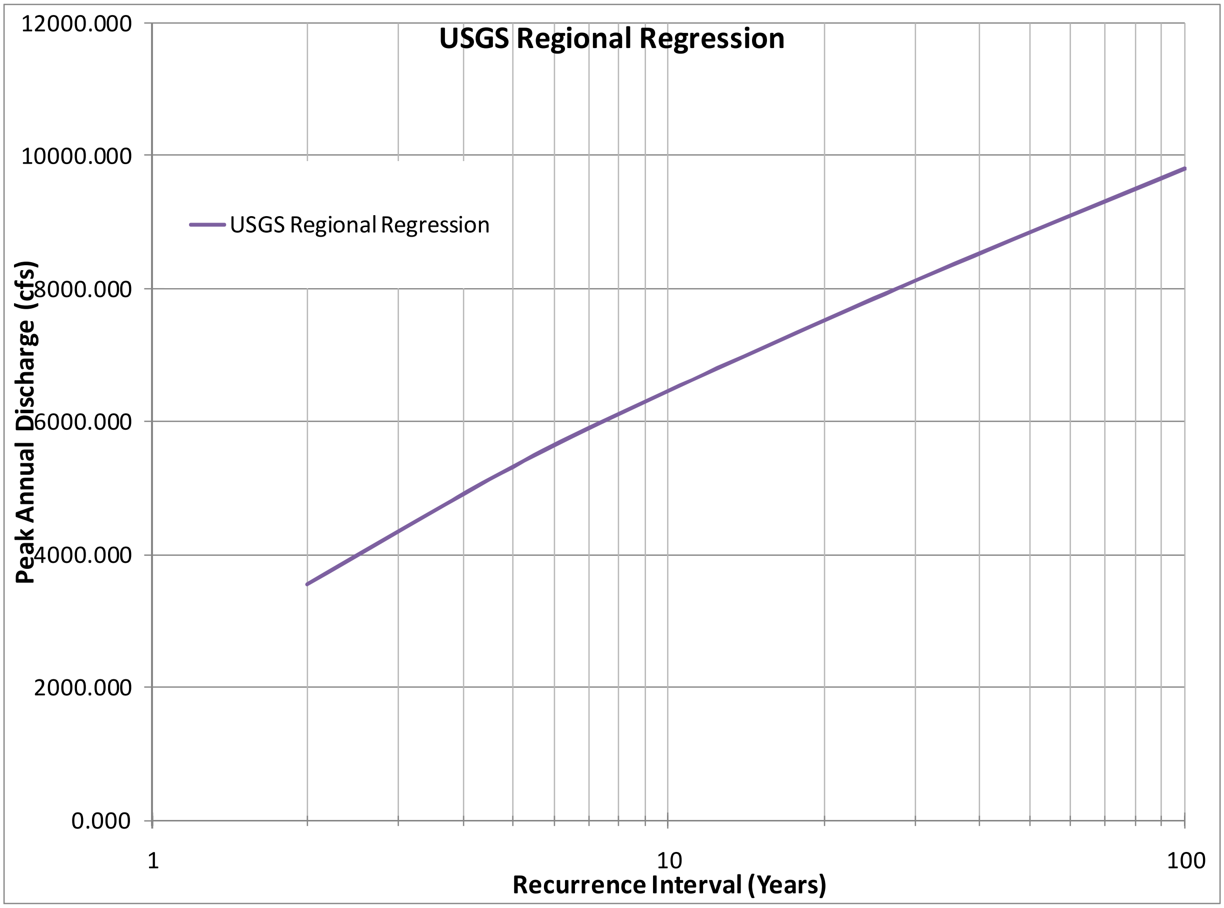
In the past, annual peak discharges were estimated using indirect methods. However, use of indirect methods assumes a channel free of ice and snow. These assumed conditions are not representative of the channel during spring breakup when in-channel ice and snow are present. As a result, the accuracy of annual peak discharge estimates based on indirect methods is highly uncertain. The potential error associated with indirect peak discharge estimates invalidates their use in a single-station frequency analysis. The weighted USGS approach, based in part on a single-station analysis, is thus also deemed an inappropriate method of flood frequency analysis at Ublutuoch RM 6.8.

In this situation, USGS regional regression equations are most appropriate, and are therefore recommended for flood frequency design values. Though the average standard error of prediction is 52% for the 100-yr regional regression equation, use of the USGS regional regression equations yields the best estimate of peak annual discharge available.

TABLE 5.1: UBLUTUOCH RIVER FLOOD FREQUENCY ANALYSIS RESULTS

Recurrence Interval (Years)	Discharge (cfs)	
	USGS Region 7 Regression Equations RM 6.8[1]	URS Regression Equations RM 8[2]
2	3,600	2,400
5	5,300	3,800
10	6,500	4,800
25	7,900	6,300
50	8,800	7,600
100	9,800	8,900
Notes:	1. Baker 2009 2. URS 2002	

GRAPH 5.1: UBLUTUOCH RIVER FLOOD FREQUENCY ESTIMATES



5.1.2 STAGE FREQUENCY

It is generally considered inaccurate to extrapolate stage data for a river impacted by snow and ice beyond the observed record (USACE 2002 and FEMA 2003). At RM 6.8 the observed record of stage is only five years and each year the spring breakup event has been impacted by snow and ice. However, for lack of better information a statistical analysis was used to extend the record out to 100 years. A recurrence interval was assigned to each of the annual peak stage values using the Weibull plotting position equation (USACE 1982). The 2003 to 2009 peak annual stage probability and recurrence intervals are presented in Table 5.2.

The peak annual stage record was extended to a 100-year recurrence interval using HYFRAN hydrologic frequency analysis software (INRS-ETE 2002) based on the Log-Pearson III distribution. Stage frequency recurrence intervals are presented in Table 5.2. Results from the Ublutoch River stage frequency analysis at RM 6.8 are presented graphically in Graph 5.2.

In 2003, a HEC-RAS model of the Ublutuoch River at UB 6.8 was developed by Baker which estimated a 100-year peak stage of 12.5 feet BPMSL (Baker 2003). This value is presented in Graph 5.2 for comparison with the 2009 analysis results.

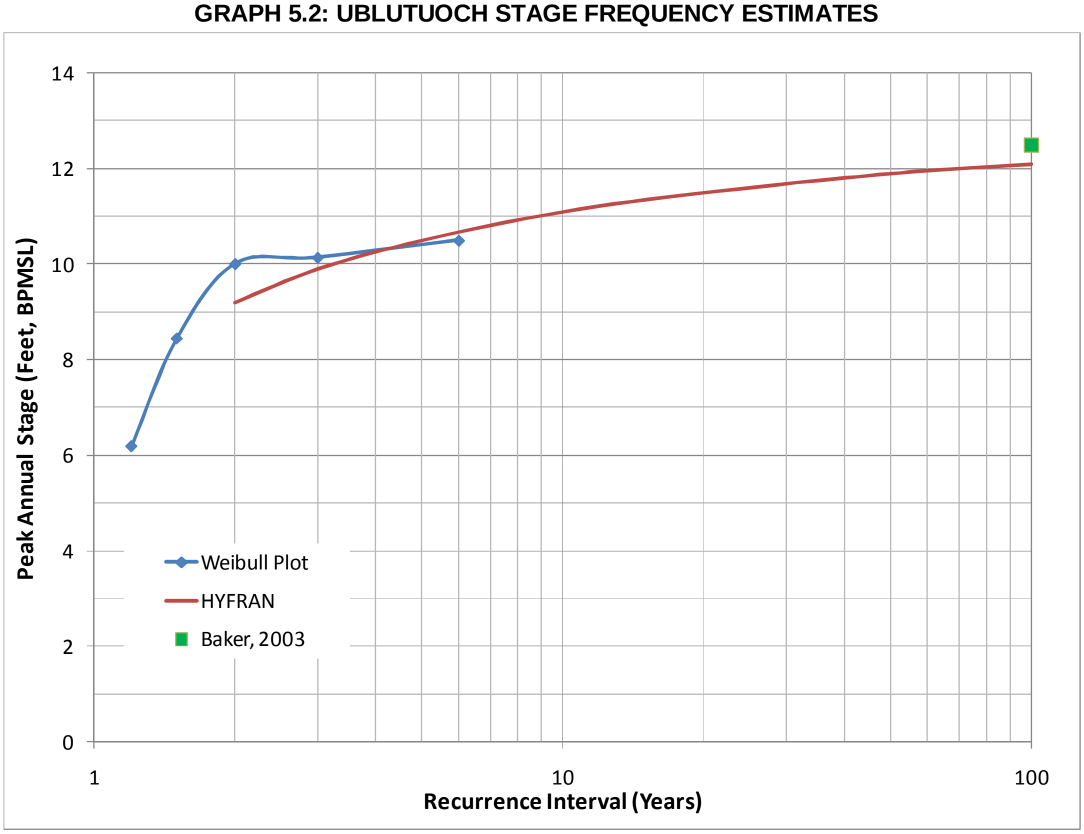
TABLE 5.2: HISTORIC STAGE RECURRENCE INTERVALS AT UB 6.8

Year	Peak Annual Stage (Feet, BPMSL)	Probability	Recurrence Interval (Years)	Reference
2009	8.45	0.67	1.5	This Report
2006	6.19	0.83	1.2	Baker 2006
2005	10.01	0.50	2.0	Baker 2005c
2004	10.50	0.17	6.0	Baker 2005a
2003	10.14	0.33	3.0	Baker 2003a

TABLE 5.3: UBLUTUOCH PEAK ANNUAL STAGE ESTIMATES

Recurrence Interval (Years)	Peak Annual Stage (Feet, BPMSL)
2	9.2
5	10.5
10	11.1
50	11.9
100	12.1

GRAPH 5.2: UBLUTUOCH STAGE FREQUENCY ESTIMATES



To develop adequate design criteria for the proposed Ublutuoch crossing a detailed HEC-RAS model, beyond that developed in 2003, is required. However, given the current stage frequency analysis and the 2003 HEC-RAS estimate, peak stage for a 100-year event is estimated to be 12.5 feet at RM 6.8.

5.2 SMALL STREAM SITES

Prior to 2009, flood frequency analyses were performed on a variety of small streams within GMT1 in support of ASDP. In 2003 and 2004, PND, Inc. monitored various drainages during the breakup season (PND 2003, 2005). Flood frequency estimates were calculated for four drainages using approximate drainage areas and USGS regional regression equations. In 2005 and 2006, Baker conducted spring breakup monitoring at nine potential small stream crossings, including four drainages monitored by PND. In 2006, Baker conducted a flood frequency analysis on the nine small streams using the USGS regional regression equations. In 2009, after a two year break in the monitoring of the small stream sites, Baker identified seven potential small stream sites for monitoring in addition to the GMT1 pad location. Four of the seven streams identified for monitoring had been monitored in 2005 and 2006.

5.2.1 FLOOD FREQUENCY

Peak flow of the seven sites and the proposed pad location were estimated using the USGS regional regression equations (Curran, Meyer, and Tasker 2003). Drainage basin areas contributing to flow at the locations identified (see Figure 2.2, Figure 2.6, and Figure 2.10) were estimated by Baker in 2005, 2006 and 2009 using AeroMap contours, satellite imagery, and aerial photography.

Table 5.3 presents the estimated drainage basin area and annual peak discharge values ranging between 2- and 100- year return intervals.

TABLE 5.4: GMT1 SMALL STREAMS FLOOD FREQUENCY ANALYSIS RESULTS

		Probable Peak Discharge (cfs)							
		Site S1	Site S2	Site S3	Site S4	Site S5	Site S6	Site S7	Site S8
Drainage Area (mi^2)		2.4	4.1	0.9	0.7	3.6	0.9	0.9	1.1
Return Interval	2-year	62	99	26	21	87	24	26	31
	5-year	103	162	43	35	144	42	43	52
	10-year	132	205	56	45	182	53	56	66
	25-year	167	259	72	58	231	69	72	85
	50-year	194	300	84	68	267	80	84	99
	100-year	220	339	95	78	303	92	95	113

5.2.2 FLOOD FREQUENCY ANALYSIS COMPARISON AND DESIGN CRITERIA

The 2009 flood frequency analysis was completed using the USGS regression equations for Region 7. The accuracy of resulting values is limited by the detail of data used to estimate individual drainage basins and error associated with regional regressions equations. Caution must be used when interpreting predicted peak discharge estimates from regression equations. Significant issues associated with the regression equations used here include:

- The regression equations for Region 7 were developed by the USGS from a small number of gaged streams (25) across a wide area, extending as far southwest as Nome, east to the Canadian border, and encompassing the entire North Slope and Brooks Range. The resulting regression equations yield an average standard error of prediction of approximately 50%, relative to the 25 drainages used.

- The minimum applicable drainage area for the given equations is 1.13 square miles; a value that is larger than five of the eight delineated drainage areas (Table 5.4).

- The affects of storage area can differ significantly between drainage areas and flood return intervals. The number and size of lakes and wetlands can significantly alter the amount of flow across a given drainage by increasing the storage capacity of the basin. The presence of lakes, such as Oil Lake near Site S1, can retain flood waters until a critical overbank elevation is reached, at which time residual floodwater is released. In such a case, flow may not be observed until a large magnitude flood occurs.

- Nearly all of the 25 streams and rivers the USGS used to generate the regression equations for Region 7 were in areas having limited or no storage, and only one gaging station (Nunavak Creek near Barrow, Alaska) had a drainage basin morphology representative of the GMT1 area (polygons, wetlands, and/or ponds).

Though limitations and uncertainties exist, alternative applicable methods are generally unavailable. While appreciating the limits of the regression equations, a comparison of the flood frequency results and direct discharge measurements suggests that the flood frequency results provide a conservative estimate of low-recurrence flood discharge at the small stream sites.

Generally, the topographic relief and storage capacity of drainage basins impacted by the proposed GMT1 facilities limit the number of defined channels and increase the distribution of sheetflow and divided streamlets during the breakup season. In a few cases, flow is confined to a single well-defined channel, similar to that observed at Sites S4 and S5. As the recurrence interval for flooding increases, floodwater is less affected by storage capacity and begins to move down slope as overland flow. With the placement of the GMT1 access road, flow will be confined as it is routed to, and flows through, placed drainage structures.

For the purpose of evaluating potential fish passage through drainage structures, mean annual and low-flow design criteria are suggested to be based on observed historic flows. For the purpose of developing design criteria for the sizing of the proposed drainage structures, the 100-year peak discharge is suggested to be based on the weighted peak discharge calculations.

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6.1 REFERENCE LIST

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6.2 ACRONYMS

ADP	Alpine Development Project
ASDP	Alpine Satellite Development Plan
BPMSL	British Petroleum Mean Sea Level
CPAI	ConocoPhillips, Alaska, Inc.
CRD	Colville River Delta
EOW	Edge of Water
EOW	Edge of Water
FCB	Fish Creek Basin
FEMA	Federal Emergency Management Agency
GMT1	Greater Moose's Tooth 1
GPS	Global Positioning System
NAD83	North American Datum of 1983
NPR-A	National Petroleum Reserve, Alaska
OSW	Office of Surface Water
PT	Pressure Transducer
RM	River Mile
UB	Ublutuoch River
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WSE	Water Surface Elevations

6.3 GLOSSARY

Ablation
Loss of a part (as ice from a glacier or the outside of a nose cone) by melting or vaporization

Alpine
CD1 pad

Alpine Facilities
CD1, CD2, CD3, and CD4 pads, including access roads and bridges

Breakup
Period of disintegration of ice cover in rivers and lakes

Catchment Basin
See Drainage Basin

Direct Discharge
A measurement of discharge based on observed flow velocities and the local cross sectional area of flow.

Discharge
The volume of a fluid passing through a cross section of a stream per unit time

Drainage Basin
A region of land where water from rain or snowmelt drains downhill into a body of water (e.g. river or lake)

Flood Frequency Analysis
Procedure of interpreting a record of flood events in terms of future probabilities of flood magnitude (discharge) occurrence

Floodplain
Land area adjoining a water body that is not normally submerged but may be submerged during flood conditions

Gage
Fixed vertical graduated scale for determining water surface elevation at a specific location

Ice Jam
A stationary accumulation of fragmented ice or frazil, which restricts or blocks a stream channel

Indirect Discharge
An estimate of discharge based on hydraulic equations relating the discharge to the water surface profile and the geometry of the channel. Measured water surface elevation and channel characteristics collected during field surveys are used in the discharge calculation.

Monument
Benchmark of known elevation and horizontal position relative to a defined datum, used for horizontal and vertical control in surveying.

Pressure Transducer
A type of measurement device that converts pressure-induced mechanical changes into an electrical signal

Reach
(1) The length of a channel uniform with respect to discharge, depth, area, and slope (e.g. "typical channel reach"), (2) the length of a stream between two specified gaging stations, control points, or computational points

Recurrence Interval
The average time interval between the actual occurrence of a hydrological event of a given or greater magnitude

Return Period
See Recurrence Interval

Runoff
Flow that is discharged from an area by stream channels; sometimes subdivided into surface runoff, ground water runoff, and seepage

Snow Water Equivalent (SWE)
The liquid-water equivalent of the snowpack, expressed in terms of depth.

Sounding
Water depth measurement using a weighted line

Spring Breakup
See Breakup

Staff Gage
See Gage

Stage
The vertical distance from any selected and defined datum to the water surface

Stage Frequency Analysis
Procedure of interpreting a stage record of events in terms of future probabilities of flood stage occurrence

Thalweg
Deepest portion of the river channel; the line of major flow

Transect
A sample area, cross section, or line chosen as the basis for sampling one or more characteristics of a particular assemblage

Velocity Measurement Depth
Depth down from water surface; commonly 60% total depth in water of 2.5 feet or less or 20% and 80% total depth in water greater than 2.5 feet in depth.

Water Slope
Change in water surface elevation per unit distance

Water Surface Elevation (WSE)
See Stage

Appendix A SURVEY CONTROL AND GAGE SUMMARY

TABLE A 1: 2009 GMT1 CONTROL

Control	Elevation (BPMSL - Feet)	Latitude (NAD 83)	Longitude (NAD83)	Control Type	Reference
CP08-18-27C	20.414	N 70° 18' 23.4"	W 151° 11' 39.8"	Alcap	LCMF 2008
CP08-18-29B	18.840	N 70° 18' 20.1"	W 151° 12' 36.3"	Alcap	LCMF 2008
CP08-18-29C	19.560	N 70° 18' 18.2"	W 151° 13' 12.9"	Alcap	LCMF 2008
ALMA	25.263	N 70° 16' 45.7"	W 151° 19' 53.2"	Alcap	LCMF 2009
BRAD	25.780	N 70° 16' 37.4"	W 151° 22' 10.5"	Alcap	LCMF 2005
CAID	25.420	N 70° 16' 33.5"	W 151° 22' 04.3"	Alcap	LCMF 2005
CHAR	24.248	N 70° 16' 54.9"	W 151° 17' 41.8"	Alcap	LCMF 2009
CLARA	23.228	N 70° 16' 49.3"	W 151° 19' 59.0"	Alcap	LCMF 2009
COAL	20.524	N 70° 16' 52.4"	W 151° 17' 46.9"	Alcap	LCMF 2009
GYPSY	29.330	N 70° 15' 49.6"	W 151° 29' 30.9"	Alcap	LCMF 2005
JACK	23.450	N 70° 16' 55.4"	W 151° 15' 52.6"	Alcap	LCMF 2005
KELLY	27.630	N 70° 15' 49.4"	W 151° 29' 19.7"	Alcap	LCMF 2005

TABLE A 2: 2009 GMT1 GAGES

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Ublutuoch 6.7	UB6.7-A	N 70° 17' 08.1"	W 151° 15' 45.3"	Mon JACK
	UB6.7-B[1]	N 70° 17' 08.0"	W 151° 15' 45.7"	
	UB6.7-C	N 70° 17' 07.7"	W 151° 15' 45.9"	
	UB6.7-D	N 70° 17' 06.7"	W 151° 15' 47.6"	
Ublutuoch 6.8	UB6.8-A	N 70° 17' 05.0"	W 151° 15' 33.3"	Mon JACK
	UB6.8-B	N 70° 17' 04.4"	W 151° 15' 36.1"	
	UB6.8-C	N 70° 17' 04.1"	W 151° 15' 37.9"	
	UB6.8-D	N 70° 17' 03.4"	W 151° 15' 40.9"	
Ublutuoch 6.9	UB6.9-A[1]	N 70° 17' 00.2"	W 151° 15' 24.2"	Mon JACK
	UB6.9-B	N 70° 17' 00.1"	W 151° 15' 24.8"	
	UB6.9-C	N 70° 17' 00.1"	W 151° 15' 28.7"	
	UB-BARO[2]	N 70° 17' 00.7"	W 151° 15' 31.1"	
S1	S1	N 70° 18' 21.7"	W 151° 11' 40.9"	CP08-18-27C
S2	S2	N 70° 18' 16.7"	W 151° 13' 09.8"	CP08-18-29B
S3	S3	N 70° 17' 46.6"	W 151° 14' 12.5"	CP08-18-29C
S4	S4-A	N 70° 16' 54.5"	W 151° 17' 33.6"	Mon CHAR & Mon COAL
	S4-B	N 70° 16' 51.9"	W 151° 17' 37.6"	
	S4-C	N 70° 16' 49.3"	W 151° 17' 43.8"	
S5	S5-A	N 70° 16' 49.4"	W 151° 19' 47.7"	Mon CLARA & Mon ALMA
	S5-B	N 70° 16' 47.0"	W 151° 19' 47.5"	
	S5-C	N 70° 16' 45.1"	W 151° 19' 48.5"	
S6	S6	N 70° 16' 40.4"	W 151° 22' 08.4"	Mon BRAD
S7	S7	N 70° 16' 20.2"	W 151° 23' 34.4"	Mon BRAD
S8	S8	N 70° 15' 15.6"	W 151° 29' 39.5"	Mon GYPSY & Mon KELLY

[1] pressure transducer installed on this gage
[2] barometer

Appendix B DIRECT DISCHARGE MEASUREMENTS

B.1 Ublutuoch

2009 Michael Baker Jr., Inc.

Comp. By SMC
Check By HLR

Discharge Measurement Notes

Station No. Ublutuoch 6.8 Start: 1230 Finish: 1330

Date 5/29/2009 Party JPM, JWW, JMS

Width 281 ft Area 1106 sq ft Vel. 1.75 fps Disch. 1932 cfs

Method 0.6, 0.2-0.8 No. Secs. 21 Count Variable

GAGE READINGS

Gage	Start	Finish	Change
6.9B	2.05	2.09	0.04
6.8B	1.79	1.75	-0.04
6.7C	2.00	1.95	-0.05

Wading, cable, ice, **boat**

Upstrm or Dwnstrm side of bridge

Meter 0.6 ft above bottom of weight

Weight 30 lbs

Spin Test 2 minutes after ok Meter, No. Price AA, MJBA01

Measurement Rated Excellent Good **Fair** Poor based on the following conditions

Cross Section: Some snow and slush on right bank, shallow willows in mid-section, a few horizontal angles, some grounded ice

Flow: Falling stage, near peak Weather: Dry, breeze

Other: Temp: 30°F

Gages: Gages UB 6.7, UB 6.8, UB 6.9

Remarks: Some stationary ice downstream of 6.7, may be a little backwater

Discharge Measurement Data

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)	Mean in Vertical (fps)	Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
LEW @ 1230											
1.00	23	3.5	0.00	6/10							
1.00	30	8.5	4.40	6/10	30	40	1.68		1.68	37.4	63.0
1.00	40	12.5	4.10	6/10	40	46	1.95		1.95	51.3	99.9
0.90	55	15.0	3.90	6/10	40	52	1.73		1.55	58.5	90.9
0.90	70	15.0	3.10	6/10	47	40	2.63		2.37	46.5	110.0
1.00	85	15.0	2.60	6/10	40	51	1.76		1.76	39.0	68.7
1.00	100	15.0	2.20	6/10	40	48	1.87		1.87	33.0	61.7
1.00	115	15.0	4.30	6/10	40	61	1.47		1.47	64.5	95.1
1.00	130	15.0	3.80	6/10	30	50	1.35		1.35	57.0	77.0
1.00	145	15.0	3.50	6/10	40	43	2.08		2.08	52.5	109.4
1.00	160	15.0	4.20	0/10	30	40	1.68		1.68	63.0	106.1
1.00	175	15.0	5.80	8/10	30	42	1.60	1.92	1.92	87.0	167.2
1.00				2/10	40	40	2.24				
1.00	190	15.0	5.60	8/10	40	52	1.73	2.07	2.07	84.0	173.6
1.00				2/10	43	40	2.41				
1.00	205	15.0	5.60	8/10	30	45	1.50	1.82	1.82	84.0	152.6
1.00				2/10	40	42	2.13				
1.00	220	15.0	5.60	8/10	30	50	1.35	1.67	1.67	84.0	140.4
1.00				2/10	40	45	1.99				
1.00	235	15.0	5.10	8/10	25	48	1.18	1.50	1.50	76.5	115.0
1.00				2/10	40	49	1.83				
1.00	250	15.0	4.30	8/10	20	40	1.13	1.41	1.41	64.5	90.7
1.00				2/10	30.00	40.00	1.68				
1.00	265	15.0	3.40	8/10	25.00	40.00	1.41	1.51	1.51	51.0	76.8
1.00				2/10	30.00	42.00	1.60				
1.00	280	12.5	3.30	8/10	30	45	1.50	1.59	1.59	41.3	65.7
1.00				2/10	30	40	1.68				
1.00	290	12.0	2.60	6/10	39	40	2.18		2.18	31.2	68.1
1.00	304	7.0	0.10	6/10							
REW @ 1330											
Totals											
		281.0								**1106.1**	**1931.9**

B.2 Site S4

2009 Michael Baker Jr., Inc.

Comp. By JMS
Check By JWW

Discharge Measurement Notes

Station No. S4 GMT1 Start: 1257 Finish: 1342

Date 5/31/2009 Party JWW, JMS

Width 25 ft Area 12.3 sq ft Vel. 0.43 fps Disch. 5.6 cfs

Method 0.6 No. Secs. 26 Count

GAGE READINGS			
Gage	Start	Finish	Change
S4B	0.76		
S4A			

Wading, cable, ice, boat

Upstrm or Dwnstrm side of bridge

Meter ft above bottom of weight

Weight lbs

Spin Test after Meter, No. Marsh McBirney

Measurement Rated Excellent Good **Fair** Poor based on the following conditions

Cross Section: No channel ice, no frozen bottom, good even flow, channel open upstream and downstream, both banks clear of snow

Flow: Weather: Mostly sunny, breeze

Other: Temp: Low 40's

Gages: This location is S4, read gages S5N and the gage immediately upstream

Remarks:

Discharge Measurement Data

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 @ 1257											
1.00	1	0.5	0.30	6/10			0.05	0.05	0.05	0.2	0.0
0.98	2	1.0	0.50	6/10			0.28	0.28	0.27	0.5	0.1
1.00	3	1.0	0.40	6/10			0.14	0.14	0.14	0.4	0.1
1.00	4	1.0	0.40	6/10			0.59	0.59	0.59	0.4	0.2
1.00	5	1.0	0.70	6/10			0.75	0.75	0.75	0.7	0.5
1.00	6	1.0	0.50	6/10			0.76	0.76	0.76	0.5	0.4
1.00	7	1.0	0.60	6/10			0.07	0.07	0.07	0.6	0.0
1.00	8	1.0	0.40	6/10			0.48	0.48	0.48	0.4	0.2
1.00	9	1.0	0.50	6/10			0.19	0.19	0.19	0.5	0.1
1.00	10	1.0	0.40	6/10			0.53	0.53	0.53	0.4	0.2
1.00	11	1.0	0.40	6/10			0.48	0.48	0.48	0.4	0.2
1.00	12	1.0	0.60	6/10			0.81	0.81	0.81	0.6	0.5
1.00	13	1.0	0.40	6/10			0.73	0.73	0.73	0.4	0.3
1.00	14	1.0	0.40	6/10			1.02	1.02	1.02	0.4	0.4
1.00	15	1.0	0.50	6/10			0.39	0.39	0.39	0.5	0.2
1.00	16	1.0	0.60	6/10			0.19	0.19	0.19	0.6	0.1
1.00	17	1.0	0.70	6/10			0.15	0.15	0.15	0.7	0.1
1.00	18	1.0	0.60	6/10			0.31	0.31	0.31	0.6	0.2
1.00	19	1.0	0.60	6/10			0.13	0.13	0.13	0.6	0.1
1.00	20	1.0	0.40	6/10			0.26	0.26	0.26	0.4	0.1
1.00	21	1.0	0.30	6/10			0.46	0.46	0.46	0.3	0.1
1.00	22	1.0	0.50	6/10			0.63	0.63	0.63	0.5	0.3
1.00	23	1.0	0.70	6/10			1.04	1.04	1.04	0.7	0.7
1.00	24	1.0	0.50	6/10			0.52	0.52	0.52	0.5	0.3
1.00	25	1.0	0.50	6/10			0.19	0.19	0.19	0.5	0.1
1.00	26	0.5	0.10	6/10			0.11	0.11	0.11	0.1	0.0
REW @ 1342											
Totals											
		25.0								**12.3**	**5.6**

B.3 Site S5

2009 Michael Baker Jr., Inc. Comp. By JMS

Check By JWW

Discharge Measurement Notes

Station No. S5 GMT1 Start: 1508 Finish: 1530

Date 5/30/2009 Party JWW, JMS

Width 40 ft Area 48.15 sq ft Vel. 0.15 fps Disch. 6.8 cfs

Method 0.6 No. Secs. 15 Count

GAGE READINGS			
Gage	Start	Finish	Change
S5C		0.99 @ 1603	

Wading, cable, ice, boat

Upstrm or Dwnstrm side of bridge

Meter ft above bottom of weight

Weight lbs

Spin Test ok after ok Meter No. Marsh McBirney

Measurement Rated Excellent Good Fair Poor based on the following conditions

Cross Section: Willows entirely across channel downstream, channel narrowed both sides by snow, channel bottom ice and slush

Flow: Weather: Dry, Mostly cloudy

Other: Temp: 30°F

Gages:

Remarks: Wading rod w/ Marsh McBirney meter

Discharge Measurement Data

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 @ 1508											
1.00	4	1.0	1.00	6/10			0.10	0.10	0.10	1.0	0.1
1.00	6	2.0	1.40	6/10			0.64	0.64	0.64	2.8	1.8
1.00	8	2.0	1.40	6/10			0.50	0.50	0.50	2.8	1.4
1.00	10	2.0	1.20	6/10			0.36	0.36	0.36	2.4	0.9
1.00	12	2.0	1.00	6/10			0.25	0.25	0.25	2.0	0.5
1.00	14	2.0	1.20	6/10			0.27	0.27	0.27	2.4	0.7
1.00	16	2.0	1.00	6/10			0.23	0.23	0.23	2.0	0.5
1.00	18	2.0	1.00	6/10			0.16	0.16	0.16	2.0	0.3
1.00	20	2.0	1.00	6/10			0.09	0.09	0.09	2.0	0.2
1.00	22	3.0	1.00	6/10			0.03	0.03	0.03	3.0	0.1
1.00	26	4.0	1.00	6/10			0.04	0.04	0.04	4.0	0.2
1.00	30	4.0	1.20	6/10			0.02	0.02	0.02	4.8	0.1
1.00	34	4.0	1.50	6/10			0.03	0.03	0.03	6.0	0.2
1.00	38	4.5	1.30	6/10			0.00	0.00	0.00	5.9	0.0
1.00	43	3.0	1.70	6/10			0.00	0.00	0.00	5.1	0.0
1.00	44	0.5	0.00	6/10			0.00	0.00	0.00	0.0	0.0
REW @ 1530											
Totals											
		40.0								**48.2**	**6.8**