Colville River Delta

Spring Breakup Monitoring
&
Hydrological Assessment

ConocoPhillips
Alaska

Baker

2011

Colville River Delta Spring Breakup
2011 Hydrologic Assessment

January 2012

Submitted to:

ConocoPhillips
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Submitted by:

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EXECUTIVE SUMMARY

This report presents the observations and findings of the Colville River Delta (CRD) Spring Breakup 2011 Hydrologic Assessment conducted by Michael Baker Jr., Inc. for ConocoPhillips Alaska (CPAI). The assessment supports the Alpine Development Project and the Alpine Satellite Development Plan.

Observations and measurements were recorded at locations across the CRD, at critical areas near the facilities, and along the road access system. Monitoring locations included:

- Eleven sites along the Colville River, Colville River East Channel (East Channel), and Nigliq Channel
- Seventeen sites in the vicinity of Alpine facilities, roads, and drinking water lakes
- CD2 and CD4 access roads' drainage structures and road prisms
- Two primary ice road crossings at the East Channel and the Kachemach River and six secondary ice road crossings
- Three sites at the CD3 pipeline crossings
- Three sites at proposed CD5 access road crossings

The Colville River peak discharge of 590,000 cubic feet per second (cfs) occurred May 28, 2011. The peak stage at Monument 1 (MON1) occurred May 28, with a water surface elevation (WSE) of 19.56 feet British Petroleum mean sea level (BPMSL). This value is 0.27 feet lower than the maximum peak WSE observed during the historic record. The WSE at the time of peak discharge was estimated at 15.01 feet BPMSL. The peak discharge has a recurrence interval of twenty two years, based on the Colville River flood frequency analysis.

Ice jams affected spring breakup flood flows throughout the CRD in 2011. An approximately nine-mile-long ice jam was observed backing upstream from MON1 May 27. The ice jam released on the evening of May 28 and cleared ribbon ice from the Colville River East Channel as it flowed downstream. The ice jammed again north of the Tamayayak Channel, releasing on May 29.

Ice floes from the May 28 release also traveled into the Nigliq Channel, where they jammed on ribbon ice near Nuiqsut. This ice jam released May 30, clearing the channel of the majority of the ribbon ice. Floes also entered the Sakoonang Channel and the Tamayayak, jamming and releasing as they moved downstream. An ice jam formed upstream of the Tamayayak pipeline crossing and the Ulamnigiaq bifurcation May 29, releasing overnight May 30. The horizontal directional drilled (HDD) Colville River crossing site and Alpine facilities were not adversely affected.

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ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
2D	Two-Dimensional
ADCP	Acoustic Doppler Current Profiler
ADF&G	Alaska Department of Fish and Game
ADP	Alpine Development Project
ASDP	Alpine Satellite Development Project
ASP	Alpine sales pipeline
Baker	Michael Baker Jr. Inc.
BPMSL	British Petroleum mean sea level
CD	Colville Delta
cfs	cubic feet per second
CMP	corrugated metal pipe
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
DGPS	differential global positioning system
DNR	Alaska Department of Natural Resources
fps	feet per second
G	gage
GPS	global positioning system
HDD	horizontal directional drilled
HWM	high water mark
lat-long	latitude and longitude
MON	monument
mph	miles per hour
NAD83	North American Datum of 1983
NUC	non-uniform channel
OSW	Office of Surface Water
PT	pressure transducer
RM	river mile
SONAR	sound navigation ranging
UC	uniform channel
UMIAQ	Previously known as Kuukpik/LCMF LLC, Inc. (LCMF)
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WAAS	wide-area augmentation system
WGS 84	World Geodetic System of 1984
WSE	water surface elevation

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1.0 INTRODUCTION

This Colville River Delta (CRD) Spring Breakup 2011 Hydrologic Assessment supports the Alpine Development Project (ADP) and the Alpine Satellite Development Plan (ASDP). Michael Baker Jr., Inc. (Baker) conducted spring breakup monitoring to determine the extent and magnitude of this annual flooding event within the CRD at the request of ConocoPhillips Alaska, Inc. (CPAI). Primary tasks included documentation of the distribution of floodwater and the measurement of water levels and discharge quantities. Additional observations of lake recharge, ice jam activities, ice road crossing degradation, and post-breakup floodwater effects were collected. Measurements and observations were used to determine peak discharge and stage at various CRD locations, which are evaluated and compared to current flood and stage frequency values and the CRD two-dimensional (2D) surface water model results. Hydrologic observations in the CRD were conducted at the Colville River East Channel, Nigliq Channel, Alpine facilities and roads, Colville Delta (CD) 3 pipeline crossings, and proposed CD5 road crossings. The results of the 2011 spring breakup monitoring activities are presented in this report.

Alpine
CD1 pad

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

Proposed Alpine Facilities
CD5

Spring Breakup
Period of disintegration of ice cover in rivers and lakes

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

Spring breakup on the North Slope typically occurs during a three-week period. CRD breakup is the largest annual flooding event in the region. Monitoring is integral to understanding regional hydrology, establishing appropriate design criteria for proposed facilities, and maintaining the continued safety of the environment, oilfield personnel, and facilities during the flooding event. After spring breakup, flow generally declines during the summer months with some temporary flow increases from rainfall. Figure 1.1 shows the CRD drainage basin delineation.

In many areas of the Alaska North Slope, including the CRD, similar hydrologic and hydraulic characteristics are created in part by the arctic climate and presence of continuous regional permafrost. Groundwater is shallow and is generally restricted to isolated zones beneath deep lakes and river channels. Groundwater influx is largely nonexistent. Surface water, including ponds, lakes, small streams, and drainages, is frozen for much of the year.

Operated by CPAI, the Alpine facilities are owned by CPAI and Anadarko Petroleum Company. Figure 1.2 shows the existing Alpine facilities, the proposed CD5 facilities, the Colville River and Nigliq Channel monument monitoring locations, and the locations of the ice road crossings. The existing Alpine facilities are the CD1 processing facility (Alpine); CD2, CD3, and CD4 drilling pads; access roads; and associated pipelines. Alpine facilities CD1 and CD2 were built for the ADP and CD3 and CD4 were built as part of the ASDP. Proposed CD5 facilities are also part of the ASDP. Existing and proposed Alpine facilities and associated monitoring locations are shown in Figure 1.3. The proposed CD5 facilities presented in Figure 1.3 were provided by PND Engineers, Inc. (PND) and are current as of the time of this report.

Spring breakup monitoring activities have been conducted in the CRD since 1992. Monitoring was expanded in 2004 to include ASDP facilities. The 2011 hydrologic field program is the 20th consecutive year of CRD spring breakup investigations.

This report is organized as outlined below.

Section 1—Introduction: Discusses the objectives of the monitoring program and presents climatic and breakup timing information.

Water Surface Elevation (Stage)
The vertical distance from any selected and defined datum to the water surface

Section 2—2011 Monitoring Locations: Presents the 2011 monitoring sites.

Section 3—Methods: Describes the methods of the fieldwork and the data analyses.

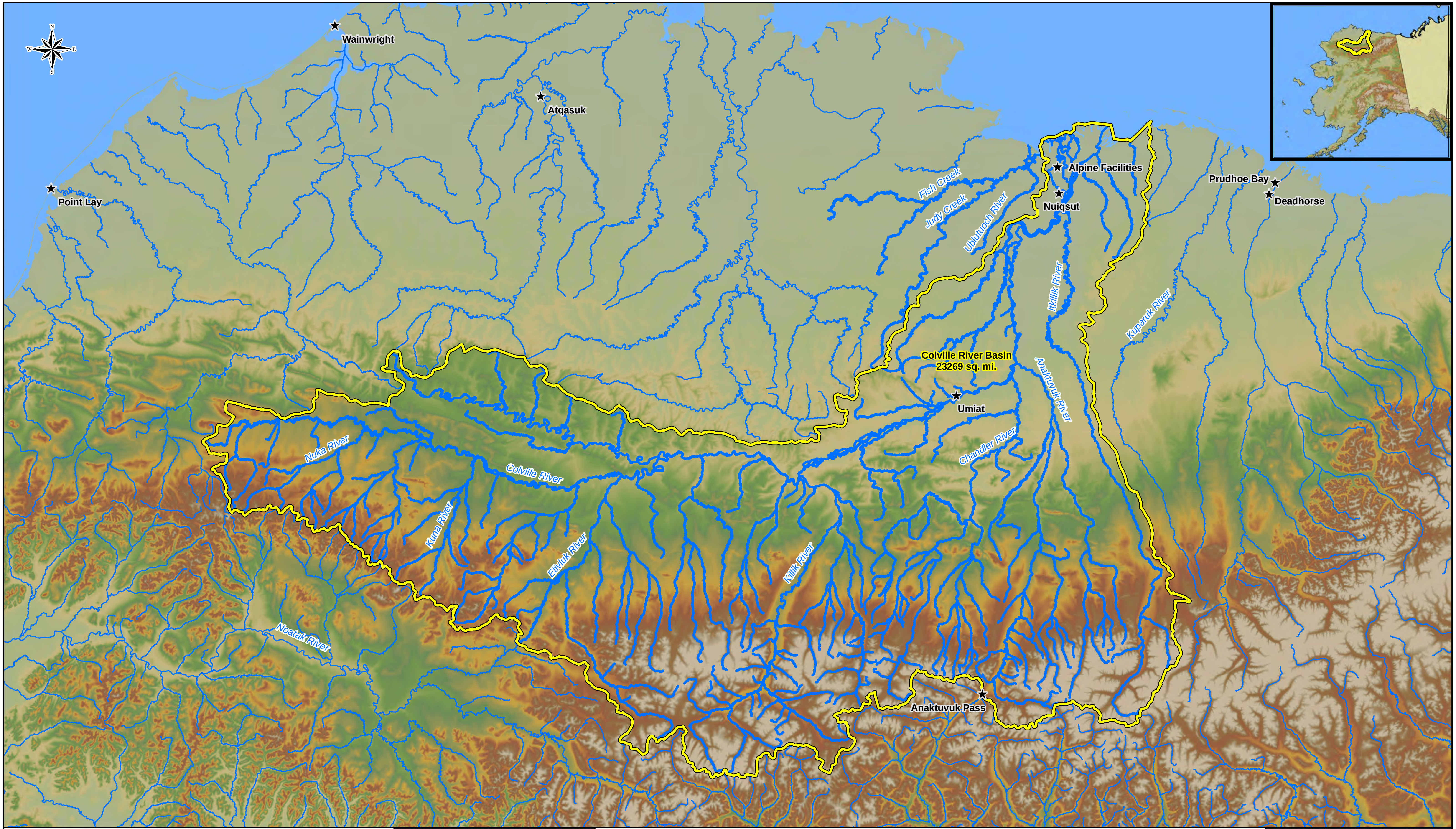
Section 4—2011 Spring Breakup—Hydrologic Observations: Presents the 2011 hydrologic observations and water surface elevations in the CRD, including the Colville River, Colville River East Channel (East Channel), Nigliq Channel, Alpine facilities, and roads, including drinking water lakes, drainage structures, pads or roads erosion and ice bridge degradation, CD3 pipeline crossings, and proposed CD5 road crossings.

Section 5—2011 Discharge: Presents the 2011 CRD direct-measured and peak-calculated discharge results. A comparison of CRD peak stage and discharge values to the current CRD stage or flood frequency recurrence intervals and a comparison to stage values to the 2009 2D hydrodynamic modeling analysis is also included.

Section 6—References: Contains the references used in the development of this report.

Appendices: Appendix A includes survey control for monitoring gages and the geographic locations for gages and control. Monument 1 (MON1) discharge notes are provided in Appendix B. Appendix C contains discharge notes for measurements performed at the Alpine swale bridges and Appendix D includes a comparison of direct and indirect discharge values with the rating curve developed at MON1.

UMIAQ (previously Kuukpik/LCMF LLC, Inc., or LCMF), the Alpine environmental coordinators, and Bristow Helicopters provided support during the 2011 CRD breakup field work and contributed to a safe and productive monitoring season.



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Legend

★ Place Names

— Streams

▭ Colville River Basin

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2011 SPRING BREAKUP

COLVILLE RIVER DELTA

Drainage Basin

FIGURE: 1.1

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2011 SPRING BREAKUP
COLVILLE RIVER DELTA
MONITORING LOCATIONS

FIGURE: 1.2

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2011 SPRING BREAKUP

Alpine Area Facilities

Monitoring Locations

FIGURE: 1.3

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1.1 MONITORING OBJECTIVES

Annual monitoring provides a basis for the record used to evaluate the effect of breakup flooding events on existing facilities and infrastructure. Data is also used for analysis and design of proposed infrastructure projects.

As during past spring breakup monitoring seasons, the primary objective of the 2011 CRD Spring Breakup Hydrologic Assessment was to monitor and estimate the magnitude of breakup flooding within the CRD.

The 2011 spring breakup program also documented observations of any effects to flow and channel morphology caused by the construction of winter ice bridges across the Colville River East Channel (East Channel) at the horizontal directional drilling (HDD) crossing and the Kachemach River.

Objectives

- Visual observation of breakup events
- Documentation of the distribution of floodwater
- Measurement of water levels throughout the project area
- Direct discharge measurement at select locations
- Analysis of collected data

Permit stipulations identified in U.S. Army Corps of Engineers (USACE) Permit No. POA-2004-253 and the State of Alaska Department of Natural Resources (DNR) Fish Habitat Permit FH04-III-0238 require monitoring of the Alpine facilities during spring breakup. Permit requirements include direct and indirect measurements of discharge through drainage structures and documentation of pad and access road erosion caused by spring breakup flooding.

Alaska Department of Fish and Game (ADF&G) permits FG99-III-0051-Amendment #7 and FG97-III-0190-Amendment #5 require monitoring of recharge to Lakes L9312 and L9313. The Alpine facilities rely on water withdrawal from these lakes for daily operations, the volume of which is dictated in part by annual spring recharge.

1.2 CLIMATIC REVIEW

For an approximate three-week period, spring on the Alaska North Slope is dominated by breakup flooding. Various factors contribute to the breakup cycle, including snow pack, sustained cold or warm temperatures, ice thickness, wind speed and direction, precipitation, and solar radiation. The open water season for the CRD is generally limited to a four-month period from June through September.

The Brooks Range stretches approximately 700 miles across northern Alaska and the Yukon Territory of Canada. The annual spring runoff in the Brooks Range contributes to rising stage in the Colville River and other regionally related streams. The Brooks Range is located approximately 150 air miles south of the head of the CRD. Monument 1 (MON1, Figure 1.2), located at the head of the delta, is the site farthest downstream (north) on the Colville River where the majority of contributing flow is confined to a single channel before the channel bifurcates as it approaches the coast of the Beaufort Sea.

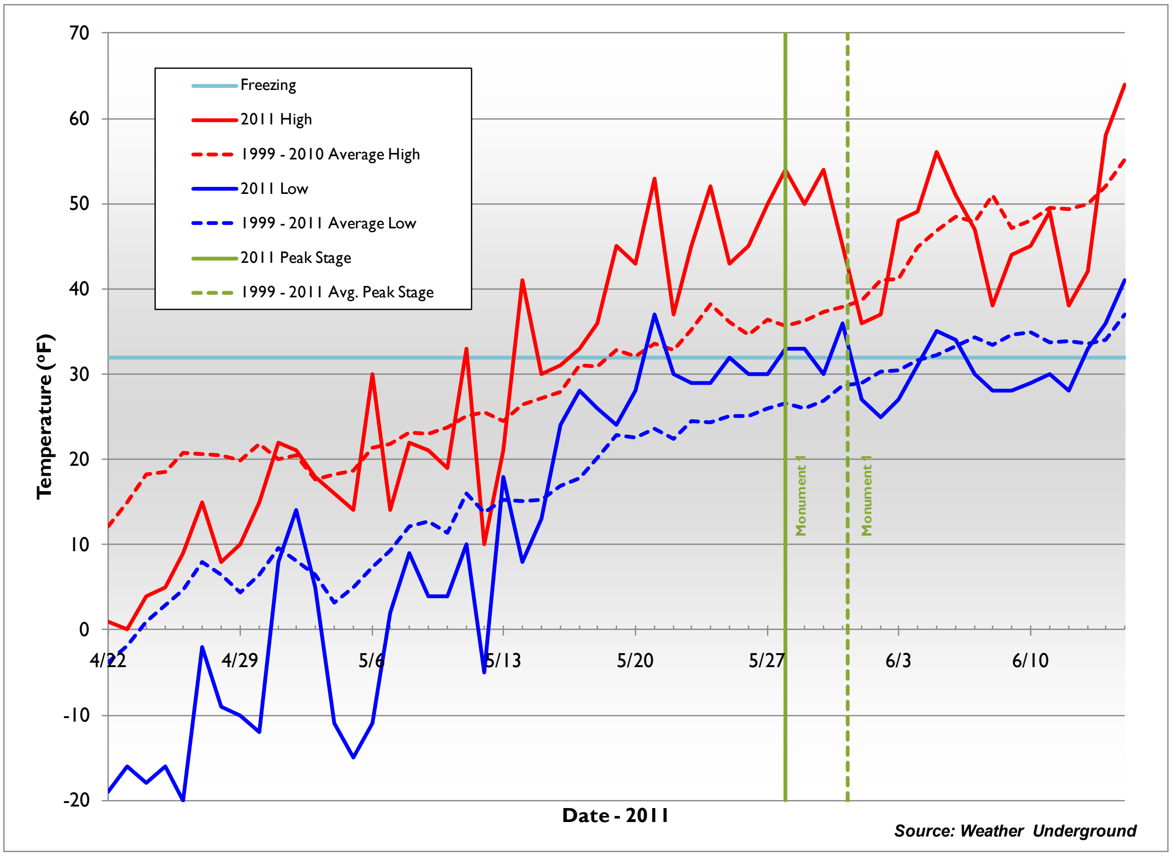
Increasing spring temperatures initiate breakup processes. Although not solely responsible, of particular importance is the rise of daily high ambient air temperatures in the Brooks Range, where the headwaters of the Colville River originate. As these daily highs begin to approach and exceed

freezing, breakup processes accelerate, melting snow in the area of the Colville River headwaters. This melting process produces water, which progresses downstream towards the CRD.

Climate data for this region of the Brooks Range foothills are available from the Umiat weather station. Umiat (shown in Figure 1.1) is located approximately 60 air miles south of MON1. Graph 1.1 illustrates high and low ambient air temperatures for Umiat, as recorded from April 22 to June 15, during the 2011 breakup monitoring period. Average highs and lows for the same period for 1999 through 2011 are shown as dashed lines. Dates of 2011 peak stage and average peak stage from 1999 to 2011 from the centerline gage at Monument 1 (MON1C) are included for comparison.

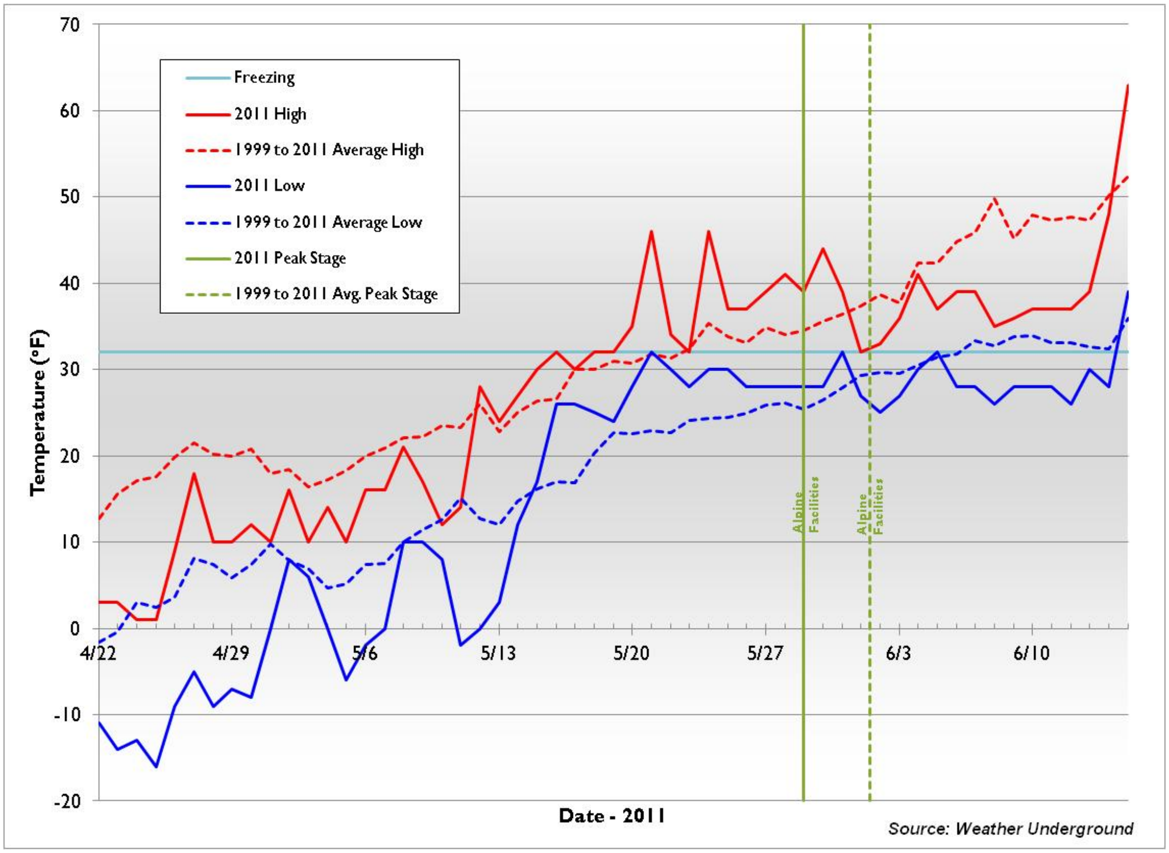
Review of daily high and low ambient air temperatures are used in the evaluation of breakup timing. Graph 1.1 illustrates the ambient air temperatures at Umiat, which were generally below historical averages, with the exception of mid-May through early June. Nighttime ambient air temperatures did not stay above freezing until mid-June.

Temperatures for the Alpine area were obtained from the Nuiqsut weather station. Nuiqsut is located on the west bank of the Nigliq channel, approximately 3.5 air miles northwest of MON1, and approximately nine air miles southwest of the Alpine facilities, as shown in Figure 1.2. Graph 1.2 provides high and low ambient air temperatures for Nuiqsut, as recorded during 2011 breakup monitoring. Local melting in the vicinity of the Alpine facilities was initiated as daily highs and lows in the area approached and exceeded freezing. Ambient air temperatures at Nuiqsut remained below freezing until around May 19. Generally nighttime ambient air temperatures did not reach freezing during the breakup monitoring period.



Source: Weather Underground

GRAPH 1.1: DAILY HIGH AND LOW BREAKUP AMBIENT AIR TEMPERATURES AT UMIAT AND PEAK STAGE AT MON1



Source: Weather Underground

GRAPH 1.2: DAILY HIGH AND LOW BREAKUP AMBIENT AIR TEMPERATURES AT NUIQSUT AND PEAK STAGE AT ALPINE FACILITIES

1.3 BREAKUP TIMING

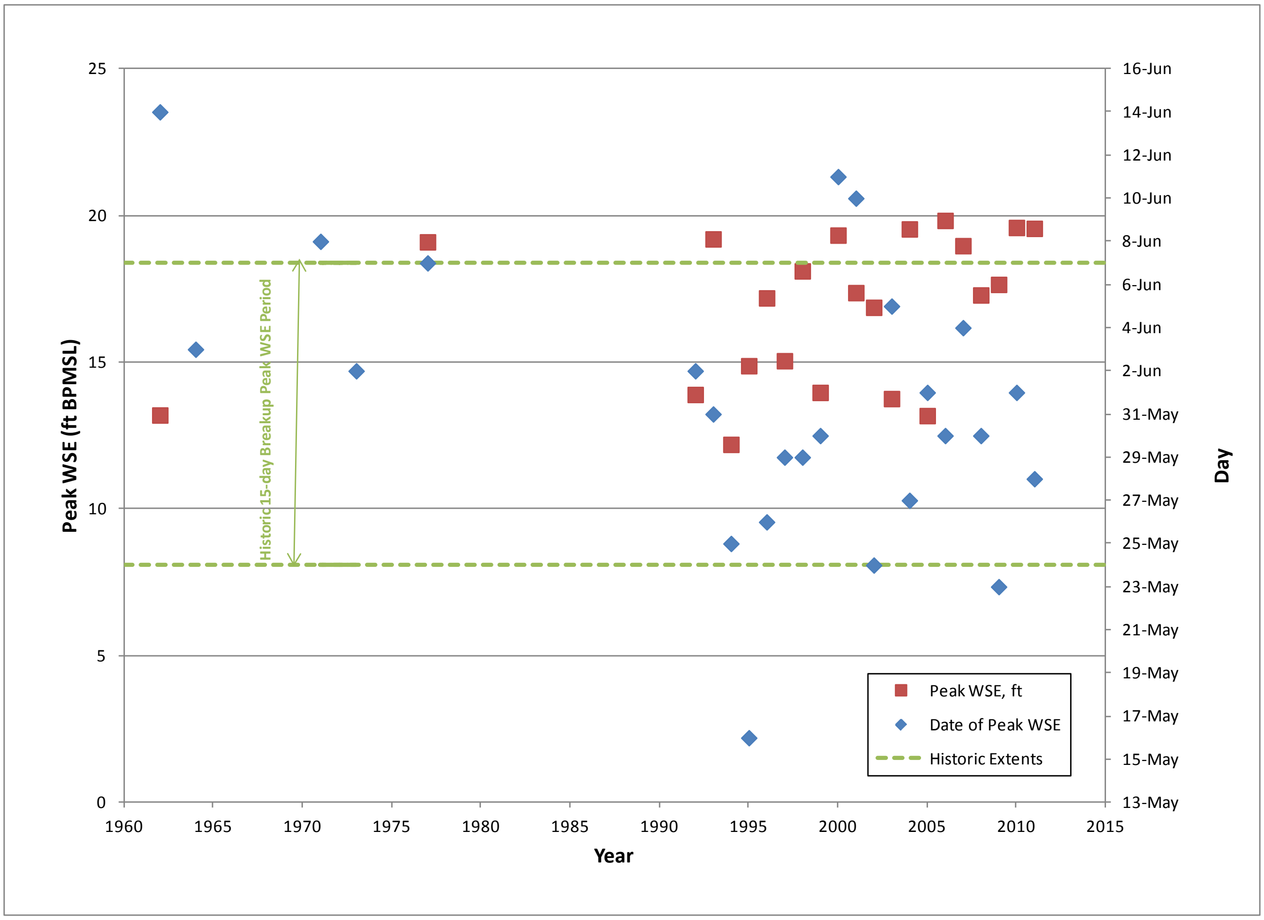
Since initial breakup studies began in 1962, Colville River breakup monitoring has been intermittently conducted at various locations in the delta. Monitoring of MON1 provides the most consistent historical record of breakup peak stage and discharge observations available. Located at the head of the delta, it represents the farthest downstream reach of the Colville River, where all flow is confined to a single channel before entering the delta (see Figure 1.2).

Table 1.1 shows the annual peak discharge, peak stage, and the respective dates for both at MON1. In Table 1.1, the 2011 peak WSE and peak discharge are represented by data collected at MON1C, as this location is typical for the Acoustic Doppler Current Profiler (ADCP) measurement. Also, the 2011 indirect discharge calculation at MON1 is based on the breakup data collected from the gages at MON1C.

TABLE 1.1: COLVILLE HISTORICAL PEAK DISCHARGE, STAGE & DATE

Year	Discharge		Stage (WSE)		Reference
	Peak Discharge (cfs)	Date	Peak Stage (ft BPMSL)	Date	
2011	**590,000**	**28-May**	**19.56**	**28-May**	**This report**
2010	320,000	31-May	19.59	1-Jun	Baker 2010d
2009	266,000	23-May	17.65	23-May	Baker 2009c
2008	221,000	28-May	17.29	30-May	Baker 2008
2007	270,000	3-Jun	18.97	4-Jun	Baker 2007b
2006	281,000	30-May	19.83	30-May	Baker 2007a, 2007b
2005	195,000	9-Jun	13.18	1-Jun	Baker 2005b
2004	360,000	26-May	19.54	27-May	Baker 2005a
2003	232,000	11-Jun	13.76	5-Jun	Baker 2006
2002	249,000	27-May	16.87	24-May	Baker 2006
2001	255,000	11-Jun	17.37	10-Jun	Baker 2006
2000	580,000	11-Jun	19.33	11-Jun	Baker 2000
1999	203,000	30-May	13.97	30-May	Baker 1999
1998	213,000	3-Jun	18.11	29-May	Baker 1998a
1997	177,000	-	15.05	29-May	Baker 2002b
1996	160,000	26-May	17.19	26-May	Shannon & Wilson 1996
1995	233,000	-	14.88	16-May	ABR 1996
1994	159,000	25-May	12.20	25-May	ABR 1996
1993	379,000	31-May	19.20	31-May	ABR 1996
1992	188,000	-	13.90	2-Jun	ABR 1996
1977	407,000	-	19.10	7-Jun	ABR 1996
1973	-	-	-	2-Jun	ABR 1996
1971	-	-	-	8-Jun	ABR 1996
1964	-	-	-	3-Jun	ABR 1996
1962	215,000	-	13.20	14-Jun	ABR 1996

Based on the 17 recorded peak discharge dates, the average date of peak discharge is May 31. The 2011 peak discharge was estimated to have occurred on May 28, three days earlier than the historical average. Based on the 25 recorded peak stage dates, the average date of peak stage is also May 31. In 2011, peak stage occurred on May 28, three days earlier than the historical average. Graph 1.3 presents the date and stage of peak WSE near MON1 for those years with available data.



Graph 1.3: MON1 Annual Peak Water Surface Elevation and Dates

Based on the dates available for the 25-year historical peak stage record, 75 percent of peak WSE for the CRD at MON1 have occurred during the 15-day period from May 24 to June 7, as illustrated on Graph 1.3. Eliminating the extreme WSE dates of May 16 and June 14, nearly 82 percent of the peak stage dates, including the May 28, 2011 peak stage, falls within this 15-day window. The 2011 peak stage at MON1 occurred on May 28, which falls within the 15-day timeframe.

The 2011 peak stage value was 19.56 feet BPMSL. The maximum historical peak stage was 19.83 feet BPMSL (Baker 2007b) in 2006. The average historical peak stage is 16.81 feet BPMSL. The timing and magnitude of peak WSE in the vicinity of the Alpine facilities is typically one or two days following the peak at MON1. The pattern was consistent in 2011 with peak stage occurring around the facilities overnight between May 29 and May 30.

Section 4.0 further discusses the timing of spring breakup events within the CRD. Additional historical WSE information relating to flood and stage frequency is provided in Section 5.8.

2.0 2011 MONITORING LOCATIONS

The CRD 2011 monitoring locations were consistent with those presented in the *2010 Colville River Delta Spring Breakup and Hydrologic Assessment* (Baker 2010). An overview of the 2011 proposed and existing Alpine facilities is shown in Figure 1.2.

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

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

Monitoring is accomplished using a network of gages that have been established in the CRD. The monuments are located at the head of the Colville River and along the Nigliq Channel and East Channel of the Colville River, downstream of the bifurcation. Existing Alpine facility gages are located between the Sakoonang and Nigliq Channels. These facility gages allow for the monitoring of WSE and flow at major hydrologic features adjacent to existing Alpine pads and roads. Selected locations are also monitored for lake recharge, gravel road prism erosion, and the breakup of seasonal ice bridges. Proposed Alpine facility gages are located at key locations identified as sites at which spring breakup events would interact with proposed CD5 infrastructure.

The 2011 facility gaging and monument monitoring sites are listed in Table 2.1. The monument gage locations are shown in Figure 1.2, and the facility gage locations are presented in Figure 1.3. Additional monitoring sites are presented in Table 2.2. Referenced survey control for all locations is provided in Appendix A.

The selection of monitoring locations is based on topography, the proximity of existing and proposed facilities to relevant terrain features, hydraulically significant locations, and historical hydrologic and hydraulic observation sites within the region. Repair and survey of all gages was completed during setup between May 3 and May 11, 2011.

As part of the narrative, locations are often identified in river miles (RM). Measurement of RM commences at RM 0, which is generally at the point of a stream or river terminus where a smaller channel joins a larger channel or a stream or river enters a large water body, such as a lake or ocean. The measurement increases with increased distance upstream.

For the East and Nigliq Channels, RM 0 is located at the mouth of the delta at Harrison Bay. Therefore, measurement upstream is identified along the East (E) and Nigliq (N) channels of the Colville River. For example, RM N7.0 indicates a location seven miles upstream from Harrison Bay on the Nigliq Channel. Note that RM locations in this report are based on the assumption that Monument 35 (MON35) is located at RM E3.0 for East Channel locations and Monument 28 (MON28) is located at RM N0.8 for Nigliq Channel locations.

TABLE 2.1: COLVILLE RIVER DELTA PRIMARY MONITORING LOCATIONS

Monitoring Area	
Location	Notes
Monuments - Colville East Channel	
MON1 (MON1U, MON1C & MON1D)	Entire Colville Flow confined to a single channel
MON9	HDD crossing
MON35	Helmericks Homestead
Monuments - Nigliq Channel	
MON20	South of CD4
MON22	South of CD2
MON23	North of CD2
MON28	At Harrison Bay
Alpine Facilities and Roads	
G1	CD1 betweeen Pad and Sakoonang Channel
G9	CD1 Pad area, Lake L9312
G10	CD1 Pad area, Lake L9313
G3	CD2 Access Road, S side, swale bridge vicinity
G4	CD2 Access Road, N side, swale bridge vicinity
G12	CD2 Access Road, S side of road
G13	CD2 Access Road, N side of road
G6	CD2 Access Road, S side of road
G7	CD2 Access Road, N side of road
G8	CD2 between Pad and Nigliq Channel
G11	CD3 Pad area
G15	CD4 Access Road, W side
G16	CD4 Access Road, E side
G17	CD4 Access Road, W side
G18	CD4 Access Road, E side
G19	CD4 between SE corner of Pad and Lake L9324
G20	CD4 between W end of Pad and Nigliq Channel
CD3 Pipeline Stream Crossings	
SAK	Sakoonang (Pipe Bridge #2)
TAM	Tamayayak (Pipe Bridge #4)
ULAM	Ulamnigiaq (Pipe Bridge #5)
Proposed CD5 Crossings	
G21	East Bank, Nigliq Channel
G22	West Bank, Lake L9341
G23	West Bank, Nigliagvik

Bold, larger font gage names indicate direct-read permanent staff gage

TABLE 2.2: COLVILLE RIVER DELTA ADDITIONAL MONITORING LOCATIONS

Additional Monitoring Areas	
Location	**Notes**
Alpine Swale Bridges	
62-foot bridge	Along CD2 Access Road
452-foot bridge	Along CD2 Access Road
Alpine Culverts	Performance surveys
CD2 Road	26 culverts
CD4 Road	38 culverts
Alpine Roads	Post-breakup erosion visual surveys
CD2 Access Road	
CD4 Access Road	
Ice Road Stream Crossings	Area visual surveys
Colville East Channel	North of HDD
Kachemach River	South of pipeline crossing to 2L Pad - Kuparuk

2.1 MONUMENTS

The CRD is bounded upstream by MON1 at the head of the delta. Photo 2.1 shows the Colville River bifurcation at MON1, located at RM E27.1. The Colville River divides into the Nigliq and East Channels approximately one mile downstream from MON1. The larger East Channel flows east of the Alpine facilities. The smaller Nigliq Channel flows past the village of Nuiqsut, to the west of the Alpine facilities. The mouth of the delta lies downstream at the end of a series of braided channels where the many channels empty into Harrison Bay.

PHOTO 2.1: COLVILLE RIVER AT MON1, LOOKING DOWNSTREAM (NORTH); MAY 28, 2011

2.1.1 EAST CHANNEL

Located farthest upstream, MON1 has been monitored annually since 1992 and sporadically since 1962. Three gaging stations are installed at MON1; one upstream (MON1U) at approximate RM E23.5, another at RM E22.9, designated MON1 centerline (MON1C), and one downstream (MON1D) at approximate RM E22.3. Locations are shown in Figure 1.2 and Photo 2.2.

Between the MON1 and MON35 monitoring locations, a gaging station at Monument 9 (MON9 at RM E16.8) in Figure 1.2, was selected to monitor the HDD crossing of the Alpine Sales Pipeline (ASP) (Photo 2.3 and Photo 2.4). This location is downstream of the Putu Channel and upstream of the Sakoonang distributaries. MON9 has been monitored annually since 2005.

PHOTO 2.2: COLVILLE RIVER AT MON1 PRIOR TO BREAKUP, LOOKING UPSTREAM (SOUTH); MAY 24, 2011

PHOTO 2.3: EAST CHANNEL AT MON9 (HDD) PRIOR TO BREAKUP, LOOKING WEST; MAY 21, 2011

PHOTO 2.4: EAST CHANNEL AT MON9 (HDD), LOOKING EAST; MAY 28, 2011

The Helmericks Homestead (Colville Village) monitoring location of MON35 (RM E3.0) is located nearest to Harrison Bay and is the farthest downstream gage site on the East Channel (Photo 2.5). MON35 has been monitored intermittently since 1999.

PHOTO 2.5: EAST CHANNEL AT MON35 (HELMERICKS HOMESTEAD) LOOKING SOUTHWEST (PHOTO PROVIDED BY JIM HELMERICKS); MAY 26, 2011

2.1.2 NIGLIQ CHANNEL

Four monitoring locations are positioned along the Nigliq Channel; Monument 20, Monument 22, Monument 23, and Monument 28. Monument 20 (MON20) is positioned approximately 11 miles downstream from MON1C along the Nigliq Channel at RM N12.2 (Photo 2.6).

PHOTO 2.6: NIGLIQ AT MON20 PRIOR TO BREAKUP, LOOKING UPSTREAM (SOUTHWEST); MAY 21, 2011

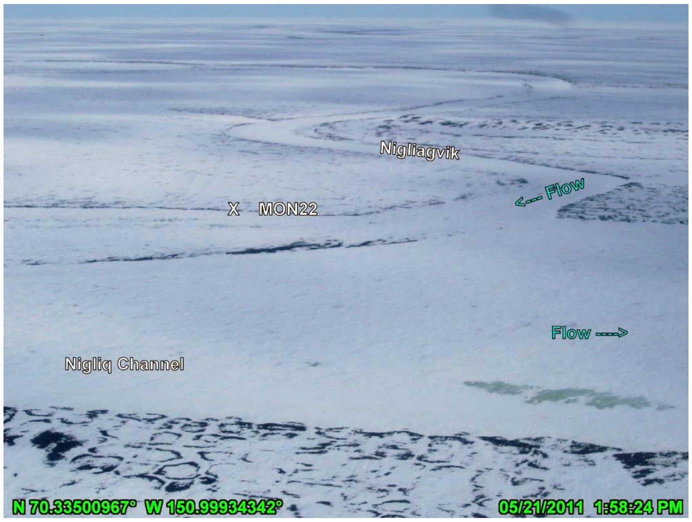


PHOTO 2.7: NIGLIQ AT MON22 PRIOR TO BREAKUP, LOOKING WEST; MAY 21, 2011

PHOTO 2.8: NIGLIQ AT MON23 PRIOR TO BREAKUP, LOOKING DOWNSTREAM (NORTH); MAY 21, 2011

PHOTO 2.9: NIGLIQ AT MON28, LOOKING DOWNSTREAM (NORTH); MAY 28, 2011

Monument 22 (MON22), the next site downstream (north) along the Nigliq Channel, is located approximately midway between CD2 and CD4 at RM N8.8. Gages are located on the west bank. Photo 2.7 shows the MON22 gage location and its proximity to the tailwater of the Nigliagvik.

Monument 23 (MON23) gages are on the east bank at RM N6.9, north of CD2. A plan view and historical 2005 cross-section at the MON23 gage location is provided in Section 5.3. Photo 2.8 shows the MON23 gage location and its proximity to CD2.

Monument 28 (MON28) at RM N0.8 nearest Harrison Bay represents the northernmost gage location along the Nigliq Channel (Photo 2.9).

All Nigliq Channel gages have been monitored intermittently since 1998, except MON28, at which intermittent monitoring began in 1999.

Two additional sites in the downstream vicinity of the Nigliq Channel were monitored in 2011. These areas are identified as FWR1 and FWR2 and are located in the northwest section of the CRD.

2.2 ALPINE AREA FACILITIES

Both direct-read permanent staff gages and indirect-read staff gages are utilized to monitor WSE at Alpine facilities and lakes. Section 3.2.1 further discusses gage assemblies.

2.2.1 LAKES

Recharge of Lakes L9312 and L9313 is monitored using direct-read gages G9 and G10, in accordance with lake water-use permit requirements, as discussed in Section 1.1. Photo 2.10 shows L9312 and L9313 near Alpine facilities prior to breakup.

2.2.2 DRAINAGE STRUCTURES

Drainage structures installed along the Alpine access roads are intended to allow passage of sediment-laden floodwaters, provide fish passage, and to maintain the structure and function of habitats near the facilities. These drainage structures include a series of single culverts and multi-culvert batteries along both Alpine access roads (to CD2 and CD4) and two bridges along the CD2 access road, the 62-foot (short) and the 452-foot (long) swale bridges (Photo 2.11 and Photo 2.12).

PHOTO 2.10: CD1 WITH LAKE L9312 AND L9313 PRIOR TO BREAKUP, LOOKING UPSTREAM (SOUTHWEST); MAY 24, 2011

PHOTO 2.11: CD2 ROAD DRAINAGE STRUCTURES PRIOR TO BREAKUP, LOOKING WEST; MAY 21, 2011

2.2.3 EROSION

Following breakup, the Alpine access roads were evaluated for visual evidence of erosion caused by flooding. Data were collected from observations along the length of both shoulders of the gravel roads and pads within the Alpine system.

2.2.4 ICE BRIDGES

During the winter of 2010-2011, an ice road was constructed connecting the 2L Pad at Kuparuk and the Alpine facilities. The ice road crossed several drainages and channels, the most significant being the Kachemach River (Photo 2.13) and the East Channel (less than one-half-mile upstream from the HDD crossing, Photo 2.14). A spur road was constructed south from the west bank of the Colville River at the ice bridge crossing, extending along the Nigliq Channel to the village of Nuiqsut. The ice bridge crossings of the Kachemach and the Colville rivers were the primary focus before, during, and after breakup monitoring. Monitoring included visual observation and photography of each crossing.

PHOTO 2.12: CD2 ROAD CULVERTS CLEARED OF SNOW AT INLETS AND OUTLETS PRIOR TO BREAKUP TO FACILITATE PASSAGE OF FLOOD FLOWS AND SEDIMENT, LOOKING NORTHWEST; MAY 21, 2011

PHOTO 2.13: ICE ROAD CROSSING AT THE KACHEMACH RIVER SLOTTED PRIOR TO BREAKUP TO FACILITATE THE PASSAGE OF FLOOD FLOW, LOOKING NORTHEAST; MAY 26, 2011

PHOTO 2.14: COLVILLE RIVER ICE ROAD CROSSING AND NIGLIQ CHANNEL ICE ROAD PRIOR TO BREAKUP, LOOKING SOUTHWEST; MAY 21, 2011

2.3 CD3 PIPELINE RIVER CROSSINGS

The CD3 pipeline crosses three significant channels between CD1 and CD3. These locations include Crossing #2 on the southwest bank of the Sakoonang (Photo 2.15), Crossing #4 on the south bank of the Tamayayak, and Crossing #5 on the northeast bank of the Ulamnigiaq. Gages (SAK, TAM and ULAM) were installed at the three crossings to monitor breakup conditions. Monitoring has been conducted at these locations intermittently since 2000.

PHOTO 2.15: LOCAL MELT NEAR SAKOONANG PIPELINE BRIDGE (CROSSING #2), LOOKING UPSTREAM (SOUTH); MAY 26, 2011

2.4 PROPOSED CD5 ROAD CROSSINGS

There are three monitoring sites along the proposed CD5 road. These are crossing locations at G21 on the east bank of the Nigliq Channel, G22 on the west bank of Lake L9341 (Photo 2.16), and G23 on the east bank of the Nigliagvik (formerly reported as Cody Creek, Photo 2.17).

PHOTO 2.16: PROPOSED CD5 ROAD CROSSINGS AT THE NIGLIQ CHANNEL (G21) AND LAKE L9341 (G22) PRIOR TO BREAKUP, LOOKING UPSTREAM (SOUTH); MAY 24, 2011

PHOTO 2.17: PROPOSED CD5 ROAD CROSSING AT THE NIGLIAGVIK (G23) PRIOR TO BREAKUP, LOOKING UPSTREAM (SOUTH); MAY 21, 2011

3.0 METHODS

Visual observations of melt water flow and distribution of breakup flooding, documentation of WSE at the gaging locations, and measurement of discharge at various channels and structures are the primary methods utilized during the 2011 monitoring program. These field methods were based on standard techniques that have been proven to be safe, reliable, efficient, and accurate for the conditions found on the North Slope of Alaska during spring breakup. Collection of the data was most affected by conditions related to safety, logistics, and weather.

3.1 VISUAL OBSERVATIONS

Pre-breakup setup and visual observations of breakup events in the project area were conducted from the ground via Hägglund BV206 tracked vehicles from May 3 to May 11, 2011. Spring breakup observations were conducted by helicopter from May 18 to May 31, 2011, with a final monitoring on June 9.

PHOTO 3.1: PRE-BREAKUP SETUP AT MON28, HÄGGLUND BV206 IN BACKGROUND; MAY 9, 2011

Photo 3.1 shows a pre-breakup level loop survey of the MON28 gages with the UMIAQ-operated Hägglund BV206 nearby. Field observations were recorded daily in field notebooks by team members. Progression of spring breakup prior to, during, and after peak flooding events was documented using digital photographs. The geographic position of the camera in latitude and longitude (lat-long), date, and time were automatically imprinted onto each photo. As in past years, the photo datum was World Geodetic System of 1984 (WGS 84). At times when the camera had difficulty locking onto a geographic position, the locations were manually geographically referenced, confirmed, and then imprinted onto each photograph.

3.2 WATER SURFACE ELEVATION

3.2.1 STAFF GAGES

As indicated in Table 2.1, both permanent and temporary staff gages are located throughout the delta. Permanent, direct-read staff gages are located at CD1 and CD2. These consist of metal gage faceplates attached to drill stems. The direct-read gages are permanently mounted staff gages that have been surveyed and assembled so that the gage faceplate corresponds to actual BPMSL elevation. Therefore, a high-water-mark (HWM) reading of 8.64 on G3 along the CD2 road indicates a HWM elevation of 8.64 feet BPMSL.

Direct-read staff gages include G1, G3, G4, G6, G7, G9, G10, and G19. The faceplates are surveyed each breakup season to correct any errors in elevation. In June 2011, UMIAQ surveyed and adjusted elevation on all direct-read permanent staff gages. Photo 3.2 shows permanent, direct-read staff gage G3 near the CD2 road swale bridges.

PHOTO 3.2: PERMANENT DIRECT-READ STAFF GAGE G3 NEAR CD2 ROAD SWALE BRIDGES; MAY 27, 2011

Temporary, indirect-read gage sets (Photo 3.3) consist of between two and seven staff gage assemblies at a monitoring location. Each gage assembly consists of a metal gage faceplate mounted on a two-by-four timber. The timber is attached with u-bolts to a 1.5-inch-wide angle iron post driven into the ground. Indirect-read staff gages are established with a faceplate that does not directly correspond to actual elevation. Baker surveyed these gages relative to a known benchmark elevation to establish a correction factor. The correction factor is then applied to the faceplate reading to obtain the elevation in feet BPMSL. For example, a HWM reading of 2.88 on G20-B is corrected based on a Baker survey of local control. In this particular case, the gage correction is 7.76 feet. After an adjustment is made, the indirect staff gage reading of 2.88 corresponds to a HWM elevation of 10.64 feet BPMSL. Installation of the temporary staff gages was completed prior to the arrival of breakup floodwater.

PHOTO 3.3: TEMPORARY INDIRECT-READ GAGES AT THE SAKOONANG PIPELINE CROSSING; GAGE A IS NEAREST TO THE CHANNEL CENTERLINE, LOOKING NORTHEAST; MAY 9, 2011

Water level is recorded based on the observed level on the gage plate during site visits. Chalk is applied to the angle iron during each site visit. Subsequent HWMs are recorded when floodwaters remove the chalk, as noted during field visits. When water levels were not sufficiently high to be recorded on the staff gage faceplates, standard level-loop survey techniques were used to measure WSE. The horizontal position of each gage was recorded using a handheld Garmin® Rino® 520HCx in North American Datum of 1983 (NAD83).

Each gage faceplate elevation was surveyed from a local benchmark tied to BPMSL using standard level-loop techniques. The basis of elevation for each gage and the horizontal positions of respective benchmarks and gages are presented in Appendix A. The most current basis of elevation of vertical control was used for each survey.

Gages were identified based on the site location. In locations where terrain elevation varied by more than three feet, or where the loss of gages due to ice impacts was considered to be likely, more than one gage was installed to effectively capture WSE data. Gages were further identified with alphabetical designations “A,” “B,” “C,” or “D,” with “A” typically being located nearest (lowest) to the edge of water.

3.2.2 PRESSURE TRANSDUCERS

Pressure Transducer (PT)
Measurement device that converts pressure-induced mechanical changes to an electrical signal

Pressure transducers (PT) measure the absolute pressure imparted by the atmosphere and water at the sensor, allowing the depth of water above the sensor to be calculated. Resulting data yield a more comprehensive record of the fluctuations in WSE than can be captured by visual measurements alone. Each PT consists of an unvented pressure sensor that is designed to collect and store pressure and temperature data at discrete pre-set intervals.

In-Situ® Level TROLL® 500 PTs were installed at five locations; MON1U, MON1C, MON1D, G21, and G21U (approximately 0.5 miles upstream of G21, near the proposed CD5 road crossing of the Nigliq Channel). Solinst® Levelogger® Model 3001 PTs were installed at two locations; MON9 and MON9D.

The reported pressure datum is the sum of the forces imparted by both the water column and atmospheric conditions. Variations in barometric pressure are taken into account, using two independent barometric pressure loggers; In-Situ BaroTROLL® (primary) and Solinst Barologger® (secondary). A correction of local barometric pressure was obtained from the BaroTROLL sensor located at MON9 and Barologger at the Ublutuoch River at RM 6.9. The barometric pressure logger locations are considered to be representative of the CRD. See Appendix A for PT and barometric pressure logger basis-of-elevation and horizontal positions.

Gage Pressure
Pressure relative to atmospheric pressure

Before mobilization to Alpine, the PTs were each put though a functional test and calibration by Baker. The PTs were configured using Win-Situ® LT 5.1.1.0 (for the Level TROLL 500s) or Solinst Levelogger v3.4.1 (for the Solinst Leveloggers) prior to placement in the field. Absolute pressure was set to zero. Each PT was housed in a segment of perforated galvanized steel pipe, clamped to the angle iron or the base of a gage assembly, and placed in the active channel as near to the channel bottom as possible. The PT sensor was surveyed during setup to establish a vertical datum using local control. For 2011, the PTs were programmed to collect gage pressure and water temperature at 15-minute intervals from May 20, 2011, to July 8, 2011.

PT-based WSE values were determined by adding the calculated water depth and the surveyed sensor elevation. Additionally, gage WSE readings were used to validate the data collected by the PTs. A standard conversion using the density of water at 0 degrees Celsius (°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 affect WSE calculations, due to the limited range in temperature and observed water depths.

3.3 DISCHARGE MEASUREMENTS

Discharge was measured directly and calculated indirectly based on field observations. Standard U. S. Geological Survey (USGS) midsection techniques and an ADCP 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 TECHNIQUES

Standard USGS midsection techniques (USGS 1982) and a Price AA velocity meter were used to directly measure velocities and discharge at the two CD2 road swale bridges.

Swale bridge depth and velocity measurements were taken from the upstream side of each bridge deck using a sounding reel mounted on a wooden boom. The velocity meter was attached to the sounding reel and stabilized with a 30-pound Columbus-type lead sounding weight. Photo 3.4 shows the Price AA velocity meter assembly used to measure direct discharge at the CD2 road swale bridges and Photo 3.5 shows the sounding reel and boom. A tag line was placed along the upstream bridge rail to define the cross section and to delineate measurement subsections within the channel. The Price AA velocity meter was rated by the USGS at the Office of Surface Water (OSW) Hydraulic Laboratory in 2011. A spin test of the meter was successfully completed before and after the swale bridge measurements. To ensure accurate performance of meters, procedures outlined in OSW Technical Memorandum No. 99.06 (USGS 1999) were followed.

PHOTO 3.4: PRICE AA VELOCITY METER AND 30-POUND COLUMBUS-TYPE SOUNDING WEIGHT; MAY 29, 2011

PHOTO 3.5: PERFORMING A DISCHARGE MEASUREMENT ON THE UPSTREAM (SOUTH) SIDE OF THE LONG SWALE BRIDGE USING A PRICE AA VELOCITY METER AND SOUNDING REEL MOUNTED ON A BOOM; MAY 29, 2011

Velocity measurements of flow through the Alpine culverts were not conducted during 2011 breakup because of logistics related to the timing of peak stage at MON1. Visual observations with regard to flow passage and overall condition at each culvert were recorded and indirect discharge calculations were performed.

3.3.2 ACOUSTIC DOPPLER CURRENT PROFILER

Acoustic Doppler Current Profiler (ADCP)
An instrument that uses broadband sound navigation ranging (SONAR) to produce a record of water current velocities for a range of depths. ADCP is used to measure how fast water is moving through a water column.

A direct discharge measurement of the Colville River during the breakup season presents unique and extreme challenges. Implementation of accurate USGS midsection techniques can be difficult because of the remote location, water depths, velocities of flow, channel ice moving downstream, and harsh weather conditions. As an alternative, use of ADCP allows for the direct measurement of repeatable and accurate direct river discharge measurements in challenging conditions. The ADCP discharge measurement system can be faster than traditional methods while providing equivalent levels of accuracy (USGS 2006).

With the exception of 2010, a direct discharge measurement has been taken at MON1 using an ADCP each year since 2005. In 2010, a direct discharge measurement was not possible because of weather and helicopter transportation. For 2011, direct discharge measurements at MON1 were performed using ADCP techniques and procedures following the USGS *Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers* (2005).

3.3.2.1 HARDWARE AND SOFTWARE

A Teledyne RD Instruments 600-kilohertz RiverRay broadband ADCP was used. The unit has a phased array, Janus four-beam transducer with a 30-degree beam angle. The ADCP unit and supporting laptop (Panasonic Toughbook® CF-19) were self powered via their respective internal batteries.

BBTalk v3.06, a DOS-based communication program, was used to perform pre-deployment tests. WinRiverII v2.07 was used to configure, initiate, and communicate with the ADCP while on the river. WinRiverII was also used to review and evaluate collected discharge data after returning from the field.

3.3.2.2 PRE-DEPLOYMENT TESTING

Prior to deployment of the ADCP unit, a full suite of tests were run in accordance with the manufacturer's instructions using BBTalk. The tests confirmed that the signal path and all major signal processing subsystems were functioning properly. Tests also confirmed accurate tilt and pitch readings. A beam continuity test was performed to verify that the transducer beams were connected and operational. Additional diagnostic tests were performed using WinRiverII. Pre-deployment tasks also included compass calibration and verification. Internal compass error was within the specified two-degree limit.

3.3.2.3 ADCP DEPLOYMENT AND DATA COLLECTION

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

as river conditions required. Photo 3.6 and Photo 3.7 show the field crew in a boat configured for the collection of a direct discharge on the Colville River at MON1.

PHOTO 3.6: FIELD CREW CONDUCTING DIRECT DISCHARGE MEASUREMENT AT MON1U; MAY 29, 2011

PHOTO 3.7: FIELD CREW CONDUCTING DIRECT DISCHARGE MEASUREMENT AT MON1U; MAY 29, 2011

A cross section was identified at an established monitoring site (MON1). A minimum of four transects were completed so that the measured discharges varied by less than five percent of their mean. Cross section end points were dependent on a minimum water depth of about eight feet to provide acceptable data.

Cross section end points were marked with handheld global positioning system (GPS) units having wide area augmentation system (WAAS)-enabled accuracy. The position of the boat was determined by tracking the bottom of the channel with the ADCP. Distances to the right and left edge of water from respective end points were estimated from GPS coordinates.

3.3.2.4 ADCP BACKGROUND AND DATA PROCESSING

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

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

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

3.3.3 INDIRECT DISCHARGE CALCULATIONS

Headwater and Tailwater
Water located immediately upstream or downstream from a hydraulic structure, such as a dam, bridge, or culvert

Hydraulic Gradient
Slope of the water surface

Indirect discharge for the CD2 and CD4 road culverts, the swale bridges, the Colville River, and the Nigliq Channel were calculated using physical characteristics obtained during field observations. These physical characteristics, including WSE, culvert dimensions, and channel cross-sectional area, are used as hydraulic equation input variables to calculate indirect discharge.

Industry-accepted engineering methods and software were used to estimate discharge through the CD2 and CD4 road culverts. Time and magnitude of peak discharge through the culverts was determined based on recorded WSEs and peak stage observations. Average velocity and discharge through the culverts assumes ice-free open-water conditions, and were estimated based on several variables, including:

- Headwater and tailwater elevations at each culvert (hydraulic gradient)
- Culvert diameter and length from UMIAQ as-built surveys (UMIAQ 2002). As-built information is not available for the slip-lined culverts; field measurements and approximations for slip-lined culverts were used
- Culvert upstream and downstream invert elevation (UMIAQ surveys June 2011)
- Culvert Manning’s roughness coefficient (0.012 for smooth steel and 0.024 for corrugated metal pipe (CMP)

The calculation for peak indirect discharge through the swale bridges was performed by correlating the hydraulic depths measured during the direct discharge measurements with the observed peak discharge conditions.

The slope-area method (Benson and Dalrymple 1967) for a uniform channel (UC) and non-uniform channel (NUC) was used to develop the estimates of peak indirect discharge for the Colville

River and the Nigliq Channel. WSE and hydraulic gradient data were obtained from observations made at nearby gages. Cross-sectional geometry was based on historic cross sections that were surveyed by UMIAQ in 2004 on the Colville River, 2005 near MON23, and 2008 near the proposed CD5 bridge crossing on the Nigliq Channel (UMIAQ 2004, 2005, and 2008).

The slope-area method for a NUC was specifically used at the MON1 location. The two methods differ by the number of cross sections used in the calculations. The NUC method uses all three cross sections at MON1 and the UC method uses a single cross section at MON1C.

3.4 FLOOD AND STAGE FREQUENCY ANALYSIS

Typically, peak discharge at select locations in the CRD is analyzed every three years in terms of flood frequency, as one year's data would not be expected to significantly affect results. The results of this analysis are the discharge magnitudes that are used in facility design. The basis for comparison is the 2002 design-magnitude flood frequency analysis for the Colville River at MON1 (Baker and Hydroconsult 2002). The 2002 values continue to be the recommended design magnitudes, to which the 2011 peak discharge value is compared. The last flood frequency analysis for the CRD was performed in 2009. Section 5.8 discusses flood frequency in greater detail.

Similarly, WSE at select locations in the CRD are analyzed every three years in terms of stage frequency. The most recent was performed in 2009. Peak stage values are compared annually to the most current stage frequency analysis results and to the 2D surface water model elevations. The 2D model was developed during the original design of Alpine and has been updated throughout the life of the Alpine facilities, most recently in 2009 (Baker 2009a).

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4.0 2011 SPRING BREAKUP – HYDROLOGIC OBSERVATIONS AND WATER SURFACE ELEVATIONS

The images, data, and observations of the 2011 field program are presented in this chapter. Setup commenced on May 3, 2011. Data and observations described in the following sections were documented between May 21 and June 1, 2011. Limited observations were made during setup (May 2 to May 20) and cleanup (June 2 to June 9). Figure 4.1 provides a visual timeline summary addressing the major 2011 CRD breakup milestones.

4.1 COLVILLE RIVER DELTA

Breakup floodwaters into the CRD originate upstream in the Brooks Range. This melt accumulates along the base of the mountains and flows into the Colville River via a network of smaller drainages before the Colville branches out into a delta and then drains into Harrison Bay (Figure 1.1 through Figure 1.3), as discussed in Section 1.2. MON1 is located at the head of the delta, and breakup events are monitored upstream of this location as floodwaters progress downstream toward the CRD.

Confluence
A flowing together of two or more streams

The confluence of the Anaktuvuk River into the Colville River lies approximately 65 river miles upstream of the head of the CRD (MON1). No signs of flow were observed during the first reconnaissance flight on May 18, 2011, in either the Anaktuvuk River upstream from the confluence or the Colville River upstream from the confluence.

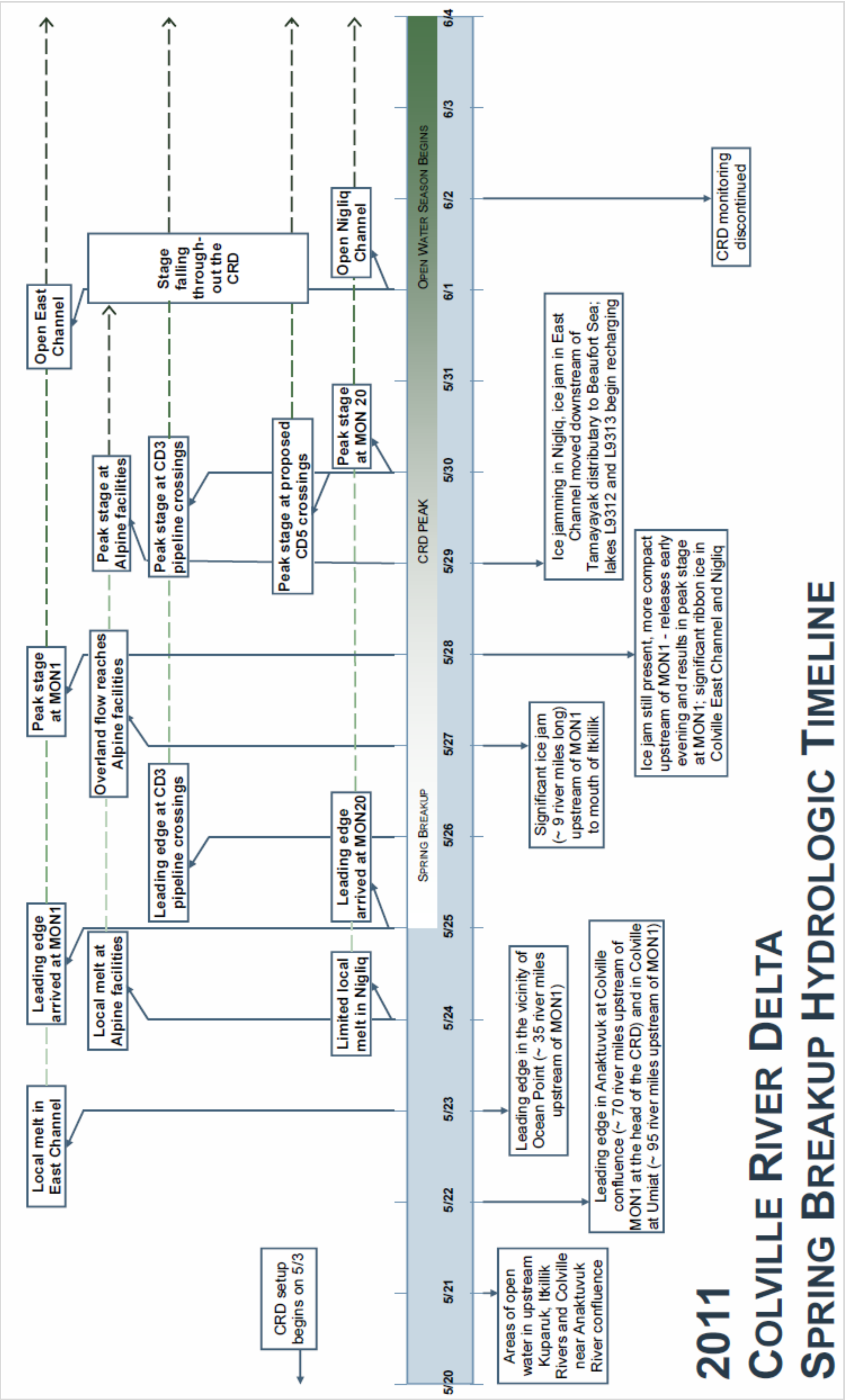


FIGURE 4.1: 2011 SPRING BREAKUP HYDROLOGIC TIMELINE

PHOTO 4.1: COLVILLE RIVER AT UMIAT, FROM UMIAT LIVE CAMERA PROVIDED BY USGS; MAY 22, 2011 AT 7:30PM

PHOTO 4.2: LEADING EDGE IN COLVILLE RIVER PASSING UMIAT, FROM UMIAT LIVE CAMERA PROVIDED BY USGS; MAY 22, 2011 AT 7:40PM

Leading Edge
The initial flood flow as it moves downstream

Turbidity
The cloudiness or haziness of a fluid caused by suspended solids

On May 22, 2011, at around noon, Baker personnel took a reconnaissance flight upstream of MON1. A leading edge was observed in the Anaktuvuk River at approximately 4.5 RM upstream of the Anaktuvuk-Colville River confluence. Later on May 22, the Umiat live camera recorded a leading edge in the Colville River passing through Umiat sometime between 7:30 p.m. and 7:40 p.m. (Photo 4.1 and Photo 4.2). Umiat is approximately 93 RM upstream of MON1.

On May 23 at around 2:00 p.m., the leading edge was observed in the Colville River about 35 RM upstream of MON1 (Photo 4.3). The breakup water appeared to be highly turbid and many ice floes were seen. After 7:00 p.m. on May 22, the speed of the leading edge in the Colville River was estimated at approximately three miles per hour (mph).

On May 24 at 2:00 p.m. the Colville River leading edge had moved through Ocean Point and was located at about 15 RM upstream of MON1 (Photo 4.4). Photo 4.4 was taken approximately 2 hours prior to the leading edge passing Ocean Point. During the course of the previous 24 hours, the average speed of the leading edge had slowed to approximately one mph.

PHOTO 4.3: LEADING EDGE IN COLVILLE RIVER ~35 RM UPSTREAM OF MON1, LOOKING DOWNSTREAM (NORTH); MAY 23, 2011

PHOTO 4.4: LEADING EDGE IN COLVILLE RIVER APPROACHING OCEAN POINT, LOOKING DOWNSTREAM (NORTH); MAY 24, 2011

Thalweg
The deepest part of the channel that marks the natural direction of the channel and normally contains the fastest flow

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

By 10:00 a.m. on May 25, the leading edge in the Colville River had passed through MON1. Breakup water was observed flowing over the top of the channel ice and was mainly limited to the thalweg of channels within the CRD. The first recorded WSE for MON1 was recorded on MON1U-A. At MON1C and MON1D gage sets, the WSE was not high enough to be recorded. By the late afternoon, the leading edge had reached MON28 in the Nigliq Channel and MON35 (Photo 4.5) in the East Channel. Flow from the East Channel had also entered the Sakoonang and Tamayayak channels later in the day. No flow was observed moving into the Ulamnigiaq. No ice jams were seen within the CRD and, for the most part, WSEs were not high enough to be recorded by the stream gages.

PHOTO 4.5: LEADING EDGE IN EAST CHANNEL ARRIVES AT MON35 (HELMERICKS HOMESTEAD) LOOKING UPSTREAM (PHOTO PROVIDED BY JIM HELMERICKS); MAY 25, 2011

On May 26, WSE and discharge continued to rise throughout the CRD. Channel ice began to break up at MON1 and MON20 and ice rafts were seen moving downstream with flow. The Nigliq was observed recharging Nanuq Lake, but no flow was observed in the vicinity of the Alpine facilities. Generally, WSE within the CRD was high enough to be recorded by the stream gages by May 26.

4.2 MONUMENTS

The leading edge reached MON1 on the morning of May 25. From here, floodwaters continued downstream into either the East Channel or the Nigliq Channel. The leading edge on May 25 is shown in Photo 4.6 and Photo 4.7. By the evening of May 25, the leading edge had arrived at the farthest gage downstream in the East Channel (MON35).

4.2.1 COLVILLE RIVER EAST CHANNEL

Daily monitoring of the East Channel gages began on May 25, with the leading edge passing through MON9 and, later, MON35. The first measureable WSE was collected on gage MON1U-A. WSE were not high enough to reach the gages at MON1C and MON1D in the morning of May 25.

From May 25 through May 27, the stage continued to increase at a relatively constant rate for each of the East Channel monitoring sites; approximately 0.1 feet per hour at the MON1 and MON9 gages, and about 0.02 feet per hour at MON35. Ribbon ice was present in the channel. Occasional floes were seen but no ice jamming was observed between MON1 and MON35 (Photo 4.8 and Photo 4.9).

PHOTO 4.6: LEADING EDGE IN COLVILLE RIVER DELTA LOOKING UPSTREAM (SOUTH); MAY 25, 2011

PHOTO 4.7: LEADING EDGE IN THE EAST CHANNEL, LOOKING DOWNSTREAM (NORTH); MAY 25, 2011

PHOTO 4.8: INTACT RIBBON ICE IN THE EAST CHANNEL LOOKING DOWNSTREAM (NORTH); MAY 26, 2011

PHOTO 4.9: INTACT RIBBON ICE IN THE EAST CHANNEL LOOKING UPSTREAM (SOUTH); MAY 27, 2011

Early in the morning of May 27, data recorded by the PTs at MON1 and the presence of rafted ice approximately 1.5 RM upstream suggested that an ice jam had formed and then released upstream of MON1U. The ice jam caused the stage at the MON1 gages to rise and spike. The spike in WSE to approximately 15.68 feet BPMSL was recorded by the PT at MON1U. This spike on May 27 can be seen in the MON1 hydrographs (Table 4.1 and Table 4.2). Further downstream at MON9, an attenuated spike can be seen in the hydrograph (Table 4.3). The visual observations at MON35 did not show significant increases in WSE as a result of this spike. By noon on May 27, the effects of the ice jam on WSE had settled and the rate of WSE rise in the East Channel resumed. Ribbon ice was intact through the East Channel at this time, but was beginning to break up in some locations.

At midday on May 27, a major ice jam was observed upstream of MON1. This jam was probably responsible for the spike in WSE earlier in the day. The downstream edge of the jam was forming on ribbon ice that spanned the channel from the left (west) bank to the right (east) bank at the confluence of the Itkillik River (Photo 4.10). The upstream edge of the jam was approximately nine RM from MON1, and significant flow had backed upstream of the CRD (Photo 4.11). Downstream channels were flowing at less than bankfull stage.

Bankfull stage
Water surface elevation at which flow completely fills the channel to the top of the channel banks

Photo 4.10: Major ice jam caught on cross-channel ice at mouth of Itkillik River upstream of MON1, looking upstream (south); May 27, 2011

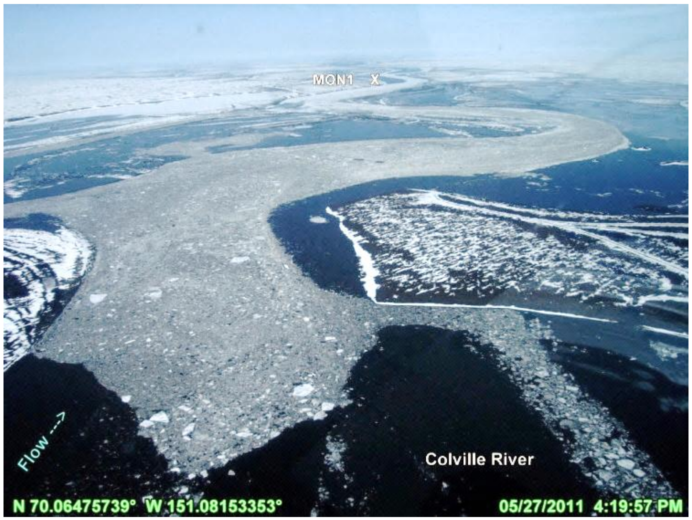


Photo 4.11: Major ice jam upstream of MON1, upstream edge, looking downstream (north); May 27, 2011

Photo 4.12: Ice floes in the vicinity of MON9 (HDD)—the result of a major ice jam release upstream of MON1, looking downstream (northwest); May 28, 2011

During a reconnaissance flight on May 28 at around 1:30 p.m., the ice jam was still intact, though it had become more compacted. Later on May 28, at around 3:00 p.m., recorded PT data at MON1 indicated that the ice jam had released. As the surge of water moved through MON1, a peak WSE of 19.99 feet BPMSL was recorded by the MON1U PT. At about 4:30 p.m., ice floes were first observed in the vicinity of MON9 as the remnants of the jam filtered past (Photo 4.12). Portions of the ice jam went into the Nigliq, Sakoonang, and the Tamayayak Channels. Shortly after midnight on May 29, the MON9 PT recorded the passing of the surge of water with a peak WSE of 12.02 feet BPMSL. The majority of the floes jammed again downstream of the entrance to the Tamayayak on May 29 (Photo 4.13) and, later, floes associated with the release of this jam were observed at MON35 at around mid-day on May 30 (Photo 4.14).

PHOTO 4.13: ICE JAM DOWNSTREAM OF THE TAMAYAYAK ENTRANCE, LOOKING DOWNSTREAM (NORTH); MAY 29, 2011

PHOTO 4.14: FLOES IN THE VICINITY OF MON35 (HELMERICKS), REMAINDER OF EAST CHANNEL ICE JAM, LOOKING DOWNSTREAM (PHOTO PROVIDED BY JIM HELMERICKS); MAY 30, 2011

On May 30 at 6:00 p.m., Jim Helmericks observed a peak WSE of 5.62 feet BPMSL at MON35 (Table 4.4).

After the effects of the ice jam release moved through MON1 on May 28, WSE began to decrease. Generally after peak WSE, channels in the CRD become increasingly clear of ice and snow and more easily convey water. With the exception of the MON1 gages, the rate at which stage decreased in the East Channel was quicker than the rate at which stage rose. The rate at which stage began to fall was about 0.9 feet per hour at MON1, 0.13 feet per hour at MON9, and 0.04 feet per hour at MON35. All ribbon ice was cleared from the East Channel once the jam had passed, though some floes remained. The East Channel was observed to be free of ice on June 1.

In the afternoon on May 29, about a day and a half after peak WSE, a direct discharge measurement was taken at MON1. The direct discharge measurement was hampered by the presence of ice floes along the right bank, yielding an incomplete measurement. On the morning of June 1, a successful direct discharge measurement was completed as MON1. Recognizing the consistent decrease in stage and discharge, visual observations in the East Channel ceased after June 1.

TABLE 4.1: WATER SURFACE ELEVATION DATA FOR MON1C

Date and Time	WSE (feet BPMSL)	Observations
	MON1C	
5/25/11 4:45 PM	-	Leading edge past; no water on gage
5/26/11 3:45 PM	12.58	Ribbon ice in channel
5/28/11 1:40 PM	17.11	Ice jam just upstream of MON1U
5/28/11 5:15 PM	**19.56**	**Peak Stage**; recorded by pressure transducer only
5/29/11 4:05 PM	17.14	Ice jam moved to Nigliq Channel downstream of Colville bifurcation and in East Channel downstream of Tamayayak bifurcation
5/29/11 5:35 PM	16.81	
5/30/11 2:18 PM	15.08	Stage peaks at Umiat gage location
6/1/11 10:20 AM	-	

Notes:

1. Elevations are based on MONUMENT 1 at 27.93 feet BPMSL, surveyed by LCMF in 2006.
2. Direct discharge measurements w ere taken at this location on 5/29 and 6/1 for 2011.

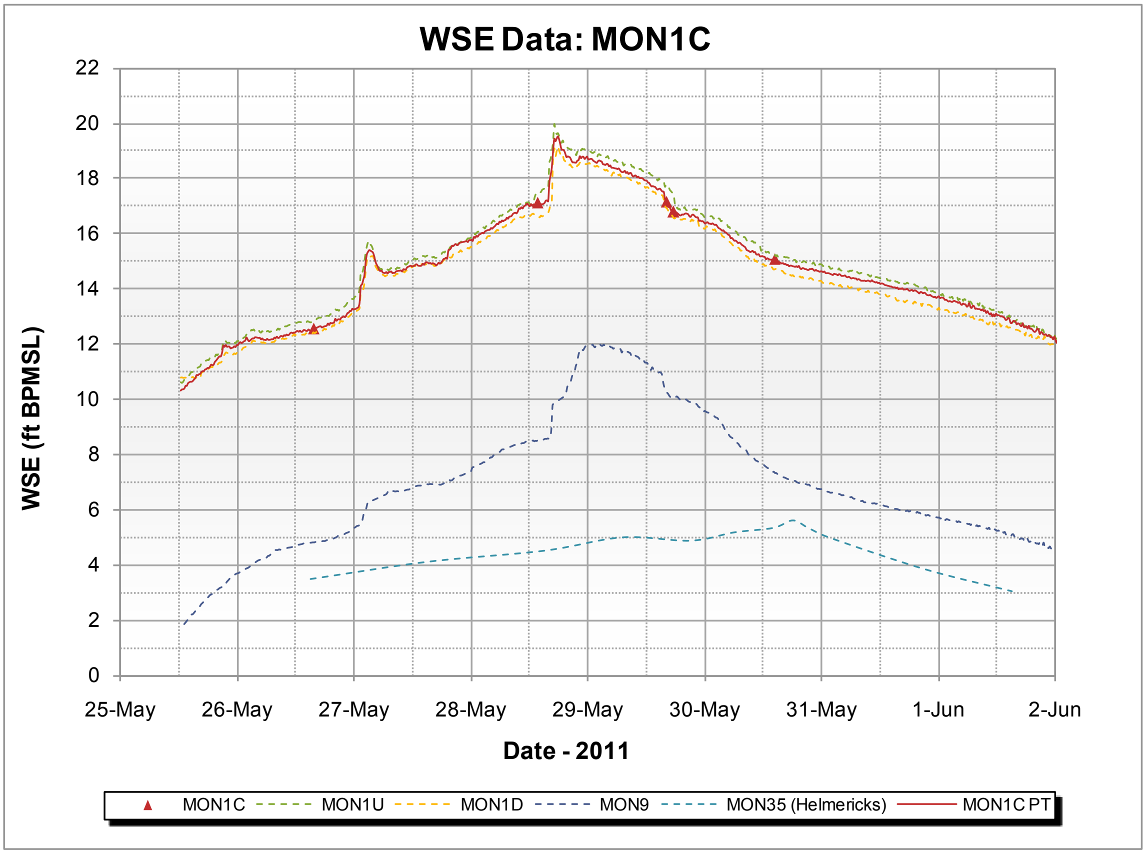


TABLE 4.2: WATER SURFACE ELEVATION DATA FOR MON1U AND MON1D

Date and Time	WSE (feet BPMSL)		Observations
	MON1U	MON1D	
5/25/11 9:40 AM	9.53	-	Leading edge past MON1U
5/26/11 3:35 PM	12.86	-	Ribbon ice in channel, Leading edge past MON1D no water on gage
5/27/11 4:45 PM	15.10	14.84	Major ice jam upstream of Itkillik confluence
5/28/11 1:20 PM	17.46	16.98	Ice jam just upstream of MON1U; ribbon ice in channel, no floes
5/28/11 5:00 PM	**19.99**	**19.18**	**Peak Stage**; recorded by pressure transducer only
5/29/11 1:45 PM	18.10	-	
5/29/11 4:10 PM	17.73	16.95	Ice jam moved to Nigliq Channel downstream of Colville bifurcation and in East Channel downstream of Tamayayak bifurcation
5/29/11 5:40 PM	17.13	16.58	
5/30/11 2:26 PM	15.20	14.72	Stage peaks at Umiat gage location
5/31/11 12:38 PM	14.36	13.61	Secondary peak; Colville East Channel clear of ice
6/1/11 10:00 AM	13.27	12.74	

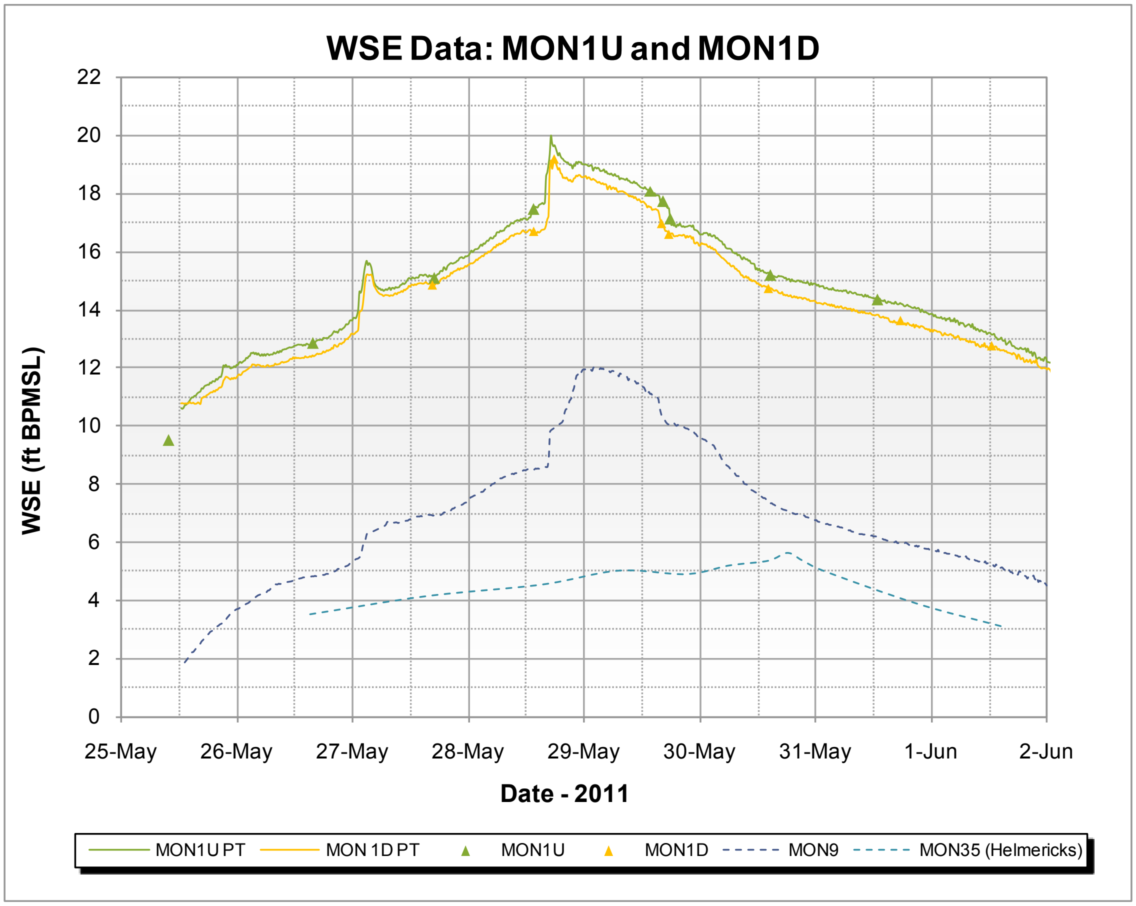


Table 4.3: Water Surface Elevation Data for MON9

Date and Time	WSE (feet BPMSL)	Observations
	MON9	
5/25/11 2:40 PM	2.27	Leading edge past; no water on gage
5/26/11 4:00 PM	4.86	Major ice jam upstream of Itkillik confluence; ribbon ice in channel
5/27/11 4:05 PM	6.99	Ice jam just upstream of MON1U
5/28/11 2:30 PM	8.53	Ribbon ice in channel
5/28/11 4:50 PM	9.33	Ice jam upstream of MON1U released, begins to reform downstream
5/29/11 2:00 AM	**12.02**	**Peak Stage**; recorded by pressure transducer only
5/29/11 6:15 PM	10.13	Stage peaks at Umiat gage location
5/30/11 1:50 PM	7.42	
5/31/11 12:24 PM	6.23	

Notes:

1. Elevations are based on Monument 09 at 25.06 feet BPMSL, surveyed by LCMF in 2008.

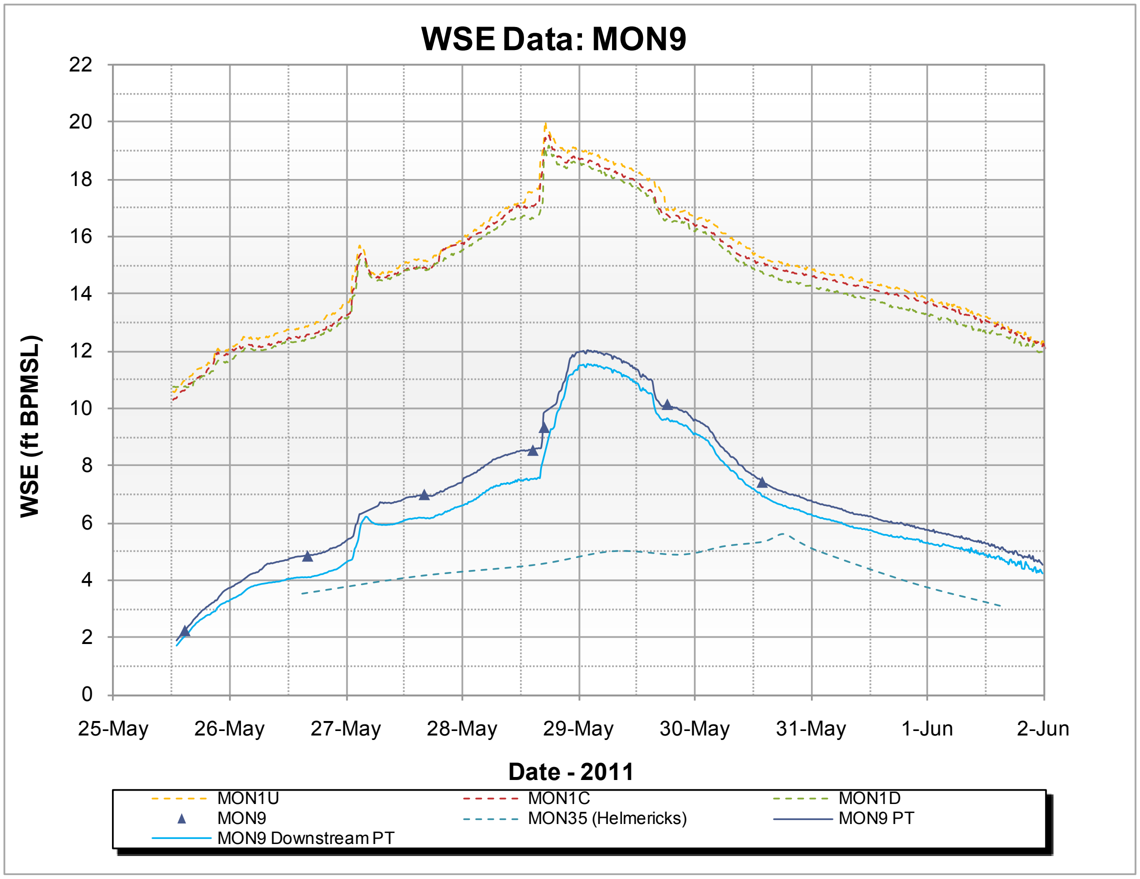
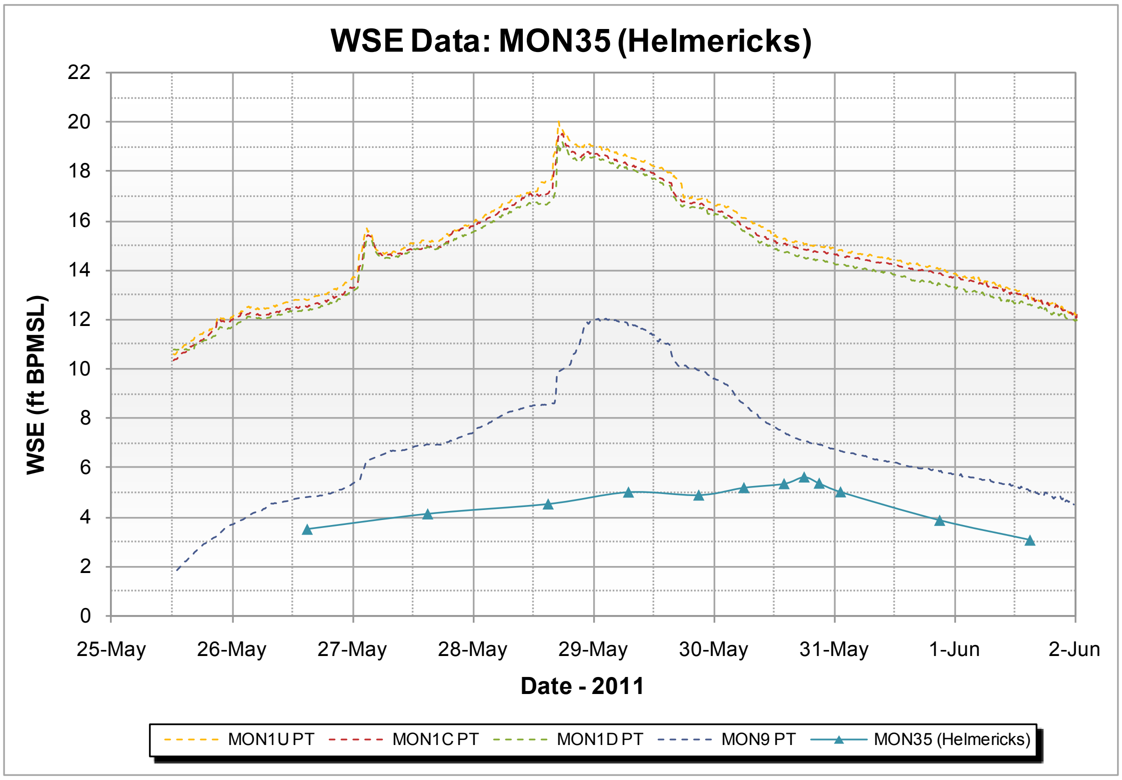


TABLE 4.4: WATER SURFACE ELEVATION DATA FOR MON35 (HELMERICKS HOMESTEAD)

Date and Time	WSE (feet BPMSL)	Observations
	MON35 (Helmericks)	
5/25/11 4:00 PM	-	Leading edge arrives
5/26/11 3:00 PM	3.51	
5/27/11 3:00 PM	4.13	
5/28/11 3:00 PM	4.53	
5/29/11 7:00 AM	5.01	
5/29/11 9:00 PM	4.89	No local channel ice movement; ice jam ~ 3.5 miles upstream
5/30/11 6:00 AM	5.19	Floes in channel
5/30/11 2:00 PM	5.35	Ice jam release from upstream, abundant floes; WSE begins to rise rapidly
5/30/11 6:00 PM	**5.62**	**Peak Stage**
5/30/11 9:00 PM	5.37	Channel ice and floes move out of channel; channel ice-free
5/31/11 1:15 AM	5.02	
5/31/11 9:00 PM	3.87	More floes move by
6/1/11 3:00 PM	3.07	Channel ice-free
6/2/11 3:00 PM	2.35	

Notes:

1. Elevations are based on Monument 28 at 3.65 feet BPMSL, updated by LCMF (GPS) in 2002.



4.2.2 NIGLIQ CHANNEL

Early in the morning on May 25, the leading edge had entered the Nigliq (Photo 4.15). By approximately 5:15 p.m., the leading edge had reached MON28, the farthest downstream gage in the Nigliq Channel (Photo 4.16).

PHOTO 4.15: A.M.—LEADING EDGE IN NIGLIQ CHANNEL IN THE VICINITY OF CD4, LOOKING DOWNSTREAM (NORTH); MAY 25, 2011

PHOTO 4.16: P.M.—LEADING EDGE IN NIGLIQ CHANNEL IN THE VICINITY OF MON28, LOOKING DOWNSTREAM (NORTH); MAY 25, 2011

PHOTO 4.17: NIGLIQ CHANNEL NEAR NUIQSUT, LOOKING DOWNSTREAM (WEST); MAY 26, 2011

On May 26, stage continued to rise in the Nigliq Channel and most of the channel ice remained intact. Ribbon ice was intact throughout the majority of the channel from upstream of MON20 to MON28. There were no ice jams near facilities, and the Colville-Nigliq bifurcation was mostly clear of ice (Photo 4.17), although there were some rafted floes. Channel ice was observed breaking up in the vicinity of Nuiqsut, likely the result of the ice jam activity upstream of MON1.

Conditions were similar in the Nigliq Channel on May 27 through the morning of May 28. Occasional ice floes were observed, and some had begun to catch behind channel ice that spanned from the left (west) to the right (east) bank of the Nigliq at MON20, as seen in Photo 4.18. By 1:00 p.m., WSE were high enough to reach the lowest gages at each Nigliq Channel monitoring location (Table 4.5 through Table 4.8). By the afternoon of the May 27, flow from the Sakoonang was observed entering the Nigliq Channel via Lake L9324, and Nanuq Lake was recharging (Photo 4.19).

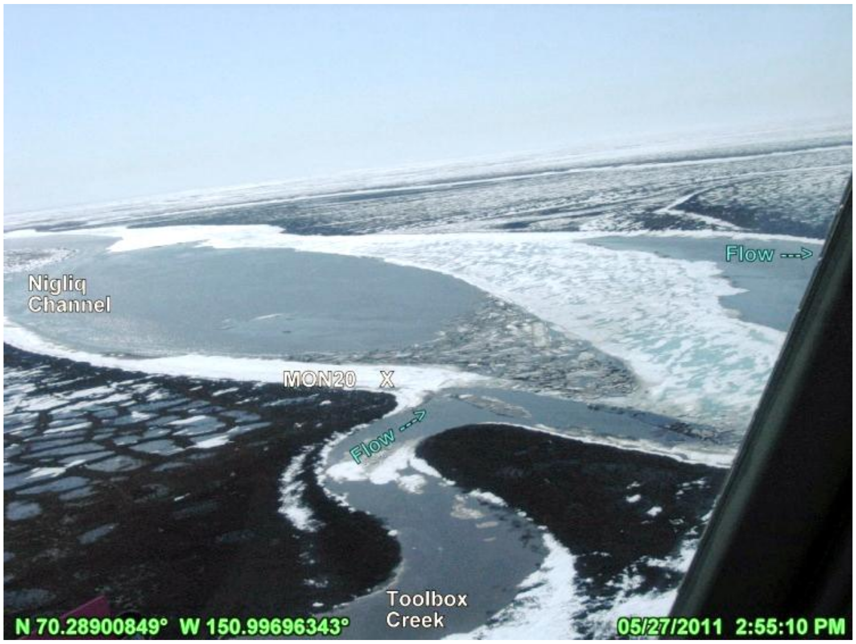


Photo 4.18: Floes beginning to jam on intact channel ice near MON20, looking upstream (southwest); May 27, 2011

Photo 4.19: Flow entering Nigliq from Sakoonang via Lake L9324; Nigliq recharging Nanuq Lake, looking downstream (north); May 27, 2011

A major ice jam located at of the head of the delta (MON1), approximately two RM upstream of the East Channel-Nigliq bifurcation, released on the afternoon of May 28. Some floes diverted into the Nigliq Channel (Photo 4.20), jamming on intact ribbon ice near Nuiqsut. The small surge of flow that passed by Nuiqsut slowly advanced down the Nigliq Channel and was recorded later in the evening by the G21PT. A spike in the G21 hydrograph can be seen at approximately 6:00 p.m. (Table 4.18). This spike in WSE is not evident in the hydrographs of other gage sites along the Nigliq Channel because, in 2011, PTs were only installed at the Nigliq monitoring locations that were associated with the proposed CD5 bridge crossing. Hydrographs for MON20, MON22, and MON23 are based on visual observations and, normally, visual observations are not conducted away from facilities between 6:00 p.m. and 6:00 a.m. In absence of a PT, spikes in WSE from ice jam releases may elude hydrographs that are based exclusively on visual observations. High-water marks can provide the WSE of hydrograph spikes, but the timing of such spikes must be estimated and these data alone are not always reliable.

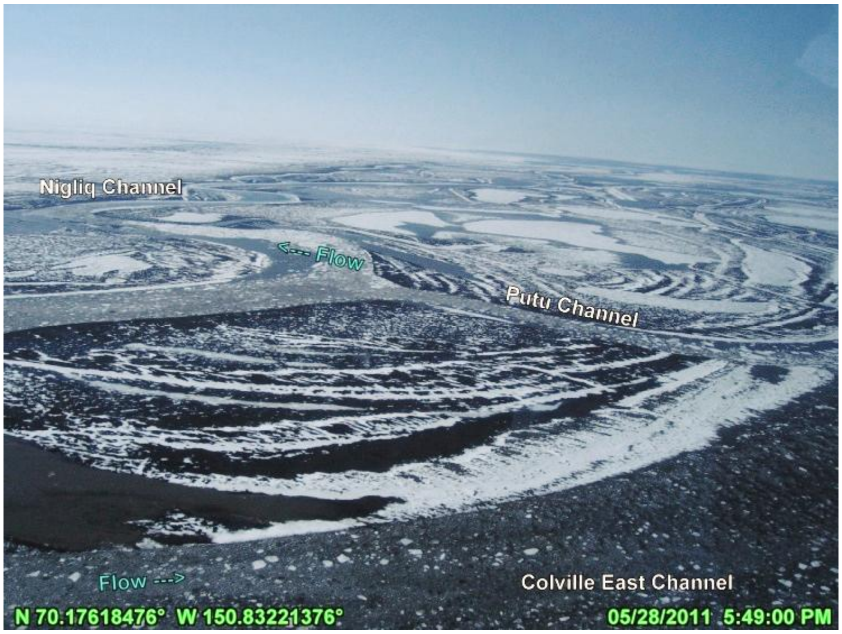


Photo 4.20: Ice Floes resulting from an ice jam release upstream of MON1 entering the Nigliq Channel, looking downstream; May 28, 2011

On May 29, WSE in the Nigliq Channel remained relatively unchanged. The floes diverted down the Nigliq Channel when the ice jam upstream of MON1 released on May 28 had not progressed downstream and were jamming on channel ice near Nuiqsut. As a result, water was diverting overland into Lake B8530 (Photo 4.21). Another effect of the ice jam was to reduce flood flow entering the Nigliq Channel, the majority instead passing through the East Channel. Ribbon ice, generally intact partially because of the relatively lower breakup flow, was still present downstream of Nuiqsut from MON20 to MON28 (Photo 4.22). Occasional floes in the channel were caught on cross-channel ice.

Photo 4.21: Floes released from jam upstream of MON1 in Nigliq near Nuiqsut, looking upstream (south); May 29, 2011

Photo 4.22: Intact ribbon ice in Nigliq Channel from MON20 downstream, looking upstream (southwest); May 29, 2011

Around noon on May 30, the G21 PT indicated that the ice jams near Nuiqsut had cleared and released a surge of water. The surge of water resulted in a peak WSE of 10.97 feet BPMSL at MON20 at midday. As the surge of water moved down the Nigliq Channel, a series of peak WSE were recorded at the monitoring locations.

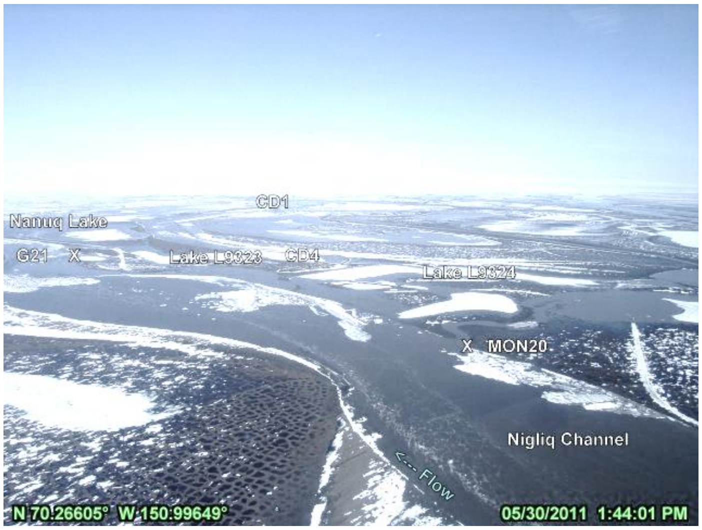


PHOTO 4.23: RIBBON ICE IN NIGLIQ CLEARED, OCCASIONAL FLOES REMAINING NEAR CD4, LOOKING DOWNSTREAM (NORTHEAST); MAY 30, 2011

PHOTO 4.24: RIBBON ICE NEAR MON23 AND CD2, FLOES JAMMED ON CROSS-CHANNEL ICE AT MON22, LOOKING DOWNSTREAM (NORTHEAST); MAY 30, 2011

Channel ice had mostly cleared in the vicinity of MON20, CD4, and Nuiqsut by midday on May 30, though some floes remained (Photo 4.23). Ribbon ice was still intact in the channel from MON22 downstream to MON28 and floes were jamming on channel ice in the vicinity of MON22 (Photo 4.24). Release of ice at this location was estimated to have occurred around 4:00 p.m., resulting in a peak WSE at MON22 of 8.97 feet BPMSL based on a HWM on the gage (Table 4.6). As the surge of water continued to progress downstream, a peak WSE of 8.15 feet BPMSL at MON23 was estimated to have happened four hours later, at around 8:00 p.m., based on a HWM (Table 4.7). At around 10:00 p.m. on May 30, the majority of flood flow passed through the final portions of the Nigliq Channel, MON28 recorded a peak WSE of 3.92 feet BPMSL (Table 4.8).

After May 30, WSE in the Nigliq Channel steadily decreased as ice in the channel progressively moved to MON28 (Photo 4.25). By the end of the day on May 31, monitoring of the Nigliq ended.

PHOTO 4.25: FLOES IN THE NIGLIQ CHANNEL AT MON28; MAY 31, 2011

TABLE 4.5: WATER SURFACE ELEVATION DATA FOR MON20

Date and Time	WSE (feet BPMSL)	Observations
	MON20	
5/25/11 4:20 PM	5.29	Leading edge past
5/26/11 4:25 PM	7.98	Ribbon ice in channel
5/27/11 2:55 PM	9.04	Ice jam forming near Nuiqsut
5/28/11 2:35 PM	10.22	Ribbon ice in channel
5/29/11 6:25 PM	10.61	Ice jams near Nuiqsut; small jam forming in vicinity - floes caught in ribbon ice
5/30/11 12:45 PM	**10.97**	**Peak Stage, no HWM** (see Note 2); channel ice breaking up in vicinity
5/31/11 11:15 AM	8.26	Nigliq Channel ice-free to MON28
5/31/11 4:45 PM	8.03	

Notes:

1. Elevations are based on MONUMENT 20 at 19.098 feet BPMSL, updated by Baker in 2011.
2. Gages ruined by ice floes, no observable HWM; peak stage likely higher but less than 11.69 feet BPMSL.

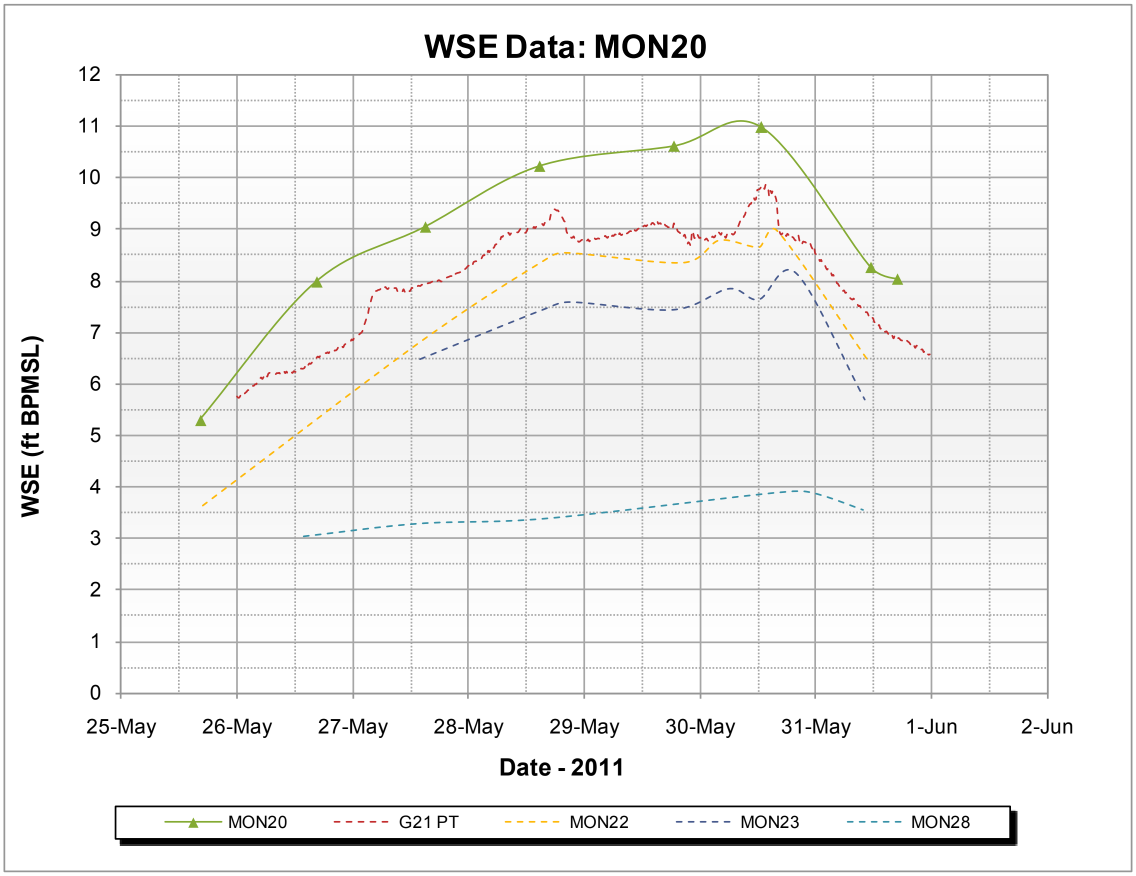


TABLE 4.6: WATER SURFACE ELEVATION DATA FOR MON22

Date and Time	WSE (feet BPMSL)	Observations
	MON22	
5/25/11 4:45 PM	3.65	Leading edge past
5/27/11 2:00 PM	6.82	Ribbon ice in channel; Ice jam forming near Nuiqsut
5/28/11 3:15 PM	8.36	Ribbon ice in channel
5/28/11 8:00 PM	8.54	HWM - time estimated
5/29/11 8:38 PM	8.35	Ice jams near Nuiqsut
5/30/11 4:00 AM	8.78	HWM - time estimated
5/30/11 12:23 PM	8.65	Small ice jam forming in vicinity on ribbon ice crossing channel
5/30/11 4:00 PM	**8.97**	**Peak Stage** based on HWM - time estimated
5/31/11 10:58 AM	6.45	Nigliq Channel ice-free to MON28

Notes:

1. Elevations are based on MONUMENT 22 at 10.030 feet BPMSL, surveyed by Baker in 2010.

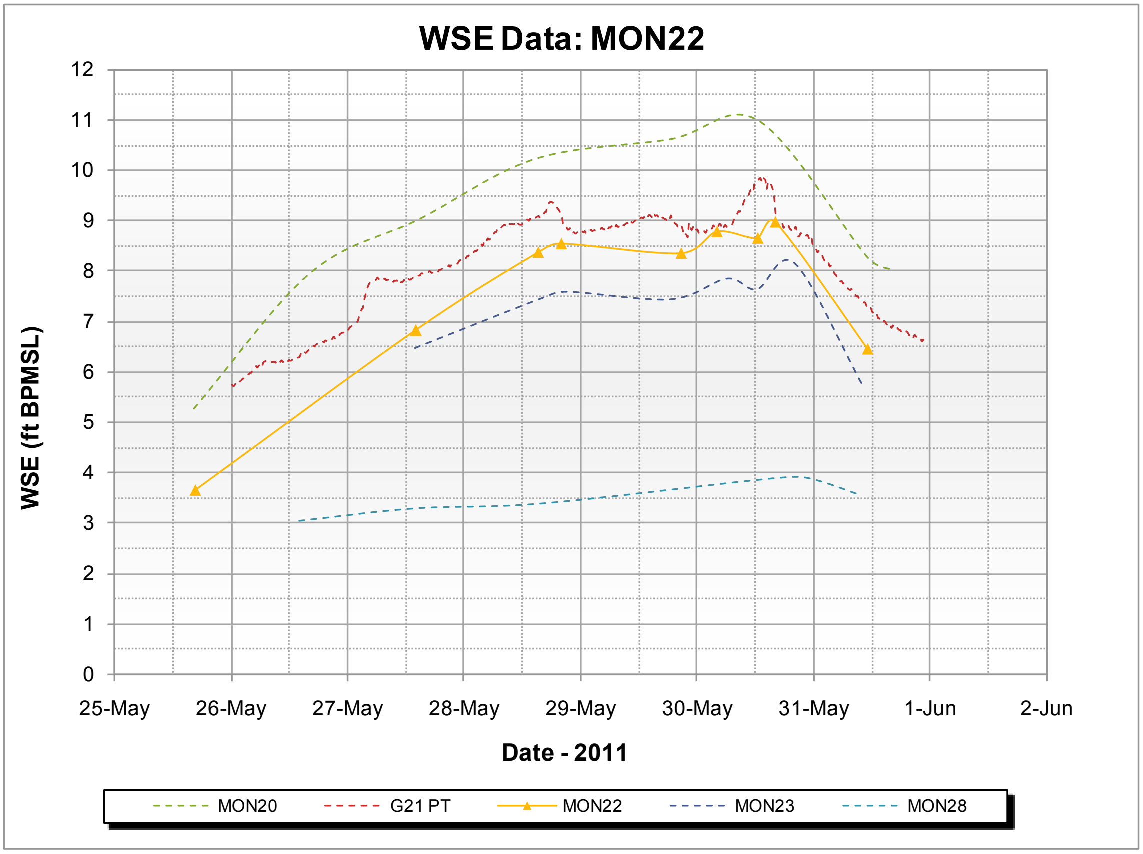


Table 4.7: Water Surface Elevation Data for MON23

Date and Time	WSE (feet BPMSL)	Observations
	MON23	
5/25/11 5:05 PM	-	Leading edge past; no water on gage
5/27/11 1:50 PM	6.48	Ribbon ice in channel; ice jam forming near Nuiqsut
5/28/11 3:20 PM	7.44	Ribbon ice in channel
5/28/11 9:00 PM	7.59	HWM - time estimated
5/29/11 6:30 PM	7.44	Ice jams near Nuiqsut
5/30/11 6:00 AM	7.85	HWM - time estimated
5/30/11 12:15 PM	7.64	Nuiqsut ice jam cleared; ribbon ice in channel; no floes in vicinity
5/30/11 8:00 PM	**8.15**	**Peak Stage** based on HWM, time estimated
5/31/11 10:13 AM	5.69	Nigliq Channel ice-free to MON28

Notes:

1. Elevations are based on Monument 23 at 9.546 feet BPMSL, surveyed by Baker in 2009.

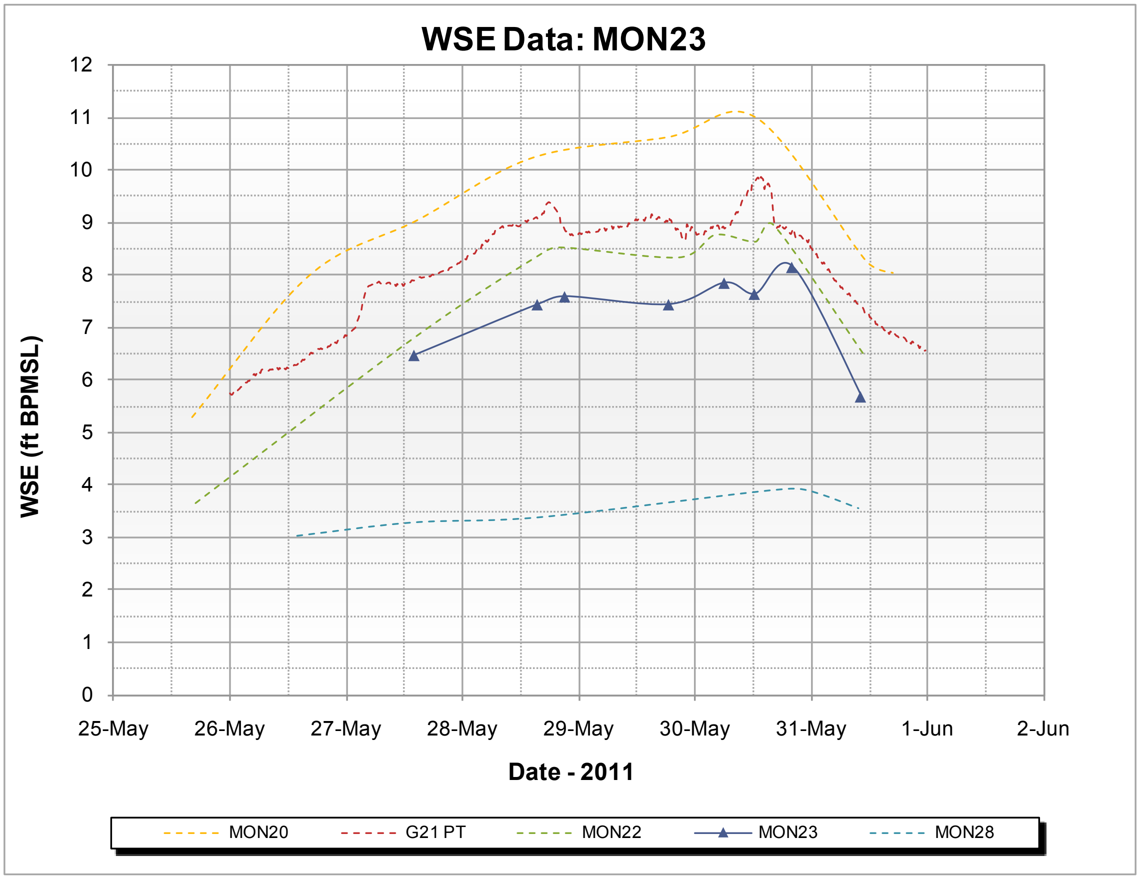
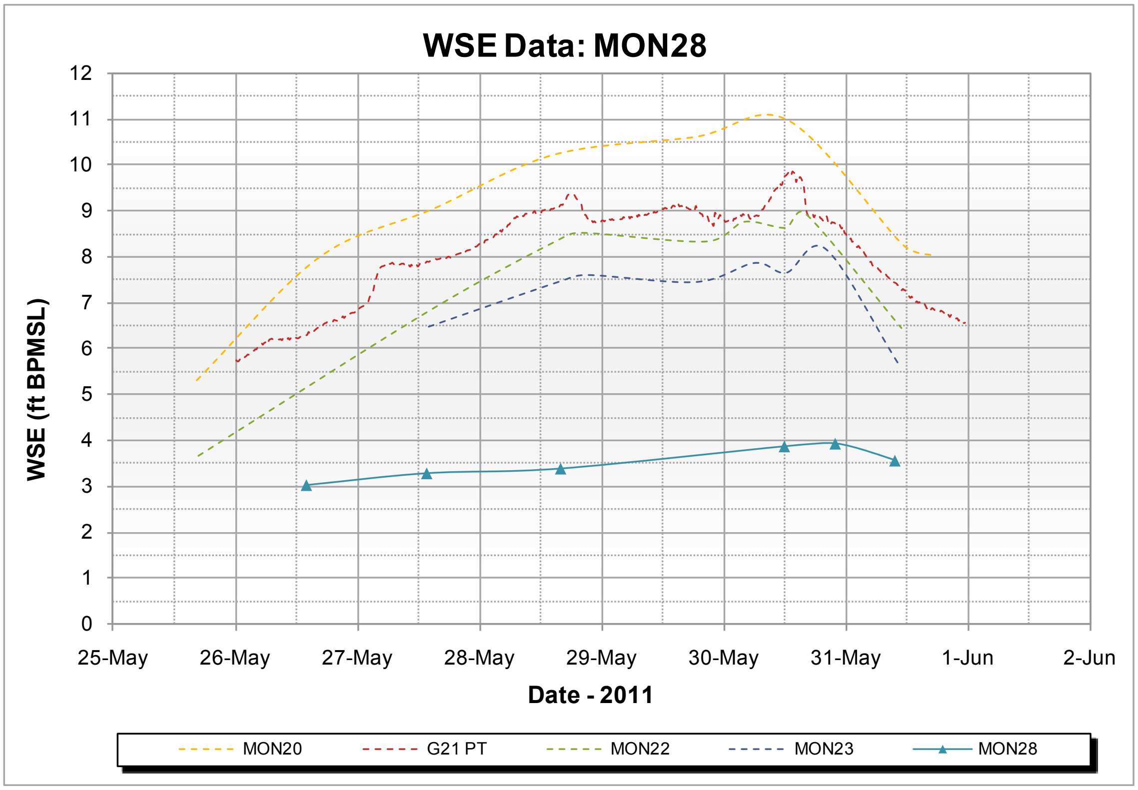


TABLE 4.8: WATER SURFACE ELEVATION DATA FOR MON28

Date and Time	WSE (feet BPMSL)	Observations
	MON28	
5/25/11 5:15 PM	-	Leading edge arrives here; no water on gage
5/26/11 2:00 PM	3.04	Ribbon ice in channel
5/27/11 1:40 PM	3.29	Ribbon ice in channel
5/28/11 4:00 PM	3.39	Ribbon ice in channel
5/30/11 12:00 PM	3.86	Ribbon ice in channel
5/30/11 10:00 PM	**3.92**	**Peak Stage** based on HWM, time estimated
5/31/11 9:44 AM	3.56	Floes in channel; Nigliq clear of ice to here

Notes:

1. Elevations are based on Monument 28 at 3.65 feet BPMSL, updated by LCMF (GPS) in 2002.



The FWR1 and FWR2 monitoring locations are in low-lying ponded areas near Lake L9301, located in the vicinity of the western bank of lower portion of the Nigliq Channel. No well-defined drainages exist at either monitoring site. Monitoring of FWR1 and FWR2 began May 25, and local melt was observed in the area May 29. Measureable WSE data was collected between May 30 and June 3. Monitoring was discontinued after June 9.

Spring breakup at both FWR1 and FWR2 was characterized by quick, and then slower, snow-melt into pools of standing water. There was no channelized hydraulic connection observed between Lake L9301 and the ponded areas to the northwest (FWR1) or southwest (FWR2) and there were no measureable velocities in the vicinity of either gage location during spring breakup monitoring. Photo 4.26 and Photo 4.27 show FWR1 during peak stage and Photo 4.28 and Photo 4.29 show FWR2 during peak stage.

PHOTO 4.26: FWR1 MONITORING LOCATION DURING PEAK STAGE, LOOKING NORTH; MAY 31, 2011

PHOTO 4.27: FWR1 DURING PEAK STAGE, NO EVIDENCE OF CHANNELIZED FLOW OBSERVED, LOOKING NORTH; MAY 31, 2011

WSE and peak stage data are considered to be the result of local melt and overland sheet flow and, therefore, hydrographs for these monitoring locations were not included in this report. Photo 4.30 and Photo 4.31 show FWR1 and FWR2, respectively, during the final field observation for these locations.

PHOTO 4.28: FWR2 MONITORING LOCATION DURING PEAK STAGE, LOOKING SOUTHWEST; MAY 31, 2011

PHOTO 4.29: FWR2 DURING PEAK STAGE, NO EVIDENCE OF CHANNELIZED FLOW OBSERVED, LOOKING SOUTHWEST; MAY 31, 2011.

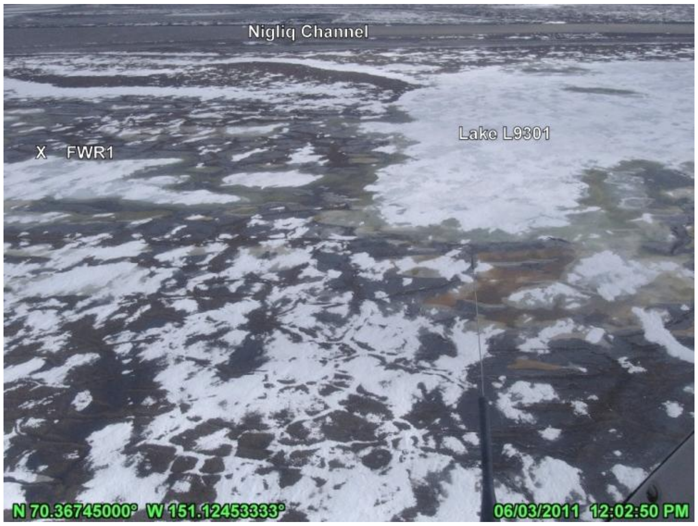


PHOTO 4.30: FWR1 AREA AS MONITORING IS DISCONTINUED, LOOKING EAST; JUNE 3, 2011

PHOTO 4.31: FWR2 AREA AS MONITORING IS DISCONTINUED, LOOKING SOUTH; JUNE 9, 2011

4.3 ALPINE FACILITIES AND ROADS

Gage monitoring at Alpine facilities and roads occurred between May 25 and June 1. Peak stage at the Alpine facilities and roads was estimated to have occurred at around midnight on May 30. Initial breakup flow in the vicinity of facilities was in the evening of May 26 and flow had reached all facilities gages except CD3 (G11) by May 28. The CD2 pad (G8) did not receive any floodwater. Photo 4.32 through Photo 4.35 show the Alpine facilities on May 26, prior to breakup.

PHOTO 4.32: LOCAL MELT IN SAKOONANG NEAR CD1, LOOKING UPSTREAM (NORTHEAST); MAY 26, 2011

PHOTO 4.33: LOCAL MELT NEAR CD2 ROAD ACCESS STRUCTURES, LOOKING WEST; MAY 26, 2011

PHOTO 4.34: LOCAL MELT NEAR CD3 FACILITIES, LOOKING EAST; MAY 26, 2011

PHOTO 4.35: TAPPED LAKE AND NANUQ LAKE RECHARGING FROM NIGLIQ, LOOKING NORTHEAST; MAY 26, 2011

Photo 4.36: Flow in Sakoonang Channel near CD1, looking downstream (north); May 27, 2011

Photo 4.37: Flow through CD2 road swale bridges from Lake M9524 via Nanuq Lake, looking downstream (north); May 27, 2011

4.3.1 GAGES

By May 26, flow was present in both the upstream (flowing upstream from the Tamayayak) and downstream (flowing downstream from the East Channel) portions of the Sakoonang Channel) portions of the Sakoonang but had not yet reached Alpine facilities (G1). Tapped Lake west of CD4 pad (G20) was hydraulically connected to the Nigliq Channel at this time, as was Nanuq Lake. Tapped Lake is typically connected by spring flood flow to the Nigliq and, as a result, WSE at G20 is influenced by events that occur in the Nigliq. Table 4.15 presents the hydrograph for G20 and WSEs for MON20 and G21 are plotted for comparison.

On May 27, flow in the Sakoonang reached Alpine facilities (Photo 4.36) and water was flowing through the swale bridges (G3 and G4) (Photo 4.37). The flow in the Sakoonang at G1 was still backwater from the Tamayayak, and this phenomenon can be seen in the hydrograph in Table 4.9.

Flow entering the Sakoonang from the East Channel had diverted into an unnamed swale southeast of CD4 and was passing under the pipeline into the Nigliq Channel via Lake L9324 (Photo 4.19). The swale bridges, which pass the majority of the flow through the CD2 road prism, were passing floodwaters downstream (north) from Lake M9524, which was being recharged from the Nigliq Channel via Nanuq Lake.

On May 27, water depth at the short swale bridge was about 2.5 feet and there was snow blocking the majority of flow underneath on the downstream side of the bridge (Photo 4.38). The long swale bridge also had some blockage on the downstream side of the bridge (Photo 4.39). Flood stage had risen sufficiently to pass flow through some culverts near the swale bridges. The hydrograph for G3 and G4 is included in Table 4.10.

PHOTO 4.38: INITIAL FLOW THROUGH THE 62-FOOT SWALE BRIDGE, SNOW BLOCKAGE ON DOWNSTREAM (NORTH) SIDE, LOOKING EAST; MAY 27, 2011

PHOTO 4.39: FLOW THROUGH THE 452-FOOT SWALE BRIDGE, SOME SNOW BLOCKAGE ON DOWNSTREAM (NORTH) SIDE, LOOKING WEST; MAY 27, 2011

The Sakoonang was flowing downstream past G1 in the morning of May 28 and the majority of the small ice jams had cleared, though some snow was observed in the shallower portions of the channel. Floes entered the Sakoonang later in the evening as the result of an ice jam release upstream of MON1. Both swale bridges were generally clear of snow by the morning of May 28 (Photo 4.40 and Photo 4.41); flow had reached and was passing through all culverts near the remaining CD2 road gages (G6-G7 and G12-G13). Hydrographs for G6-G7 and G12-G13 are included in Table 4.11 and Table 4.13, respectively. Photo 4.42 shows flow through facilities on May 28.

PHOTO 4.40: FLOW PASSING MOSTLY UNIMPEDED BY SNOW THROUGH THE 62-FOOT SWALE BRIDGE, DOWNSTREAM (NORTH) LOOKING WEST; MAY 28, 2011

PHOTO 4.41: FLOW PASSING UNIMPEDED BY SNOW THROUGH THE 452-FOOT SWALE BRIDGE, DOWNSTREAM (NORTH) LOOKING EAST; MAY 28, 2011

PHOTO 4.42: FLOW THROUGH CD2 ROAD DRAINAGE STRUCTURES, AND FLOW IN THE SAKOONANG DOWNSTREAM PAST CD1, LOOKING DOWNSTREAM (NORTH); MAY 28, 2011

Photo 4.43: Hydraulic connection between Lakes M9525, L9323, and L9324, looking north; May 29, 2011

By May 29, floodwaters had progressed closer to facilities, and Lakes M9525, L9323, and L9324 became hydraulically connected (Photo 4.43). Lake M9525 was receiving floodwaters from Sakoonang overflow under the pipeline from the east and was hydraulically connected to Lake L9313 to the northeast (Photo 4.44). Lake L9324 was also receiving floodwaters from Sakoonang overflow under the pipeline from the southeast and was hydraulically connected to the Nigliq Channel to the northwest (Photo 4.45). By this time, flood flow was passing through the CD4 road culverts near G15-G16 between Lakes M9525 to the north and L9323 to the south and G17-G18 between Lakes L9323 to the north and L9324 to the south by May 29. The hydrograph for G15-G16 and G17-G18 is provided in Table 4.14.

Photo 4.44: Hydraulic connection between the Sakoonang, Lake M9525, and Lake L9313, looking east; May 29, 2011

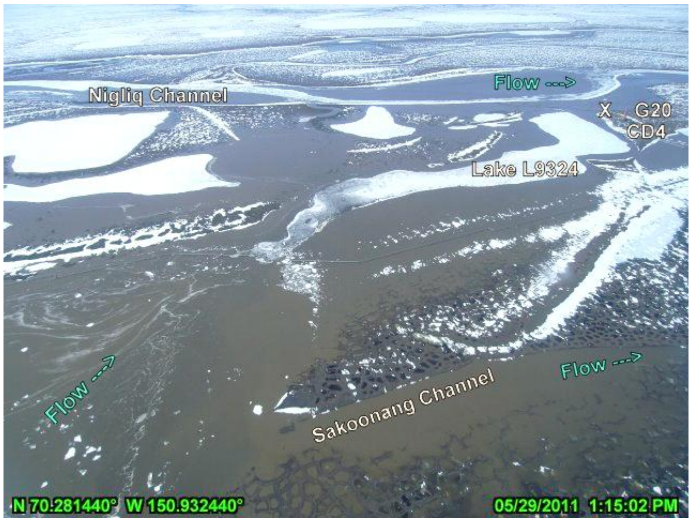


Photo 4.45: Hydraulic connection between the Sakoonang, Lake L9324, and the Nigliq, looking west; May 29, 2011

Some ice floes remained in the Sakoonang on May 29, which were creating and releasing small ice jams. As the floes moved downstream and overland under the pipeline, the Sakoonang overtopped its banks south of CD4 to the northwest toward Lake L9324.

On May 29, ice jams in the Nigliq were observed upstream of G20 in the vicinity of Nuiqsut and stage at G20 fell slightly as a consequence. Ribbon ice was intact in the Nigliq in the vicinity of the facilities. Some ice floes were caught on cross-channel ice; none were moving into Nanuq Lake.

PHOTO 4.46: FLOW THROUGH CHANNEL WEST OF CD3, LOOKING DOWNSTREAM (NORTH); MAY 29, 2011

Flow had entered the channel west of CD3 from the Ulamnigiaq by May 29, though stage was not high enough to reach G11 (Photo 4.46). The hydrograph for G11 is presented in Table 4.12.

Peak stage at the Alpine facilities occurred at some time between the evening of May 29 and the morning of May 30. Spring breakup flood flows receded following peak stage, and facilities monitoring was discontinued after June 1.

Based on a HWM and observation of nearby facilities, peak stage at CD1 (G1) was 9.33 feet BPMSL and is estimated to have occurred on the morning of May 30. Occasional ice floes were in the vicinity of G1 at this time (Photo 4.47); the Sakoonang was clear by June 1. Photo 4.48 shows CD1 facilities and nearby pipelines and roads on May 30.

PHOTO 4.47: G1 IN THE SAKOONANG OFF CD1 AFTER PEAK STAGE, LOOKING EAST; MAY 30, 2011

PHOTO 4.48: CD1, CD2, AND CD4 ROADS AFTER PEAK STAGE, LOOKING EAST; MAY 30, 2011.

Photo 4.49: Upstream (south) side of long swale bridge after peak stage, looking west; May 30, 2011

Photo 4.50: Upstream (south) side of short swale bridge after peak stage, looking east; May 30, 2011

Based on a HWM, WSE at G3 and G4 near the swale bridges peaked sometime at night on May 30. Peak stage at G3 and G4 was 8.89 and 8.59 feet BPMSL, respectively. Photo 4.49 and Photo 4.50 show the long and short swale bridge correspondingly, on May 30, just after peak stage. Ponded water was present under the short swale bridge on May 31 and was observed passing under the long swale bridge until observations were ended on June 1. The remaining gages near G12-G13 and G6-G7 showed a similar rise of floodwater, all peaking at around midnight on May 30. Photo 4.51 shows G13 just after peak stage. Photo 4.52 and Photo 4.53 show the culverts near G6 and G7, respectively, on May 30. Stage at these CD2 road locations receded steadily following peak until there was no longer flow through the nearby culverts on May 31.

Photo 4.51: G13 on the downstream (north) side of CD2 road after peak stage, looking downstream; May 30, 2011

Floodwaters did not reach G8 on the west side of CD2 pad in 2011 (Photo 4.54), as a result no hydrograph was generated. During peak stage, floodwater did pass in the vicinity of the east, west, and south sides of the CD2 pad via the road drainage structures, Nigliq Channel, and Nanuq Lake (Photo 4.55).

Photo 4.52: CD2 road culverts near G6 passing flow after peak stage, looking upstream (south); May 30, 2011

Photo 4.53: CD2 road culverts near G7 passing flow after peak stage, looking downstream (north); May 30, 2011

Photo 4.54: No evidence of breakup flood flow in the vicinity of G8 on the west side of CD2 pad, looking north; May 30, 2011

Photo 4.55: CD2 pad after peak stage, looking east; May 30, 2011

Flood flow did briefly reach G11 near the CD3 pad in 2011. Based on a HWM, peak WSE was 9.13 feet BPMSL, and it was estimated to have occurred in the morning on May 30. The surge of water recorded at G11 was likely the result of an ice jam release in the Tamayayak, which is suggested by the accompanied hydrographs in Table 4.12 and the presence of ice floes grounded in the area (Photo 4.56). By midday, stage had receded at this location and flow was confined within the banks of the channel. Overbank flow was not observed for the rest of the monitoring season.

PHOTO 4.56: G11 ON THE WEST SIDE OF CD3, GROUNDED FLOES IN CHANNEL FROM OVERNIGHT ICE JAM RELEASE, LOOKING WEST; MAY 30, 2011.

Relatively little spring breakup flow passed through the CD4 road culverts in 2011, due in part to topography and the impacts of ice on the flow characteristics of water through the CRD. Based on HWMs, stage at G15 and G16 probably peaked at around midnight on May 30, at 10.71 and 10.82 feet BPMSL, respectively. WSE at G17 also peaked around this time, at 12.12 feet BPMSL, and G18 peaked in the late afternoon on May 29, at 12.84 feet BPMSL. Photo 4.57 and Photo 4.58 show the culverts in the vicinity of G15 and G16, respectively, just after peak stage. Photo 4.59 and Photo 4.60 show the culverts in the vicinity of G17 and G18, respectively, just after peak stage. Floodwaters receded quickly after peak stage at the CD4 culverts. Flow between G17 (L9323) and G18 (L9324) culverts had ceased by May 31. Low flow between G15 (L9525) and G16 (L9323) culverts was still present by the time monitoring was discontinued on June 1.

PHOTO 4.57: CD4 ROAD CULVERTS IN THE VICINITY OF G15 (LAKE M9525) AFTER PEAK STAGE, LOOKING NORTHEAST; MAY 30, 2011

PHOTO 4.58: CD4 ROAD CULVERTS IN THE VICINITY OF G16 (LAKE L9323) AFTER PEAK STAGE, LOOKING SOUTHWEST; MAY 30, 2011

Photo 4.59: CD4 road culverts in the vicinity of G17 (Lake L9323) after peak stage, looking east; May 30, 2011

Photo 4.60: CD4 road culverts in the vicinity of G18 (Lake L9324) after peak stage, looking west; May 30, 2011

Photo 4.61: G20 on the west side of CD4 pad adjacent to Tapped Lake after peak stage; May 30, 2011

Based on a HWM, peak stage at G20 on the west side of CD2 pad was estimated to have occurred in the morning of May 30, with a maximum WSE of 10.64 feet BPMSL. Shortly after peak WSE, stage fell sharply until June 1, when monitoring ceased for this location. No grounded ice was observed in the vicinity of G20 following breakup (Photo 4.61).

The 2011 spring breakup floodwaters did not increase enough to reach G19 on the south side of the CD4 pad (Photo 4.62) and, as a result, a hydrograph was not generated. Flood flow did pass on the west, east, and south sides of the pad through Lake L9324 into the Nigliq Channel via Tapped Lake and into Lake L9323 (Photo 4.63).

Photo 4.62: No evidence of breakup flood flow in the vicinity of G19 on the south side of CD4 pad, looking south; May 30, 2011

Photo 4.63: Just after peak stage at CD4 pad, looking north; May 30, 2011

TABLE 4.9: WATER SURFACE ELEVATION DATA FOR G1

Date and Time	WSE (feet BPMSL)	Observations
	G1	
5/27/11 11:35 AM	3.30	
5/27/11 5:00 PM	3.72	Backwater flow in Sakoonang Channel
5/28/11 11:41 AM	6.19	Wind and waves; Sakoonang Channel flowing downstream
5/28/11 6:47 PM	6.46	
5/29/11 5:40 PM	8.10	Some ice floes in Sakoonang
5/30/11 6:00 AM	**9.33**	**Peak Stage**; high water mark - time estimated
5/30/11 3:30 PM	9.23	
5/31/11 10:06 AM	7.55	Occasional floes present

Notes:

1. Elevations are based on Monument 21 at 13.28 feet BPMSL, updated by LCMF in 2008.
2. Gage 1 is a permanent staff gage surveyed and adjusted for elevation by LCMF in June of 2011.

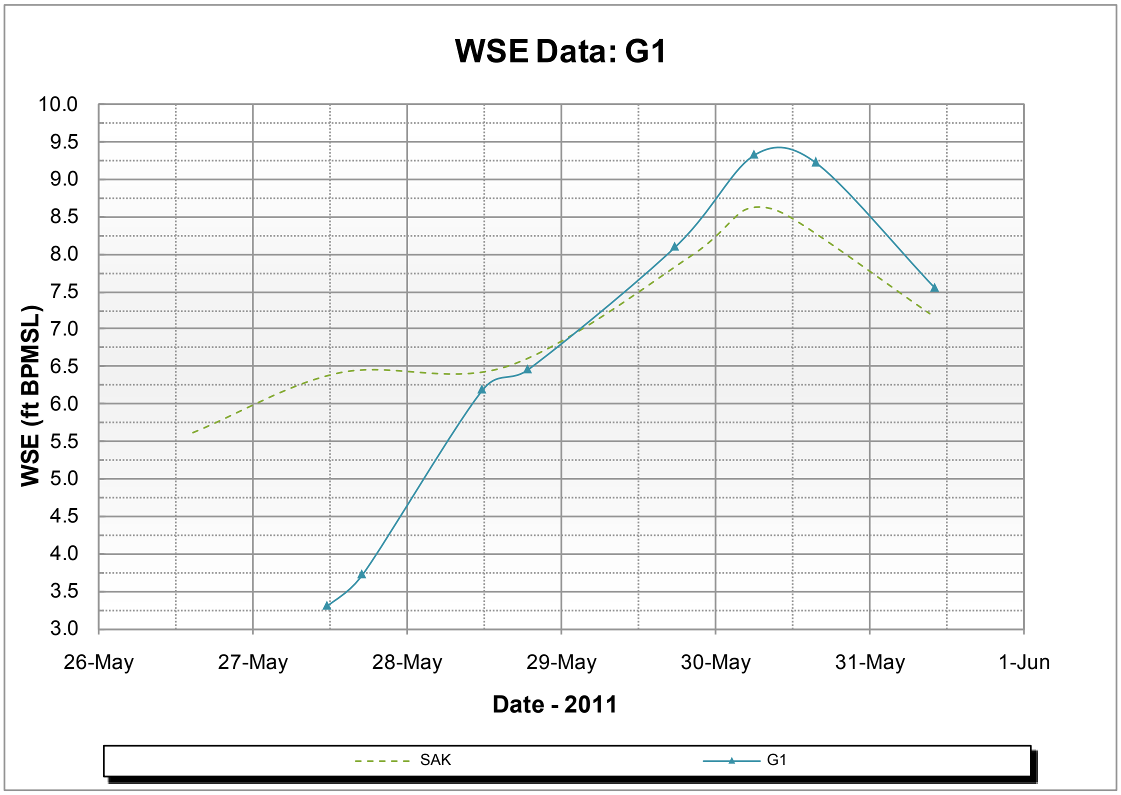


TABLE 4.10: WATER SURFACE ELEVATION DATA FOR G3 AND G4

Date and Time	WSE (feet BPMSL) G3	WSE (feet BPMSL) G4	Observations
5/27/11 10:05 AM	7.08	6.66	Large swale bridge clear of snow; some snow still present under small swale bridge. No flow present prior.
5/27/11 3:35 PM	6.95	6.61	
5/28/11 9:25 AM	7.91	7.37	Both bridges clear of snow below; snow still present around abutments
5/29/11 9:30 AM	8.11	7.73	
5/29/11 11:50 AM	8.21	7.80	
5/29/11 2:50 PM	8.44	7.97	Most CD2 road culverts passing flow
5/29/11 10:00 PM	**8.89**	**8.59**	**Peak Stage**; high water mark - time estimated
5/30/11 9:25 AM	8.68	8.49	
5/30/11 5:45 PM	8.70	8.46	
5/31/11 9:07 AM	7.12	7.01	Flow through both swale bridges
6/1/11 9:10 AM	5.63	5.53	Flow through large swale bridge; ponded water at small swale bridge

Notes:

1. Elevations are based on Monument 12 at 9.00 feet BPMSL, updated by LCMF in 2009.
2. Gages 3 and 4 are permanent staff gages surveyed and adjusted for elevation by LCMF in June of 2011.

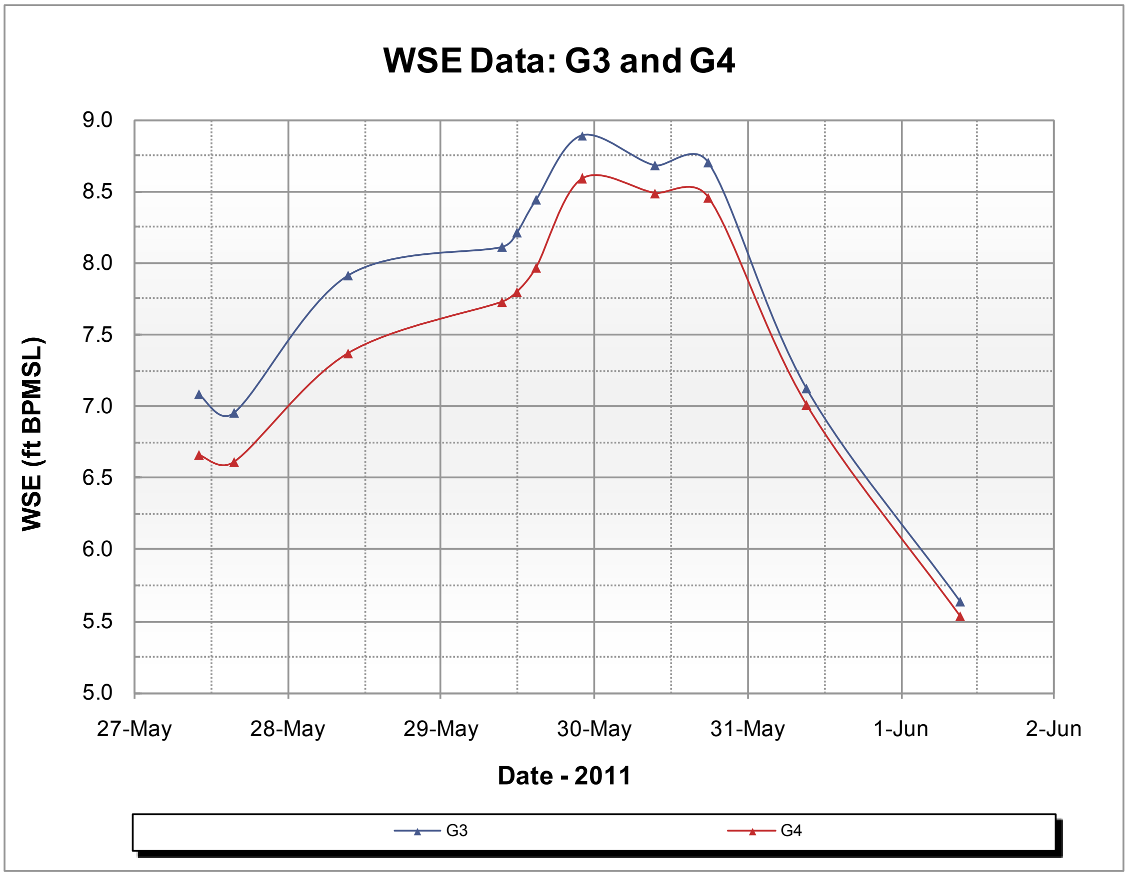


TABLE 4.11: WATER SURFACE ELEVATION DATA FOR G6 AND G7

Date and Time	WSE (feet BPMSL) G6	WSE (feet BPMSL) G7	Observations
5/28/11 5:50 PM	8.58	8.24	Flow present through area culverts; no flow present prior
5/29/11 9:45 AM	8.40	8.26	
5/29/11 3:00 PM	8.66	8.32	
5/30/11 2:00 AM	**9.02**	**8.62**	**Peak Stage**; high water mark - time estimated
5/30/11 10:30 AM	8.90	8.53	
5/31/11 9:10 AM	7.68	7.74	No flow present through area culverts

Notes:

1. Elevations are based on Monument 12 at 9.00 feet BPMSL, updated by LCMF in 2009.
2. Gages 6 and 7 are permanent staff gages surveyed and adjusted for elevation by LCMF in June of 2011.

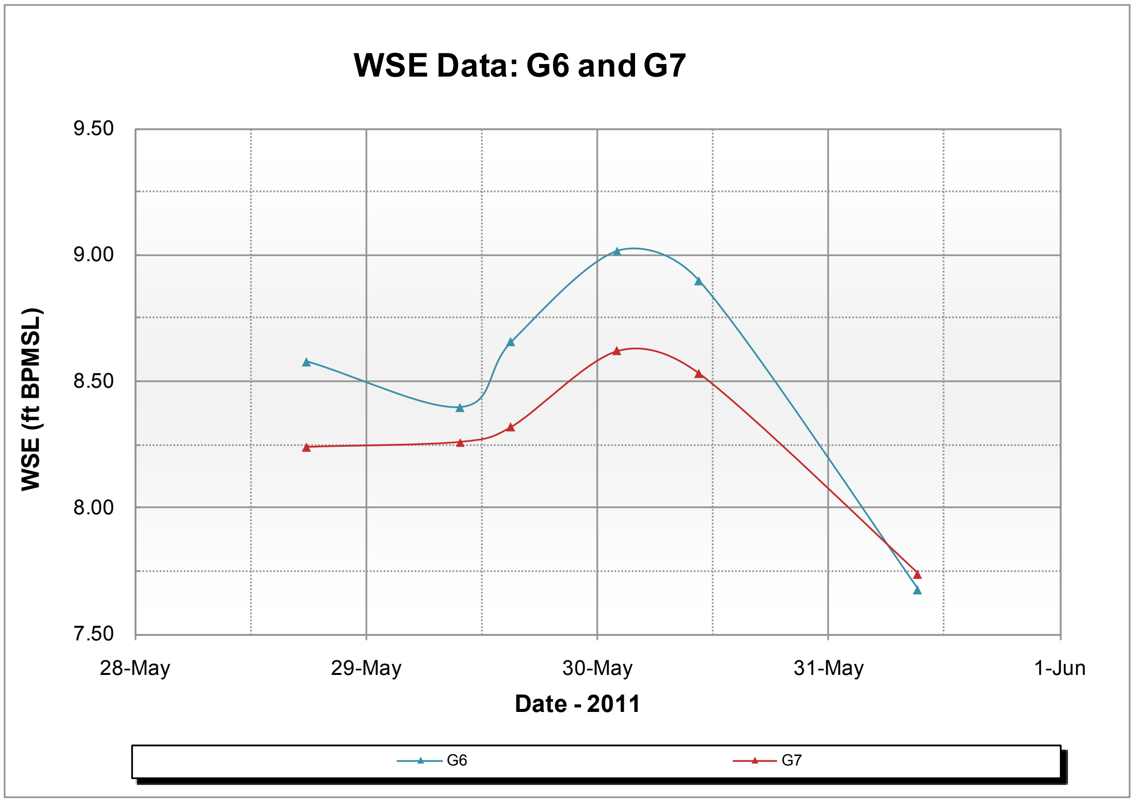


TABLE 4.12: WATER SURFACE ELEVATION DATA FOR G11

Date and Time	WSE (feet BPMSL)	Observations
	G11	
5/28/11 3:45 PM	8.27	Local melt only
5/29/11 8:28 PM	8.24	Flow beginning to enter channel west of CD3 from Ulamnigiak; local melt
5/30/11 5:00 AM	**9.13**	**Peak Stage**; HWM - time estimated, result of ice jam release in Tamayayak
5/30/11 11:43 AM	8.31	Local melt
5/31/11 9:31 AM	8.23	

Notes:

1. Elevations are based on PBM-Q at 20.972 feet BPMSL, updated by LCMF in 2011.

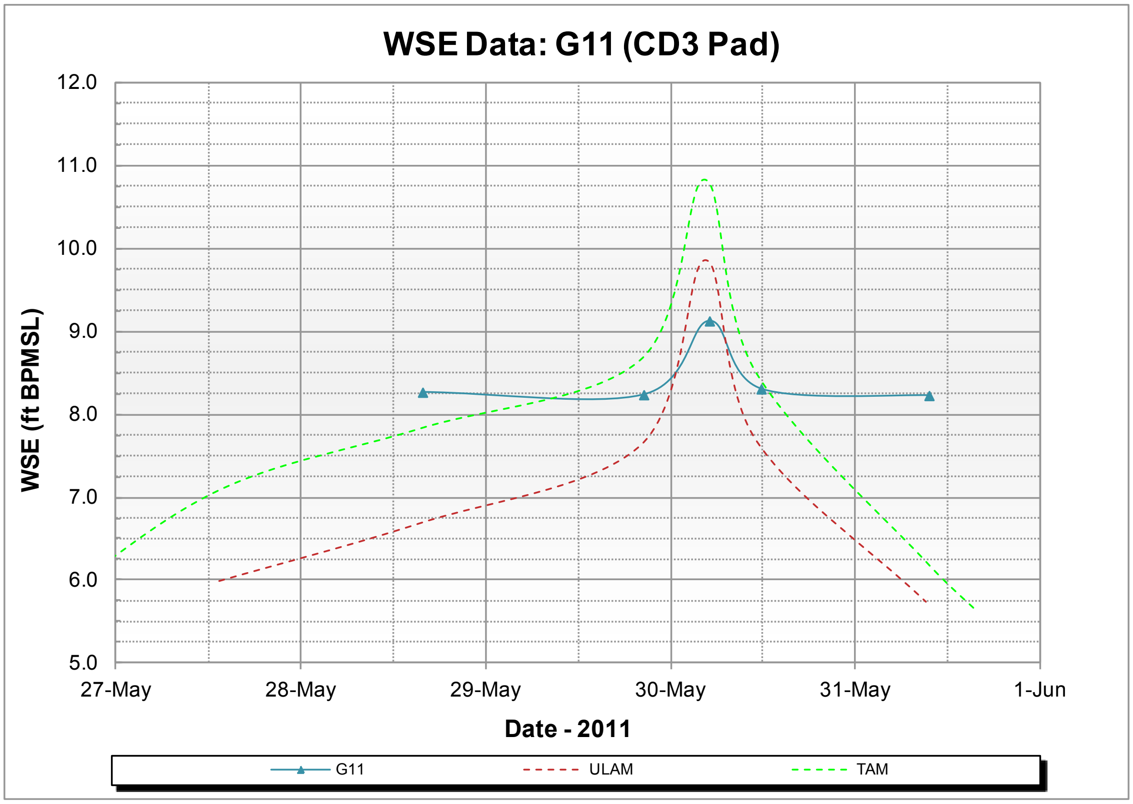


TABLE 4.13: WATER SURFACE ELEVATION DATA FOR G12 AND G13

Date and Time	WSE (feet BPMSL)		Observations
	G12	G13	
5/28/11 9:30 AM	8.29	8.11	Flow present through area culverts; no flow present prior
5/28/11 5:50 PM	8.63	8.22	
5/29/11 9:35 AM	8.45	8.31	
5/29/11 2:55 PM	-	8.39	G12 reading inaccurate
5/29/11 11:00 PM	**9.13**	**8.74**	**Peak Stage**; high water mark - time estimated
5/30/11 9:40 AM	8.84	8.55	
5/31/11 9:10 AM	-	7.69	
6/1/11 9:15 AM	-	-	Gages dry

Notes:

1. Elevations are based on CD2 access road culvert CD2-14 south top at 11.03 feet BPMSL, updated by LCMF in 2011.

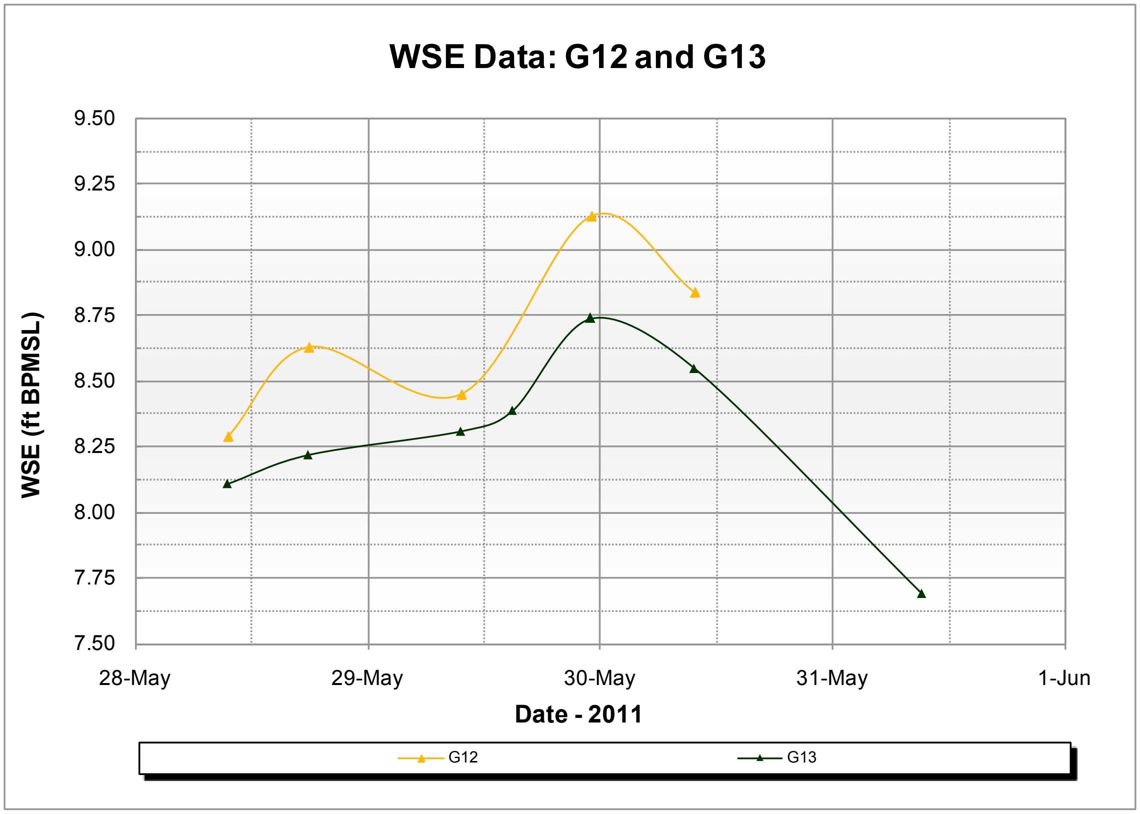


TABLE 4.14: WATER SURFACE ELEVATION DATA FOR G15-G16 AND G17-G18

	WSE (feet BPMSL)				
Date and Time	**G15**	**G16**	**G17**	**G18**	**Observations**
5/28/11 6:07 PM	-	-	-	-	No flow through CD4 culverts
5/29/11 10:20 AM	7.03	7.00	11.98	12.82	
5/29/11 3:40 PM	9.27	9.32	11.97	**12.84**	**Peak Stage**; reading
5/30/11 1:00 AM	**10.71**	**10.82**	**12.12**	-	**Peak Stage**; high water mark - time estimated
5/30/11 11:40 AM	10.61	10.65	-	-	
5/30/11 2:10 PM	-	-	11.82	11.77	
5/31/11 9:30 AM	9.06	9.05	-	-	

Notes:

1. Elevation for Gage 15 and Gage 16 is based on culvert CD4-21 west end top at 7.432 feet BPMSL, updated by LCMF in 2011.
2. Elevation for Gage 17 and Gage 18 is based on culvert CD4-32 east end top at 12.591 feet BPMSL, updated by LCMF in 2011.

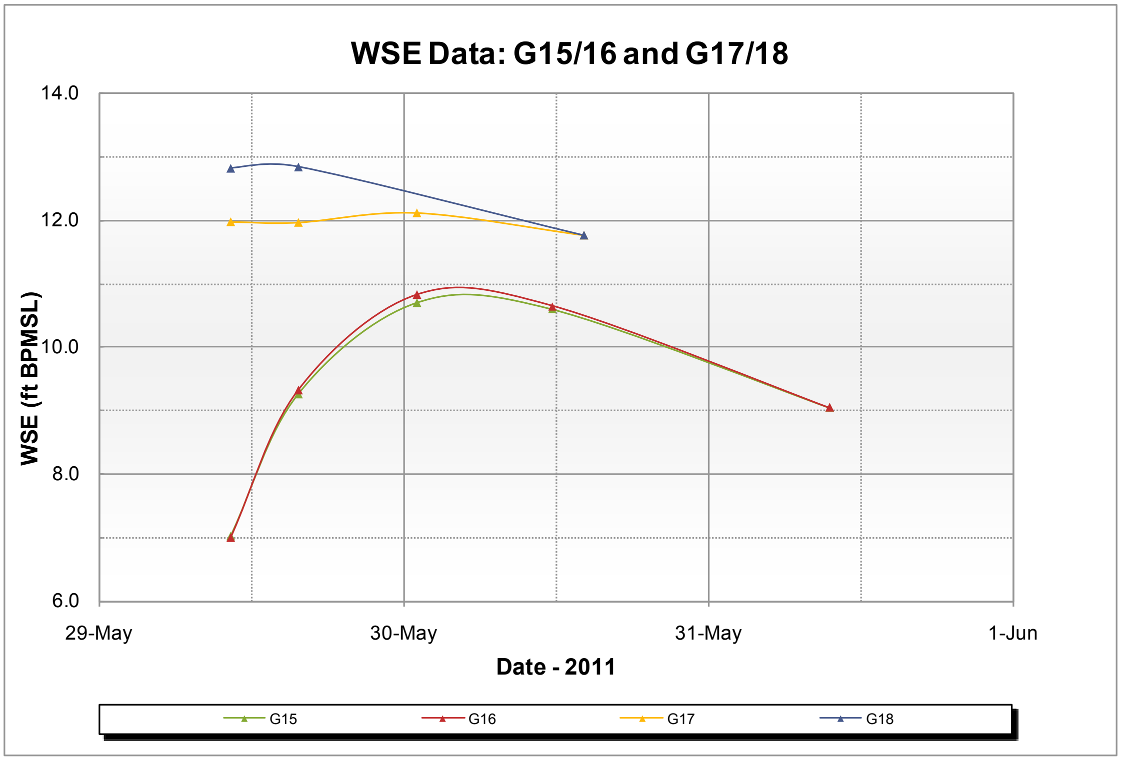
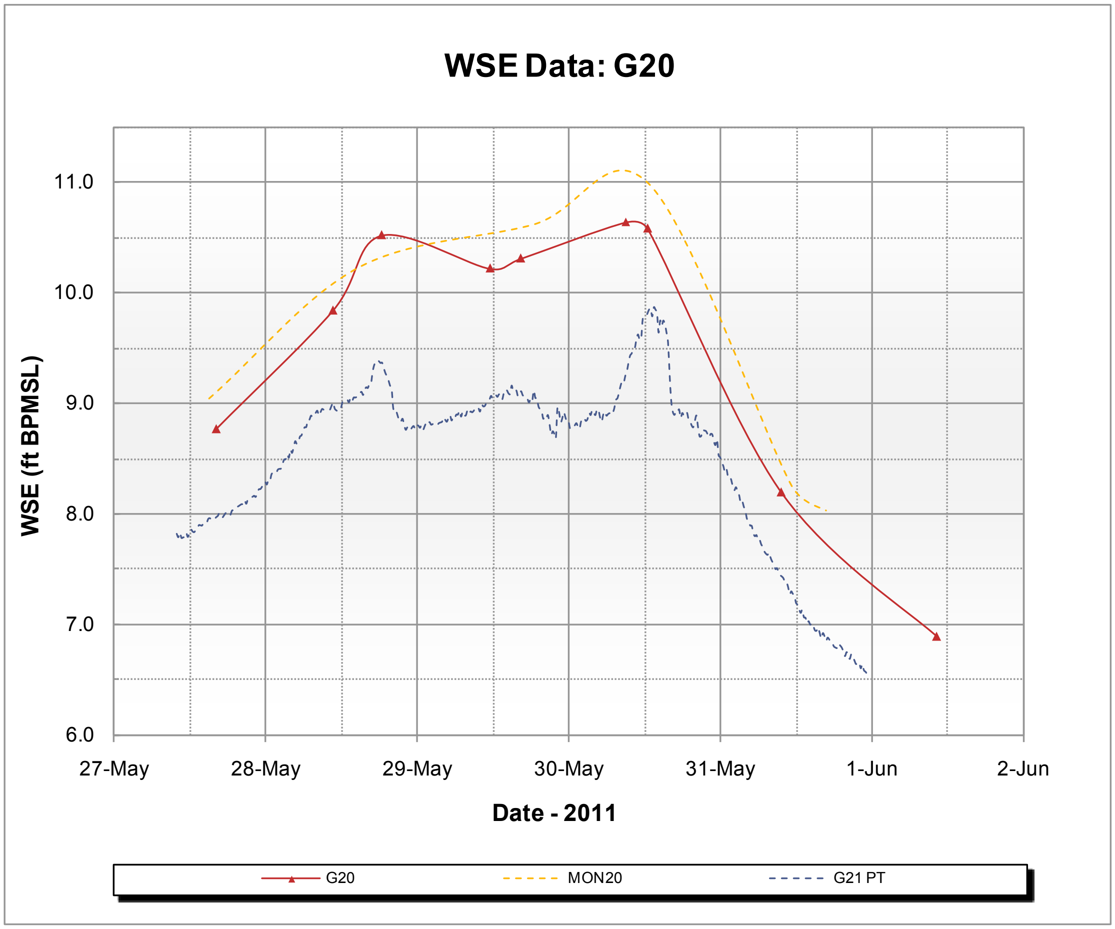


TABLE 4.15: WATER SURFACE ELEVATION DATA FOR G20

Date and Time	WSE (feet BPMSL)	Observations
	G20	
5/27/11 11:05 AM	8.64	Flow between Sakoonang Channel and Tapped Lake to Nigliq via Lake L9324
5/27/11 4:10 PM	8.77	
5/28/11 10:38 AM	9.84	
5/28/11 6:20 PM	10.52	
5/29/11 11:30 AM	10.22	Ice jams present in the Nigliq Channel near Nuiqsut
5/29/11 4:20 PM	10.31	Ice jams near Nuiqsut clearing
5/30/11 9:00 AM	**10.64**	**Peak Stage**; high water mark - time estimated
5/30/11 12:25 PM	10.58	Small ice jams forming downstream on cross-channel ribbon ice
5/31/11 9:32 AM	8.20	Nigliq Channel ice-free
6/1/11 10:07 AM	6.90	

Notes:

1. Elevations are based on PBM-Q at 20.972 feet BPMSL, updated by LCMF in 2011.



4.3.2 ALPINE DRINKING WATER LAKES

Documentation of recharge conditions of the Alpine drinking water lakes L9312 and L9313 was conducted in accordance with ADF&G permits FG99-III-0051, Amendment #7, and FG97-III-0190-Amendment #5. Lakes L9312 and L9313 were monitored before, during, and after breakup to assess recharge and to evaluate recharge mechanisms.

Recharge of Lakes L9312 and L9313 was determined by visual observations of floodwaters and direct measurements of WSE at each lake during breakup. Photographic evidence, water level surveys, and analysis of hydrographs generated by WSE observations at gages G9 (L9312) and G10 (L9313) were the primary references used to evaluate lake recharge. Photo 4.64 shows lakes L9312 and L9313 prior to breakup.

PHOTO 4.64: LAKE L9312 (G9) AND LAKE L9313 (G10) PRIOR TO BREAKUP, LOOKING NORTH; MAY 27, 2011

TABLE 4.16: WATER SURFACE ELEVATION DATA FOR G9 (L9312) AND G10 (L9313)

	WSE (feet BPMSL)		
Date and Time	G9 L9312	G10 L9313	Observations
5/29/11 5:30 PM	-	9.68	Floodwaters begin recharging L9313 (AM) and L9312 (PM)
5/30/11 12:00 AM	-	**10.67**	**Peak Stage L9313**; high water mark - time estimated
5/30/11 3:10 PM	10.23	10.25	
5/31/11 12:00 AM	**10.72**	-	**Peak Stage L9312**; high water mark - time estimated
5/31/11 9:55 AM	-	8.93	
5/31/11 4:55 PM	8.62	-	
6/1/11 2:28 PM	-	7.27	

Notes:

1. Gage 9 is located on Lake L9312 and Gage 10 is located on Lake L9313.
2. Elevations for Gage 9 are based on TBM 02-01-39O of 11.450 feet BPMSL, established by LCMF in 2007.
3. Elevations for Gage 10 are based on TBM L99-32-60 of 15.894 feet BPMSL, established by LCMF in 2008.
4. Gages 9 and 10 are permanent staff gages surveyed and adjusted for elevation by LCMF in June of 2011.

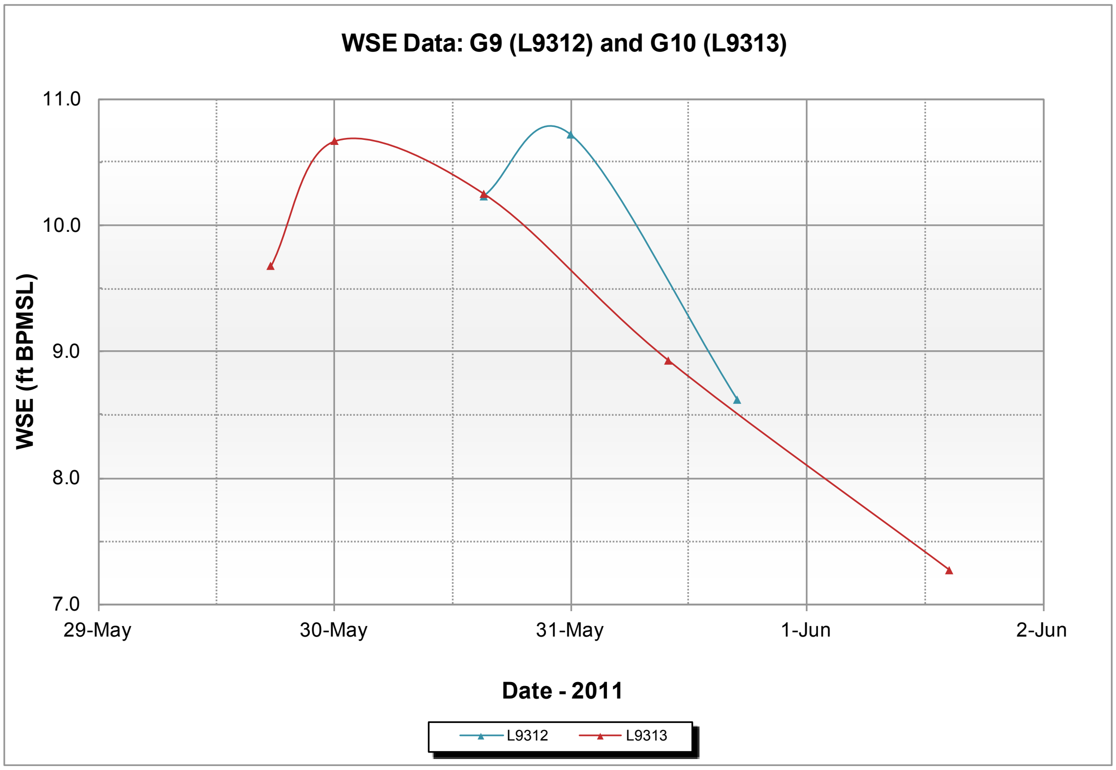


Photo 4.65: Lake L9312 receiving initial recharge from the Sakoonang and Lake L9313, looking east; May 29, 2011

4.3.2.1 LAKE L9312 RECHARGE

Lake L9312, located southwest of the CD1 pad, is surrounded by higher tundra than is Lake L9313. Historically, Lake L9313 typically receives annual floodwater recharge, while L9312 does less frequently.

On the evening of May 29, Lake L9312 began receiving floodwaters from the Sakoonang to the west and from Lake L9313 to the east (Photo 4.65). Lake L9312 fully recharged to bankfull between May 30 and May 31, as stage rose overnight and then quickly decreased. Peak WSE at Lake L9312 (G9) was 10.72 feet BPMSL based on a HWM collected by field crews on May 31. Ice remained on the lake throughout the breakup season and into June. A hydrograph for L9312 (G9) is presented in Table 4.16.

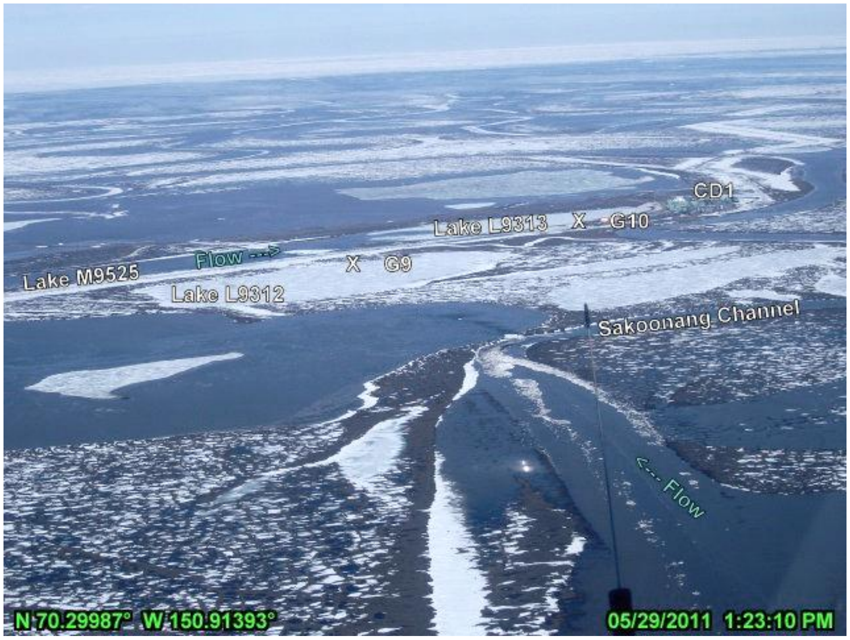


Photo 4.66: Lake L9313 receiving initial recharge from the Sakoonang via Lake M9525, looking north; May 29, 2011

4.3.2.2 LAKE L9313 RECHARGE

Lake L9313 is situated adjacent to the southwest side of the CD1 pad. On the morning of May 29, Lake L9313 began receiving overland flow from the Sakoonang via Lake M9525 to the west (Photo 4.66). Lake L9313 fully recharged to bankfull between May 29 and May 30, as stage rose overnight and then quickly decreased. Peak WSE at Lake L9313 (G10) was 10.67 feet BPMSL based on a HWM collected by field crews on May 30. Given the historical record, bankfull elevation is approximately 6.5 feet BPMSL (Baker 2006, 2007). Ice also remained on this lake throughout the breakup season and into June. A hydrograph for Lake L9313 (G10) is provided in Table 4.16.

Photo 4.67 shows Lakes L9312 and L9313 over bankfull conditions.

PHOTO 4.67: LAKE L9312 (G9) AND LAKE L9313 (G10) RECHARGED OVER BANKFULL, LOOKING EAST; MAY 30, 2011

4.3.3 DRAINAGE STRUCTURES

On May 27, initial floodwaters began to reach the CD2 road and the swale bridges, and some CD2 road culverts began to pass water. By May 28, most CD2 road culverts were passing water, and the swale bridges were largely clear of snow blockage. Flow passed unimpeded through both swale bridges after snow blockage was clear on May 29.

Direct discharge measurements were taken at the long swale bridge on May 29 and June 1 and at the short swale bridge on May 28 and May 30. Photo 4.68 shows the field crew taking a discharge measurement at the 452-foot swale bridge on May 28, closest to peak stage. Discharge measurement data for both the 452-foot swale bridge and the 62-foot swale bridge is provided in Appendix C.

PHOTO 4.68: DISCHARGE MEASUREMENT FROM THE 452-FOOT SWALE BRIDGE, LOOKING EAST; MAY 29, 2011

As discussed in Section 3.3, velocity measurements were not taken at the culverts in 2011 due to logistics related to the timing of peak stage at MON1. See Section 5.6 for further discussion on culverts. Along the CD2 road, water levels reached gages G3-G4 by the morning on May 27, and G12-G13 and G6-G7 by the morning of May 28. Peak stage along the CD2 road was estimated to have occurred near midnight on May 30 at all Alpine facilities monitoring locations. During peak stage along the CD2 road, 25 of the 26 culverts were observed passing flow.

Along the CD4 road, water levels reached the gages G15-G16 and G17-G18 in the morning on May 29. Peak stage along the CD4 road was on May 29 for G17 and G18 and May 30 for G15 and G16. During peak stage along the CD4 road, 23 of the 37 were observed passing flow. The flow through the culverts in the vicinity of G15-G16 was affected by floodwaters approaching from the north (Lake M9525) and south (Lake L9323) sides, though the predominant direction of flow through all culverts near G15-G16 and G17-G18 was from the south to the north.

Obstructions to flow passage were minor and included snow, ice, vegetation, plywood remnants, plastic remnants, and metal culvert cover brackets displaced by flow.

4.3.4 EROSION

The peak stage of floodwater passing by Alpine roads and facilities was relatively moderate in 2011, based on a historical record comparison. In addition, no significant ice floes were observed in the area. Breakup effect on gravel pads, roads, and drainage structures was negligible. Floodwater did not inundate any of the gravel pad embankments at the CD1, CD2, CD3, or CD4 pads.

The Alpine gravel pads and access roads were inspected for erosion before, during, and after breakup. Photographic documentation of the condition of the gravel facilities was first recorded on June 5.

On May 27, floodwater was first observed coming into contact with the CD2 road prism in the vicinity of the swale bridges (G3 and G4). By May 28, floodwater had reached the remainder of the CD2 road prism (G6, G7, G12, and G13).

Following peak stage, visual inspections of the CD2 and CD4 gravel road prism were conducted. High-water marks due to erosion were identified by debris stranded on the road prism side slopes or where silts and fine-grained sands had washed away. Photo 4.69 shows an example of fine-grained material washed away as a result of erosion on the upstream side of the CD2 road near culvert CD2-23. Orange-topped lath were positioned into the road prism to better show the location and upper limit of erosion due to floodwater. The lath placed into the road prism was used to highlight erosion limits for photos and were removed after the photos were taken.

High-water marks in the road prism were observed along the CD2 road as a result of floodwater erosion. Photo 4.70, Photo 4.71, and Photo 4.72 are representative photos of the observed erosion along the CD2 gravel road prism following peak stage of breakup floodwater. Generally, the erosion of the CD2 access road was limited to the upstream (south) side of the road prism in the vicinity of the swale bridges.

PHOTO 4.69: FINE-GRAINED MATERIAL REMOVED FROM ROAD PRISM, SOUTH SIDE OF CD2 ROAD, LOOKING EAST; JUNE 5, 2011

Floodwater reached the base of the CD4 gravel road prism in some areas; however, the amount of floodwater was not enough to result in any noteworthy erosion. Photo 4.73, Photo 4.74, and Photo 4.75 are representative photos of the conditions observed along the CD4 gravel road prism post peak stage.

No indications of significant erosion due to breakup floodwater were observed on the Alpine gravel pads or facilities.

PHOTO 4.70: EROSION SURVEY OF CD2 ROAD PRISM POST-BREAKUP, LOOKING EAST; JUNE 5, 2011

PHOTO 4.71: EROSION SURVEY CD2 ROAD PRISM POST-BREAKUP, LOOKING WEST; JUNE 5, 2011

PHOTO 4.72: EROSION SURVEY CD2 ROAD POST-BREAKUP, BETWEEN SWALE BRIDGES, LOOKING EAST; JUNE 5, 2011

PHOTO 4.73: EROSION SURVEY CD4 ROAD PRISM POST-BREAKUP, LOOKING SOUTH; JUNE 5, 2011

PHOTO 4.74: EROSION SURVEY CD4 ROAD PRISM POST-BREAKUP VICINITY OF CD4 PAD, LOOKING NORTH, JUNE 5, 2011

PHOTO 4.75: EROSION SURVEY CD4 ROAD, ORGANIC DEBRIS LEFT FROM RECEDED WATER AT TOE OF ROAD PRISM, LOOKING NORTH; JUNE 5, 2011

PHOTO 4.76: ICE ROAD CROSSINGS ARE DUG OUT PRIOR TO BREAKUP TO FACILITATE THE PASSAGE OF FLOOD FLOW; TAMAYAYAK ICE ROAD CROSSING; MAY 9, 2011

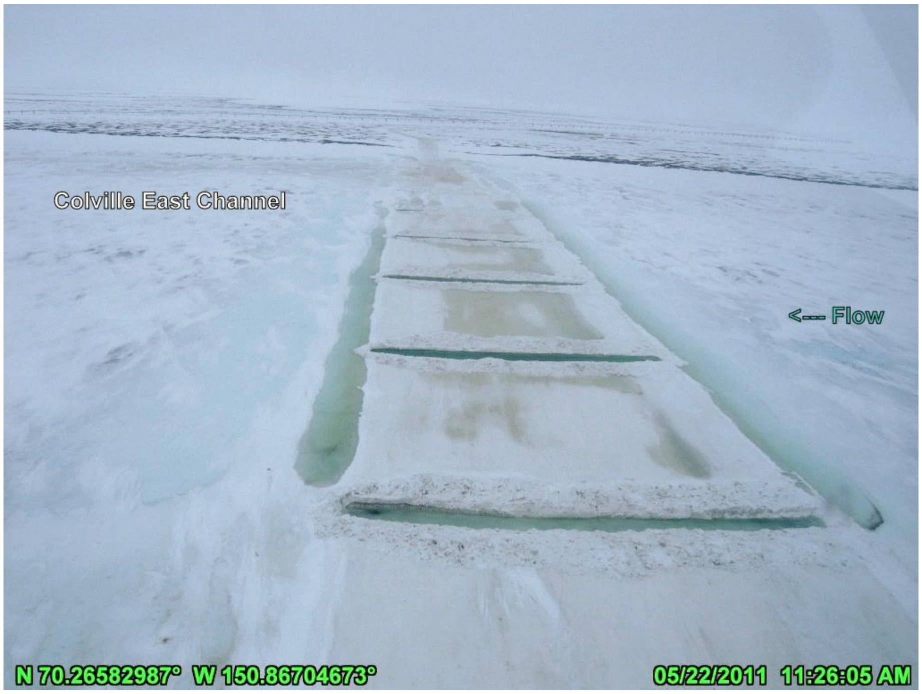


PHOTO 4.77: SLOTS CUT IN THE COLVILLE RIVER ICE BRIDGE PRE-BREAKUP, LOOKING EAST; MAY 22, 2011

4.3.5 ICE BRIDGES

Ice road crossings were dug out prior to breakup, as shown in Photo 4.76. Ice bridge melt progressed smoothly throughout the breakup period at the East Channel and Kachemach River crossings; no significant erosion or scour was observed as a result of the ice bridges.

The East Channel ice bridge is located approximately one-half mile upstream (south) of MON9. The first visual evidence of melt at the ice bridge was recorded on May 22, when water was observed within the slots cut into the ice bridge (Photo 4.77). By May 25, the leading edge had passed through the ice bridge and floodwater was beginning to flow through the area. During this time, the ice bridge did not appear to be adversely impacting flow (Photo 4.78). Photo 4.79 shows the Colville River ice bridge as floes from an ice jam release upstream of MON1 move through, clearing the channel of ribbon ice, and Photo 4.80 and Photo 4.81 show the remaining west and east sides on June 9, when monitoring was discontinued.

PHOTO 4.78: COLVILLE RIVER ICE BRIDGE, LOOKING UPSTREAM (SOUTHWEST); MAY 25, 2011

PHOTO 4.79: COLVILLE RIVER ICE BRIDGE AS MAJOR ICE JAM RELEASE CLEARS CHANNEL ICE, LOOKING DOWNSTREAM (NORTHWEST); MAY 28, 2011

PHOTO 4.80: COLVILLE RIVER ICE BRIDGE WEST SIDE POST-BREAKUP, LOOKING DOWNSTREAM (NORTH); JUNE 9, 2011

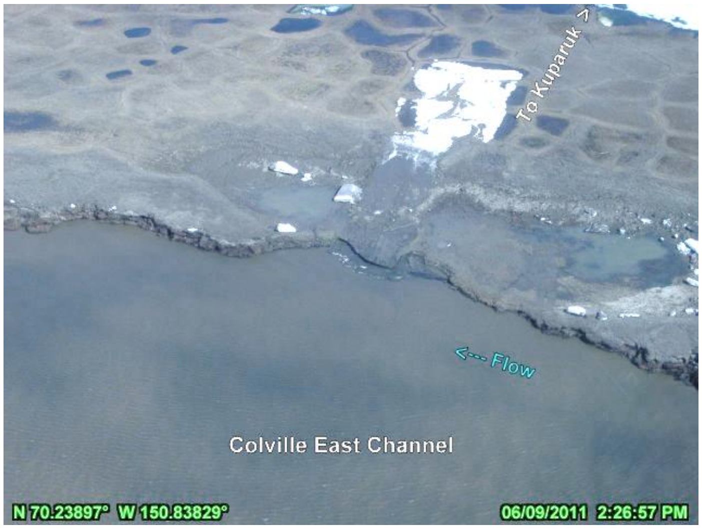


PHOTO 4.81: COLVILLE RIVER ICE BRIDGE EAST SIDE POST-BREAKUP, LOOKING EAST; JUNE 9, 2011

Initial aerial reconnaissance of the Kachemach River ice bridge crossing location was performed on May 26. The Kachemach River ice bridge was effectively wholly intact, with a slot cut into it near the center of the crossing (Photo 4.82). No evidence of flowing water was observed. On June 9, a second reconnaissance flight over the Kachemach River ice bridge was conducted and the channel seemed to be largely clear of ice. No indications of channel migration or bank erosion were observed. Ice rafts were perched on the banks and the ice bridge approaches were mainly intact (Photo 4.83).

Breakup flooding at all ice road crossings in the CRD progressed unimpeded.

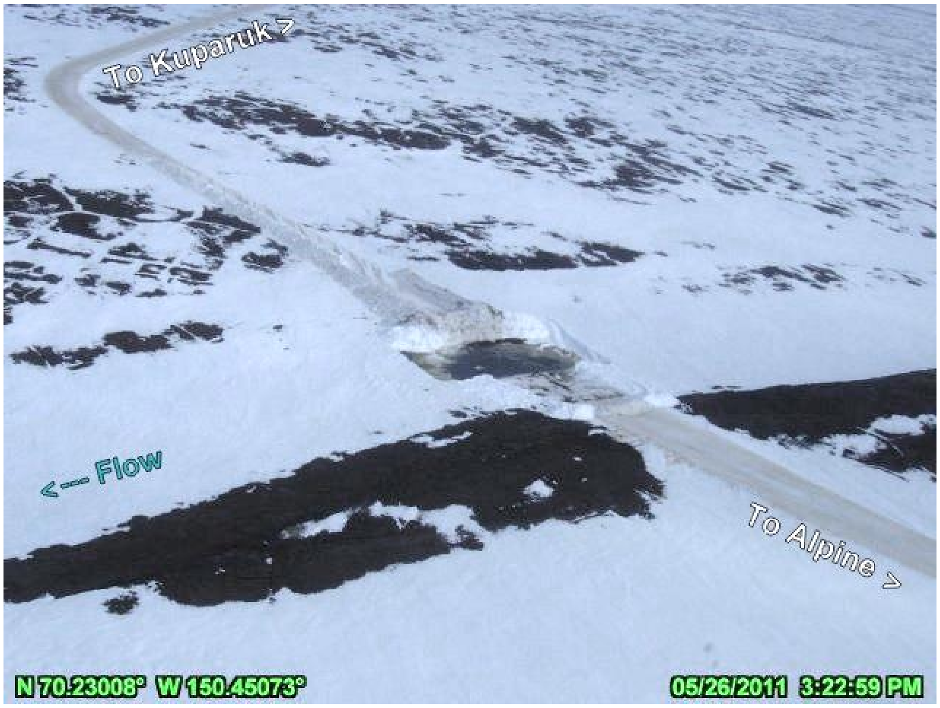


PHOTO 4.82: KACHEMACH RIVER ICE BRIDGE SLOTTED PRE-BREAKUP, LOOKING SOUTHEAST; MAY 26, 2011

PHOTO 4.83: KACHEMACH RIVER ICE BRIDGE AS BREAKUP FLOWS RECEDE, LOOKING SOUTHEAST; JUNE 9, 2011

4.4 CD3 PIPELINE CROSSINGS

Daily monitoring of the pipeline crossings began May 25. Photo 4.84 shows the Sakoonang pipeline crossing with local melt in the vicinity. Photo 4.85 shows water beginning to enter the Tamayayak from the East Channel.

PHOTO 4.84: SAKOONANG PIPELINE CROSSING PRIOR TO BREAKUP, LOOKING DOWNSTREAM (NORTH); MAY 25, 2011

PHOTO 4.85: LEADING EDGE IN THE EAST CHANNEL ENTERING THE TAMAYAYAK, LOOKING DOWNSTREAM (WEST); MAY 25, 2011

PHOTO 4.86: FLOW FROM THE TAMAYAYAK BACKING UPSTREAM IN THE SAKOONANG PAST THE PIPELINE CROSSING, LOOKING UPSTREAM (SOUTH); MAY 26, 2011

WSE was initially measureable on all pipeline crossing gages by May 26. At that time, water flowing downstream in the Sakoonang had not yet reached the pipeline crossing and water from the Tamayayak was backing up the Sakoonang (Photo 4.86). Because of this, flow in these channels had a relatively low velocity. Photo 4.87 and Photo 4.88 show breakup progression at the Tamayayak and Ulamnigiaq pipeline crossings on May 26.

PHOTO 4.87: TAMAYAYAK PIPELINE CROSSING AS BREAKUP FLOWS PROGRESS, LOOKING DOWNSTREAM (WEST); MAY 26, 2011

PHOTO 4.88: ULAMNIGIAQ PIPELINE CROSSING AS BREAKUP FLOWS PROGRESS, LOOKING UPSTREAM (SOUTHEAST); MAY 26, 2011

On May 27, backwater was forcing flow upstream (south) in the Sakoonang and a small ice jam had formed near the pipeline crossing. A small ice jam had also formed downstream of the Tamayayak pipeline crossing and other small ice jams were present in the channel.

PHOTO 4.89: FLOES FROM ICE JAM RELEASE UPSTREAM OF MON1 DIVERT INTO THE TAMAYAYAK, LOOKING DOWNSTREAM (NORTHWEST); MAY 28, 2011

By May 28, flow had normalized in the Sakoonang and no further backwater effects were observed for the remainder of the breakup season. Ribbon ice was still present in portions of all pipeline crossing channels and snow was present along the banks. Later in the day, ice floes began entering the Sakoonang and Tamayayak (Photo 4.89) from the East Channel as the result of an ice jam release upstream of MON1. Overnight, the ice floes from the jam re-formed in the East Channel just downstream of the Tamayayak bifurcation.

On May 29, an ice jam had formed in the Tamayayak upstream of the Ulamnigiaq bifurcation (Photo 4.90 and Photo 4.91). Rafted ice was seen near the Sakoonang pipeline crossing (Photo 4.92). Photo 4.93 shows the progression of breakup at the Ulamnigiaq pipeline crossing on May 29.

Photo 4.90: Ice jam upstream of the Tamayayak-Ulamnigiaq bifurcation, looking upstream (southeast); May 29, 2011

Photo 4.91: Ice jam in Tamayayak upstream of the pipeline crossing and Ulamnigiaq bifurcation, looking southwest; May 29, 2011

Photo 4.92: Sakoonang pipeline crossing just prior to peak stage, looking upstream (southeast); May 29, 2011

Photo 4.93: Ulamnigiaq pipeline crossing just prior to peak stage, looking south; May 29, 2011

PHOTO 4.94: TAMAYAYAK PIPELINE CROSSING JUST AFTER PEAK STAGE, LOOKING WEST; MAY 30, 2011

This jam released overnight, sending a surge of water downstream, which caused a spike in the WSE at both the Tamayayak and Ulamnigiaq monitoring locations. Stranded ice was observed on the banks of the Tamayayak (Photo 4.94 and Photo 4.95) and Ulamnigiaq pipeline crossings on May 30.

Peak stage at all locations was estimated to have occurred early in the morning on May 30 and was 8.60, 10.84, and 9.86 feet BPMSL, respectively, for the Sakoonang, Tamayayak, and Ulamnigiaq. After peak, stage receded quickly at all monitoring locations (Photo 4.95 though Photo 4.99). Table 4.17 presents observations and WSE recorded for the Sakoonang, Tamayayak, and Ulamnigiaq.

PHOTO 4.95: GROUNDED ICE IN THE VICINITY OF THE TAMAYAYAK PIPELINE CROSSING, LOOKING NORTHWEST; MAY 30, 2011

PHOTO 4.96: ULAMNIGIAQ PIPELINE CROSSING JUST AFTER PEAK STAGE, LOOKING SOUTH; MAY 30, 2011

PHOTO 4.97: SAKOONANG PIPELINE CROSSING AS BREAKUP FLOWS RECEDE, LOOKING NORTHEAST; MAY 31, 2011

PHOTO 4.98: TAMAYAYAK PIPELINE CROSSING AS BREAKUP FLOWS RECEDE, LOOKING NORTHEAST; MAY 31, 2011

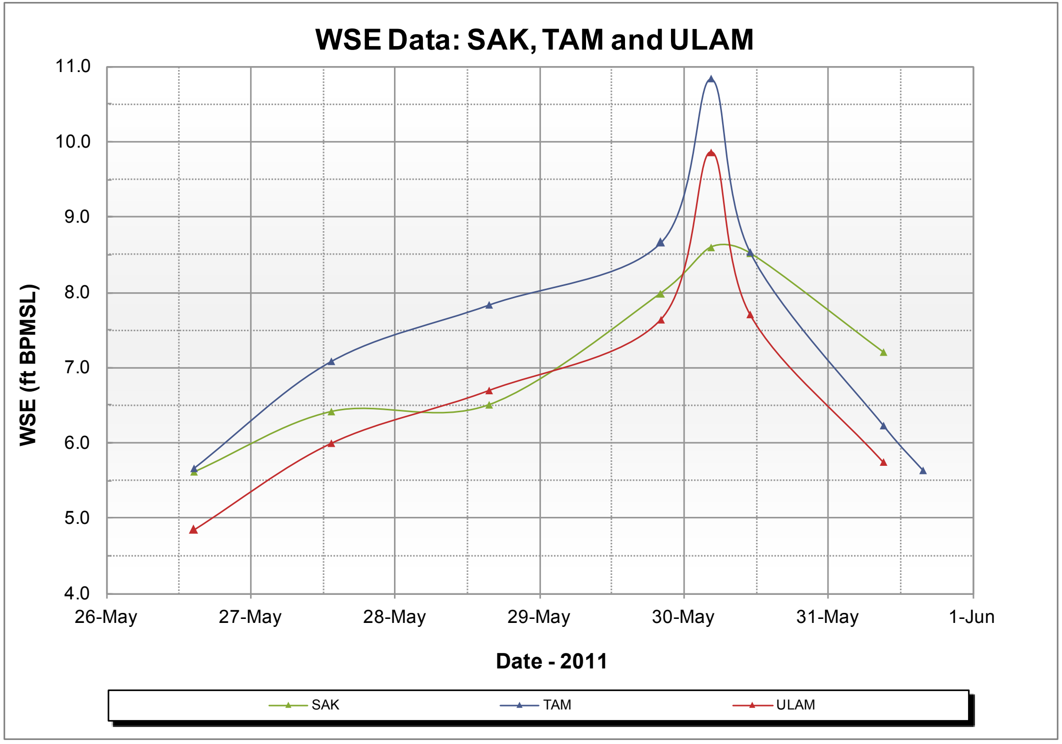
PHOTO 4.99: ULAMNIGIAQ PIPELINE CROSSING AS BREAKUP FLOWS RECEDE, LOOKING WEST; MAY 31, 2011

TABLE 4.17: WATER SURFACE ELEVATION DATA FOR SAK, TAM AND ULAM (CD3 PIPELINE CROSSINGS)

Date and Time	WSE (feet BPMSL)			Observations
	SAK	TAM	ULAM	
5/26/11 2:30 PM	5.62	5.66	4.85	
5/27/11 1:20 PM	6.42	7.08	6.00	Flow moving upstream in Sakoonang; small ice jam downstream of TAM
5/28/11 3:35 PM	6.51	7.83	6.70	Flow moving downstream in Sakoonang; some floes in SAK and TAM vicinity
5/29/11 8:10 PM	7.99	8.66	7.64	Ice jam in Tamayayak upstream of the Ulamnigiak birfurcation
5/30/11 4:30 AM	**8.60**	**10.84**	**9.86**	**Peak Stage**; high water mark - time estimated
5/30/11 11:00 AM	8.52	8.54	7.71	
5/31/11 9:10 AM	7.21	6.23	5.75	Grounded ice on left banks - more near TAM and ULAM than SAK
5/31/11 3:45 PM	-	5.64	-	

Notes:

1. SAK at Saknoonang (Pipe Bridge Crossing #2), TAM at Tamayayak (Pipe Bridge Crossing #4), ULAM at Ulamnigiak (Pipe Bridge Crossing #5)
2. Elevations for SAK are based on Pile 568 SW corner Bolt Pile Cap at 23.719 feet BPMSL , updated by LCMF in 2010
3. Elevations for TAM are based on CP-08-11-23 of 8.524 feet BPMSL established by LCMF in 2008.
4. Elevations for ULAM are based on CP-08-11-35 of 9.146 feet BPMSL established by LCMF in 2008.



4.5 PROPOSED CD5 ROAD CROSSINGS

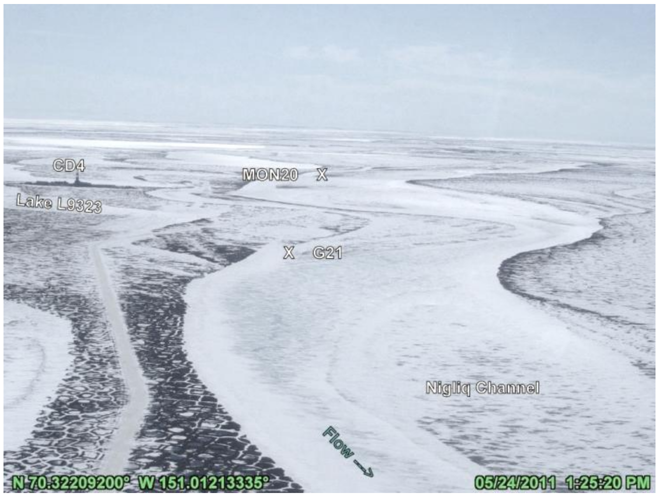


PHOTO 4.100: PROPOSED CD5 BRIDGE CROSSING AT THE NIGLIQ CHANNEL (G21) PRIOR TO BREAKUP, LOOKING UPSTREAM (SOUTH); MAY 24, 2011

PHOTO 4.101: PROPOSED CD5 BRIDGE CROSSING AT LAKE L9341 (G22) PRIOR TO BREAKUP, LOOKING WEST; MAY 24, 2011

Monitoring of the three proposed CD5 road bridge crossing locations was conducted at G21 (Nigliq, Photo 4.100), G22 (Lake L9341, Photo 4.101), and G23 (Nigliagvik, Photo 4.102). In addition to visual observations and documentation of gage readings, a pressure transducer was deployed at G21 and G21 upstream (G21U).

PHOTO 4.102: PROPOSED CD5 BRIDGE CROSSING AT THE NIGLIAGVIK (G23) PRIOR TO BREAKUP, LOOKING UPSTREAM (SOUTH); MAY 21, 2011

The G21 monitoring location is located between MON20 and MON22 on the Nigliq Channel at the proposed CD5 bridge crossing location. The G21 location and other nearby Nigliq Channel gages experienced similar breakup events, including discharge, stage, and ice effects. The leading edge in the Nigliq Channel reached G21 on May 25 (Photo 4.103). At that time, flow had entered the Nigliagvik.

PHOTO 4.103: LEADING EDGE IN THE NIGLIQ CHANNEL, PAST G21, LOOKING DOWNSTREAM (NORTH); MAY 25, 2011

Water reached G23 along the Nigliagvik on May 27, when low-velocity flow was observed moving through the channel (Photo 4.104). Significant snow was present along both banks but no ice floes were seen. At that time, there was abundant ribbon ice near the G21 location, and it remained in the area until the last monitoring observation on June 3. Occasional ice floes in the area were wedged between ribbon ice and the banks near G21. Stage was not high enough for water to enter Lake L9341 (G22) at either end, near the Nigliq (northeast) or near the Nigliagvik (southwest), though there was some local melt and significant snow at the monitoring location (Photo 4.105).

PHOTO 4.104: INITIAL FLOW OBSERVED IN THE NIGLIAGVIK NEAR G23, LOOKING UPSTREAM (SOUTH); MAY 27, 2011

PHOTO 4.105: LOCAL MELT IN LAKE L9341 AT G22, LOOKING WEST; MAY 27, 2011

By May 28, Lake L9341 was recharging from the northeast via the Nigliq (Photo 4.106). A major ice jam upstream of MON1, released in the early evening of May 28, sent a surge of water and ice floes downstream into the East Channel and the Nigliq (Photo 4.107). This release is represented as a small rise in WSE on the hydrograph for G21, included in Table 4.18. Ice floes from this release became lodged on channel ice near Nuiqsut, which affected the amount of flood flow that was able to progress down the Nigliq Channel.

PHOTO 4.106: LAKE L9341 BEGINS TO RECHARGE FROM THE NIGLIQ, LOOKING SOUTHEAST; MAY 28, 2011

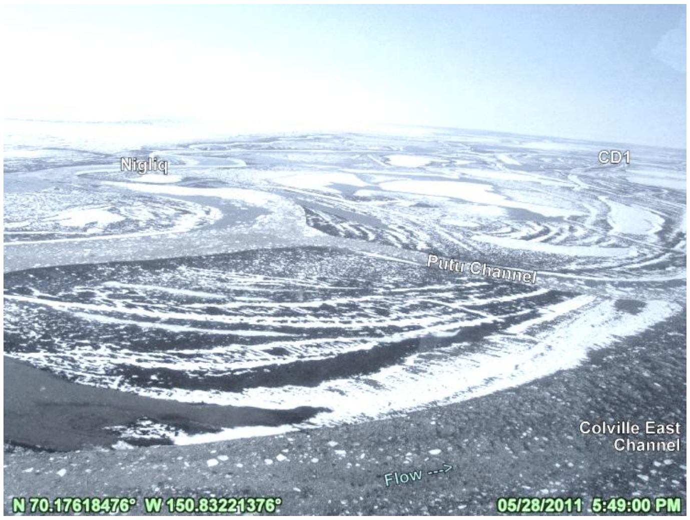


PHOTO 4.107: FLOES MOVING DOWNSTREAM INTO THE NIGLIQ CHANNEL AS THE RESULT OF AN ICE JAM RELEASE UPSTREAM OF MON1; MAY 28, 2011

PHOTO 4.108: ICE JAM IN NIGLIQ NEAR NUIQSUT, LOOKING SOUTH; MAY 29, 2011

PHOTO 4.109: RIBBON ICE IN NIGLIQ, LOOKING DOWNSTREAM (NORTHWEST); MAY 29, 2011

The ice jam near Nuiqsut was still in place on May 29 (Photo 4.108). Ribbon ice was intact in majority of the Nigliq Channel (Photo 4.109) and there were very few ice floes. By that time, Lake L9341 was connected with the Nigliagvik at the southeast end, where flow was entering and moving downstream into the Nigliq Channel.

PHOTO 4.110: PEAK STAGE AT G21 IN THE NIGLIQ AND G22 AT LAKE L9341, LOOKING UPSTREAM (SOUTHWEST); MAY 30, 2011

PHOTO 4.111: PEAK STAGE AT G23 IN THE NIGLIAGVIK, LOOKING SOUTHEAST; MAY 30, 2011

Peak stage at all proposed CD5 road crossing locations occurred on May 30, in the afternoon at G21 (9.89 feet BPMSL) and in the evening at G22 (9.50 feet BPMSL) and G23 (8.78 feet BPMSL). Peak stage at all locations was likely the result of the ice jam in the Nigliq Channel near Nuiqsut releasing earlier in the day. The quick rise in stage as the surge of water moved downstream is apparent in the hydrograph for G21 (Table 4.18). Ribbon ice in the Nigliq Channel began to break up and move downstream on May 30 (Photo 4.110). Photo 4.111 shows G23 in the Nigliagvik a few hours before peak stage.

After May 30, stage receded quickly in the Nigliq, Lake L9341, and the Nigliagvik (Photo 4.112, Photo 4.113, and Photo 4.114, respectively). Daily monitoring ended at all proposed CD5 road crossing locations on May 31. At that time, the Nigliq Channel in the vicinity of G21 was fairly clear of ice and snow, although occasional floes were observed. Ice remained on Lake L9341, which was still connected to the Nigliq Channel to the northwest. There was significant ice and snow in the Nigliagvik in the vicinity of G23, the majority along the steeper and higher left (west) bank.

WSE data and observations for G21 (Nigliq Channel), G22 (Lake L9341), and G23 (Nigliagvik) are presented in Table 4.18, Table 4.19, and Table 4.20, respectively.

PHOTO 4.112: G21 IN THE NIGLIQ AS BREAKUP FLOWS RECEDE, LOOKING NORTHWEST; MAY 31, 2011

PHOTO 4.113: G22 AT LAKE L9341 AS BREAKUP FLOWS RECEDE, LOOKING EAST; MAY 31, 2011

PHOTO 4.114: G23 IN THE NIGLIAGVIK AS BREAKUP FLOWS RECEDE, LOOKING DOWNSTREAM (NORTH); MAY 31, 2011

TABLE 4.18: WATER SURFACE ELEVATION DATA FOR G21 (NIGLIQ)

Date and Time	WSE (feet BPMSL)	Observations
	G21	
5/25/11 4:35PM	-	Leading edge past; no water on gage
5/27/11 2:50 PM	7.92	Ribbon ice in channel, no floes
5/28/11 2:50 PM	9.08	
5/30/11 12:55 PM	9.85	Ribbon ice in channel, occasional floes
5/30/11 1:30 PM	**9.89**	**Peak Stage** based on HWM, time estimated
5/31/11 10:48 AM	7.34	Nigliq Channel ice-free

Notes:

1. Elevations are based on CP08-11-53A at 7.787 feet BPMSL, surveyed by LCMF in 2008.

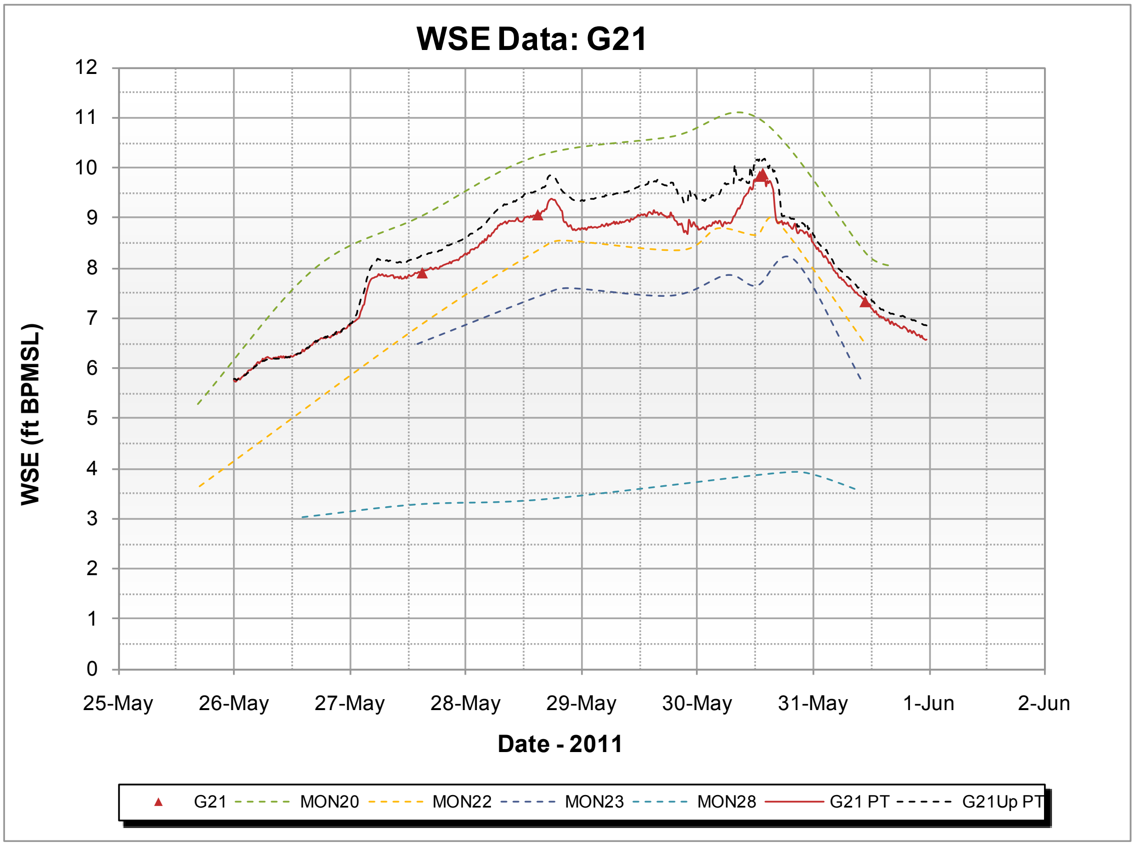


TABLE 4.19: WATER SURFACE ELEVATION DATA FOR G22 (LAKE L9341)

Date and Time	WSE (feet BPMSL)	Observations
	G22	
5/28/11 2:55 PM	7.97	L9341 recharging from Nigliq Channel via north outlet, previously local melt
5/29/11 6:00 PM	-	L9341 connected to Nigliagvik south and Nigliq north
5/30/11 1:02 PM	9.38	
5/30/11 6:00 PM	**9.50**	**Peak Stage** based on HWM, time estimated
5/31/11 10:35 AM	7.18	L9341 still connected to Nigliq north

Notes:

1. Elevations are based on CP08-11-64A at 12.305 feet BPMSL, surveyed by LCMF in 2008.

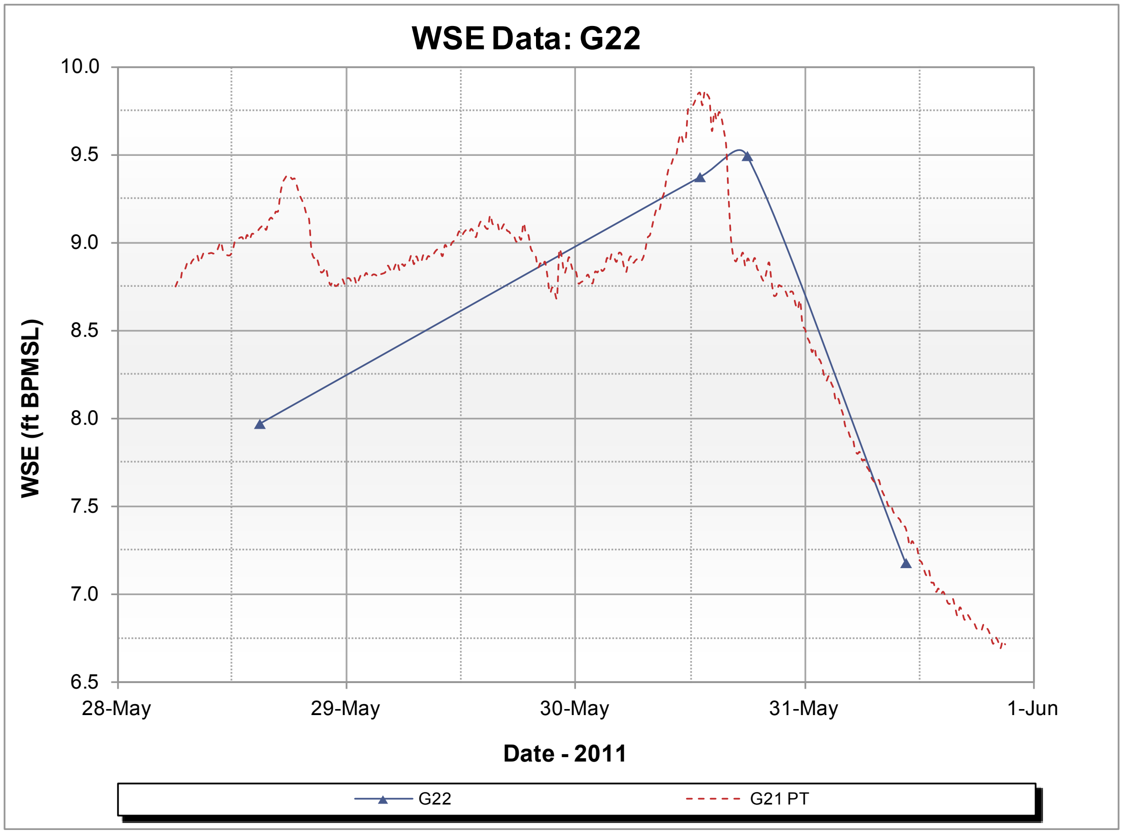
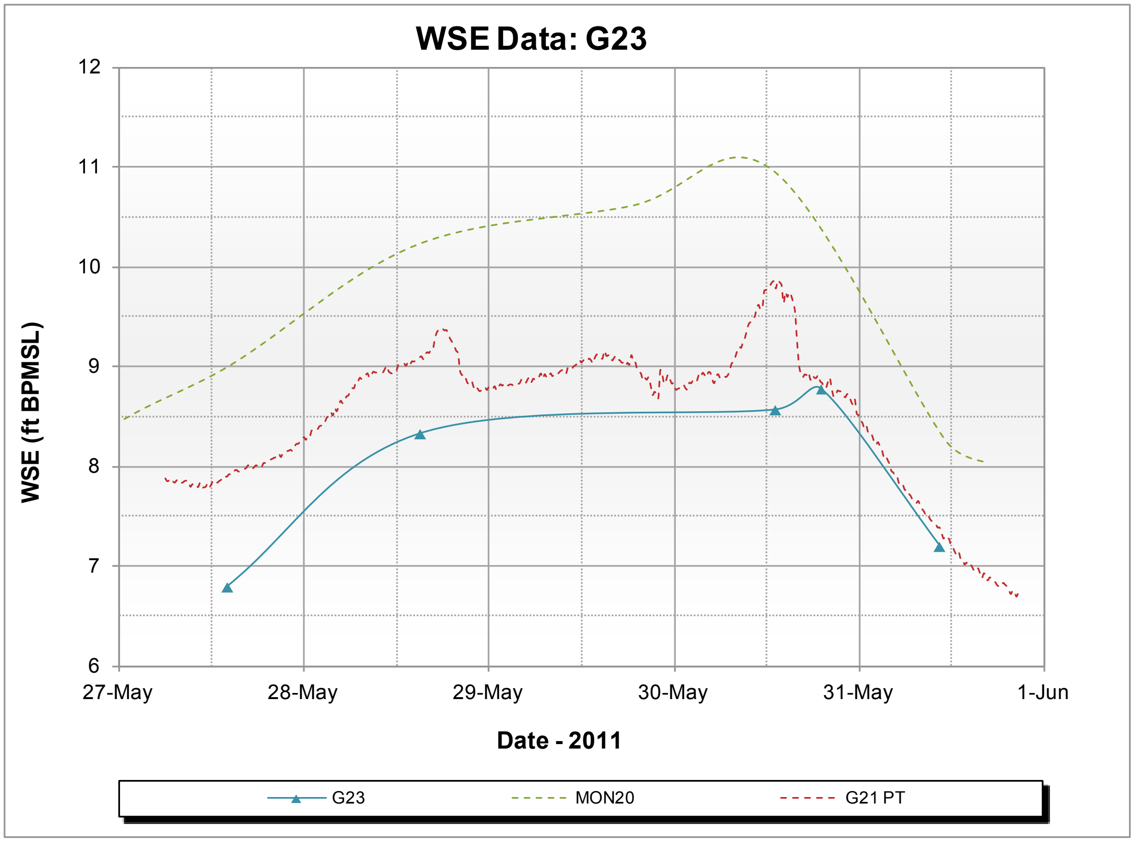


TABLE 4.20: WATER SURFACE ELEVATION DATA FOR G23 (NIGLIAGVIK)

Date and Time	WSE (feet BPMSL)	Observations
	G23	
5/27/11 2:05 PM	6.79	Flow downstream through entire channel from upstream Nigliq bifurcation
5/28/11 3:05 PM	8.33	Channel ice present
5/30/11 1:08 PM	8.57	
5/30/11 7:00 PM	**8.78**	**Peak Stage** based on HWM, time estimated
5/31/11 10:25 AM	7.20	Some floes in channel; significant snow along left bank

Notes:

1. Elevations are based on CP08-11-66C at 10.418 feet BPMSL, surveyed by LCMF in 2008.



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5.0 2011 DISCHARGE

Direct discharge measurements were made at the 452-foot swale bridge, the 62-foot swale bridge, and Monument 1. Direct discharge measurements were not performed at the CD2 and CD4 access road culverts in 2011 because of logistics related to the timing of peak stage at MON1. Indirect calculations were performed for MON1, MON9, and MON23; for the proposed CD5 bridge crossing location at Nigliq Channel (G21); for both swale bridges; for the CD2 road culverts near gages G6-G7, G12-G13 and G3-G4; and the CD4 road culverts near gages G15-G16 and G17-G18.

In open-channel conditions, peak discharge typically occurs at the same time as peak stage. This is not always the case in Arctic locations, which experience major annual flooding events during spring breakup, when flow is affected by ice and snow conditions. This often produces backwater effects, which can temporarily inflate stage or, conversely, reduce stage and velocity to quantities that are not representative of actual discharge.

5.1 MON1 DISCHARGE

5.1.1 DIRECT DISCHARGE

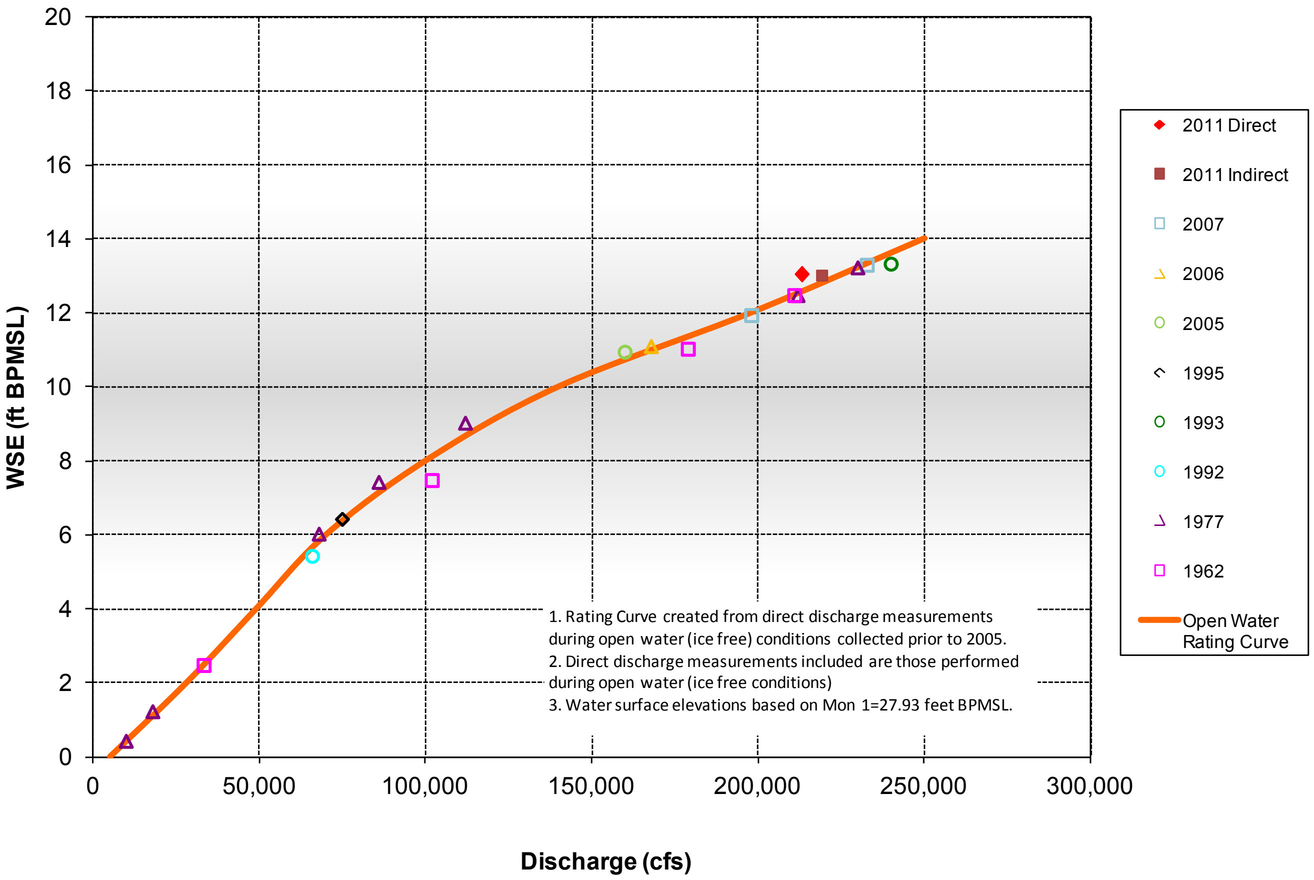
On May 29 and June 1, direct discharge measurements were conducted on the Colville River at MON1 using standard ADCP techniques. Ice floes along the right bank inhibited a complete measurement of the entire channel on May 29. The resulting discharge measurement was considered to be inaccurate and not suitable for publication. By June 1, the channel was predominantly clear of ice, and a complete discharge measurement was performed. The corrected discharge, accounting for the moving bed condition, was approximately 213,000 cfs, having an average velocity of 4.4 feet per second (fps) with a maximum measured velocity of 11.5 fps, with an associated stage of 13.05 feet. A summary of uncorrected direct discharge measurements and the WinRiverII output for each transect are presented in Appendix B. Figure 5.1 shows the location of the discharge measurement and the cross-sectional geometry at the MON1 gage locations.

Four transects and one loop test were completed during the direct-discharge measurement. A moving bed was noted and direct discharges were adjusted accordingly. Accurate measurements could not be completed prior to June 1 due to the presence of ice along the eastern bank of the Colville River, weather constraints such as wind and fog, and the presence of large ice floes in the MON1 reach. Unlike past years, a RD Instruments RiverRay unit was used in lieu of a Rio Grande Sentinel. The RiverRay did not perform as well as the Sentinel had in past measurements. This is likely due to the high sediment load in the water column. Approximately 63 percent of the channel cross section was measured by the RiverRay, which is a greater area than would be captured with standard methods. As a check, an indirect discharge calculation was also completed for the Colville at MON1, using WSE collected at the time of the direct discharge measurement. Indirect calculations yield a discharge of 219,000 cfs, approximately three percent higher than the direct discharge measurement.

Bedform
A depositional feature on the bed of a river (fluvial processes) or other body of flowing water that is formed by the movement of the bed material due to the flow

Direct and indirect discharges are plotted against the MON1 stage-discharge rating curve in Graph 5.3. Both direct and indirect discharges plot off the rating curve

by -5 percent and -2 percent of the rating discharge, respectively. The shift is likely due to sediment deposition in the channel resulting from low flow velocities. Sediment deposition can change the bedform geometry, affecting indirect calculations and changing the relationship between stage and discharge of the rating curve. The direct discharge measurement is considered to be good based on site conditions and its relationship to the rating curve and indirect discharge estimate.



1. Rating Curve created from direct discharge measurements during open water (ice free) conditions collected prior to 2005.
2. Direct discharge measurements included are those performed during open water (ice free conditions)
3. Water surface elevations based on Mon 1=27.93 feet BPMSL.

GRAPH 5.1: MON1 STAGE-DISCHARGE RATING CURVE WITH DIRECT DISCHARGE

5.1.2 INDIRECT DISCHARGE

The slope-area method for a UC and NUC was used to calculate the indirect discharge at MON1. This method calculates indirect discharge based on the energy grade-line slope approximated using the water surface slope as measured by the gages and pressure transducers at MON1U, MON1C, and MON1D; the WSE at MON1C at the time of estimated peak discharge; and the 2004 topographic survey data provided by UMIAQ (Figure 5.1). Changes in bedform geometry are likely to have occurred since the 2004 cross sections were surveyed. This can introduce error and can skew indirect discharge calculations. It would be beneficial to update the topographic surveys in 2012, as the channel bed morphology and cross sections have likely changed in the seven years since this data was last collected.

The most accurate peak indirect discharge values would be calculated at or near peak stage, during a time when the channel is relatively ice-free and with current-year channel topographic cross-sections. Under ideal open channel conditions, peak discharge would coincide with peak stage. Discharge in the CRD

during spring break up is typically ice affected, so these two events will not necessarily occur simultaneously. At the time of peak stage at MON1C (19.56 feet BPMSL at approximately 5:30 p.m. on May 28), discharge conditions were heavily influenced by the release of ice jams just upstream of MON1U (Photo 5.1 and Photo 5.2). On May 29 at approximately 4:00 p.m., the ice jam had moved to the Nigliq Channel near Nuiqsut and down the East Channel in the vicinity of MON9 near the horizontal directional drilled (HDD) crossing. This resulted in a second peak in the WSE for MON1. Ice jamming can cause significant backwater effects that are not accounted for when using UC and NUC calculation methods.

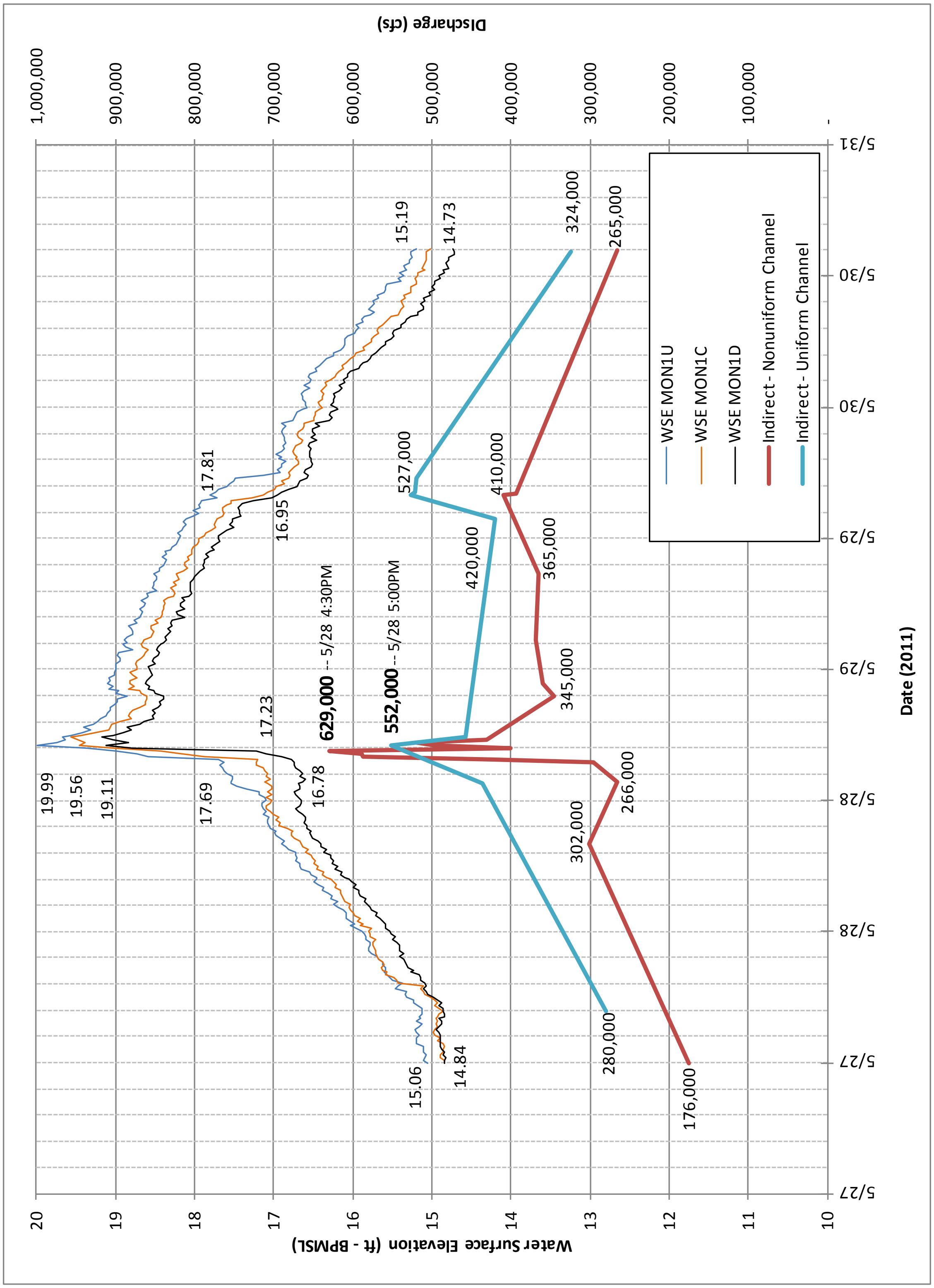
Photo 5.1: Ribbon ice and ice jam just downstream of MON1, looking downstream (north); May 28, 2011

Photo 5.2: Aerial photo of ice jam upstream of MON1; May 27, 2011

Both UC and NUC methods were used to calculate discharge to determine an accurate value of the peak discharge surge that occurred after the ice jam released upstream of MON1 on May 28. Both methods are considered to yield conservative results and are performed assuming an ice-free channel. Graph 5.2 presents the calculated indirect discharge values using the UC and NUC methods plotted versus time. The WSEs recorded by the PTs at 15-minute intervals for the three MON1 locations are plotted in Graph 5.2 as a reference.

The peak NUC discharge was 629,000 cfs on May 28 at approximately 4:30 p.m., with a WSE of 18.42 feet BPMSL. The peak UC discharge value was 552,000 cfs on May 28 at approximately 5:00 p.m., with a WSE of 19.56 feet BPMSL. The difference between the UC and NUC value is 13 percent. Averaging the maximum values from both methods results in a peak discharge at MON1 of 590,000 cfs.

GRAPH 5.2: 2011 MON1 WATER SURFACE ELEVATION AND INDIRECT DISCHARGE



ConocoPhillips
Alaska

Date:	01/24/2012	Project:	123684
Drawn:	BTG	File:	Figure 5.1
Checked:	SME	Scale:	1 in = .5 miles

Legend

●	Gage Locations
─┼─	2004 Cross Section Alignment

Baker

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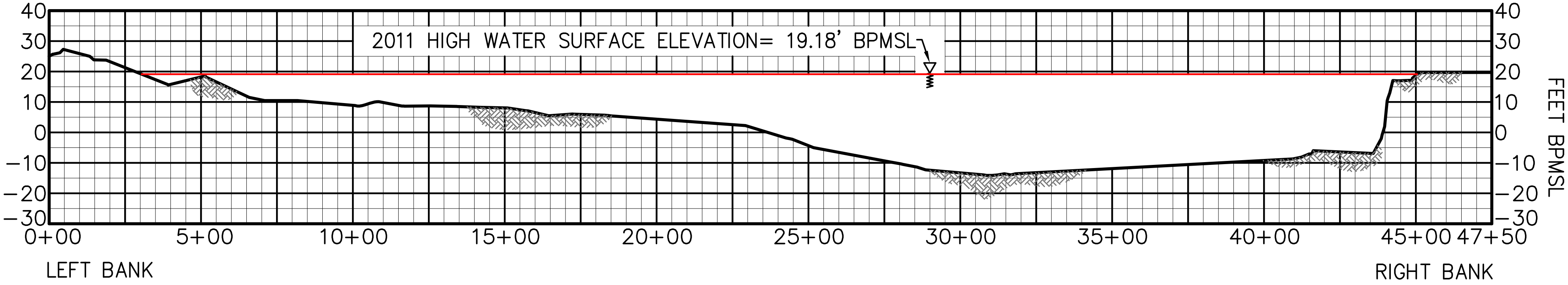
2011 SPRING BREAKUP
MONUMENT 1

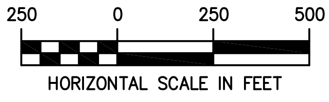
FIGURE: 5.1

(SHEET 1 of 4)

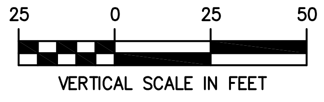
NOTES
1. BASIS OF ELEVATION, MONUMENT 1.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY KUUKPIK/LCMF INC.



1D COLVILLE RIVER CROSS SECTION AT MONUMENT 1 DOWNSTREAM



HORIZONTAL SCALE IN FEET



VERTICAL SCALE IN FEET

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DATE:	1/25/12	PROJECT:	123684
DRAWN:	EJK	FILE:	FIGURE 5.1_2.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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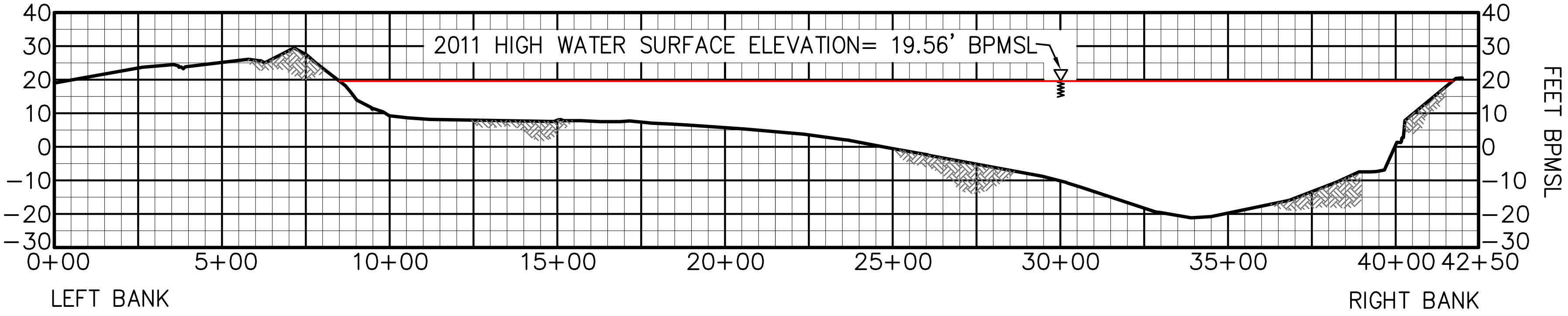
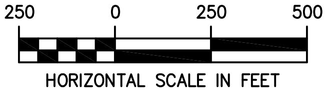
2011 SPRING BREAKUP
MONUMENT 1 DOWNSTREAM
2004 CROSS SECTION

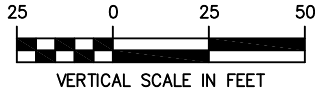
FIGURE 5.1
(SHEET 2 OF 4)

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



1C COLVILLE RIVER CROSS SECTION AT MONUMENT 1 CENTERLINE





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Alaska, Inc.

DATE:	1/25/12	PROJECT:	123684
DRAWN:	EJK	FILE:	FIGURE 5.1_2.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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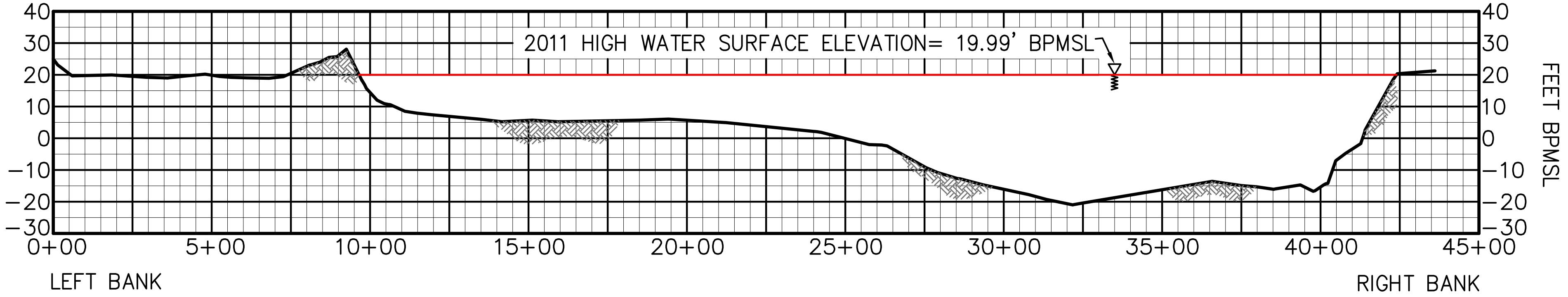
2011 SPRING BREAKUP
MONUMENT 1 CENTERLINE
2004 CROSS SECTION

FIGURE 5.1
(SHEET 3 OF 4)

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



1U COLVILLE RIVER CROSS SECTION AT MONUMENT 1 UPSTREAM

250 0 250 500
HORIZONTAL SCALE IN FEET

25 0 25 50
VERTICAL SCALE IN FEET

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DATE:	1/25/12	PROJECT:	123684
DRAWN:	EJK	FILE:	FIGURE 5.1_2.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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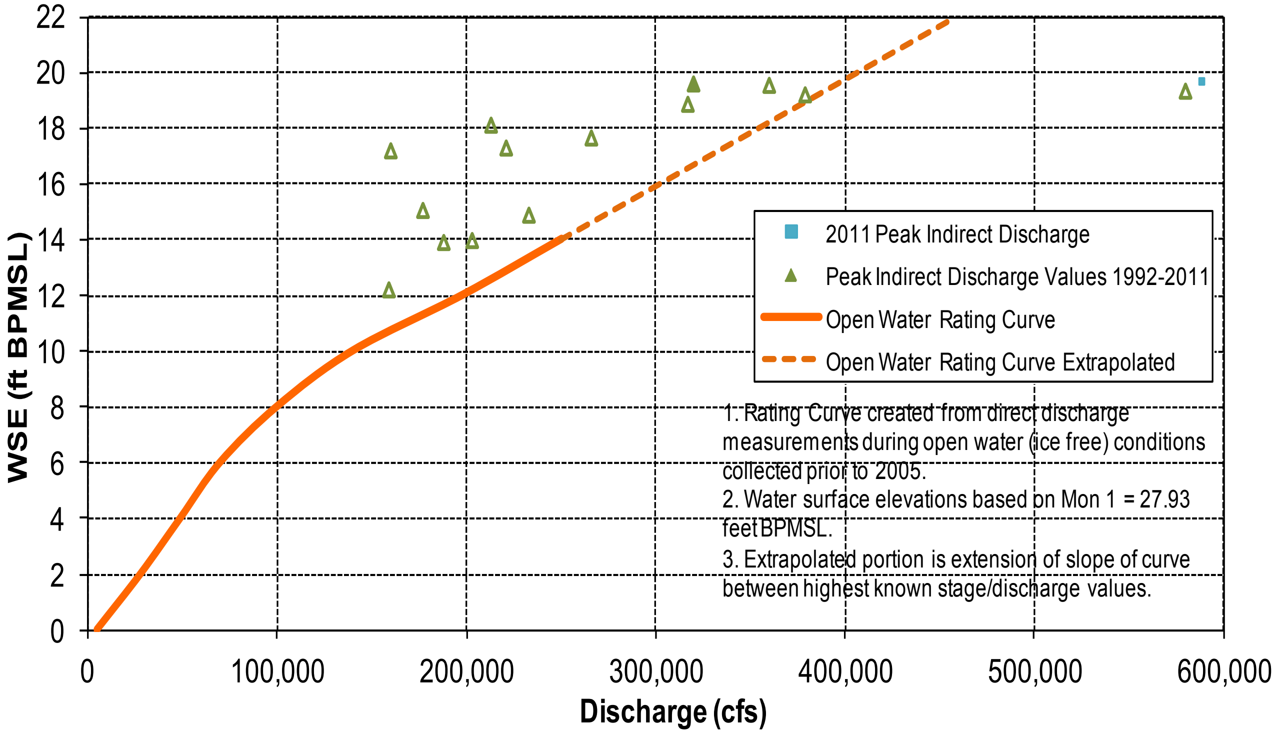
2011 SPRING BREAKUP
MONUMENT 1 UPSTREAM
2004 CROSS SECTION

FIGURE 5.1
(SHEET 4 OF 4)

The MON1 stage-discharge rating curve, provided in Graph 5.3, represents a comparison between known stage and peak indirect discharge measurements collected between 1992 and 2011. It was calculated using ice-free conditions. These values generally represent the relationship between stage and discharge at lower stage values when ice-free direct discharge measurements are possible. The stage-discharge rating curve may be used as a basis of comparison for accuracy of indirect discharge calculated values. The limitations of this curve are the ice effects on stage and discharge common during peak-flow periods. Open-water conditions rarely occur at or near recorded historical peak stage levels during breakup. In Appendix D, an additional rating curve is shown to compare both ice-affected and non-ice-affected direct discharge measurements to historical peak indirect discharge values at MON1.



1. Rating Curve created from direct discharge measurements during open water (ice free) conditions collected prior to 2005.
2. Water surface elevations based on Mon 1 = 27.93 feet BPMSL.
3. Extrapolated portion is extension of slope of curve between highest known stage/discharge values.

GRAPH 5.3: MON1 STAGE-DISCHARGE RATING CURVE WITH INDIRECT DISCHARGE

To plot 2011 stage-discharge values to the rating curve in Graph 5.3, the rating curve was extrapolated beyond known values (those values at lower stage-discharge periods). For the purpose of extrapolation, the slope is based on the highest known values. This section of the curve is used as a general reference only.

5.2 MON9 DISCHARGE

5.2.1 INDIRECT DISCHARGE

The slope-area method was used to calculate the indirect discharge at MON9. Discharge was calculated using the energy grade-line slope as approximated by the water surface slope from MON9 or MON9-PT to a pressure transducer MON9D-PT, WSE at MON9, and the 2009 UMIAQ topographic channel cross-sectional survey.

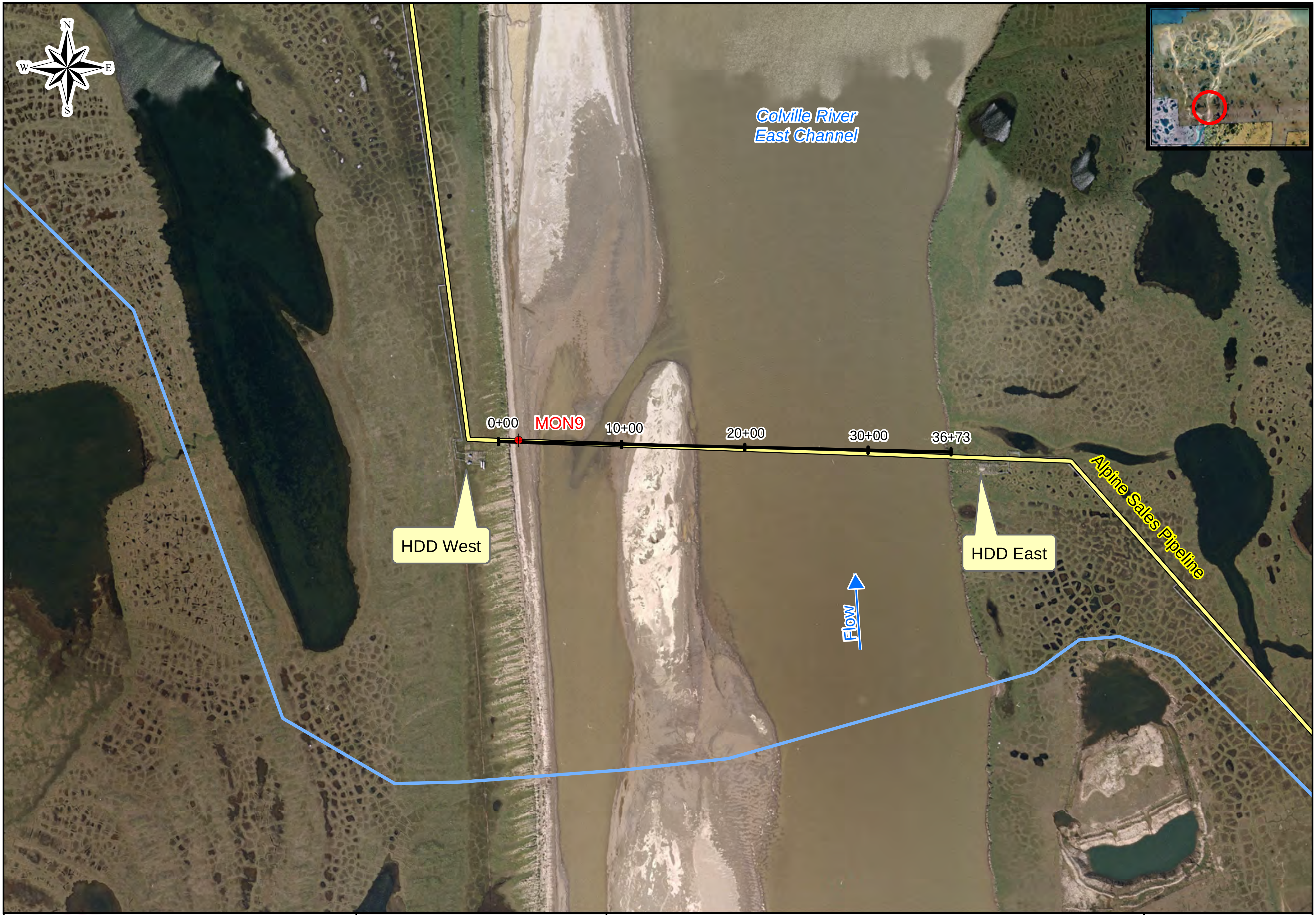
Location and cross-section of the area is presented in Figure 5.2. Indirect discharge calculations were performed assuming an ice-free channel and are considered to be a conservative estimate, due to the likelihood of persistent bottom-fast ice remaining in-channel and changes to the channel bed due to sediment transport. The assumptions are based on the presence and dimensions of in-channel ice, if ice remains in the channel.

Flow in the East Channel during 2011 breakup was influenced by ice, as shown in (Photo 5.3). Photo 5.4 shows the East Channel near MON9 becoming more ice free by May 31, 2011.

PHOTO 5.3: RIBBON ICE NEAR MON9, LOOKING DOWNSTREAM (NORTHWEST); MAY 28, 2011

PHOTO 5.4: MON9 LOOKING EAST; MAY 31, 2011

Calculated indirect peak discharge at MON9 was based on observations made in the afternoon of May 28. Peak discharge occurred approximately nine hours prior to the estimated peak stage at MON9 with a WSE of 12.02 feet BPMSL. Peak discharge was influenced by the ice jam release above MON1 on May 28. This resulted in the formation of ice jams in the Nigliq near Nuiqsut, which pushed flow into the Putu Channel and out into the East Channel just upstream of MON9. The resulting peak discharge was approximately 307,000 cfs at MON9, with a corresponding WSE of 9.81 feet BPMSL.



ConocoPhillips
Alaska

Feet
0 500 1,000

Date:	09/30/2011	Project:	123684
Drawn:	BTG	File:	Figure 5.2
Checked:	SME	Scale:	1 in = 1000 feet

Legend

- ● Gage Location
- ┼ 2003 Cross Section Alignment
- ━ Ice Road
- ═ Pipeline

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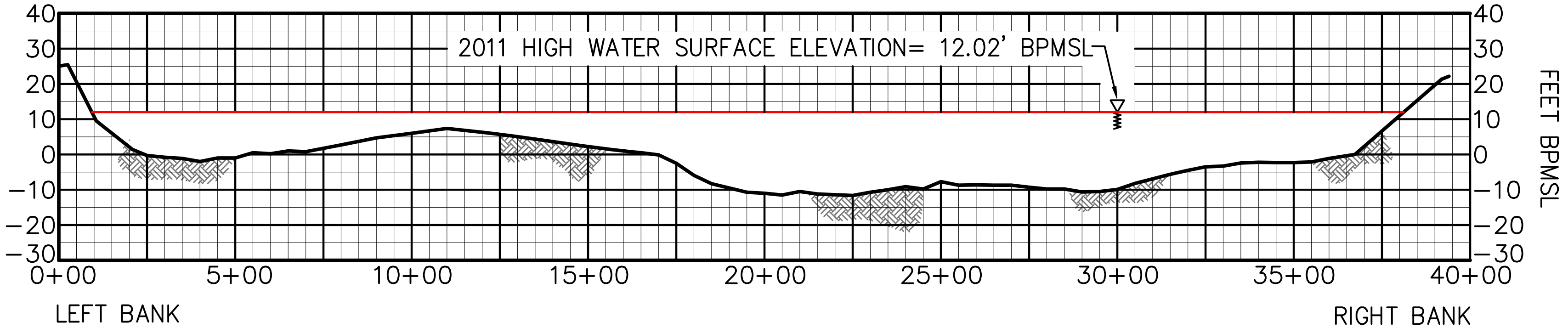
2011 SPRING BREAKUP
Monument 9
HDD Crossing

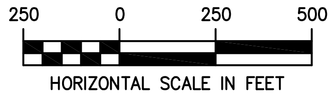
FIGURE: 5.2

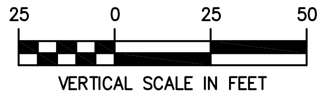
(SHEET 1 of 2)

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



① COLVILLE RIVER CROSS SECTION AT MONUMENT 9





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DATE:	1/25/12	PROJECT:	123684
DRAWN:	SMC	FILE:	FIGURE 5.2_2.DWG
CHECKED:	SME	SCALE:	AS SHOWN

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2011 SPRING BREAKUP
MONUMENT 9
2009 CROSS SECTION
FIGURE 5.2
(SHEET 2 OF 2)

5.3 MON23 DISCHARGE

5.3.1 INDIRECT DISCHARGE

Bottom-Fast Ice
Ice that is attached to the channel bed and may remain below the water surface during flooding events. It is synonymous with anchor ice.

The slope-area method was used to calculate the indirect discharge at MON23. The discharge was calculated using the energy grade-line slope as approximated by the water surface slope from MON22 to MON23, the WSE at MON23, and the 2005 UMIAQ topographic channel cross-sectional survey. Location and cross section of the area is presented in Figure 5.3. It would be beneficial to update the topographic channel cross-section survey at MON23 for future indirect calculations.

As stated, indirect discharge calculations are performed assuming an ice-free channel and are to be considered a conservative estimate. Flow in the Nigliq Channel during the 2011 breakup was influenced by ice, as shown in Photo 5.5 and Photo 5.6.

PHOTO 5.5: RIBBON ICE NEAR MON23, LOOKING DOWNSTREAM (NORTH); MAY 25, 2011

PHOTO 5.7: OCCASIONAL ICE FLOES IN NIGLIQ, LOOKING WEST; MAY 31, 2011

PHOTO 5.6: GROUNDED ICE AT MON23; MAY 31, 2011

While peak stage at MON23 occurred on May 30, significant ribbon ice was observed in the channel from May 27 until May 30. A large ice jam formed in the Nigliq Channel from floes originating in the Colville River on May 29. The ice jam eventually cleared past MON23 around May 31, resulting in a series of jam and release events as the obstructions moved downstream. The Nigliq Channel became largely ice free around May 31.

Calculated indirect peak discharge at MON23 was based on observations made in the afternoon of May 30. Peak discharge occurred approximately eight hours prior to the estimated peak stage at MON23 (8.15 feet BPMSL). Resulting peak discharge was approximately 65,000 cfs at MON23 with a corresponding WSE of 7.64 feet BPMSL. A historical record of peak discharge at MON23 is presented in Table 5.1.

Table 5.1: Nigliq Channel Breakup Peak Annual Discharge and Stage (2005 – 2011)

Year	Monument 23 Peak Discharge (cfs)			Monument 23 Peak Water Surface Elevation (feet-BPMSL)	
	Discharge	Method	Reference	Mon 23	Reference
2011	65,000	Indirect Calculation	This Report	8.15	This Report
2010	65,000	Indirect Calculation	Baker 2010	7.77	Baker 2010
2009	59,000	Indirect Calculation	Baker 2009	7.09	Baker 2009
2008	21,500	Indirect Calculation	Baker 2008	5.79	Baker 2008
2007	73,500	Indirect Calculation	Baker 2007b	7.63	Baker 2007b
2006	68,000	Indirect Calculation	Baker 2007a	8.99	Baker 2007a
2005	29,000	ADCP Measurement	Baker 2005b	5.95	Baker 2005b

ConocoPhillips
Alaska

0 500 1,000 Feet

Date:	01/24/2012	Project:	123684
Drawn:	BTG	File:	Figure 5.3
Checked:	SME	Scale:	1 in = 1000 feet

Legend

- ● Gage Locations
- ┼ 2005 Cross Section Alignment
- ▭ Pipelines
- ▨ Facilities

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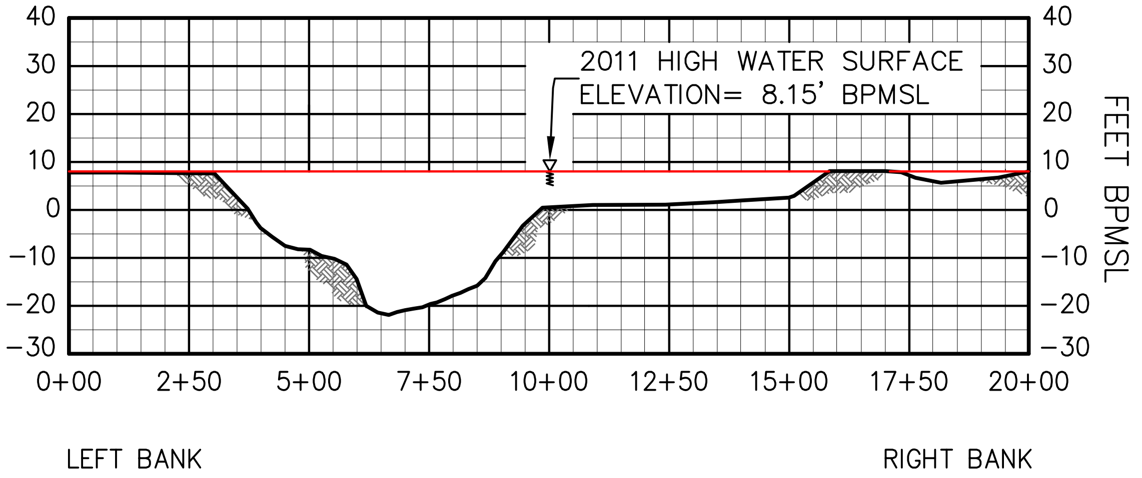
2011 SPRING BREAKUP
MONUMENT 23
PLAN

FIGURE: 5.3

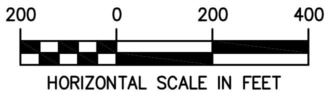
(SHEET 1 of 2)

NOTES

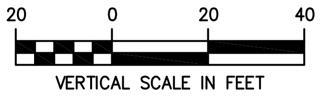
1. BASIS OF ELEVATION, MONUMENT 23.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2005 BY KUUKPIK/LCMF INC.



① MONUMENT 23 CROSS SECTION



HORIZONTAL SCALE IN FEET



VERTICAL SCALE IN FEET

ConocoPhillips
Alaska, Inc.

DATE:	1/25/12	PROJECT:	123684
DRAWN:	EJK	FILE:	FIGURE 5.3_2.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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2011 SPRING BREAKUP
MONUMENT 23
2005 CROSS SECTION

FIGURE 5.3
(SHEET 2 OF 2)

5.4 Proposed CD5 Nigliq Bridge Site Discharge

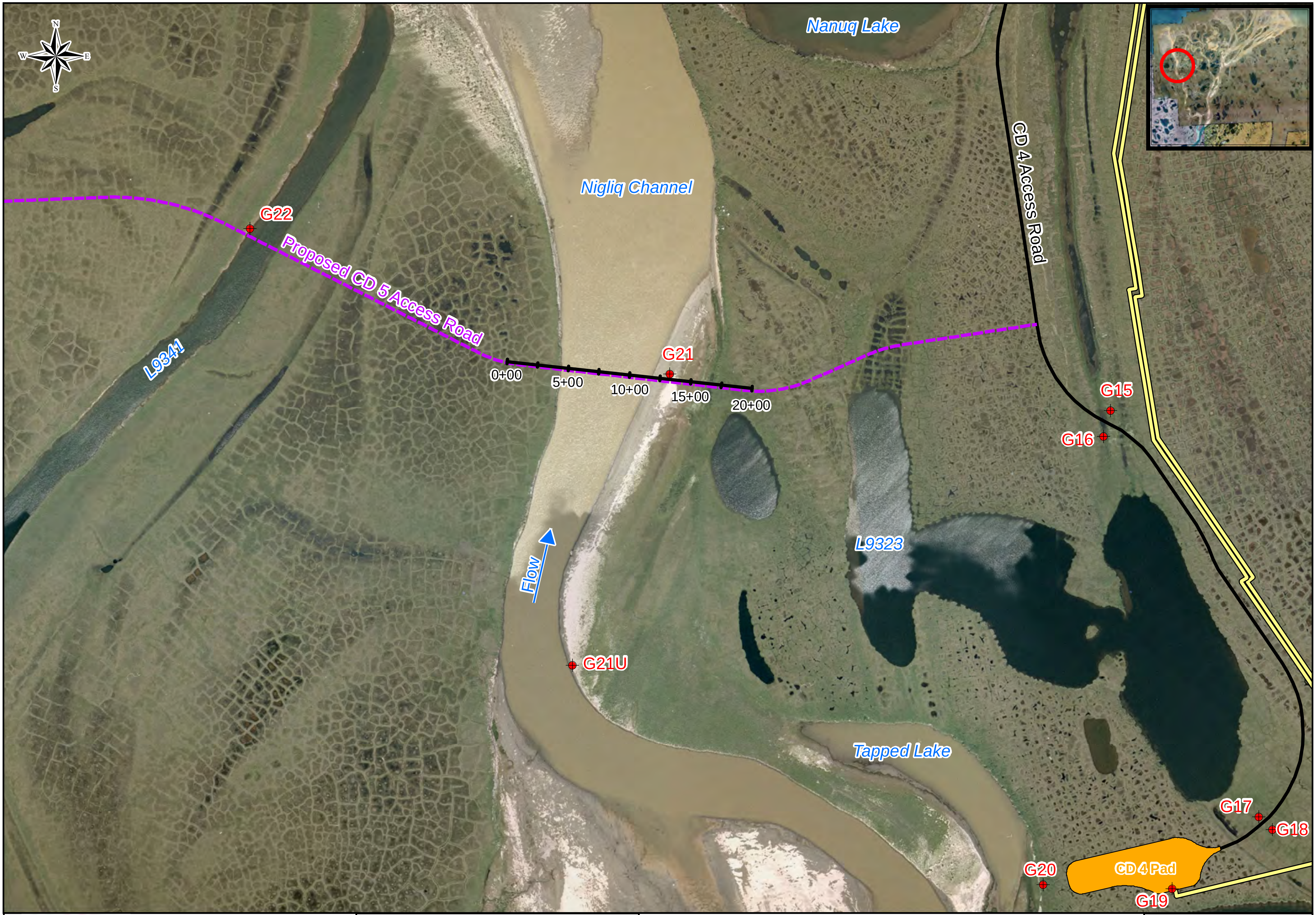
5.4.1 Indirect Discharge

Indirect discharge was calculated using the slope-area method. Discharge was calculated using the energy grade-line slope as approximated by the water surface slope from G21 or G21-PT, to a pressure transducer G21U-PT, WSE at G21, and 2008 UMIAQ topographic channel cross-section survey. Location and cross section of the area is presented in Figure 5.4. Indirect discharge calculations were performed assuming an ice-free channel and are to be considered a conservative estimate.

As discussed in Section 5.1, flow in the Nigliq Channel was affected by ice during the 2011 breakup (Photo 5.8). A comparison of the estimated indirect discharge values over time at MON23, located 3.4 RM downstream of G21, suggests that ice events were significant in the Nigliq Channel but did not equally affect both locations. The different magnitudes of ice effects at the two locations is due to ice jam proximity, loss of channelized flow downstream of G21 to overbank areas, and location of the majority of ice jam events occurring upstream of the proposed bridge crossing location.

Peak discharge at G21 was estimated to have occurred in the morning of May 30, an estimated six hours prior to peak stage at G21 (WSE of 9.89 feet BPMSL). Peak discharge was 141,000 cfs at G21, with a corresponding WSE of 9.05 feet BPMSL.

Photo 5.8: Ice jam in Nigliq near G21 and G22, looking upstream; May 30, 2011



ConocoPhillips
Alaska

Feet
0 500 1,000

Date:	09/30/2011	Project:	123684
Drawn:	BTG	File:	Figure 5.4
Checked:	SME	Scale:	1 in = 1000 feet

Legend

● Gage Locations	▬ Existing Roads
┼ 2003 Cross Section Alignment	┅ Proposed Roads
═ Pipelines	🟧 Facilities

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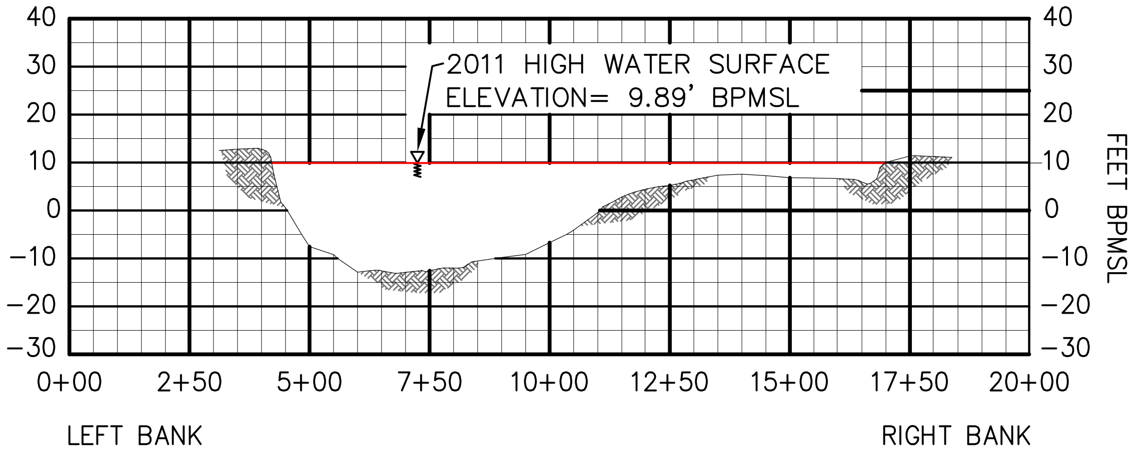
2011 SPRING BREAKUP
Gage 21
Nigliq Channel Plan

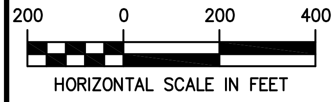
FIGURE: 5.4

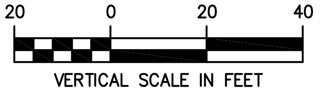
(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, TBM CP-08-11-53A.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2003 BY KUUKPIK/LCMF INC.



① GAGE 21 CROSS SECTION





ConocoPhillips
Alaska, Inc.

DATE:	1/25/12	PROJECT:	123684
DRAWN:	EJK	FILE:	FIGURE 5.4_1.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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2011 SPRING BREAKUP
GAGE 21
NIGLIQ CHANNEL PROFILE
FIGURE 5.4
(SHEET 2 OF 2)

5.5 Alpine Swale Bridges Discharge

5.5.1 Direct Discharge

Two direct discharge measurements were conducted at the 452-foot swale bridge. The resulting discharge and velocity values from the measurement performed on May 29, 2011, 3,970 cfs with an average velocity of 1.96 fps, were higher than those of the second measurement taken on June 1, 649 cfs with an average velocity of 0.82 fps, as flood flow was receding. The bridge was clear of ice and snow underneath during both measurements.

Photo 5.9: Discharge measurement at the 452-foot swale bridge; May 29, 2011

Photo 5.10: Conditions around facilities near the 452-foot swale bridge, looking southwest; May 29, 2011

There was some snow piled at the left (west) abutment on the upstream (south) side and occasional grounded ice floes in the area, neither of which were considered to significantly affect the measurement, which was rated as "good to fair," based on channel conditions (Photo 5.9 and Photo 5.10).

Two direct discharge measurements were conducted at the 62-foot swale bridge. Photo 5.11 shows preparation for the discharge measurement at the short swale bridge. The resulting discharge and velocity values from the measurement performed on May 28, 2011, 840 cfs, with 2.51 fps average velocity, were higher than those of the second measurement taken on May 30, 767 cfs, with 2.01 fps average velocity, as flood flows were receding. The bridge was approximately 90 percent clear of ice and snow on May 29; some snow remained at the left (west) downstream (north) abutment. Occasional ice floes passing through the area did not significantly affect the measurement. The measurement was rated as "fair," based on channel conditions (Photo 5.12 and Photo 5.13).

PHOTO 5.11: PREPARING FOR THE DISCHARGE MEASUREMENT AT THE 62-FOOT SWALE BRIDGE; MAY 28, 2011

PHOTO 5.12: SNOW AT THE NORTHWEST ABUTMENT OF THE 62-FOOT SWALE BRIDGE; MAY 28, 2011

PHOTO 5.13: CONDITIONS AT FACILITIES NEAR THE SHORT SWALE BRIDGE, LOOKING WEST; MAY 28, 2011

A summary of the 2011 direct discharge measurements at both bridges is presented in Table 5.2, which includes a summary of historical discharge measurements.

Complete notes for all direct discharge measurements at both swale bridges are included in Appendix C.

TABLE 5.2: DIRECT DISCHARGE SUMMARY: ALPINE SWALE BRIDGES (2000 – 2011)

Site	Date	WSE[1] (ft)	Width (ft)	Area (ft^2)	Mean Velocity $(ft/s)^2$	Discharge (cfs)	Measurement Rating[3]	Number of Sections	Measurement Type	Reference
62-foot Bridge	**05/28/11**	**8.15**	**52**	**336**	**2.51**	**840**	**F**	**27**	**Cable**	This report
	06/03/10	7.58	55	316	1.79	570	F	28	Cable	Baker 2010
	–[4]	–	–	–	–	–	–	–	–	Baker 2009
	05/29/08	6.35	55	211	0.58	120	P	14	Cable	Baker 2008b
	06/05/07	7.83	55	292	1.18	350	F	20	Cable	Baker 2007b
	05/31/06	8.49	55	615	1.59	980	F	20	Cable	Baker 2007a
	–[4]	–	–	–	–	–	–	–	–	Baker 2005b
	05/29/04	8.34	55	451	1.60	720	F	17	Cable	Baker 2005a
	–[4]	–	–	–	–	–	–	–	–	Baker 2003
	05/25/02	6.74	56.0	283	1.52	430	G	17	Cable	Baker 2002a
	06/11/01	7.64	56	336	1.79	600	G	15	Cable	Baker2001
	06/10/00	7.87	47	175	3.30	580	F	13	Cable	Baker2000
452-foot Bridge	**05/29/11**	**8.16**	**447**	**2027**	**2.22**	**4500**	**F**	**26**	**Cable**	This report
	06/01/10	7.97	441	1699	2.66	4500	G	25	Cable	Baker 2010
	05/26/09	5.89	445	1592	0.82	730	F	27	Wading	Baker 2009
	05/29/08	6.35	445	949	2.03	1930	F	21	Wading	Baker 2008
	06/05/07	7.76	447	1670	0.74	1240	F	20	Cable	Baker 2007b
	05/31/06	8.42	409	1730	1.89	3260	F	29	Cable	Baker 2007a
	06/02/05	6.13	445	841	1.37	1100	G	20	Wading	Baker 2005b
	05/29/04	8.34	446	1700	1.40	2400	F	18	Cable	Baker 2005a
	06/08/03	5.48	444	478	0.88	420	G	16	Wading	Baker 2003
	05/25/02	6.74	445	930	3.47	3200	G	17	Cable	Baker 2002a
	06/11/01	7.64	460	1538	2.4	3700	G	16	Cable	Baker2001
	06/09/00	7.34	437	1220	3.27	4000	F	15	Cable	Baker2000

Notes:

1. Source of WSE is G3.
2. Mean velocities adjusted with angle of flow coefficient
3. Measurement Rating -
    - E - Excellent: 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
4. Bridge obstructed with snow or ice, no measurement made

5.5.2 INDIRECT DISCHARGE

The 2011 peak discharge though the swale bridges is likely to have occurred prior to peak stage and corresponding high-water surface differential, as determined by comparison of G3 (headwater) and G4 (tailwater) readings. The peak stage at G3, 8.89 feet BPMSL, occurred on the night of May 29 (see Table 4.10). The headwater-tailwater differential at that time was 0.30 feet, the sixth-highest G3-G4 differential calculated during monitoring. The highest G3-G4 differential occurred in the morning of May 28, with a value of 0.54 feet.

Peak discharge through the swale bridges was estimated assuming that the measured average adjusted velocity was representative of the average velocity at peak stage. The headwater-tailwater differential for the 452-foot swale bridge at the time of the highest measured velocity was 0.38 feet. The headwater-

tailwater differential for the 62-foot swale bridge at the time of the highest measured velocity was 0.54 feet. The measurement indicates that both the velocity and discharge were likely to have been somewhat lower at peak stage.

Peak discharge was estimated to have been 5,200 cfs through the 452-foot swale bridge and 940 cfs through the 62-foot swale bridge. Table 5.3 summarizes the estimated peak annual discharge data at the Alpine swale bridges between 2000 and 2011.

TABLE 5.3: ESTIMATED PEAK DISCHARGE SUMMARY: ALPINE SWALE BRIDGES (2000 - 2011)

Date & Time[1]	Peak WSE (ft)[2]	452-Foot Bridge		62-Foot Bridge		References
		Discharge (cfs)[3]	Mean Vel (ft/s)	Discharge (cfs)[3]	Mean Vel (ft/s)	
5/29/11 10:00 PM	**8.89**	**5200**	**2.22**	**940**	**2.51**	This report
6/2/10 8:15 AM	8.64	5300	2.66	670	1.79	Baker 2010
5/25/09 1:00 PM	7.63	1400	0.82	–[4]	–[4]	Baker 2009
5/30/08 12:00 PM	6.49	2100	0.49	100	0.58	Baker 2008b
6/5/07 4:00 AM	8.60	1500	1.35	400	1.18	Baker 2007b
5/31/06 3:00 AM	9.72	4400	1.77	1100	1.59	Baker 2007a
5/31/05 8:00 AM	6.48	1400	1.37	–[4]	–[4]	Baker 2005b
5/27/04 1:30 PM	9.97	3400	1.38	900	1.59	Baker 2005a
06/07/2003[5]	6.31	700	0.88	–[4]	–[4]	Baker 2003
05/26/2002[5]	7.59	4000	3.47	500	1.52	Baker 2002a
06/11/2001[5]	7.95	3900	2.40	600	1.79	Baker 2001
06/12/2000[5]	9.48	7100	3.60	1000	4.30	Baker 2000

Notes:
1. Based on HWM, time is estimated
2. Source of WSE is Gage 3
3. Estimated peak discharge
4. Bridge obstructed with snow or ice, no measurement made
5. Unknown time of peak stage

5.6 ALPINE CULVERT DISCHARGE

During the spring breakup of 2011, CD2 and CD4 access road culverts were monitored to assess flow conditions. Peak stage and head differential were measured and peak flow and velocities were calculated using indirect methods to determine the effectiveness of the drainage structures and to comply with monitoring requirements, as outlined in USACE Permit Number POA-2004-253 and the State of Alaska Fish Habitat Permit FH04-III-0238.

Both observed WSE data and measured culvert dimensions are used to perform indirect culvert discharge calculations for a variety of conditions during the course of breakup. The CD2 and CD4 culvert invert elevations were surveyed by UMIAQ in May and June 2011. Culvert length and diameter were obtained using as-built surveys that were performed by UMIAQ in 2002 and 2005, respectively. Figure 5.5 illustrates the locations of the Alpine facilities drainage structures. WSE data for facilities gages are presented in Table 4.9 to Table 4.16.

In September 2008, changes were made to six of the corrugated metal pipe (CMP) culverts, CD2-9 through CD2-14. These culverts were deformed because of road prism loading. The CMPs were retrofitted by inserting circular smooth steel sleeves that were anchored at each end. Five 48-inch-diameter sleeves were installed in the 60-inch-diameter CMPs. One 60-inch-diameter sleeve was inserted into

the 72-inch-diameter CMP. The sleeves reduce some friction losses in the culvert but there is smaller diameter available for conveyance of flow. Also, the smooth sleeves are centered in the CMP and do not extend the full length.

Flow through the road culverts first occurred May 27, 2011. Flow was observed moving generally unobstructed through the 24 CD2 road culverts that were reached by floodwaters. Some blockage resulted from snow and ice, wood debris, and remnant plastic from winter culvert covers. Flood flow was not observed in the vicinity of culverts CD2-17 and CD2-2 during monitoring.

Flow was observed moving through the 28 CD4 road culverts that were reached by floodwaters. There were some obstructions to the flow, and the effects were similar to those at the CD2 road culverts. Flood flow was not observed in the vicinity of culverts CD4-1 through CD4-6 and CD4-15 though CD4-19. Flow obstructions included snow, wood or plastic debris, and deformed culvert sections. Due to lack of direct measurements in 2011 (see discussion at the beginning of Section 5.0), which help quantify the effect obstructions have on flow, these were not considered when calculating discharge values.

Flow through the CD2 culverts was estimated to have stopped late in the evening of May 31 or in the early morning of June 1, when water receded below culvert inverts. Flow through the CD4 culverts was estimated to have stopped in the morning of May 31, when water receded below culvert inverts.

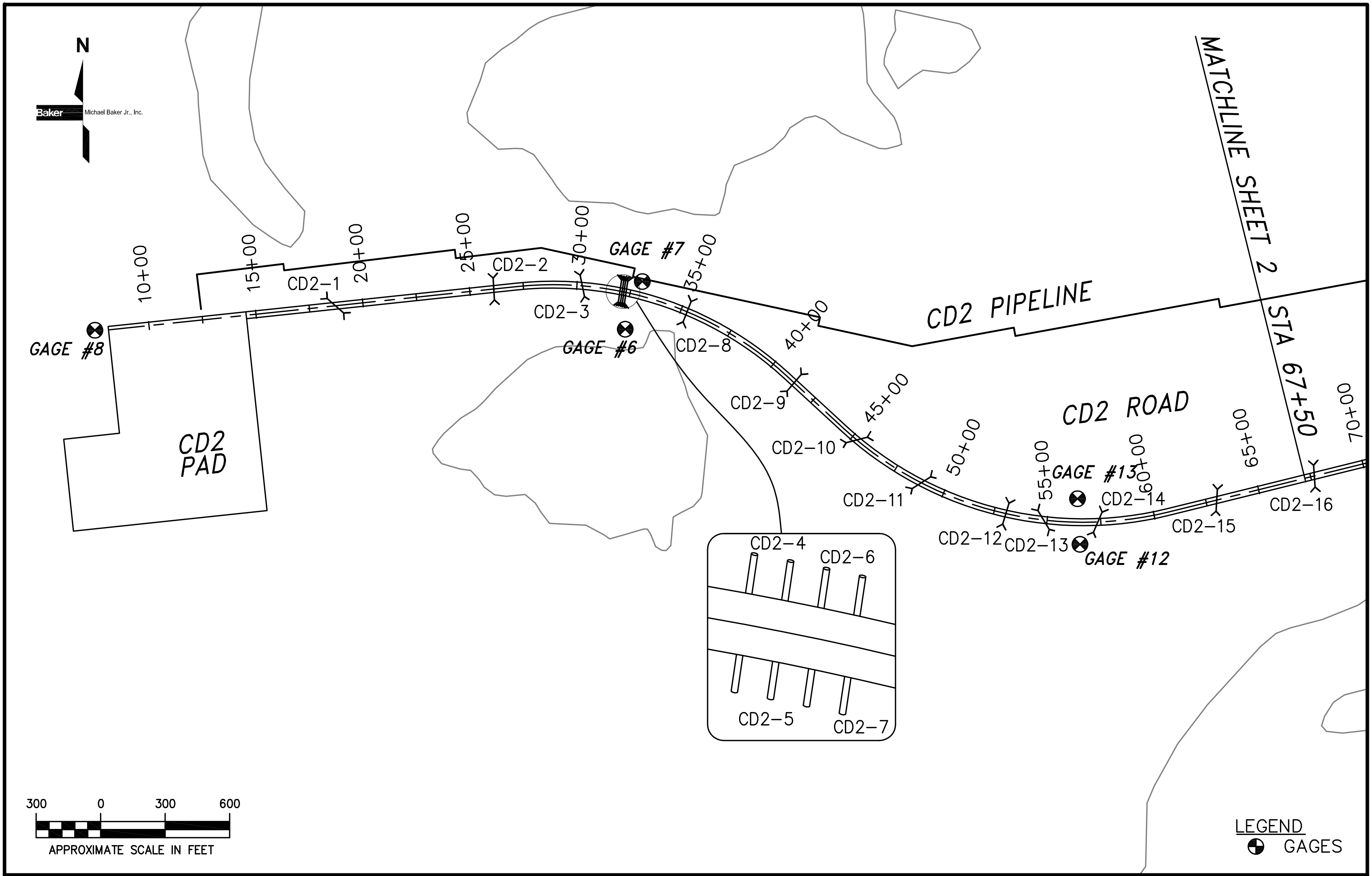
Calculated peak discharge and velocity for the culverts was estimated to have occurred between May 29 and May 30. Photo 5.14 to Photo 5.17 show culverts near G4, G6, G16, and G17 following peak stage.

Photo 5.14: Culverts near G3-G4, tailwater just after peak stage; May 30, 2011

Photo 5.15: Culverts near G6-G7, tailwater just after peak stage; May 30, 2011

PHOTO 5.16: CULVERTS NEAR G15-G16, HEADWATER JUST AFTER PEAK STAGE; MAY 30, 2011

PHOTO 5.17: CULVERTS NEAR G17-G18, TAILWATER JUST AFTER PEAK STAGE; MAY 30, 2011



ConocoPhillips
Alaska, Inc.

DATE:	9/19/11	PROJECT:	123684
DRAWN:	EJK	FILE:	FIGURE 5.5.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

Baker

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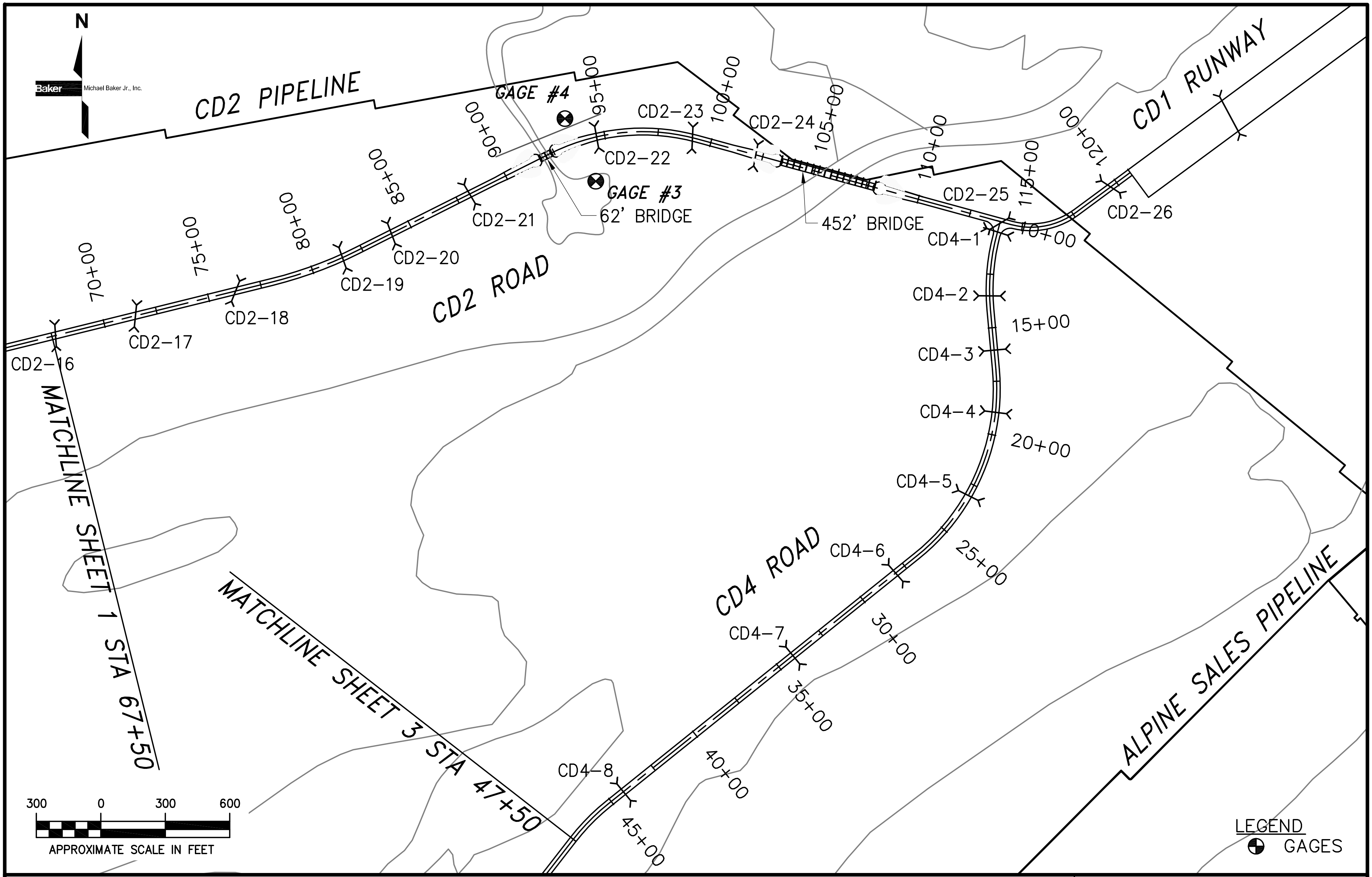
2011 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.5
(SHEET 1 OF 6)



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DATE:	9/19/11	PROJECT:	123684
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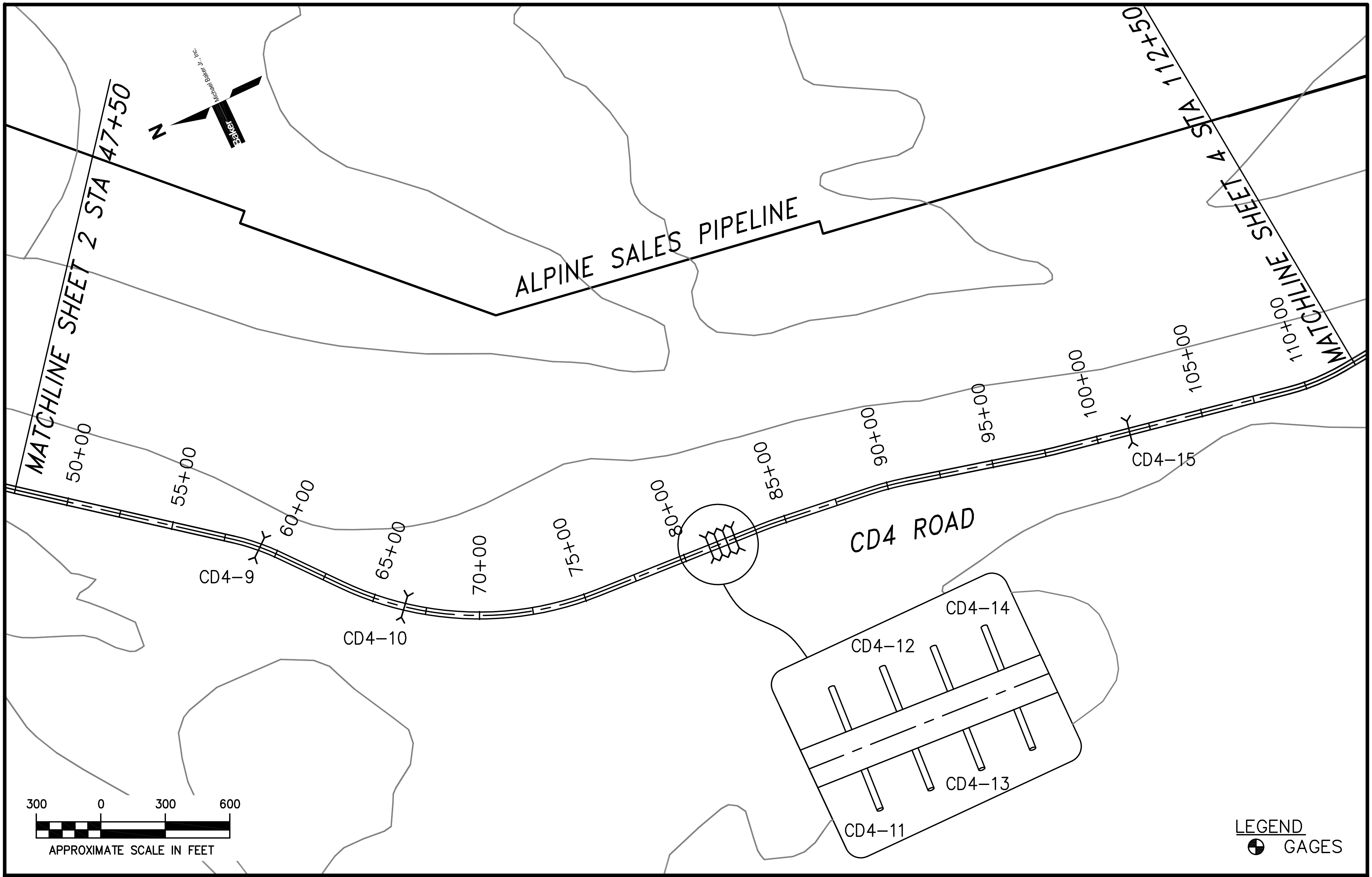
2011 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.5
(SHEET 2 OF 6)



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DATE:	9/19/11	PROJECT:	123684
DRAWN:	EJK	FILE:	FIGURE 5.5.DWG
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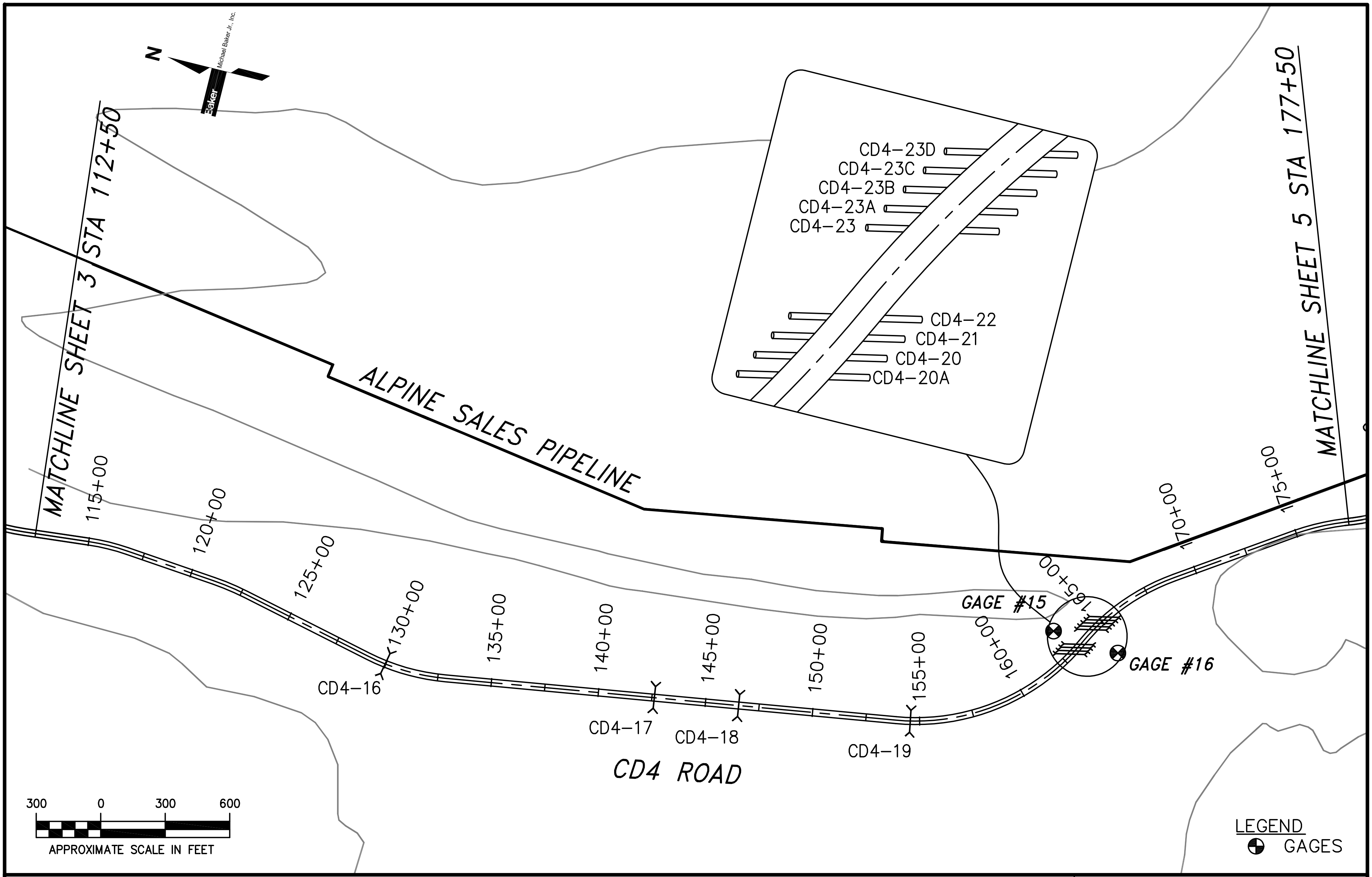
2011 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.5
(SHEET 3 OF 6)



ConocoPhillips
Alaska, Inc.

DATE:	9/19/11	PROJECT:	123684
DRAWN:	EJK	FILE:	FIGURE 5.5.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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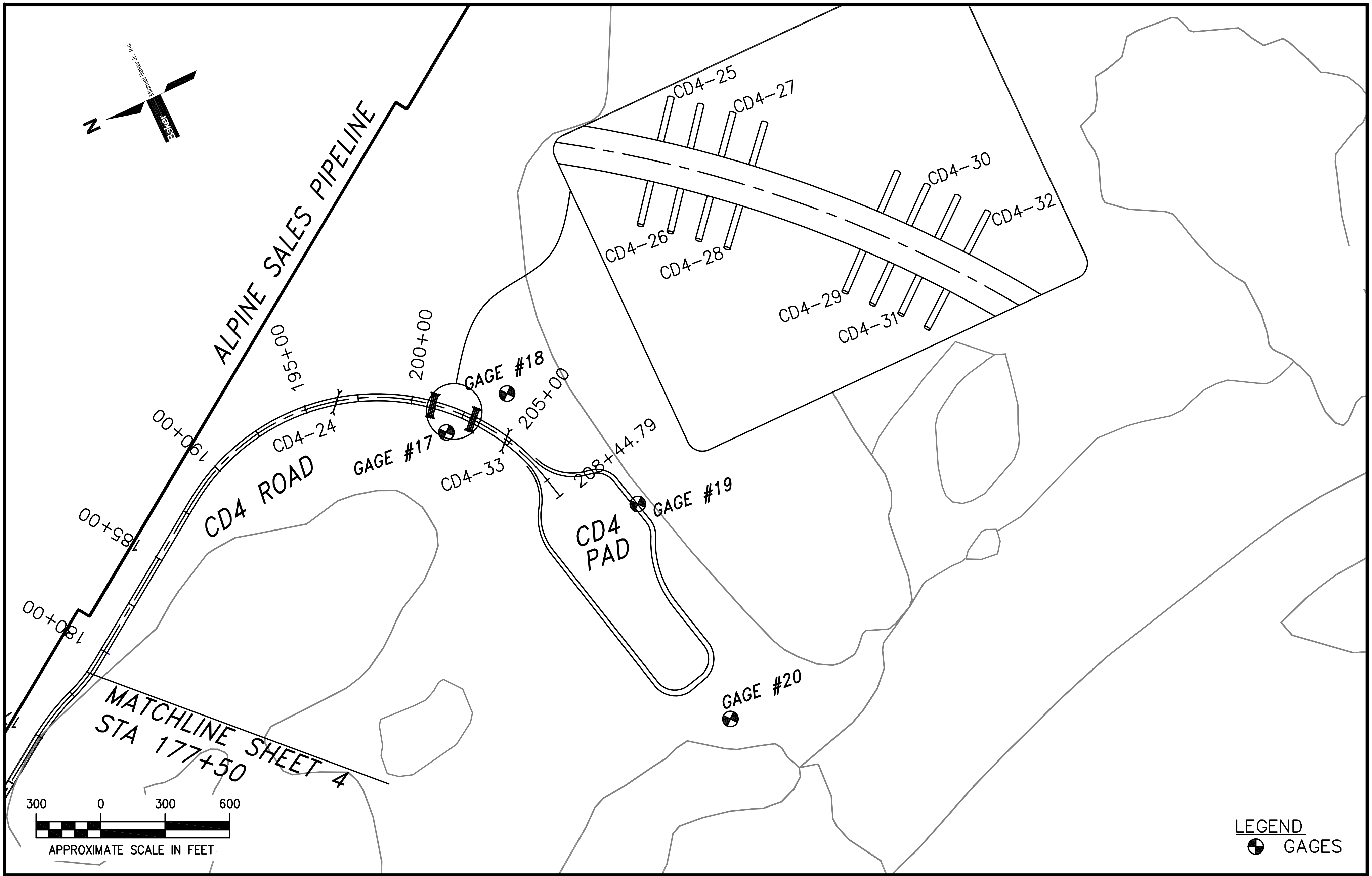
2011 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.5
(SHEET 4 OF 6)



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DATE:	9/19/11	PROJECT:	123684
DRAWN:	EJK	FILE:	FIGURE 5.5.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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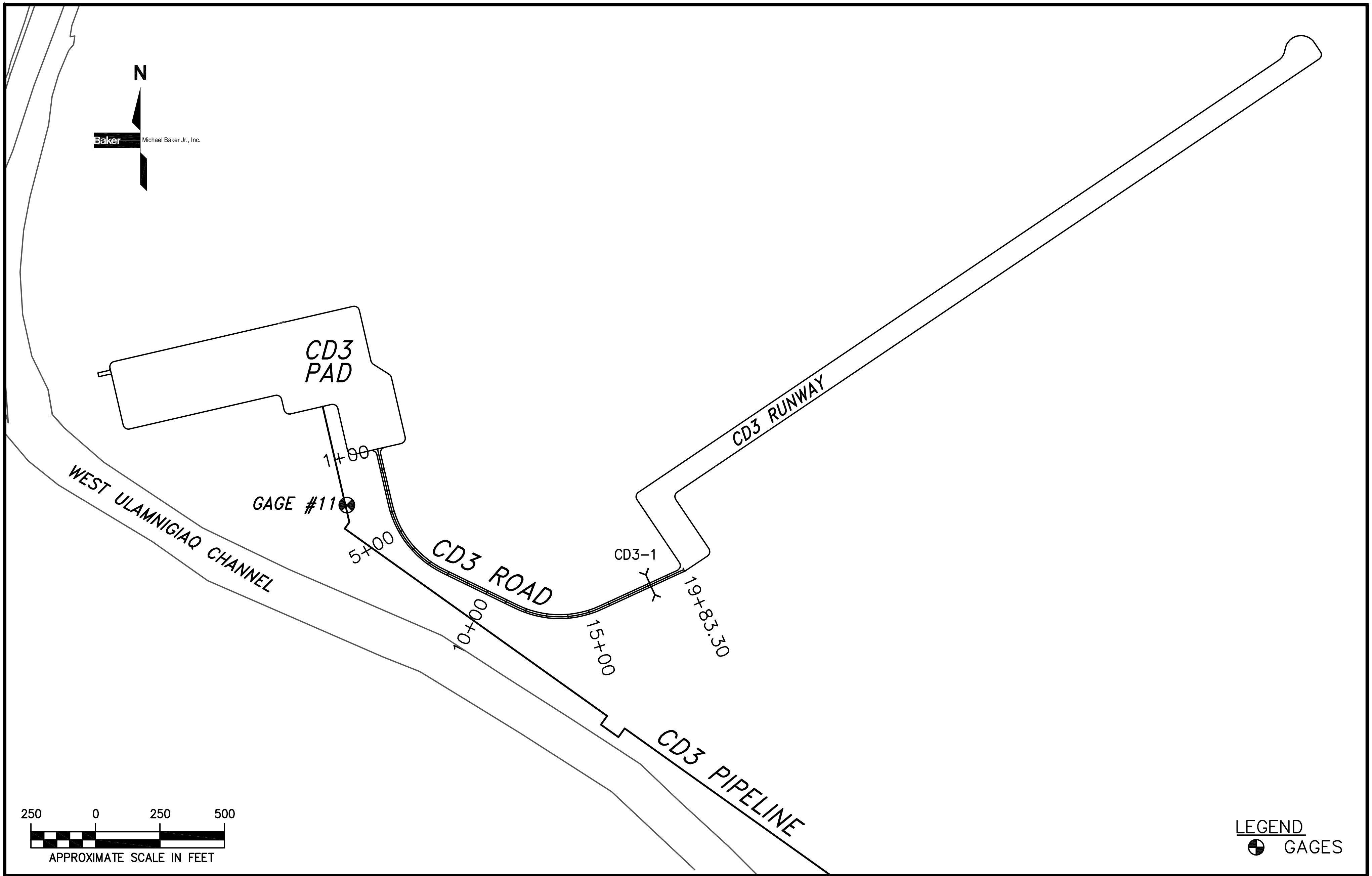
2011 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.5
(SHEET 5 OF 6)



ConocoPhillips
Alaska, Inc.

DATE:	9/19/11	PROJECT:	123684
DRAWN:	EJK	FILE:	FIGURE 5.5.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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2011 SPRING BREAK-UP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.5
(SHEET 6 OF 6)

5.6.1 DIRECT DISCHARGE AND VELOCITY

No direct velocity measurements were performed at culverts due to resources being allocated to swale bridge and Monument 1 discharge measurements. Culverts typically convey less than one percent of the overall floodwater each spring.

5.6.2 INDIRECT DISCHARGE AND VELOCITY

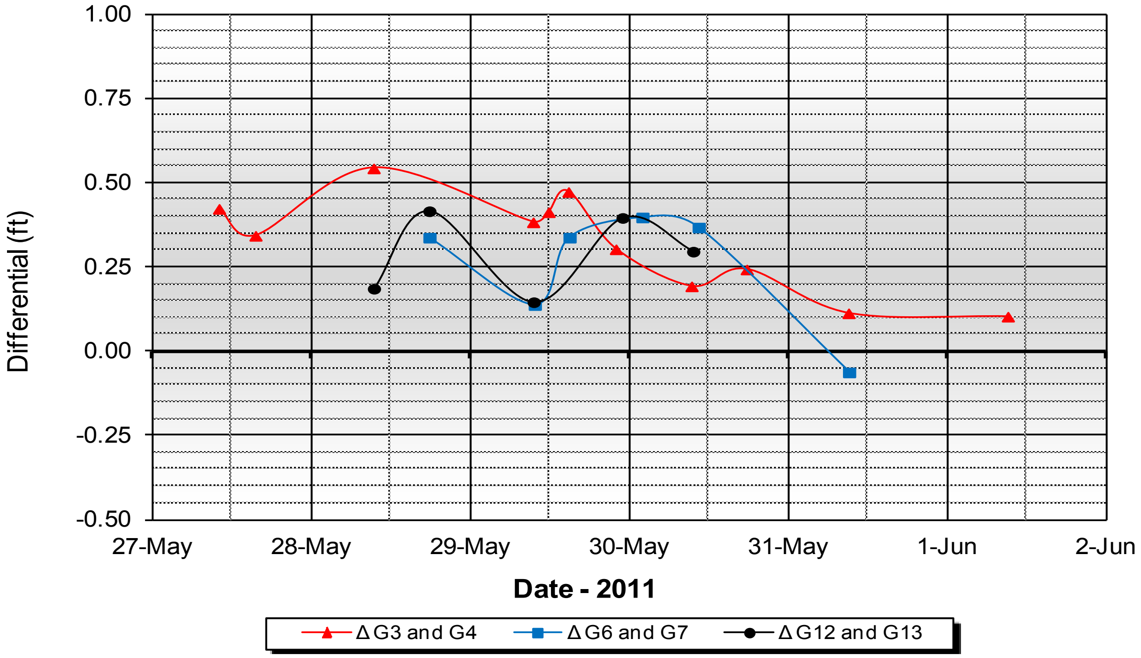
Discharge and velocity values for culverts passing flow are calculated based on observed WSE. This data is collected from gaging stations located upstream and downstream of those culverts along the CD2 and CD4 roads that pass the most significant quantity of flow.

Comparison between measured (direct) discharge and calculated (indirect) discharge values can vary as a result of modeled conditions. Debris such as snow and ice in culvert inverts, along with culvert deformations and dirt and vegetation at inlets and outlets, are factors that contribute to reductions in actual velocity and discharge values, as compared to indirect estimates. In 2010 (Baker 2010), indirect velocity values ranged from 7,260 percent greater to 19 percent lower than direct measurements; indirect velocity calculations were on average 37 percent greater than direct measurements in 2010. In 2010 (Baker 2010), indirect discharge values ranged from 6,955 percent greater to 51 percent lower than direct measurements; indirect discharge calculations were on average 50 percent greater than direct measurements in 2010. Annually, peak indirect velocity and discharge values are adjusted to account for the discrepancy between calculated and measured values. As no direct discharge measurements were performed at the CD2 or CD4 road culverts, adjustments cannot be made to calculated peak velocity and discharge values presented in this report and, therefore, peak values should be considered to be conservative.

5.6.2.1 ALPINE CULVERTS' HEADWATER AND TAILWATER DIFFERENTIAL

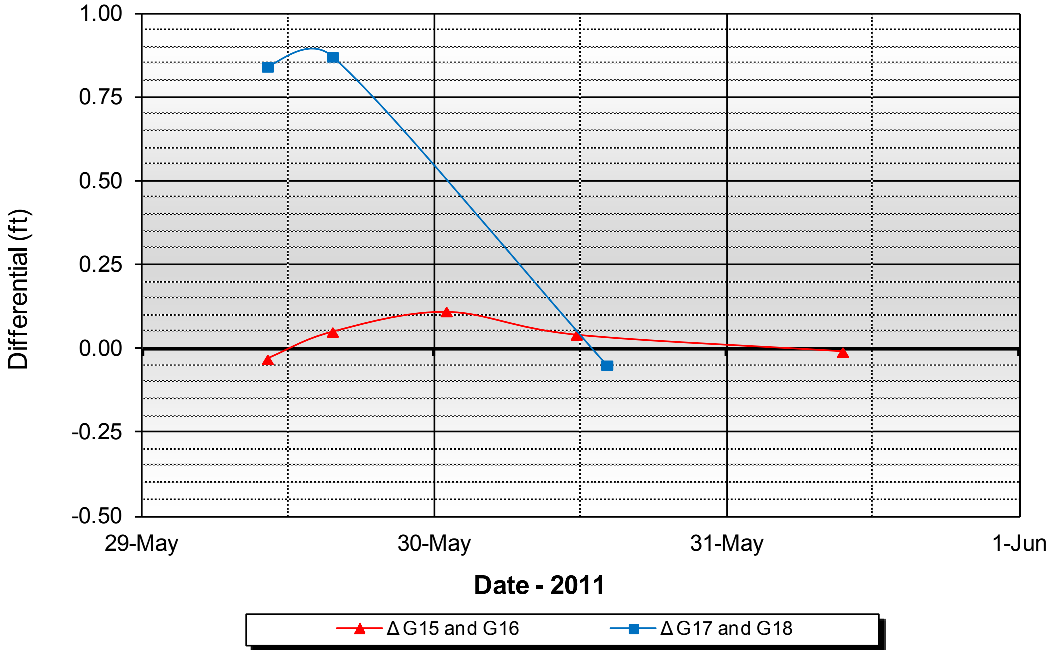
The differential between headwater and tailwater elevations for the CD2 culverts passing flow was based on the observed WSE at the paired gages G6-G7 (near culverts CD2-1 through CD2-8), G12-G13 (near culverts CD2-9 through CD2-18), and G3-G4 (near culverts CD2-19 through CD2-24). The CD4 road culvert headwater and tailwater differential uses data collected at paired gages G15-G16 (near culverts CD4-18 through CD4-23D) and G17-G18 (near culverts CD4-24 through CD4-33). The WSE used in culvert indirect discharge calculations matches the WSE at the corresponding gages based on the proximity of the gage to the culverts.

Along the CD2 road, a maximum differential of 0.40 feet between G6-G7 occurred late in the evening on May 29, coinciding with peak stage based on HWM. A maximum differential of 0.42 feet between G12-G13 occurred on the evening of May 28. A maximum differential of 0.54 feet between G3-G4 occurred on the morning of May 28. The differential WSE throughout breakup at all paired gage locations along the CD2 road is presented in Graph 5.4.



GRAPH 5.4: CD2 ROAD WATER SURFACE ELEVATION DIFFERENTIAL

Along the CD4 road, a maximum differential of 0.11 feet between G15-G16 occurred early in the morning of May 30, based on HWM. A maximum differential of 0.87 feet between G17-G18 occurred on the afternoon of May 29. The differential WSE throughout breakup at all gage locations along the CD4 road is presented in Graph 5.5.



GRAPH 5.5: CD4 ROAD WATER SURFACE ELEVATION DIFFERENTIAL

5.6.2.2 ALPINE CULVERTS' INDIRECT VELOCITY

The peak velocity for a single CD2 road culvert near G6-G7 was 3.95 fps through CD2-1. This velocity coincided with peak stage, estimated as 2:00 a.m. May 30. Average velocity for all culverts near G6-G7 during peak stage was 3.60 fps. The peak velocity for a singular CD2 road culvert near G12-G13 was 3.97 fps through CD2-15 on the evening of May 28. Average velocity for all culverts near G12-G13 during peak stage, estimated to be at around 11:00 p.m. May 29, was 3.30 fps. The peak velocity for a single CD2 road culvert near G3-G4 was 4.26 fps through CD2-23 on the morning of May 28. Average velocity for all culverts near G3-G4 during peak stage, estimated to be around 10:00 p.m. May 29, was 2.99 fps. Calculated indirect velocities for each culvert along CD2 road that passed flood flow are presented in Table 5.4, Table 5.5, and Table 5.6.

TABLE 5.4: 2011 INDIRECT VELOCITY (FPS) SUMMARY, CD2 ROAD CULVERTS NEAR G6-G7

Culvert	May 28 5:51 PM	May 29 9:45 AM	May 29 3:00 PM	*May 30 2:00 AM*	May 30 10:30 AM	May 31 9:12 AM
CD2-1	3.72	2.35	3.70	3.95	3.81	0.00
CD2-2	3.46	2.19	3.45	3.71	3.58	0.00
CD2-3	3.18	2.03	3.18	3.46	3.32	0.00
CD2-4	3.30	2.11	3.30	3.54	3.42	0.00
CD2-5	3.29	2.10	3.28	3.54	3.41	0.00
CD2-6	3.18	2.04	3.18	3.46	3.32	0.00
CD2-7	3.24	2.07	3.24	3.49	3.36	0.00
CD2-8	3.41	2.17	3.40	3.67	3.53	0.00
Average Velocity	**3.35**	**2.13**	**3.34**	**3.60**	**3.47**	**0.00**

Table 5.5: 2011 Indirect Velocity (fps) Summary, CD2 Road Culverts near G12-G13

Culvert	May 28 9:30 AM	May 28 5:50 PM	May 29 9:35 AM	*May 29 11:00 PM*	May 30 9:40 AM
CD2-9	2.35	3.64	2.07	3.52	3.02
CD2-10	2.35	3.69	2.07	3.55	3.04
CD2-11	2.25	3.46	1.99	3.39	2.90
CD2-12	2.29	3.50	2.02	3.42	2.94
CD2-13	1.95	3.05	1.73	3.01	2.56
CD2-14	2.00	3.11	1.77	3.07	2.61
CD2-15	2.59	3.97	2.26	3.77	3.25
CD2-16	0.00	0.00	0.00	2.74	1.40
CD2-17	0.00	1.08	0.00	3.18	2.32
CD2-18	2.02	3.47	1.82	3.31	2.78
Average Velocity	**1.78**	**2.90**	**1.57**	**3.30**	**2.68**

Table 5.6: 2011 Indirect Velocity (fps) Summary, CD2 Road Culverts near G3-G4

Culvert	May 27 10:05 AM	May 27 3:35 PM	May 28 9:25 AM	May 29 9:30 AM	May 29 11:50 AM	May 29 2:50 PM	*May 29 10:00 PM*	May 30 9:25 AM	May 30 5:45 PM	May 31 9:07 AM	Jun 01 9:10 AM
CD2-19	0.00	0.00	0.00	0.00	1.49	2.40	3.06	2.24	2.66	0.00	0.00
CD2-20	3.56	3.01	3.93	3.25	3.39	3.67	2.96	2.34	2.63	1.57	0.00
CD2-21	3.31	2.94	3.91	3.29	3.43	3.69	2.97	2.35	2.65	1.70	0.83
CD2-22	3.75	3.34	4.22	3.48	3.62	3.87	3.05	2.43	2.73	1.85	1.61
CD2-23	3.82	3.43	4.26	3.51	3.64	3.88	2.96	2.37	2.67	1.90	1.85
CD2-24	3.70	3.31	4.15	3.44	3.57	3.80	2.95	2.35	2.64	1.86	1.76
Average Velocity	**3.02**	**2.67**	**3.41**	**2.83**	**3.19**	**3.55**	**2.99**	**2.35**	**2.66**	**1.48**	**1.01**

Based on the calculations, the peak velocity for a single CD4 road culvert near G15-G16 was 1.79 fps through CD4-23. This velocity was estimated to have occurred during peak stage around 1:00 a.m. May 30. Calculated average velocity for all culverts near G15-G16 during peak stage was 1.45 fps. The peak velocity for a singular CD4 road culvert near G17-G18 was 5.68 fps through CD4-32. This velocity was estimated to have occurred during peak stage, at around 3:50 p.m. May 29. Average velocity for all culverts near G17-18 during peak stage was 5.22 fps.

Calculated velocities for each culvert along CD4 road that passed flood flow are presented in Table 5.7 and Table 5.8.

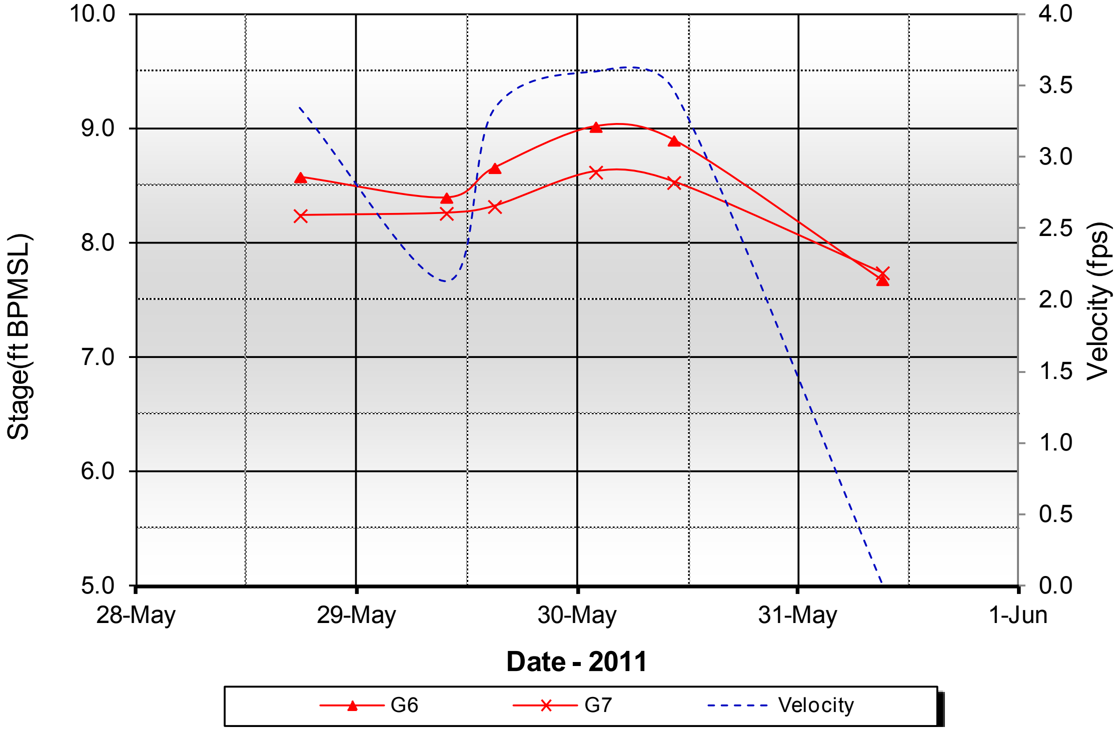
Table 5.7: 2011 Indirect Velocity (fps) Summary, CD4 Road Culverts near G15-G16

Culvert	May 29 10:15 AM	May 29 3:35 PM	*May 30 1:00 AM*	May 30 11:40 AM	May 31 9:30 AM
CD4-18	0.00	0.00	0.00	0.00	0.00
CD4-19	0.00	0.00	0.00	0.00	0.00
CD4-20A	0.00	1.20	1.78	1.07	0.00
CD4-20	0.00	1.20	1.78	1.07	0.00
CD4-21	0.00	1.20	1.78	1.07	0.00
CD4-22	0.00	1.20	1.78	1.07	0.00
CD4-23	0.00	1.27	1.79	1.09	0.00
CD4-23A	0.00	1.25	1.78	1.08	0.00
CD4-23B	0.00	1.19	1.78	1.08	0.00
CD4-23C	0.00	1.16	1.73	1.04	0.00
CD4-23D	0.00	1.17	1.74	1.05	0.00
Average Velocity	**0.00**	**0.99**	**1.45**	**0.87**	**0.00**

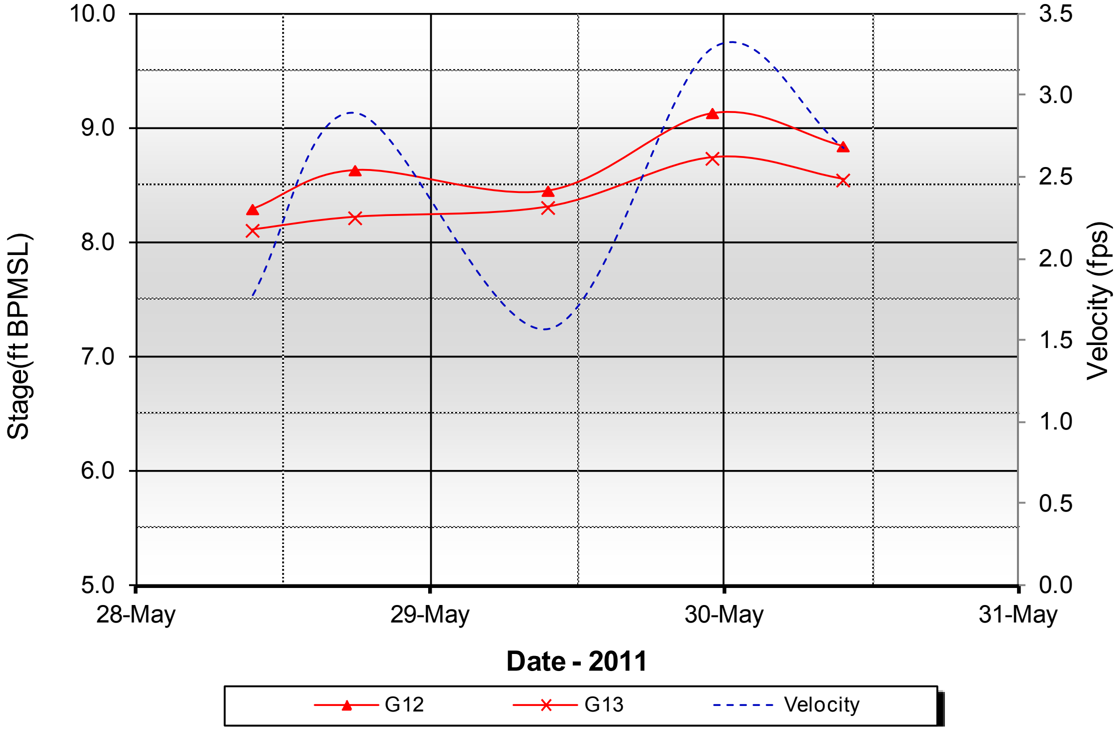
Table 5.8: 2011 Indirect Velocity (fps) Summary, CD4 Road Culverts near G17-G18

Culvert	May 29 10:30 AM	May 29 3:50 PM	May 30 2:10 PM
CD4-24	5.17	5.20	0.00
CD4-25	4.88	4.94	0.00
CD4-26	5.23	5.33	0.00
CD4-27	5.36	5.46	0.00
CD4-28	5.19	5.28	0.00
CD4-29	5.16	5.25	0.00
CD4-30	5.22	5.26	0.00
CD4-31	5.18	5.28	0.00
CD4-32	5.57	5.68	0.00
CD4-33	4.46	4.52	0.00
Average Velocity	**5.14**	**5.22**	**0.00**

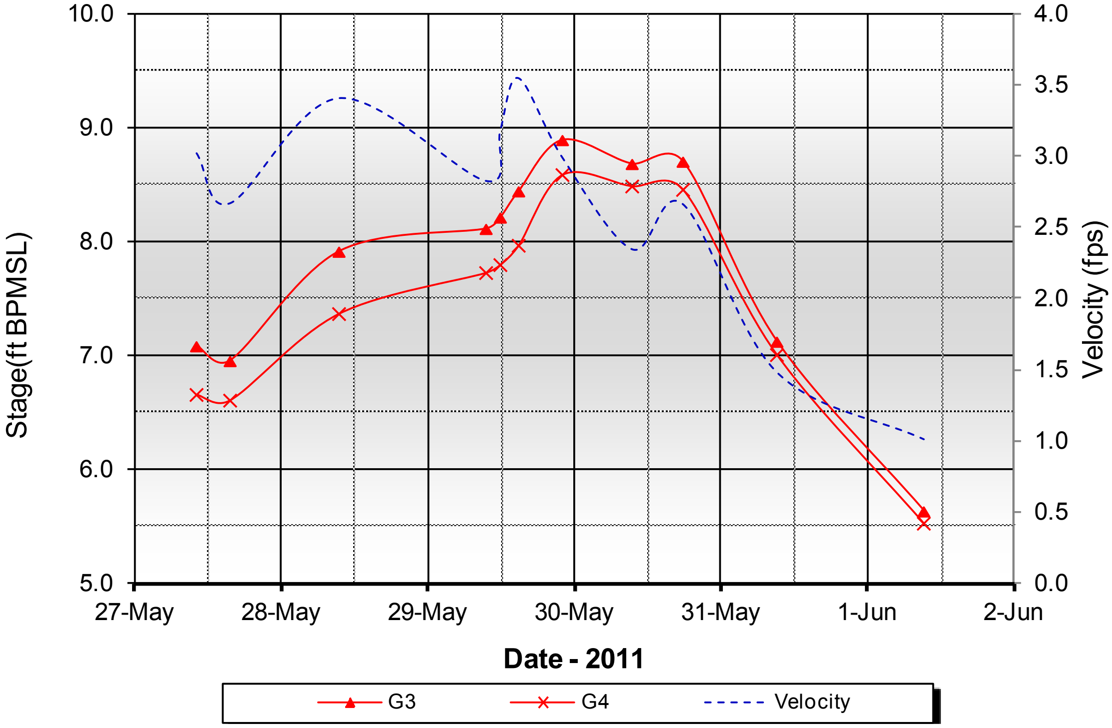
Calculated velocity for all culverts is related to WSE differentials between the culvert headwater and tailwater. A comparison of observed stage and indirect velocity during spring breakup for the CD2 and CD4 road culverts is presented in Graph 5.6 through Graph 5.10.



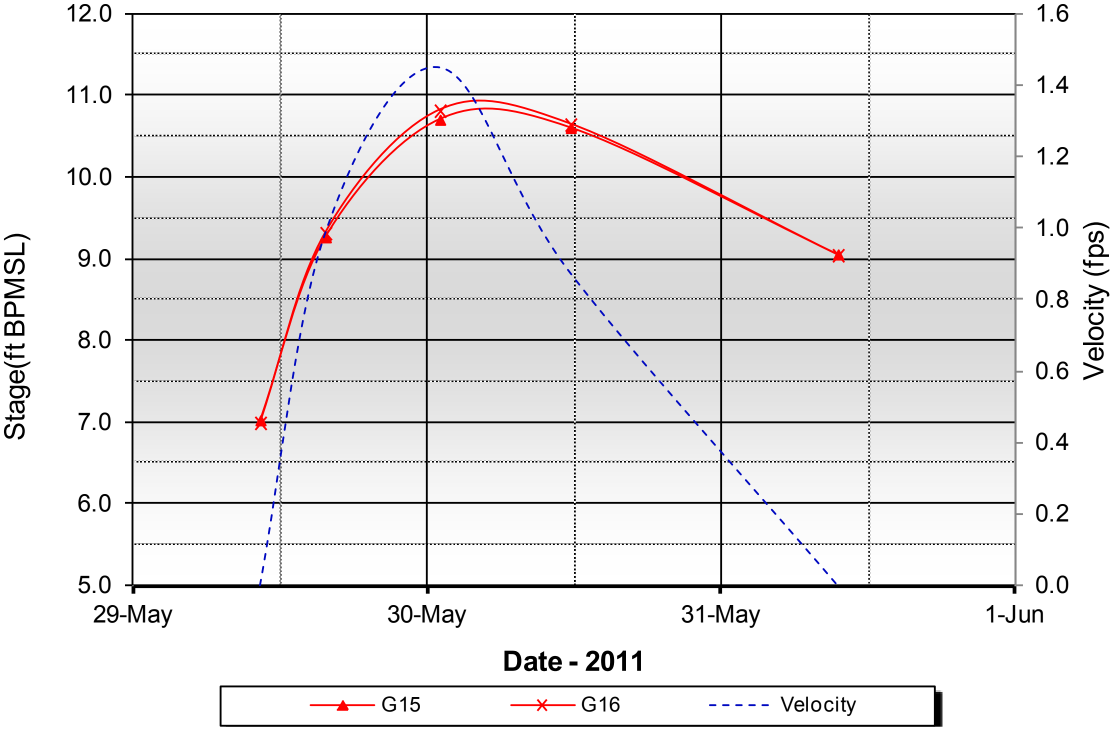
GRAPH 5.6: INDIRECT VELOCITY V. OBSERVED STAGE, CD2 ROAD CULVERTS NEAR G6-G7



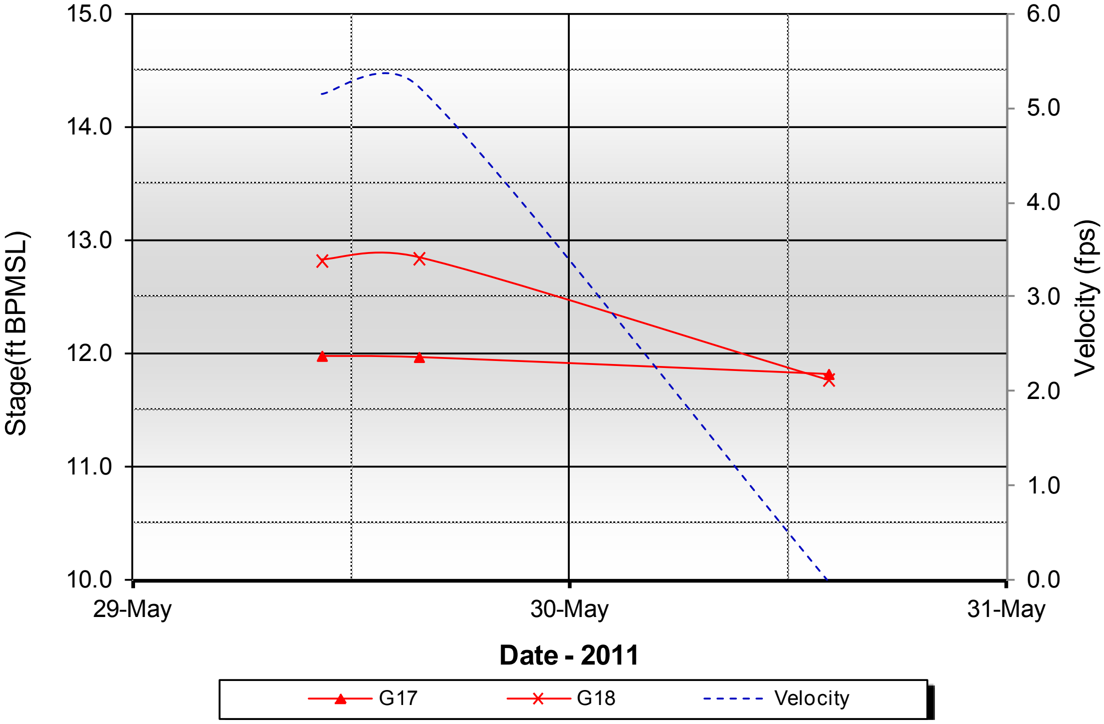
GRAPH 5.7: INDIRECT VELOCITY V. OBSERVED STAGE, CD2 ROAD CULVERTS NEAR G12-G13



GRAPH 5.8: INDIRECT VELOCITY V. OBSERVED STAGE, CD2 ROAD CULVERTS NEAR G3-G4



GRAPH 5.9: INDIRECT VELOCITY V. OBSERVED STAGE, CD4 ROAD CULVERTS NEAR G15-G16



GRAPH 5.10: INDIRECT VELOCITY V. OBSERVED STAGE, CD4 ROAD CULVERTS NEAR G17-G18

5.6.2.3 ALPINE CULVERTS' INDIRECT DISCHARGE

The peak indirect discharge for a single CD2 road culvert near G6-G7 was 41.52 cfs through CD2-7. This discharge coincided with peak stage, estimated at around 2:00 a.m. on May 30. Total peak discharge for all eight culverts near G6-G7 occurred during peak stage and was 287.97 cfs. The peak discharge for a single CD2 road culvert near G12-G13 was calculated to have been 36.99 cfs through CD2-14. This discharge coincided with peak stage, estimated at around 11:00 p.m. on May 29. Total peak discharge for all 10 culverts near G12-G13 occurred during peak stage and was calculated as 223.66 cfs. The peak discharge for a single CD2 road culvert near G3-G4 was 45.51 cfs through culvert CD2-24 on the afternoon of May 29. Calculated total peak discharge for all six culverts near G3-G4 occurred on the afternoon of May 29 and was 179.90 cfs. The calculated peak total discharge through all CD2 road culverts at a single time was 681.23 cfs, which occurred during peak stage, estimated between late in the night of May 29 and early in the morning of May 30. The CD2 road culvert indirect discharge results are presented in Table 5.9, Table 5.10, and Table 5.11.

TABLE 5.9: INDIRECT DISCHARGE (CFS) SUMMARY, CD2 ROAD CULVERTS NEAR G6-G7

Culvert	May 28 5:50 PM	May 29 9:45 AM	May 29 3:00 PM	*May 30 2:00 AM*	May 30 10:30 AM	May 31 9:10 AM
CD2-1	21.88	13.99	22.95	29.21	26.86	0.00
CD2-2	20.92	13.39	21.96	28.08	25.75	0.00
CD2-3	27.71	17.84	28.68	34.97	32.55	0.00
CD2-4	34.86	22.41	35.64	41.38	39.10	0.00
CD2-5	32.89	21.14	33.75	39.79	37.41	0.00
CD2-6	33.99	21.88	34.18	40.75	38.39	0.00
CD2-7	35.00	22.51	35.78	41.52	39.23	0.00
CD2-8	25.00	16.02	25.98	32.27	29.87	0.00
Total Discharge	**232.25**	**149.18**	**238.92**	**287.97**	**269.16**	**0.00**

TABLE 5.10: INDIRECT DISCHARGE (CFS) SUMMARY, CD2 ROAD CULVERTS NEAR G12-G13

Culvert	May 28 9:30 AM	May 28 5:50 PM	May 29 9:35 AM	*May 29 11:00 PM*	May 30 9:40 AM
CD2-9	9.10	15.69	9.61	22.40	16.91
CD2-10	12.84	22.06	13.27	30.22	23.05
CD2-11	12.49	20.75	12.65	27.34	21.25
CD2-12	14.36	23.54	14.32	30.00	23.59
CD2-13	17.01	28.26	16.82	35.70	27.94
CD2-14	17.82	29.47	17.58	36.99	29.04
CD2-15	10.85	18.32	11.21	25.17	19.24
CD2-16	0.00	0.00	0.00	1.43	0.10
CD2-17	0.00	0.03	0.00	2.56	0.75
CD2-18	2.86	6.09	3.72	11.85	8.02
Total Discharge	**97.33**	**164.21**	**99.18**	**223.66**	**169.89**

TABLE 5.11: INDIRECT DISCHARGE (CFS) SUMMARY, CD2 ROAD CULVERTS NEAR G3-G4

Culvert	May 27 10:05 AM	May 27 3:35 PM	May 28 9:25 AM	May 29 9:30 AM	May 29 11:50 AM	May 29 2:50 PM	*May 29 10:00 PM*	May 30 9:25 AM	May 30 5:45 PM	May 31 9:05 AM	Jun 01 9:10 AM
CD2-19	0.00	0.00	0.00	0.00	0.13	0.85	3.71	2.09	2.27	0.00	0.00
CD2-20	4.01	2.97	13.77	15.90	17.54	21.44	24.53	18.51	20.50	3.49	0.00
CD2-21	12.72	10.73	25.95	26.55	28.58	33.16	32.97	25.44	28.34	8.83	0.27
CD2-22	14.71	12.45	28.34	28.38	30.46	35.12	34.14	26.41	29.47	9.77	0.59
CD2-23	24.95	21.61	39.52	37.06	39.25	43.82	37.18	29.56	33.20	15.06	4.10
CD2-24	27.93	24.39	42.37	39.06	41.21	45.51	37.07	29.50	33.15	16.57	5.53
Total Discharge	**84.32**	**72.15**	**149.95**	**146.95**	**157.17**	**179.90**	**169.60**	**131.51**	**146.93**	**53.72**	**10.49**

The peak discharge for CD4 road culverts near G15-G16 was 35.01 cfs through CD4-23A and CD4-23B. This discharge coincided with peak stage, estimated as 1:00 a.m. May 30. Total peak discharge for all 11 culverts near G15-G16 occurred during peak stage and is calculated as 288.15 cfs. The peak

discharge for a single CD4 road culvert near G17-G18 was 56.86 cfs through CD4-33. This discharge coincided with peak stage, estimated as 11:00 p.m. May 29. Calculated total peak discharge for all ten culverts near G17-G18 occurred during peak stage and was 524.85 cfs.

The calculated peak total discharge through all CD4 road culverts was 711.45 cfs, which occurred on the afternoon of May 29. Peak stage at the CD4 road culverts occurred at different times, and peak discharge likely did not occur at the time of peak stage. The CD4 road culvert indirect discharge results are presented in Table 5.12 and Table 5.13.

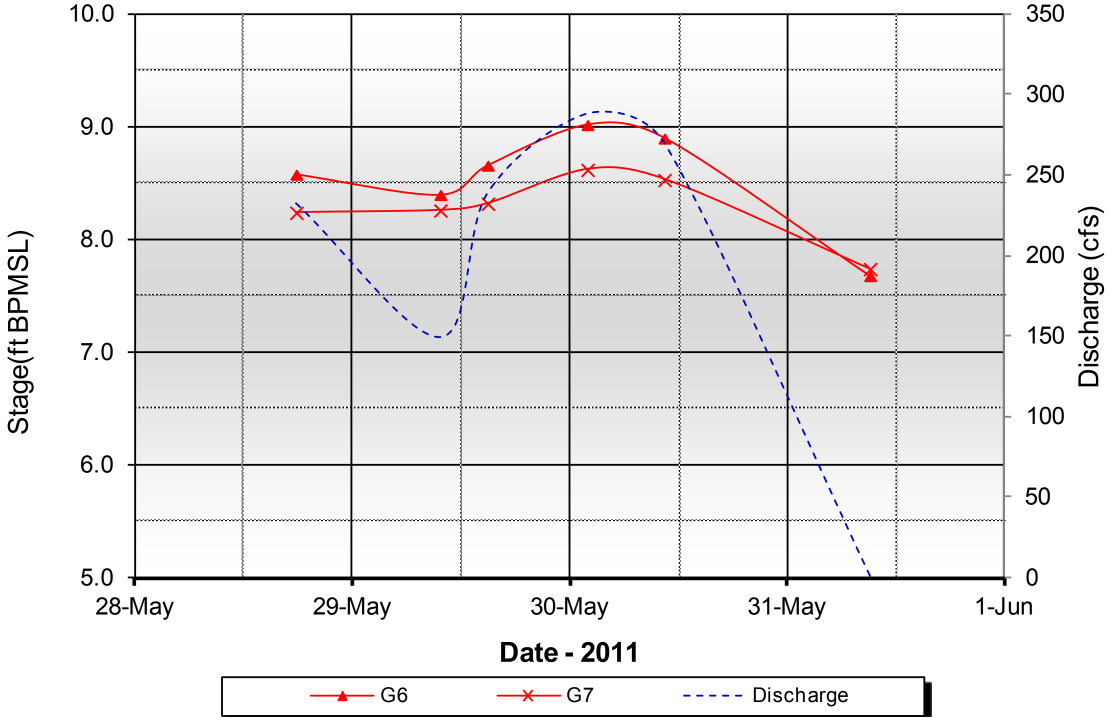
Table 5.12: Indirect Discharge (cfs) Summary, CD4 Road Culverts near G15-G16

Culvert	May 29 10:15 AM	May 29 3:35 PM	*May 30 1:00 AM*	May 30 11:40 AM	May 31 9:30 AM
CD4-18	0.00	0.00	0.00	0.00	0.00
CD4-19	0.00	0.00	0.00	0.00	0.00
CD4-20A	0.00	23.53	34.89	21.04	0.00
CD4-20	0.00	23.52	34.89	21.04	0.00
CD4-21	0.00	23.52	34.88	21.04	0.00
CD4-22	0.00	23.53	34.89	21.04	0.00
CD4-23	0.00	18.52	34.99	21.08	0.00
CD4-23A	0.00	21.39	35.01	21.11	0.00
CD4-23B	0.00	23.28	35.01	21.11	0.00
CD4-23C	0.00	14.60	21.76	13.12	0.00
CD4-23D	0.00	14.71	21.83	13.16	0.00
Total Discharge	**0.00**	**186.60**	**288.15**	**173.74**	**0.00**

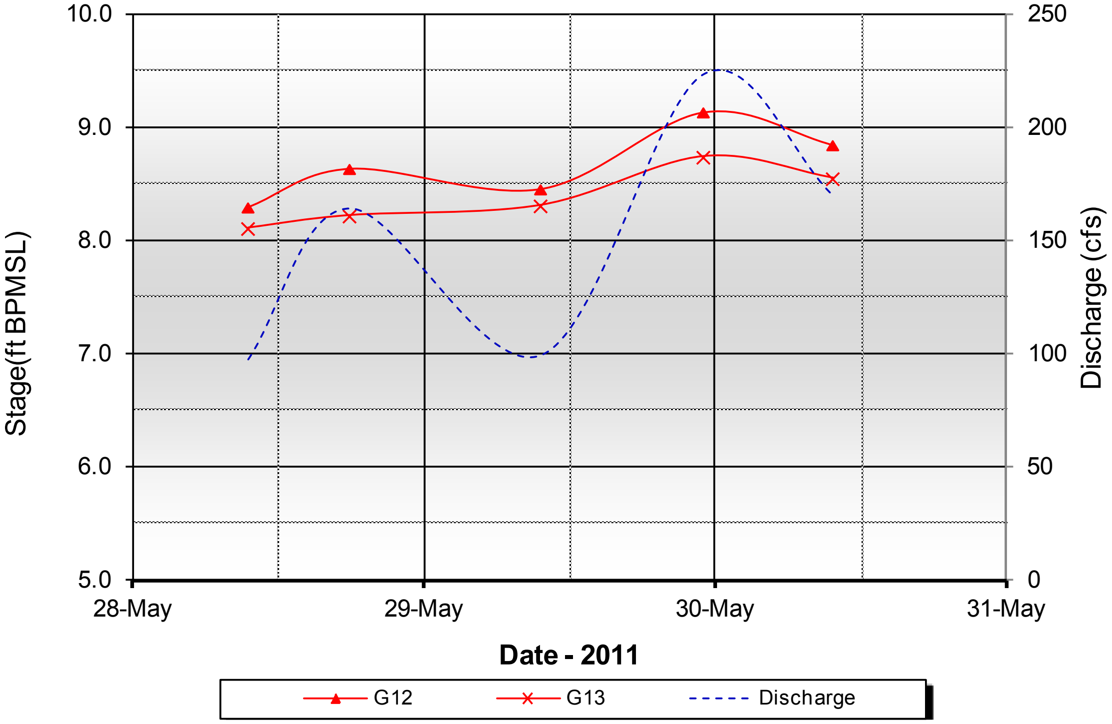
Table 5.13: Indirect Discharge (cfs) Summary, CD4 Road Culverts near G17-G18

Culvert	May 29 10:30 AM	May 29 3:50 PM	May 30 2:10 PM
CD4-24	51.17	51.97	0.00
CD4-25	44.63	45.18	0.00
CD4-26	48.23	48.97	0.00
CD4-27	51.17	51.96	0.00
CD4-28	49.72	50.48	0.00
CD4-29	55.92	56.81	0.00
CD4-30	55.77	55.95	0.00
CD4-31	53.15	53.97	0.00
CD4-32	51.88	52.70	0.00
CD4-33	56.05	56.86	0.00
Total Discharge	**517.69**	**524.85**	**0.00**

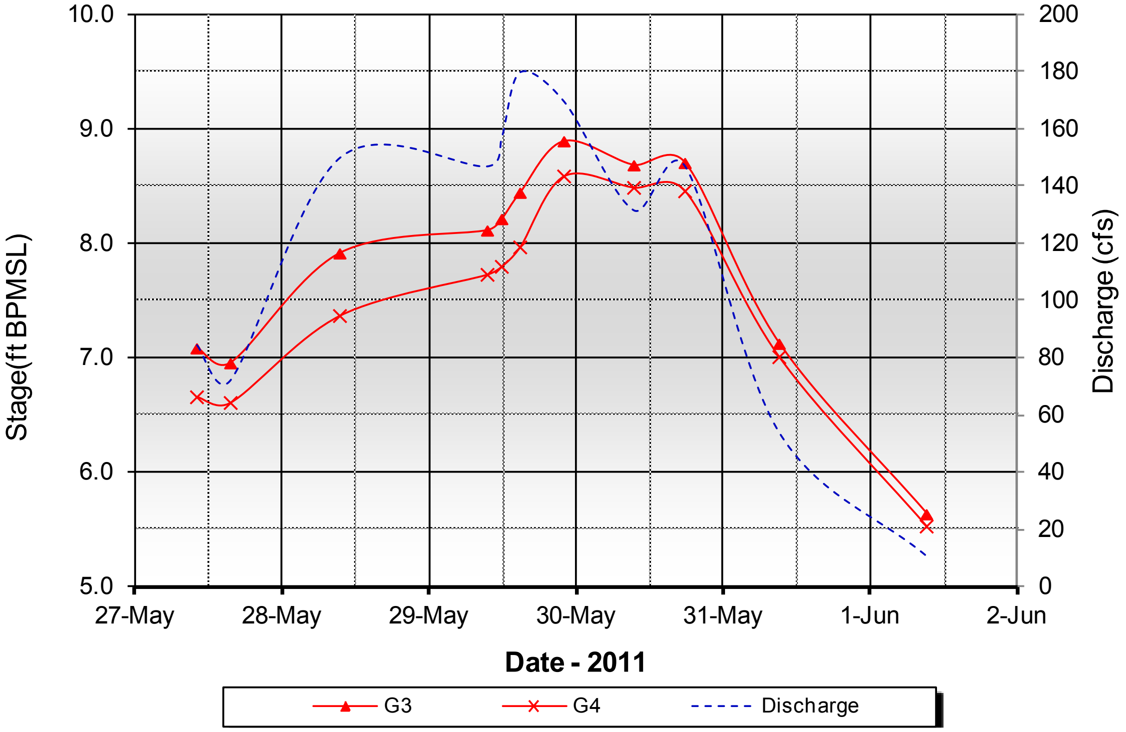
Calculated indirect discharge for all culverts is directly related to WSE. A comparison of observed stage and indirect discharge during spring breakup 2011 for CD2 and CD4 road culverts is presented in Graph 5.11 through Graph 5.15.



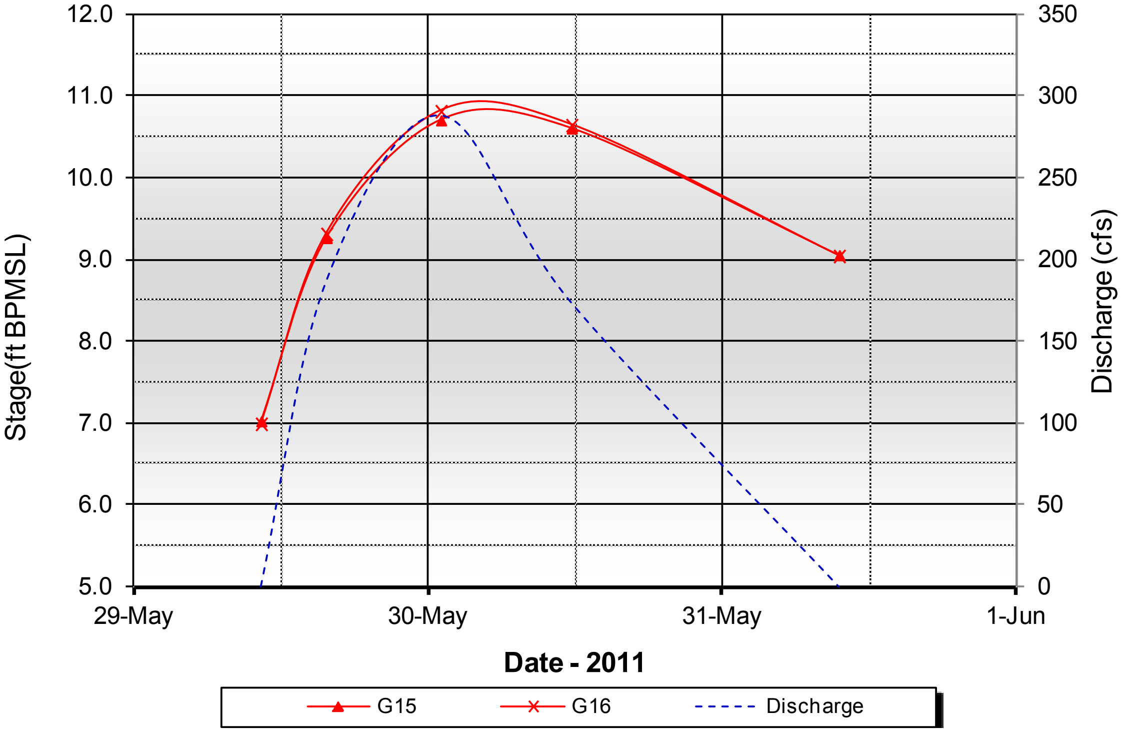
GRAPH 5.11: INDIRECT DISCHARGE V. OBSERVED STAGE, CD2 ROAD CULVERTS NEAR G6-G7



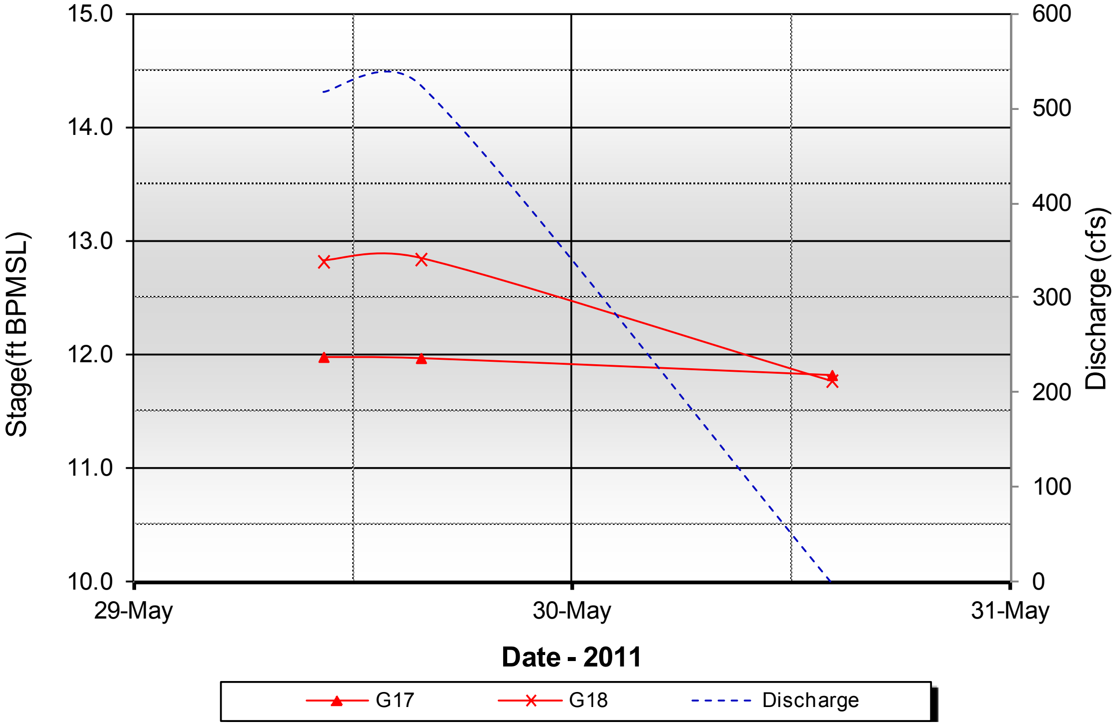
GRAPH 5.12: INDIRECT DISCHARGE V. OBSERVED STAGE, CD2 ROAD CULVERTS NEAR G12-G13



Graph 5.13: Indirect Discharge v. Observed Stage, CD2 Road Culverts near G3-G4



Graph 5.14: Indirect Discharge v. Observed Stage, CD4 Road Culverts near G15-G16



GRAPH 5.15: INDIRECT DISCHARGE V. OBSERVED STAGE, CD4 ROAD CULVERTS NEAR G17-G18

5.7 COLVILLE RIVER DELTA PEAK DISCHARGE FLOW DISTRIBUTION

Approximately 88 percent of the flow in the CRD passed through the East Channel during the 2011 spring breakup peak discharge event. Peak discharge was estimated to have occurred at MON1 late in the evening of May 28, 2011. Eleven percent of the flow passed down the Nigliq Channel at MON23. The remaining one percent of flow was calculated to have gone through the CD2 road culverts and the swale bridges. Chart 5.1 presents the 2011 estimated peak flow distribution within the CRD.

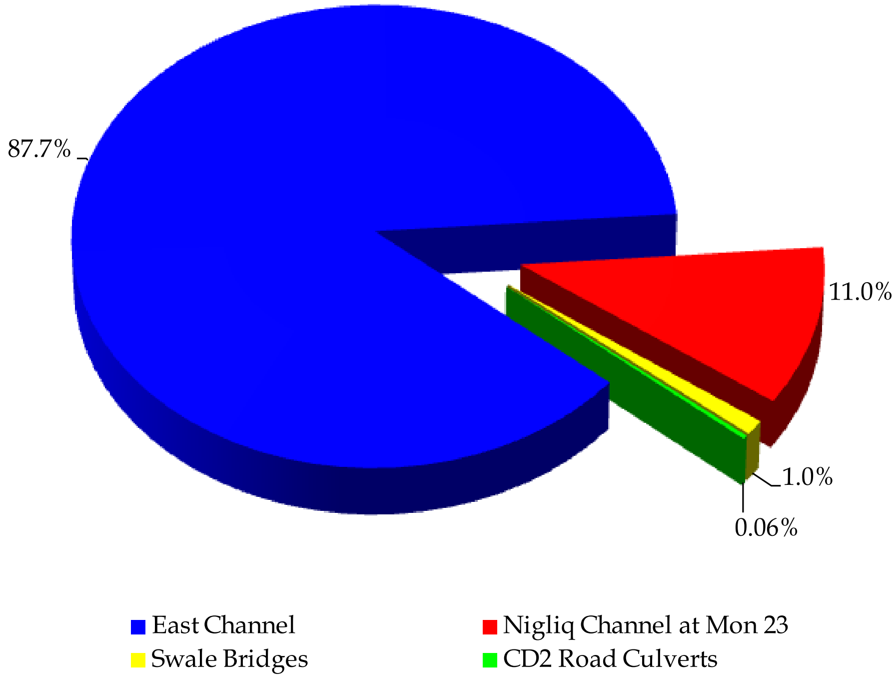


CHART 5.1: 2011 CRD ESTIMATED PEAK FLOW DISTRIBUTION

5.8 FLOOD AND STAGE FREQUENCY ANALYSIS

5.8.1 COLVILLE RIVER FLOOD FREQUENCY

A flood frequency analysis was performed in 2002 to estimate the recurrence interval and magnitude of peak flood discharge on the Colville River (Baker and Hydroconsult 2002). The analysis was revisited in 2006 (Baker 2007a) and again more recently in 2009 (Baker 2009). The results of the 2002 and 2009 analyses are presented in Table 5.14. The 2002 results are the basis for current design criteria.

TABLE 5.14: COLVILLE RIVER FLOOD FREQUENCY ANALYSIS RESULTS

2009 Results		2002 Results (Basis for Current Design Criteria)	
Return Period	Flood Peak Discharge (cfs)	Return Period	Flood Peak Discharge (cfs)
2-year	240,000	2-year	240,000
5-year	360,000	5-year	370,000
10-year	460,000	10-year	470,000
25-year	590,000	25-year	610,000
50-year	700,000	50-year	730,000
100-year	830,000	100-year	860,000
200-year	960,000	200-year	1,000,000

The 2011 peak discharge of 590,000 cfs has an estimated recurrence interval of 22 years, based on the flood frequency analysis results for current design criteria. Peak discharge, as discussed in 5.1.2, was the result of an ice jam release that sent a surge of floes and backwater through the MON1 reach and was not a sustained event. The associated recurrence interval should be considered with respect to conditions at the time of peak discharge.

5.8.2 COLVILLE RIVER DELTA TWO-DIMENSIONAL SURFACE WATER MODEL PREDICTED AND OBSERVED WATER SURFACE ELEVATIONS

The Colville River 2D surface-water model was first developed in 1997 to estimate WSE and velocities at the proposed ADP facilities locations (Baker 1998b). The model has undergone numerous revisions since 1997. Proposed CD3 and CD4 satellite developments were incorporated in 2002, including additional floodplain topographic survey data (Baker 2002b). In 2006, the model was modified to include as-built alignment conditions along the CD4 access road and pad and the 2004-2005 survey data of the Nigliq Channel near MON23 (Baker 2006b). The model was completely reconstructed in 2009 (Baker 2009).

The 2D surface-water model was developed to predict open water conditions during low-frequency, high-magnitude flood events having 50- and 200-year recurrence intervals. To estimate the relationship between discharge and stage during lower-magnitude flood events, 2- and 10-year flood events have been modeled. The model assumes open water, steady-state conditions, and does not account for the snow, channel ice, or ice jams during the 2011 spring breakup.

In general, the 2D model under-predicts stage for lower-return periods of approximately 10 years and less. This is to be expected, as the 2D model does not account for ice- and snow-related events, which can have a large effect on lower-magnitude flood events and less of an effect on higher-magnitude flood events. With an extended period of record, a stage frequency analysis can be a better estimate of low flood stage within the delta affected by recurrent ice jamming.

Graphical representation of the 2011 observed peak stage and predicted WSE for two-, 10-, 50-, and 100-year floods are shown in Graph 5.16. The current 2D surface-water model predictions and the 2011 observations are presented in Table 5.15.

TABLE 5.15: COLVILLE RIVER DELTA 2010 2D MODEL PREDICTED AND 2011 OBSERVED PEAK WATER SURFACE ELEVATION

Monitoring Sites	2D Model Predicted Water Surface Elevation [based on open water conditions] (feet BPMSL)				2011 Observed Peak WSE (feet BPMSL)	Approximate Recurrence Interval of Observed Peak WSE (years)
	2-year	10-year	50-year	200-year		
Monuments - Colville East Channel						
Monument 1 (Centerline)	13.9	19.2	23.0	25.9	19.6	12
Monument 9 (HDD)	11.5	16.1	21.1	21.1	12.0	2
Monument 35 (Helmericks)	4.3	5.4	6.1	6.5	5.6	18
Monuments - Nigliq Channel						
Monument 20	7.8	11.4	14.6	16.8	11.0	8
Monument 22	6.3	9.3	12.1	14.2	9.0	8
Monument 23	5.1	7.4	10.2	12.0	8.2	15
Monument 28	3.1	3.4	3.9	4.3	3.9	59
CD1 Pad						
Gage 1	7.2	9.6	12.6	14.8	9.3	9
Gage 9	8.3	10.8	13.4	15.7	10.7	9
Gage 10	\	10.9	13.4	15.8	10.7	<10
CD2 Pad						
Gage 8	\	8.9	10.8	12.5	-	-
CD2 Road						
Gage 3	6.4	9.4	12.0	14.0	8.9	8
Gage 4	6.2	8.5	10.1	11.7	8.6	11
Gage 6	\	9.6	12.2	14.2	9.0	<10
Gage 7	\	8.4	10.0	11.6	8.6	13
Gage 12	\	9.5	12.1	14.1	9.1	<10
Gage 13	\	8.4	10.0	11.6	8.7	15
CD3 Pad						
Gage 11	3.8	6.4	7.1	7.9	9.1	>200
CD4 Pad						
Gage 19	\	11.9	14.6	16.6	-	-
Gage 20	\	11.1	14.2	16.3	10.6	<10
CD4 Road						
Gage 15	\	10.9	13.5	15.9	10.7	<10
Gage 16	\	11.2	14.2	16.1	10.8	<10
Gage 17	\	11.2	14.2	16.2	12.1	17
Gage 18	\	12.0	14.7	16.7	12.8	16
CD3 Pipeline Crossings						
Sakoonang (Crossing #2) Gage	6.4	8.9	11.1	12.8	8.6	8
Tamayagiaq (Crossing #4) Gage	6.7	8.6	9.1	9.9	10.8	>200
Ulamnigiaq (Crossing #5) Gage	5.5	7.1	7.8	8.7	9.9	>200
Proposed CD5 Road Crossings						
Gage 21 (Nigliq Channel)	6.7	9.8	12.5	14.6	9.9	11
Gage 22 (L9341)	\	\	12.8	14.9	9.5	<50
Gage 23 (Nigliagvik)	6.9	10.0	12.7	14.9	8.8	5

Notes:
1. Sites having dry ground in 2D model are denoted with a backward slash "\"
2. Sites having no observed WSE in 2011 are denoted with a dash "-"

Overall, flood stage recurrence averaged approximately 11 years throughout the CRD, based on the 2D model results. Outlying results are generally attributable to effects related to localized ice jam events as discussed below.

Discrepancy in recurrence intervals between Monument 1, Monument 9, and Monument 35 is the result of timing of ice jam formation and release in the Colville East Channel and is not considered to be representative of actual volumes and related stage of breakup flow. Stage and discharge resulting from ice jam formation and release are not typically sustained, as they would otherwise be if sufficient breakup melt was present to induce lower-frequency flood recurrence intervals. A major ice jam formed upstream of Monument 1 during the 2011 breakup season. When it released, it re-formed briefly downstream of Monument 9 before releasing again and moving out of the CRD.

This ice jam also affected the peak stage at the Tamayayak and Ulamnigiaq pipeline crossings, as well as Gage 11 at CD3 pad. A portion of the floes diverted down the Tamayayak Channel after the initial Monument 1 release and jammed upstream of the Ulamnigiaq channel. Upon release, substantially higher stage readings were measured than those recorded previously or afterward at downstream locations.

Stage recurrence at Monument 28 is also high. This location, along with Monument 35, is the farthest from facilities within the CRD monitored during spring breakup. MON28 is located on the Nigliq Channel at the edge of Harrison Bay. It is potentially affected by tidal events and ice jam effects but to a lesser degree than ice jams affecting locations closer to facilities.

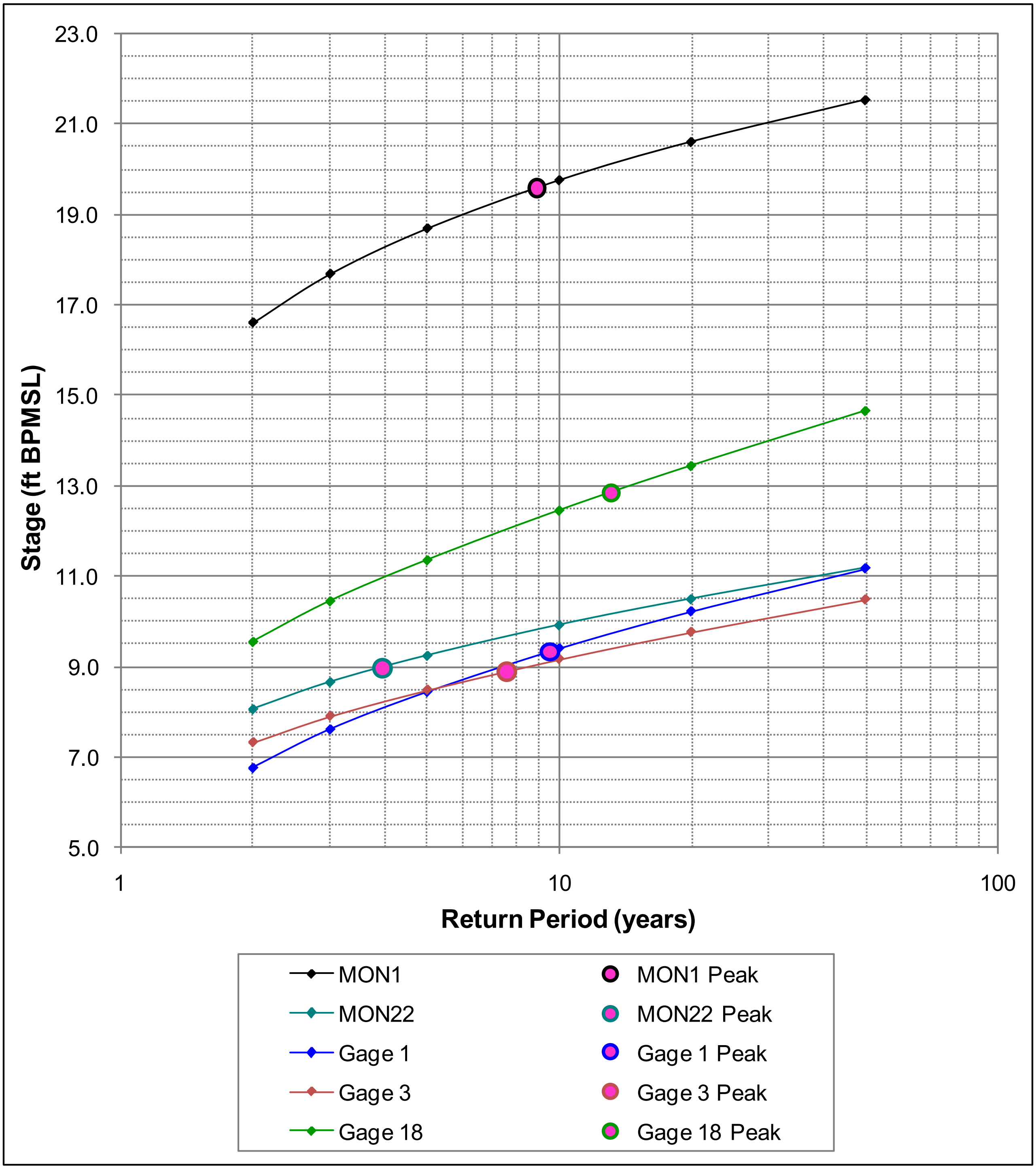
5.8.3 COLVILLE RIVER DELTA STAGE FREQUENCY

A stage frequency analysis was performed for a limited group of sites in 2006 (Baker 2007a) and again in 2009 (Baker 2009). The location and distribution of sites that have been monitored since 1992 has varied based on the objectives of each year's field program. MON1, MON22, G1, G3, and G18 were selected because each has a relatively long-term record of data. The data reflected ice-affected flooding conditions; thus, the stage analysis reflects these conditions. Resulting values from the 2009 analysis are compared to the 2011 observed peak WSE and are presented in Table 5.16 and Graph 5.16.

TABLE 5.16: COLVILLE RIVER DELTA 2009 STAGE FREQUENCY ANALYSIS RESULTS AND 2011 OBSERVED PEAK WATER SURFACE ELEVATION

Monitoring Sites	Stage Frequency - Log-Pearson Type III (feet BPMSL)						2011 Observed Peak WSE (feet BPMSL)	Approximate Recurrence Interval of Observed Peak WSE (years)
	2-year	3-year	5-year	10-year	20-year	50-year		
Monument 1	16.6	17.7	18.7	19.8	20.6	21.5	19.6	9
Monument 22	8.1	8.7	9.2	9.9	10.5	11.2	9.0	4
Gage 1	6.8	7.6	8.4	9.4	10.2	11.2	9.3	10
Gage 3	7.3	7.9	8.5	9.2	9.8	10.5	8.9	8
CD4 Pad (Gage 18)	9.5	10.4	11.4	12.5	13.4	14.7	12.8	13

Stage frequency elevations are consistently higher than those estimated by the 2D model for lower return periods, as seen in Table 5.15, for the respective recurrence intervals. The presence of in-channel ice and snow during breakup acts to stall and displace flow throughout the delta, resulting in consistently higher WSE during lower-magnitude flood events.



GRAPH 5.16: COLVILLE RIVER DELTA 2009 STAGE FREQUENCY ANALYSIS RESULTS AND 2011 OBSERVED PEAK WATER SURFACE ELEVATION FOR SELECTED LOCATIONS

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Appendix A 2011 GAGE LOCATIONS AND VERTICAL CONTROL

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2011 Gage Locations

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Monuments - Colville East Channel				
Monument 1 Upstream	MON1U-A	N 70° 09' 30.8"	W 150° 56' 42.0"	MONUMENT 1
	MON1U-B	N 70° 09' 30.7"	W 150° 56' 44.2"	
	MON1U-C	N 70° 09' 30.6"	W 150° 56' 46.2"	
	MON1U-D	N 70° 09' 30.5"	W 150° 56' 46.9"	
	MON1U-E	N 70° 09' 30.6"	W 150° 56' 47.1"	
	MON1U-F	N 70° 09' 30.6"	W 150° 56' 47.5"	
	MON1U-PT[1]	N 70° 09' 30.9"	W 150° 56' 36.5"	
Monument 1 Centerline	MON1C-A	N 70° 09' 56.7"	W 150° 56' 18.2"	MONUMENT 1
	MON1C-B	N 70° 09' 56.9"	W 150° 56' 19.9"	
	MON1C-C	N 70° 09' 57.0"	W 150° 56' 21.2"	
	MON1C-D	N 70° 09' 56.9"	W 150° 56' 21.5"	
	MON1C-E	N 70° 09' 57.0"	W 150° 56' 22.0"	
	MON1C-F	N 70° 09' 57.1"	W 150° 56' 22.8"	
	MON1-PT[1]	N 70° 09' 56.5"	W 150° 56' 16.0"	
Monument 1 Downstream	MON1D-A	N 70° 10' 25.8"	W 150° 56' 9.3"	MONUMENT 1
	MON1D-B	N 70° 10' 25.6"	W 150° 56' 11.6"	
	MON1D-C	N 70° 10' 25.5"	W 150° 56' 13.8"	
	MON1D-D	N 70° 10' 25.5"	W 150° 56' 14.5"	
	MON1D-PT[1]	N 70° 10' 26.1"	W 150° 56' 3.4"	
	MON1D-Z[2]	N 70° 10' 25.4"	W 150° 56' 15.3"	
Monument 9	MON9-A	N 70° 14' 40.7"	W 150° 51' 26.2"	MONUMENT 9
	MON9-B	N 70° 14' 40.7"	W 150° 51' 27.0"	
	MON9-C	N 70° 14' 40.7"	W 150° 51' 28.0"	
	MON9-D	N 70° 14' 40.6"	W 150° 51' 28.7"	
	MON9-E	N 70° 14' 40.6"	W 150° 51' 28.7"	
	MON9-F	N 70° 14' 40.6"	W 150° 51' 28.8"	
	MON9-G	N 70° 14' 40.7"	W 150° 51' 29.1"	
	MON9-PT[1]	N 70° 14' 40.7"	W 150° 51' 26.4"	
	MON9-BARO[3]	N 70° 14' 39.3"	W 150° 51' 37.6"	
	MON9D-PT[1]	N 70° 15' 30.9"	W 150° 51' 33.8"	
Monument 35 (Helmricks)	MON35-A	N 70° 25' 33.7"	W 150° 24' 20.7"	MONUMENT 35
	MON35-B	N 70° 25' 33.8"	W 150° 24' 20.7"	
	MON35-C	N 70° 25' 33.8"	W 150° 24' 20.9"	
	MON35-D	N 70° 25' 33.9"	W 150° 24' 20.8"	
	MON35-E	N 70° 25' 33.9"	W 150° 24' 20.9"	

[1] pressure transducer

[2] angle iron without gage

[3] BaroTROLL barometer

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Monuments - Nigliq Channel				
Monument 20	MON20-A	N 70° 16' 42.9"	W 150° 59' 55.0"	MONUMENT 20
	MON20-B	N 70° 16' 42.8"	W 150° 59' 54.7"	
	MON20-C	N 70° 16' 42.8"	W 150° 59' 53.9"	
Monument 22	MON22-A	N 70° 19' 7.0"	W 151° 03' 16.4"	MONUMENT 22
	MON22-B	N 70° 19' 6.6"	W 151° 03' 17.5"	
	MON22-C	N 70° 19' 6.5"	W 151° 03' 18.1"	
	MON22-D	N 70° 19' 5.9"	W 151° 03' 19.7"	
Monument 23	MON23-A	N 70° 20' 37.0"	W 151° 03' 57.1"	MONUMENT 23
	MON23-B	N 70° 20' 37.0"	W 151° 03' 56.5"	
	MON23-C	N 70° 20' 37.1"	W 151° 03' 54.8"	
	MON23-D	N 70° 20' 36.9"	W 151° 03' 53.7"	
Monument 28	MON28-A	N 70° 25' 32.9"	W 151° 04' 10.9"	MONUMENT 28
	MON28-B	N 70° 25' 32.6"	W 151° 04' 09.2"	
	MON28-C	N 70° 25' 32.0"	W 151° 04' 01.8"	
Alpine Facilities and Roads				
CD 1	**G1**	N 70° 20' 34.0"	W 150° 55' 15.0"	*
Lake L9312	**G9**	N 70° 20' 01.0"	W 150° 57' 07.0"	*
Lake L9313	**G10**	N 70° 20' 33.0"	W 150° 55' 58.0"	*
CD 2	**G3**	N 70° 20' 24.0"	W 150° 58' 59.0"	*
	G4	N 70° 20' 25.0"	W 150° 59' 00.0"	*
	G6	N 70° 20' 23.0"	W 151° 01' 45.0"	*
	G7	N 70° 20' 24.0"	W 151° 01' 44.0"	*
	G8	N 70° 20' 21.6"	W 151° 02' 56.6"	PBM-F
	G12	N 70° 20' 12.2"	W 151° 00' 42.2"	CD2-14S
	G13	N 70° 20' 14.3"	W 151° 00' 42.6"	
CD3	**G11**	N 70° 25' 03.0"	W 150° 54' 37.9"	Pile 08 cap SW bolt
CD 4	G15-A	N 70° 18' 08.1"	W 150° 59' 34.4"	CD4-21W
	G15-B	N 70° 18' 08.8"	W 150° 59' 38.0"	
	G16-A	N 70° 18' 06.0"	W 150° 59' 36.0"	
	G16-B	N 70° 18' 06.3"	W 150° 59' 39.5"	
	G17	N 70° 17' 35.9"	W 150° 58' 57.8"	CD4-32E
	G18-A	N 70° 17' 34.9"	W 150° 58' 54.6"	
	G18-B	N 70° 17' 32.8"	W 150° 58' 57.9"	
	G18-Z	N 70° 17' 33.1"	W 150° 59' 01.4"	
	G19	N 70° 17' 30.0"	W 150° 59' 18.0"	PBM-P
	G20-A	N 70° 17' 30.2"	W 150° 59' 48.5"	PBM-Q
	G20-B	N 70° 17' 30.2"	W 150° 59' 48.5"	

GX - direct-read permanent staff gage

* this direct-read gage is surveyed and adjusted for elevation annually by LCMF

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Pipeline River Crossings				
Sakoonang Pipe Bridge	SAK-A	N 70° 21' 52.5"	W 150° 55.0' 18.0"	Pile 568 cap SW bolt
	SAK-B	N 70° 21' 52.2"	W 150° 55.0' 19.0"	
	SAK-C	N 70° 21' 52.1"	W 150° 55.0' 19.2"	
Tamayagiaq Pipe Bridge	TAM-A	N 70° 23' 30.0"	W 150° 54' 41.4"	CP08-11-23
	TAM-B	N 70° 23' 29.4"	W 150° 54' 40.6"	
	TAM-C	N 70° 23' 29.1"	W 150° 54' 40.5"	
	TAM-Z[2]	N 70° 23' 28.3"	W 150° 54' 39.1"	
Ulamnigiaq Pipe Bridge	ULAM-A	N 70° 24' 24.5"	W 150° 53' 0.5"	CP08-11-35
	ULAM-B	N 70° 24' 24.8"	W 150° 52' 59.9"	
	ULAM-Z[2]	N 70° 24' 25.3"	W 150° 52' 59.1"	
Proposed CD5 Crossings				
Nigliq Channel	G21-A	N 70° 18' 10.4"	W 151° 01' 18.9"	CP08-11-53A
	G21-B	N 70° 18' 10.5"	W 151° 01' 18.2"	
	G21-C	N 70° 18' 10.3"	W 151° 01' 11.2"	
	G21-D	N 70° 18' 10.4"	W 151° 01' 07.8"	
	G21-PT[1]	N 70° 18' 10.5"	W 151° 01' 20.5"	
	G21U-PT[1]	N 70° 17' 47.1"	W 151° 01' 40.8"	
Lake L9341	G22-A	N 70° 18.0' 21.5"	W 151° 02' 59.6"	CP08-11-64A
	G22-B	N 70° 18.0' 22.0"	W 151° 03' 02.7"	
Nigliagvik	G23-A	N 70° 18.0' 19.9"	W 151° 07' 07.3"	CP08-11-66C
	G23-B	N 70° 18.0' 19.9"	W 151° 07' 05.5"	
Additional Monitoring Sites				
Downstream Nigliq Channel	FWR1-A	N 70° 22' 13.7"	W 151° 06' 50.7"	SHEWMAN
	FWR2-A	N 70° 22' 00.0"	W 151° 07' 18.8"	

[1] pressure transducer

[2] angle iron without gage

2011 Control

Control	Elevation (BPMSL - Feet)	Latitude (NAD 83)	Longitude (NAD83)	Control Type	Reference
CD2-14S	10.929	N 70º 20' 12.9"	W 151º 00' 40.3"	Culvert top	LCMF 2011
CD4-21W	7.432	N 70º 18' 06.6"	W 150º 59' 35.6"	Culvert top	LCMF 2011
CD4-32E	12.685	N 70º 17' 34.3"	W 150º 58' 58.2"	Culvert top	LCMF 2011
CP08-11-23	8.524	N 70° 23' 29.7"	W 150° 54' 28.3"	Alcap	LCMF 2008
CP08-11-35	9.146	N 70° 24' 23.8"	W 150° 52' 55.9"	Alcap	LCMF 2008
CP08-11-53A	7.787	N 70° 18' 08.0"	W 151° 01' 07.9"	Alcap	LCMF 2008
CP08-11-64A	12.305	N 70° 18' 20.9"	W 151° 03' 08.3"	Alcap	LCMF 2008
CP08-11-66C	10.418	N 70° 18' 18.2"	W 151° 06' 59.0"	Alcap	LCMF 2008
MONUMENT 1	27.930	N 70° 09' 57.2"	W 150° 56' 23.8"	Alcap	LCMF 2006
MONUMENT 20	18.980	N 70° 16' 48.0"	W 151° 00' 41.7"	Alcap	BAKER 2011
MONUMENT 22	10.030	N 70° 19' 05.2"	W 151° 03' 21.9"	Alcap	BAKER 2010
MONUMENT 23	9.546	N 70° 20' 40.0"	W 151° 03' 40.7"	Alcap	BAKER 2009
MONUMENT 28	3.650	N 70° 25' 31.9"	W 151° 04' 01.2"	Alcap	LCMF GPS 2002
MONUMENT 35	5.570	N 70° 25' 57.0"	W 150° 23' 00.4"	Alcap	Lounsbury 1996
MONUMENT 9	25.060	N 70° 14' 40.6"	W 150° 51' 29.6"	Alcap	LCMF 2008
PBM-F	17.995	N 70° 20' 21.6"	W 151° 02' 48.3"	PBM in Casing	LCMF 2008
PBM-P	21.406	N 70º 17' 29.0"	W 150º 59' 20.0"	PBM in Casing	LCMF 2010
PBM-Q	21.009	N 70º 17' 30.3"	W 150º 59' 42.4"	PBM in Casing	LCMF 2010
Pile 08	16.662	-	-	HSM - cap SW bolt	LCMF 2010
Pile 568	23.719	N 70° 21' 49.9"	W 150° 55' 14.2"	HSM - cap SW bolt	LCMF 2010
SHEWMAN	7.085	N 70º 22' 20.2"	W 151º 06' 53.4"	Alcap	BAKER 2009

Appendix B 2011 MONUMENT 1 ADCP DIRECT DISCHARGE DATA

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Station Number: 1UP
Station Name: Colville River

Meas. No: 0
Date: 06/01/2011

Party:
Boat/Motor:
Gage Height: 0.00 ft

Width: 2,630 ft
Area: 46,300 ft^2
G.H.Change: 0.000 ft

Processed by:
Mean Velocity: 4.43 ft/s
Discharge: 205,000 ft^3/s

Area Method: Mean Flow
Nav. Method: Bottom Track
MagVar Method: None (23.0°)
Depth Sounder: Not Used

ADCP Depth: 0.500 ft
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 ft/s
Adj.Mean Vel: 0.00 ft/s
Rated Area: 0.000 ft^2
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: NO
BT Error Vel.: 0.33 ft/s
WT Error Vel.: 32.81 ft/s
BT Up Vel.: 1.00 ft/s
WT Up Vel.: 1.64 ft/s
Use Weighted Mean Depth: YES

Max. Vel.: 11.5 ft/s
Max. Depth: 36.7 ft
Mean Depth: 17.6 ft
% Meas.: 62.86
Water Temp.: None
ADCP Temp.: 37.9 °F

ADCP:
Type/Freq.: /600 kHz
Serial #: 46457
Bin Size: 20 cm
BT Mode: Auto
WT Mode: Auto
WZ : 5

Firmware: 44.12
Blank: 19 cm
BT Pings: Dyn
WT Pings: Dyn

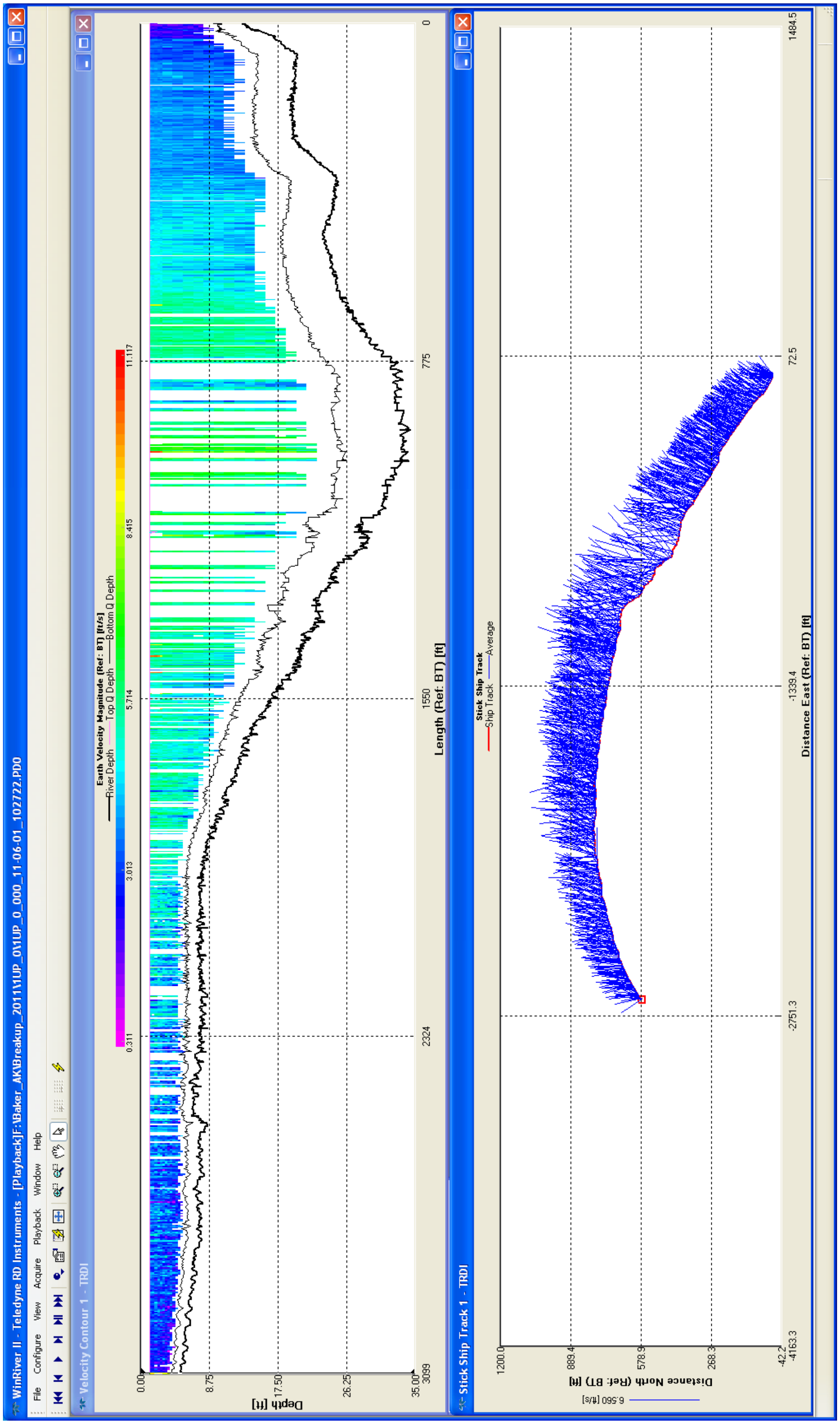
Performed Diag. Test: NO
Performed Moving Bed Test: NO
Performed Compass Test: NO
Meas. Location:

Project Name: 1up_0.mmt
Software: 2.07

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad		
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins	
000	R	75	50	1271	15913	127123	66351	295	379	210061	2834	47064	18:09	18:24	3.44	4.46	19	13	
001	L	65	10	1689	14134	126309	58064	170	27.8	198704	2635	44986	18:24	18:44	2.54	4.42	15	12	
002	R	65	10	1213	14783	131503	63952	268	33.7	210541	2582	47147	18:45	18:59	3.23	4.47	17	12	
003	L	45	10	1176	14030	130375	55968	118	38.6	200530	2466	45812	19:17	19:32	3.13	4.38	21	11	#
Mean		63	20	1337	14715	128828	61084	213	120	204959	2629	46252	**Total**	01:23	3.09	4.43	18	12	
SDev		13	20	238	866	2504	4874	82.7	173	6216	153.7	1041.9			0.38	0.04			
SD/M		0.20	1.00	0.18	0.06	0.02	0.08	0.39	1.44	0.03	0.06	0.02			0.12	0.01			

Remarks:

- transect has been subsectioned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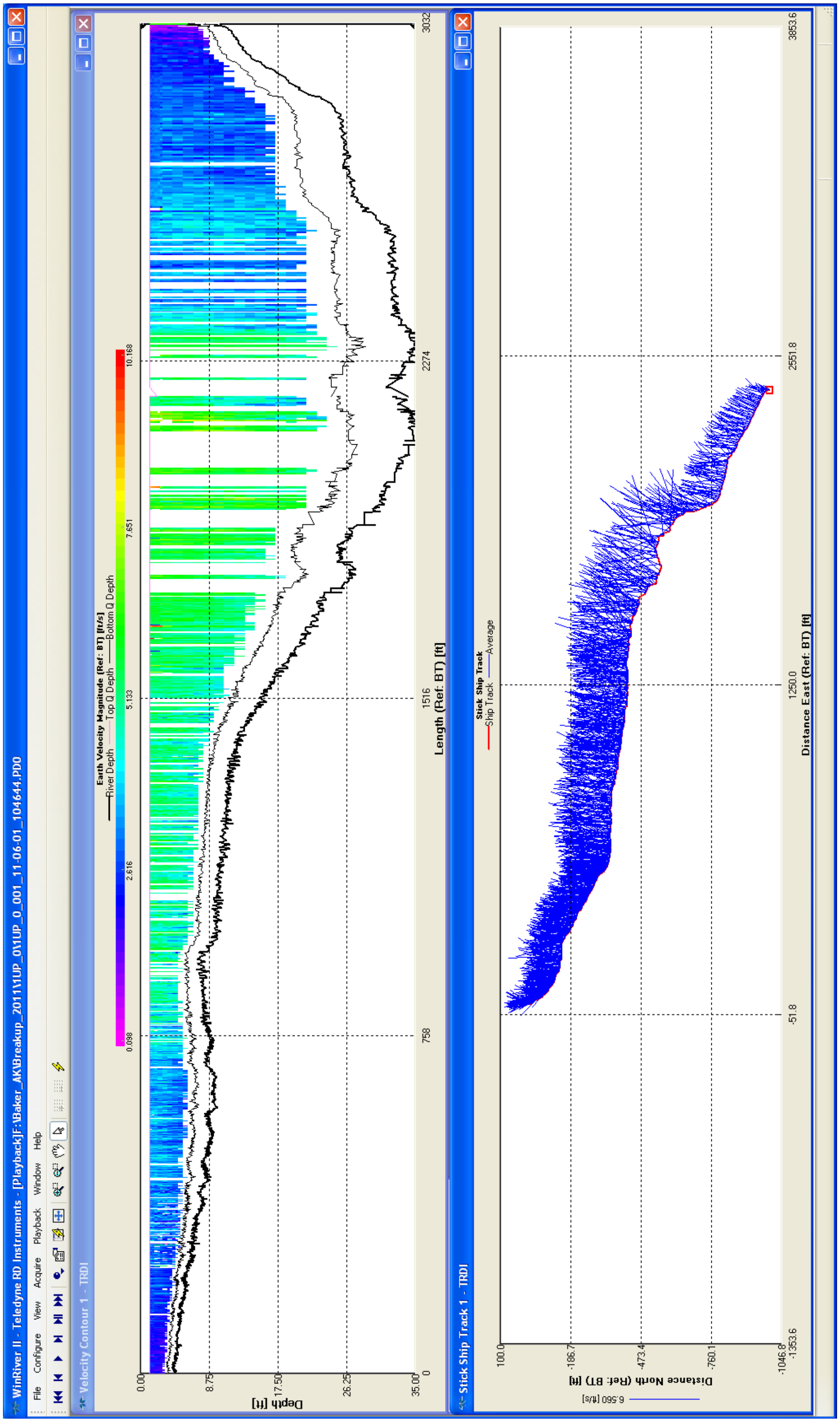
File Configure View Acquire Playback Window Help
Velocity Contour 1 - TRDI
Earth Velocity Magnitude (Ref: BT) [ft/s]
River Depth
Top Q Depth
Bottom Q Depth
0.311
3.013
5.714
8.415
11.117
Depth [ft]
0.00
8.75
17.50
26.25
35.00
Length (Ref: BT) [ft]
0
775
1550
2324
3099
Stick Ship Track 1 - TRDI
Stick Ship Track
Ship Track
Average
Distance North (Ref: BT) [ft]
1200.0
889.4
578.9
268.3
-42.2
Distance East (Ref: BT) [ft]
1484.5
72.5
-1339.4
-2751.3
-4163.3
6.560 [ft/s]



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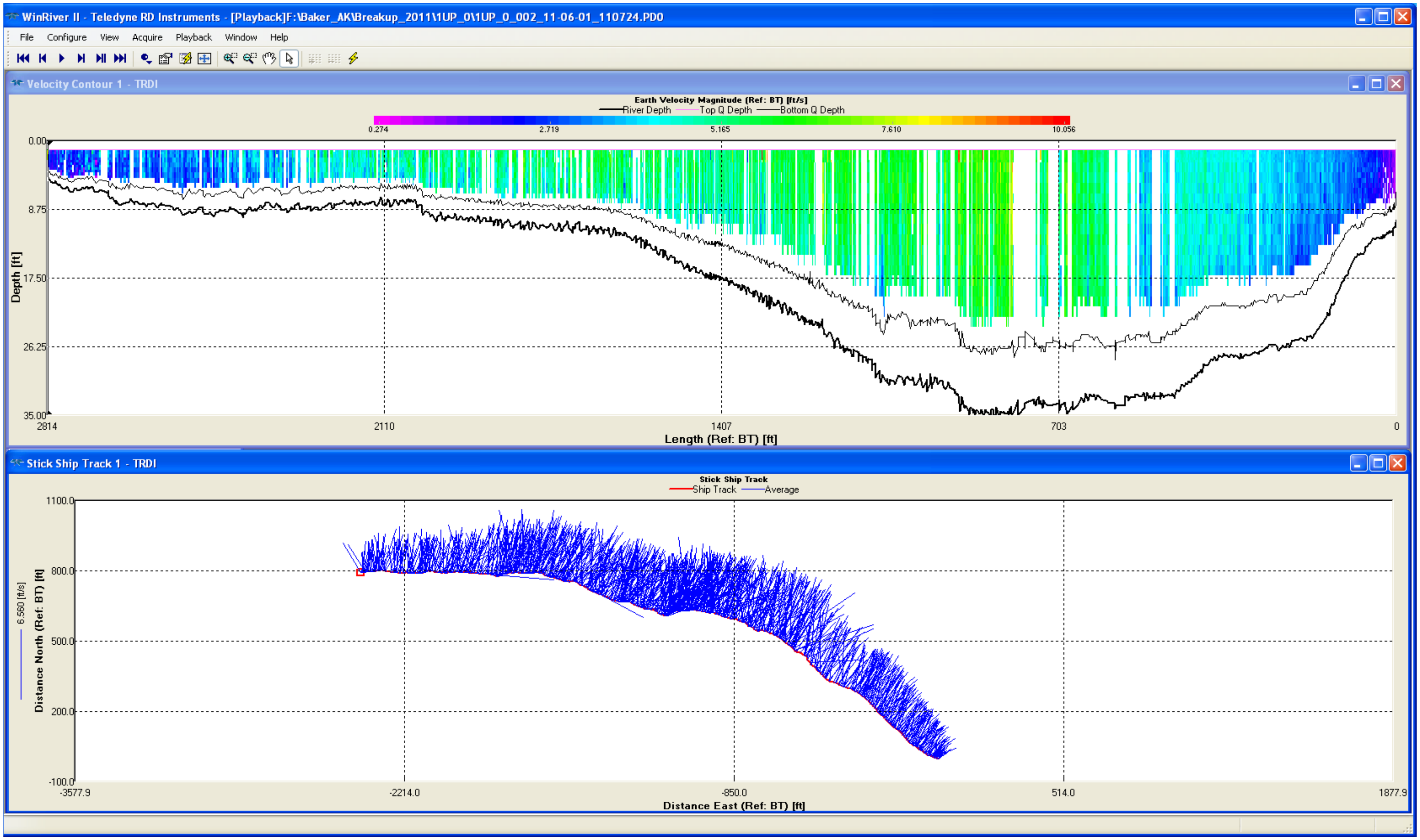
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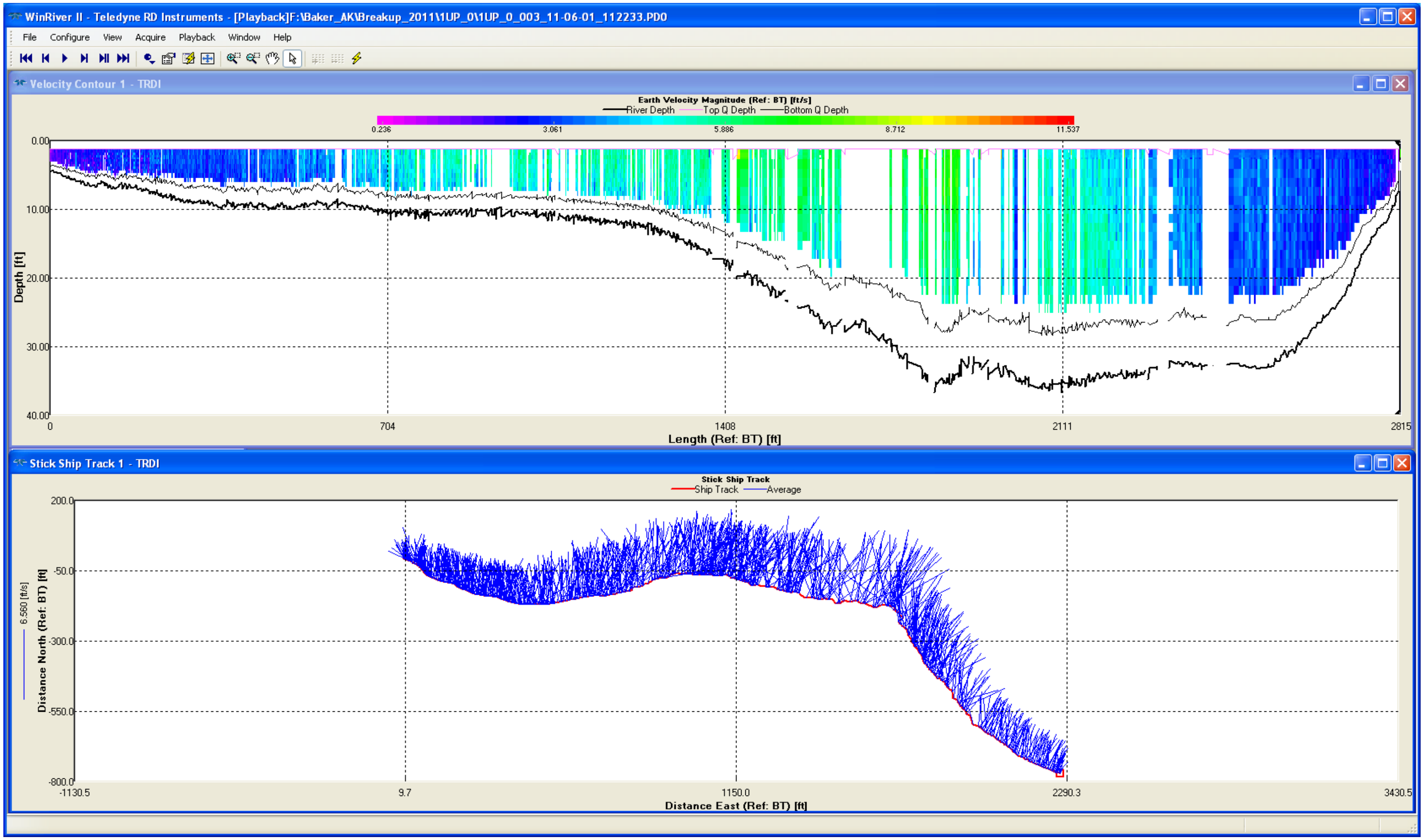
File Configure View Acquire Playback Window Help
Velocity Contour 1 - TRDI
Earth Velocity Magnitude (Ref: BT) [ft/s]
River Depth
Top Q Depth
Bottom Q Depth
0.274
2.719
5.165
7.610
10.056
Depth [ft]
0.00
8.75
17.50
26.25
35.00
2814
2110
1407
703
0
Length (Ref: BT) [ft]
Stick Ship Track 1 - TRDI
Stick Ship Track
Ship Track
Average
6.560 [ft/s]
Distance North (Ref: BT) [ft]
1100.0
800.0
500.0
200.0
-100.0
-3577.9
-2214.0
-850.0
514.0
1877.9
Distance East (Ref: BT) [ft]



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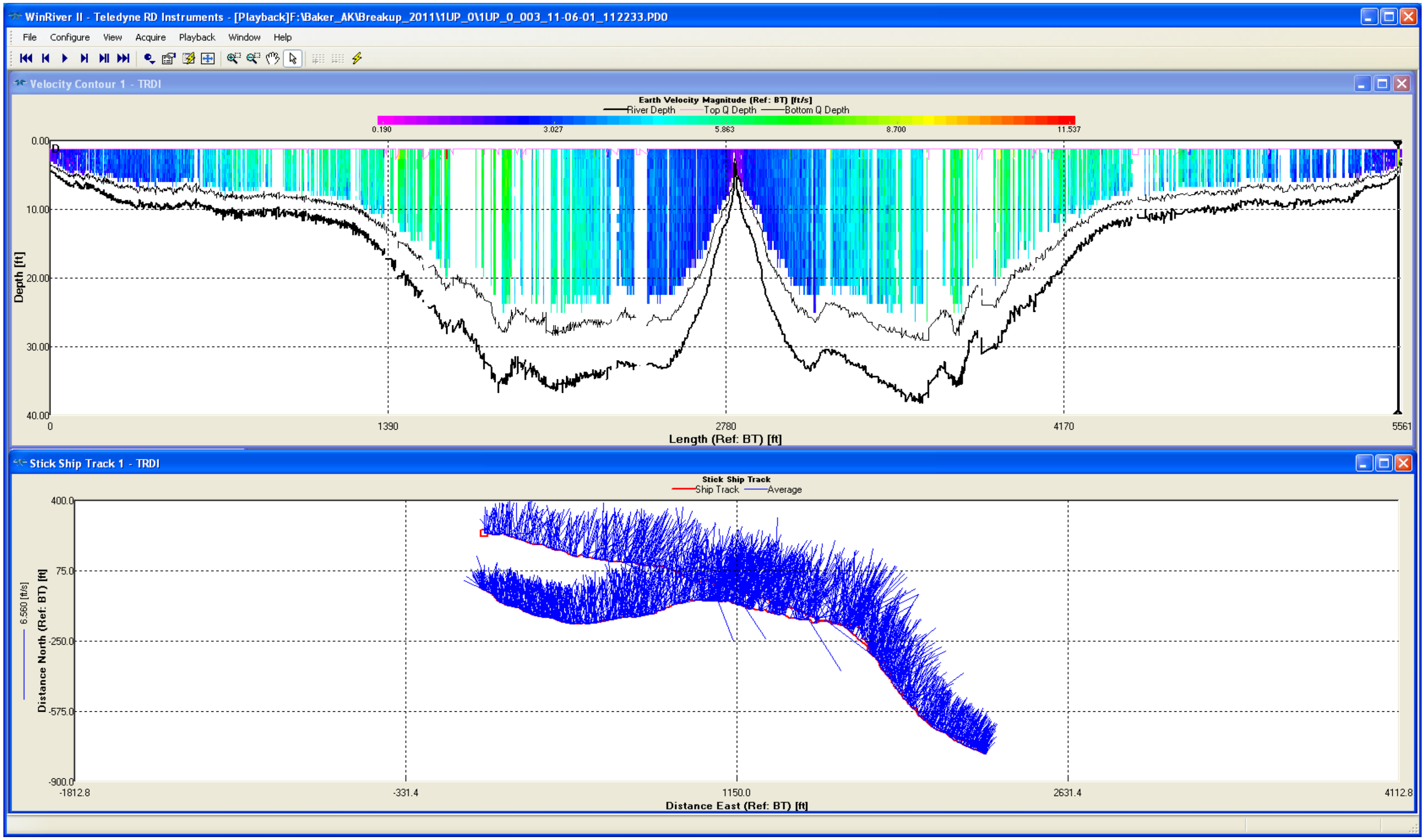
File
Configure
View
Acquire
Playback
Window
Help
Velocity Contour 1 - TRDI
Earth Velocity Magnitude (Ref: BT) [ft/s]
River Depth
Top Q Depth
Bottom Q Depth
0.236
3.061
5.886
8.712
11.537
Depth [ft]
0.00
10.00
20.00
30.00
40.00
0
704
1408
2111
2815
Length (Ref: BT) [ft]
Stick Ship Track 1 - TRDI
Stick Ship Track
Ship Track
Average
6.560 [ft/s]
Distance North (Ref: BT) [ft]
200.0
-50.0
-300.0
-550.0
-800.0
-1130.5
9.7
1150.0
2290.3
3430.5
Distance East (Ref: BT) [ft]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File
Configure
View
Acquire
Playback
Window
Help
Velocity Contour 1 - TRDI
Earth Velocity Magnitude (Ref: BT) [ft/s]
River Depth
Top Q Depth
Bottom Q Depth
0.190
3.027
5.863
8.700
11.537
0.00
10.00
20.00
30.00
40.00
Depth [ft]
0
1390
2780
4170
5561
Length (Ref: BT) [ft]
Stick Ship Track 1 - TRDI
Stick Ship Track
Ship Track
Average
400.0
75.0
-250.0
-575.0
-900.0
Distance North (Ref: BT) [ft]
6.560 [ft/s]
-1812.8
-331.4
1150.0
2631.4
4112.8
Distance East (Ref: BT) [ft]

Appendix C 2011 ALPINE BRIDGE DIRECT DISCHARGE NOTES

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Baker

Discharge Measurement Notes

Date: May 29, 2011
Computed By: WAB
Checked By: HLR

Location Name: Large Swale Bridge

Party: JPM, MDM, SMC, HLR Start: 9:30 Finish: 11:22

Temp: 35 °F Weather: Foggy

Channel Characteristics:

Width: 447 ft Area: 2,027 sq ft Velocity: 2.22 fps Discharge: 4501 cfs

Method: 0.2/0.8 Number of Sections: 26 Count: 1

Spin Test: N/A* revolutions after N/A seconds Meter: Price AA - MJBA01

Meter: 0.6 ft above bottom of weight

Weight: 30 lbs

Wading [✓ Cable] Ice Boat

[✓ Upstream] or Downstream side of bridge

GAGE READINGS			
Gage	Start	Finish	Change
3	8.11	8.21	0.10
4	7.73	7.8	0.07

GPS Data: "LG Q LEW 5-29"

Left Edge of	N	70 °	18 '	19.5 "
Water:	W	151 °	7 '	2.6 "
Right Edge of	N	°	'	"
Water:	E	°	'	"

LE Floodplain: ° ' . "

RE Floodplain: ° ' . "

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

Descriptions:

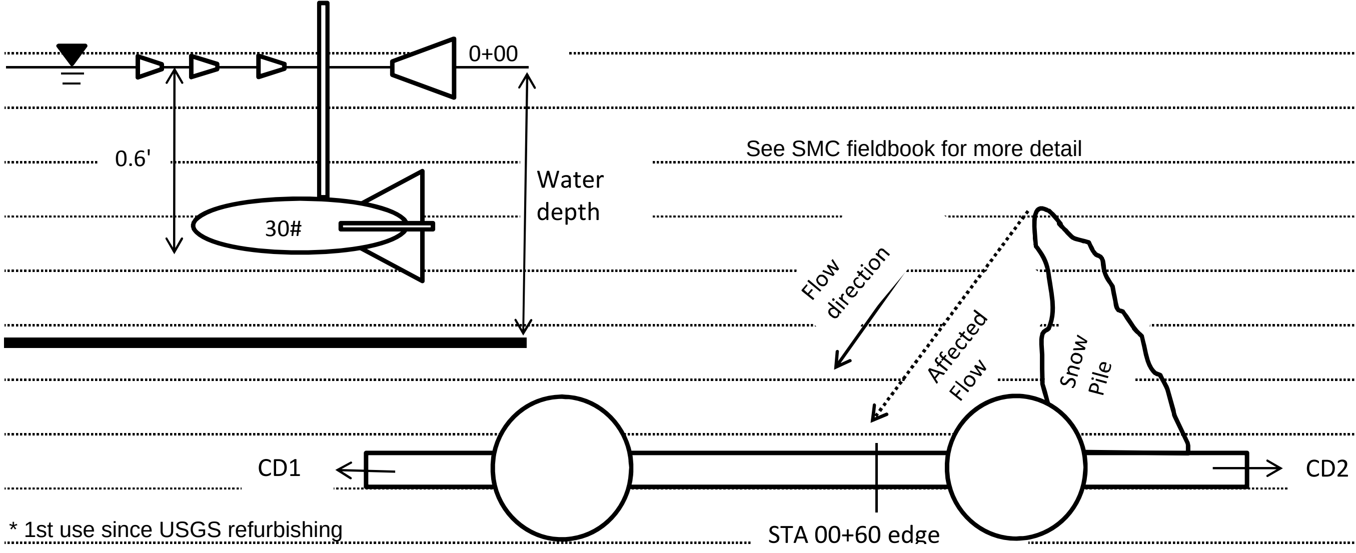
Cross Section: Uniform, firm, variable horizontal angles.

Flow: Steady- fully open.

Remarks: STA 00+15 = LEW, start at STA 00+17 at 9:30 A.M.

Some grounded ice/snow downstream of bridge, closest pile ~ 100 feet downstream ~ 2500 square feet.

JPM does not consider them to significantly affect the Q.



See SMC fieldbook for more detail

* 1st use since USGS refurbishing

Large swale
May 29, 2011

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY			Area (s.f.)	Discharge (cfs)
							At Point (fps)	Mean in Vertical (fps)	Adjusted for Angle Coeff (fps)		
LEW @ 9:30 A.M.											
1	15	1.0	3.0				0.00 0.13	0.06	0.06	3.0	0.19
1	17	2.5	4.0	0.8 0.2	5 10	45 45	0.26 0.51	0.39	0.39	10.0	3.85
0.96	20	11.5	3.2	0.8 0.2	10 15	51 43	0.45 0.79	0.62	0.59	36.8	21.85
0.96	40	20.0	3.8	0.8 0.2	40 60	51 46	1.75 2.89	2.32	2.23	76.0	169.29
0.95	60	20.0	3.9	0.8 0.2	60 80	49 47	2.72 3.77	3.24	3.08	78.0	240.39
0.97	80	20.0	4.3	0.8 0.2	60 80	57 51	2.34 3.48	2.91	2.82	86.0	242.54
0.94	100	20.0	4.4	0.8 0.2	40 60	45 42	1.98 3.17	2.57	2.42	88.0	212.80
0.97	120	20.0	3.9	0.8 0.2	40 60	47 43	1.89 3.09	2.49	2.42	78.0	188.71
0.95	140	20.0	4.2	0.8 0.2	40 60	51 46	1.75 2.89	2.32	2.20	84.0	185.16
0.94	160	20.0	4.5	0.2 0.8	30 50	42 46	1.59 2.41	2.00	1.88	90.0	169.50
0.94	180	20.0	4.0	0.2 0.8	40 60	42 47	2.12 2.83	2.48	2.33	80.0	186.12
0.95	200	20.0	4.3	0.2 0.8	50 60	40 62	2.77 2.15	2.46	2.34	86.0	201.20
0.91	220	20.0	4.8	0.2 0.8	40 40	35 58	2.54 1.54	2.04	1.85	96.0	178.04
0.94	240	20.0	4.5	0.2 0.8	50 40	45 48	2.47 1.86	2.16	2.03	90.0	182.85
0.94	260	20.0	5.1	0.2 0.8	50 40	45 45	2.47 1.98	2.22	2.09	102.0	213.10
0.94	280	20.0	5.8	0.2 0.8	60 45	48 55	2.77 1.82	2.30	2.16	116.0	250.55
0.93	300	20.0	4.7	0.2 0.8	80 50	52 49	3.41 2.27	2.84	2.64	94.0	248.16
0.94	320	20.0	4.9	0.2 0.8	70 50	48 47	3.23 2.36	2.80	2.63	98.0	257.77
0.9	340	20.0	4.9	0.2 0.8	60 40	43 47	3.09 1.89	2.49	2.24	98.0	219.99
0.9	360	20.0	4.4	0.2 0.8	50 40	42 48	2.64 1.86	2.25	2.02	88.0	178.11
0.93	380	20.0	4.9	0.2 0.8	50 60	46 47	2.41 2.83	2.62	2.44	98.0	239.09
0.95	400	20.0	4.9	0.2 0.8	50 50	44 48	2.52 2.31	2.42	2.30	98.0	225.20
0.95	420	20.0	5.0	0.2 0.8	50 40	45 65	2.47 1.37	1.92	1.83	100.0	182.50
0.99	440	20.0	4.6	0.2 0.8	50 40	45 51	2.47 1.75	2.11	2.09	92.0	191.93
0.85	460	11.0	5.1	0.2 0.8	50 50	45 50	2.47 2.22	2.35	1.99	56.1	111.83
1	462	1.0	5.0				0.00 1.00	0.50	0.50	5.0	2.49
REW @ 11:22 A.M.											

Total Discharge: **4500.55**

Baker

Discharge Measurement Notes

Date: June 1, 2011
Computed By: WAB
Checked By: HLR

Location Name: Large Swale

Party: HLR, SMC
Start: 10:47
Finish: 11:45

Temp: 27 °F
Weather: Overcast, windy ~ 15-20 MPH

Channel Characteristics:

Width: 447 ft
Area: 794 sq ft
Velocity: 0.82 fps
Discharge: 649 cfs

Method: Standard
Number of Sections: 28
Count: N/A

Spin Test: N/A revolutions after N/A seconds

Meter: Marsh McBirney

Meter: - ft above bottom of weight

Weight: - lbs

[✓ Wading] Cable Ice Boat

[✓ Upstream] or Downstream side of bridge

GAGE READINGS			
Gage	Start	Finish	Change
3	5.63	5.59	-0.04
4	5.53	5.49	-0.04

GPS Data: LSWALE LEW

Left Edge of	N	70 °	20 '	23.9 "
Water:	W	150 °	58 '	32.4 "
Right Edge of	N	°	'	"
Water:	E	°	'	"

LE Floodplain: ° ' . "

RE Floodplain: ° ' . "

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

Descriptions:

Cross Section: No ice present. Grassy bottom, muddy/soft upstream of bridge piles - scour holes

Flow: Wind, choppy

Remarks: Additional scour along riverbank abutment. No ice/snow in area, upstream or downstream.

Large Swale
June 1, 2011

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 @ 10:47 AM											
	15	1.0						1.15		0.0	0.00
	17	2.5	1.7	0.6				1.15		4.3	4.89
	20	6.5	1.8	0.6				1.08		11.7	12.64
	30	15.0	1.9	0.6				1.08		28.5	30.78
	50	20.0	1.6	0.6				0.88		32.0	28.16
	70	20.0	1.4	0.6				0.62		28.0	17.36
	90	20.0	1.4	0.6				0.42		28.0	11.76
	110	20.0	1.4	0.6				0.57		28.0	15.96
	130	20.0	1.7	0.6				0.48		34.0	16.32
	150	20.0	1.3	0.6				0.49		26.0	12.74
	170	20.0	1.5	0.6				0.60		30.0	18.00
	190	20.0	1.6	0.6				0.61		32.0	19.52
	210	20.0	1.4	0.6				0.67		28.0	18.76
	230	20.0	1.9	0.6				0.54		38.0	20.52
	250	20.0	2.0	0.6				0.53		40.0	21.20
	270	20.0	2.3	0.6				0.83		46.0	38.18
	290	20.0	2.4	0.6				1.37		48.0	65.76
	310	20.0	2.2	0.6				1.34		44.0	58.96
	330	20.0	1.8	0.6				1.10		36.0	39.60
	350	20.0	1.9	0.6				0.96		38.0	36.48
	370	20.0	1.9	0.6				0.94		38.0	35.72
	390	20.0	2.0	0.6				1.12		40.0	44.80
	410	20.0	2.1	0.6				1.14		42.0	47.88
	430	20.0	1.9	0.6				0.64		38.0	24.32
	450	12.5	1.5	0.6				0.31		18.8	5.81
	455	5.0	1.7	0.6				0.27		8.5	2.30
	460	3.5	2.3	0.6				0.10		8.1	0.81
	462	1.0						0.00		0.0	0.00
REW @ 11:45 AM											

Total Discharge: 649.22

Baker

Discharge Measurement Notes

Date: May 28, 2011
Computed By: WAB
Checked By: HLR

Location Name: SM Swale Bridge

Party: HLR, EJK, SMC Start: 15:10 Finish: 17:40

Temp: 40 °F Weather: Sunny

Channel Characteristics:

Width: 52 ft Area: 336 sq ft Velocity: 2.51 fps Discharge: 843 cfs

Method: 0.2/0.8 + 0.6 Number of Sections: 27 Count: 1

Spin Test: N/A* revolutions after N/A seconds Meter: Price AA #1 S01016 #2 MJBA01

Meter: 1.2 ft above bottom of weight

Weight: 30 lbs

Wading [✓ Cable] Ice Boat

[✓ Upstream] or Downstream side of bridge

GAGE READINGS			
Gage	Start	Finish	Change
3	8.10	8.20	0.10
4	7.67	7.73	0.06
gage readings +/-0.02			

GPS Data: "SM Q LEW 5-28"

Left Edge of Water:	N	70 °	20 '	23.8 "
	W	150 °	59 '	5 "
Right Edge of Water:	N	°	'	"
	E	°	'	"

LE Floodplain: ° ' . "

RE Floodplain: ° ' . "

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

Descriptions:

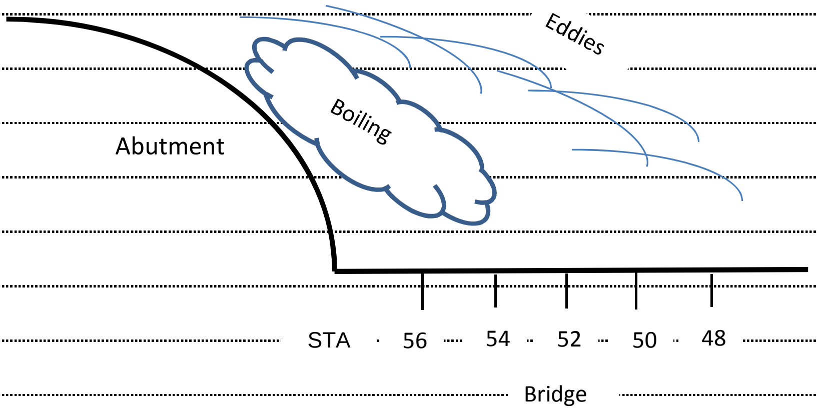
Cross Section: Measurements between bridge abutments. Maximum velocity for 30# weight ~ Station 20.00

Flow: Steady, not ice impacted. Large grounded ice ~100 feet upstream at 16:30. Large upstream ice candleing and breaking, occasional floes moving downstream…

Remarks: Begin west side moving to east side of upstream (south) side of bridge. LEW at left edge of bridge, not left edge of flood watei extents (further west a ways). LEW = STA 0.00. Begin at STA 4.00 due to angle of abutment (STA 2 and 4 in same location).

Meter #1 was lost to ice floe at 16:30, switched to meter #2 and resumed at 17:05.

Scour hole at east upstream abutment where it meets bridge, affecting STA 48-58



* USGS refurbished prior to use

Small Swale
May 28, 2011

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY			Area (s.f.)	Discharge (cfs)
							At Point (fps)	Mean in Vertical (fps)	Adjusted for Angle Coeff (fps)		
0.85	4	1.0	3.1	0.6 0.6	60 60	40 40	3.33 3.33	2.99	2.54	3.1	7.89
0.9	6	2.0	4.0	0.6 0.6	70 70	43 43	3.61 3.61	3.25	2.92	8.0	23.37
0.93	8	2.0	4.2	0.6 0.6	70 70	43 43	3.61 3.61	3.25	3.02	8.4	25.36
0.93	10	2.0	4.6	0.6 0.6	70 70	42 42	3.69 3.69	3.32	3.09	9.2	28.43
0.94	12	2.0	4.8	0.6 0.6	70 70	40 40	3.88 3.88	3.49	3.28	9.6	31.48
0.92	14	2.0	4.8	0.6 0.6	70 70	40 40	3.88 3.88	3.49	3.21	9.6	30.81
0.91	16	2.0	5.8	0.2 0.8	70 70	43 43	3.61 3.61	3.25	2.95	11.6	34.27
0.91	18	2.0	6.1	0.2 0.8	80 70	43 43	4.12 3.61	3.25	2.95	12.2	36.04
0.94	20	2.0	5.9	0.2 0.8	80 70	44 46	4.03 3.37	3.04	2.85	11.8	33.67
0.95	22	2.0	6.1	0.2 0.8	70 60	41 41	3.78 3.24	2.92	2.77	12.2	33.84
0.92	24	2.0	7.0	0.2 0.8	50 70	44 42	2.52 3.69	3.32	3.06	14.0	42.80
0.96	26	2.0	6.2	0.2 0.8	60 70	47 45	2.83 3.45	3.10	2.98	12.4	36.94
0.97	28	2.0	6.4	0.2 0.8	60 60	41 43	3.24 3.09	2.78	2.70	12.8	34.58
0.98	30	2.0	6.9	0.2 0.8	70 50	45 40	3.45 2.77	2.50	2.45	13.8	33.76
0.98	32	2.0	7.1	0.2 0.8	70 47	44 40	3.53 2.61	2.35	2.30	14.2	32.67
Pause - lost Meter #1 to ice floe at 16:30. Restart with new Meter #2 at 17:05.											
0.99	34	2.0	7.3	0.2 0.8	70 60	45 45	3.45 2.96	2.66	2.64	14.6	38.47
1	36	2.0	8.0	0.2 0.8	60 60	41 45	3.24 2.96	2.66	2.66	16.0	42.59
1	38	2.0	8.2	0.2 0.8	70 60	46 44	3.37 3.02	2.72	2.72	16.4	44.64
0.99	40	2.0	8.4	0.2 0.8	70 60	42 46	3.69 2.89	2.60	2.58	16.8	43.31
0.99	42	2.0	8.0	0.2 0.8	70 50	41 44	3.78 2.52	2.27	2.25	16.0	35.97
0.99	44	2.0	7.9	0.2 0.8	70 50	41 47	3.78 2.36	2.13	2.11	15.8	33.27
0.99	46	2.0	7.5	0.2 0.8	80 60	42 41	4.22 3.24	2.92	2.89	15.0	43.36
0.98	48	2.0	7.2	0.2 0.8	80 70	40 41	4.43 3.78	3.40	3.34	14.4	48.04
0.98	50	2.0	7.4	0.2 0.8	80 70	46 43	3.85 3.61	3.25	3.18	14.8	47.08
0	52	2.0	7.0	0.2 0.8	50 60	49 42	2.27 3.17	2.85	0.00	14.0	0.00
0	54	2.0	6.9	0.2 0.8	N/A	N/A	N/A	0.00	0.00	13.8	0.00
0	56	1.0	5.0	0.2 0.8	N/A	N/A	N/A	0.00	0.00	5.0	0.00

Total Discharge = 842.65

Baker

Discharge Measurement Notes

Date: May 30, 2011
Computed By: WAB
Checked By: HLR

Location Name: Short Swale Bridge

Party: EJK, SMC   Start: 9:45   Finish: 11:30

Temp: 35 °F   Weather: Clear, wind 5-15 MPH

Channel Characteristics:

Width: 52 ft   Area: 382 sq ft   Velocity: 2.01 fps   Discharge: 767 cfs

Method: Standard   Number of Sections: 27   Count: 1

Spin Test: revolutions after seconds   Meter: Price AA - MJBAOR1

Meter: 0.6 ft above bottom of weight

Weight: 30 lbs

Wading [✓ Cable] Ice Boat

[✓ Upstream] or Downstream side of bridge

GAGE READINGS			
Gage	Start	Finish	Change
3	8.68	8.78	0.10
4	8.49	8.51	0.02

GPS Data:

Left Edge of Water: N ° ' "
E ° ' "
Right Edge of Water: N ° ' "
E ° ' "

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

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

Descriptions:

Cross Section: Unobstructed by ice.

Flow: confined by bridge abutments.

Remarks:

Small Swale
May 30, 2011

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY			Area (s.f.)	Discharge (cfs)
							At Point (fps)	Mean in Vertical (fps)	Adjusted for Angle Coeff (fps)		
LEW ~ 6' deep scar hole, eddy											
0.7	4	1.0	5.3	0.8 0.2	30 40	54 50	1.24 1.78	1.60	1.12	5.3	5.95
0.7	6	2.0	5.6	0.8 0.2	60 50	48 48	2.77 2.31	2.08	1.46	11.2	16.33
0.85	8	2.0	6.0	0.8 0.2	60 50	45 46	2.96 2.41	2.17	1.85	12.0	22.16
0.85	10	2.0	5.7	0.8 0.2	60 40	46 50	2.89 1.78	1.60	1.36	11.4	15.54
0.85	12	2.0	6.3	0.8 0.2	50 40	42 51	2.64 1.75	1.57	1.34	12.6	16.84
0.85	14	2.0	6.0	0.8 0.2	50 50	41 40	2.71 2.77	2.50	2.12	12.0	25.46
0.85	16	2.0	6.6	0.8 0.2	50 60	45 45	2.47 2.96	2.66	2.26	13.2	29.87
0.85	18	2.0	6.8	0.8 0.2	50 60	48 47	2.31 2.83	2.55	2.17	13.6	29.47
0.92	20	2.0	6.8	0.8 0.2	50 50	48 40	2.31 2.77	2.50	2.30	13.6	31.24
0.9	22	2.0	6.6	0.8 0.2	40 50	42 40	2.12 2.77	2.50	2.25	13.2	29.66
0.85	24	2.0	7.4	0.8 0.2	40 50	43 40	2.07 2.77	2.50	2.12	14.8	31.40
0.85	26	2.0	7.1	0.8 0.2	40 50	42 42	2.12 2.64	2.38	2.02	14.2	28.71
0.9	28	2.0	6.6	0.8 0.2	40 50	41 43	2.17 2.58	2.32	2.09	13.2	27.60
0.8	30	2.0	7.6	0.8 0.2	40 50	45 44	1.98 2.52	2.27	1.82	15.2	27.61
0.85	32	2.0	7.9	0.8 0.2	50 50	51 44	2.18 2.52	2.27	1.93	15.8	30.50
0.85	34	2.0	8.3	0.8 0.2	50 50	46 43	2.41 2.58	2.32	1.97	16.6	32.78
0.9	36	2.0	8.6	0.8 0.2	50 50	47 46	2.36 2.41	2.17	1.96	17.2	33.64
0.9	38	2.0	9.0	0.8 0.2	40 50	40 44	2.22 2.52	2.27	2.04	18.0	36.79
0.9	40	2.0	9.0	0.8 0.2	40 50	42 44	2.12 2.52	2.27	2.04	18.0	36.79
0.94	42	2.0	8.8	0.8 0.2	40 50	41 49	2.17 2.27	2.04	1.92	17.6	33.76
0.97	44	2.0	9.0	0.8 0.2	40 50	44 46	2.02 2.41	2.17	2.11	18.0	37.94
0.99	46	2.0	8.2	0.8 0.2	40 50	45 44	1.98 2.52	2.27	2.25	16.4	36.87
1	48	2.0	7.7	0.8 0.2	40 50	45 44	1.98 2.52	2.27	2.27	15.4	34.97
1	50	2.0	7.7	0.8 0.2	40 50	49 43	1.82 2.58	2.32	2.32	15.4	35.78
0.98	52	2.0	7.7	0.8 0.2	40 50	50 41	1.78 2.71	2.44	2.39	15.4	36.76
0.9	54	2.0	7.5	0.8 0.2	40 60	50 46	1.78 2.89	2.60	2.34	15.0	35.16
0.8	56	1.0	7.9	0.8 0.2	25 25	41 44	1.36 1.27	1.14	0.91	7.9	7.23
	58		7.0								
REW estimated 7.0 feet deep at wall											
										Total Discharge:	**766.81**

Appendix D MON1 STAGE-DISCHARGE RATING CURVE WITH INDIRECT DISCHARGE

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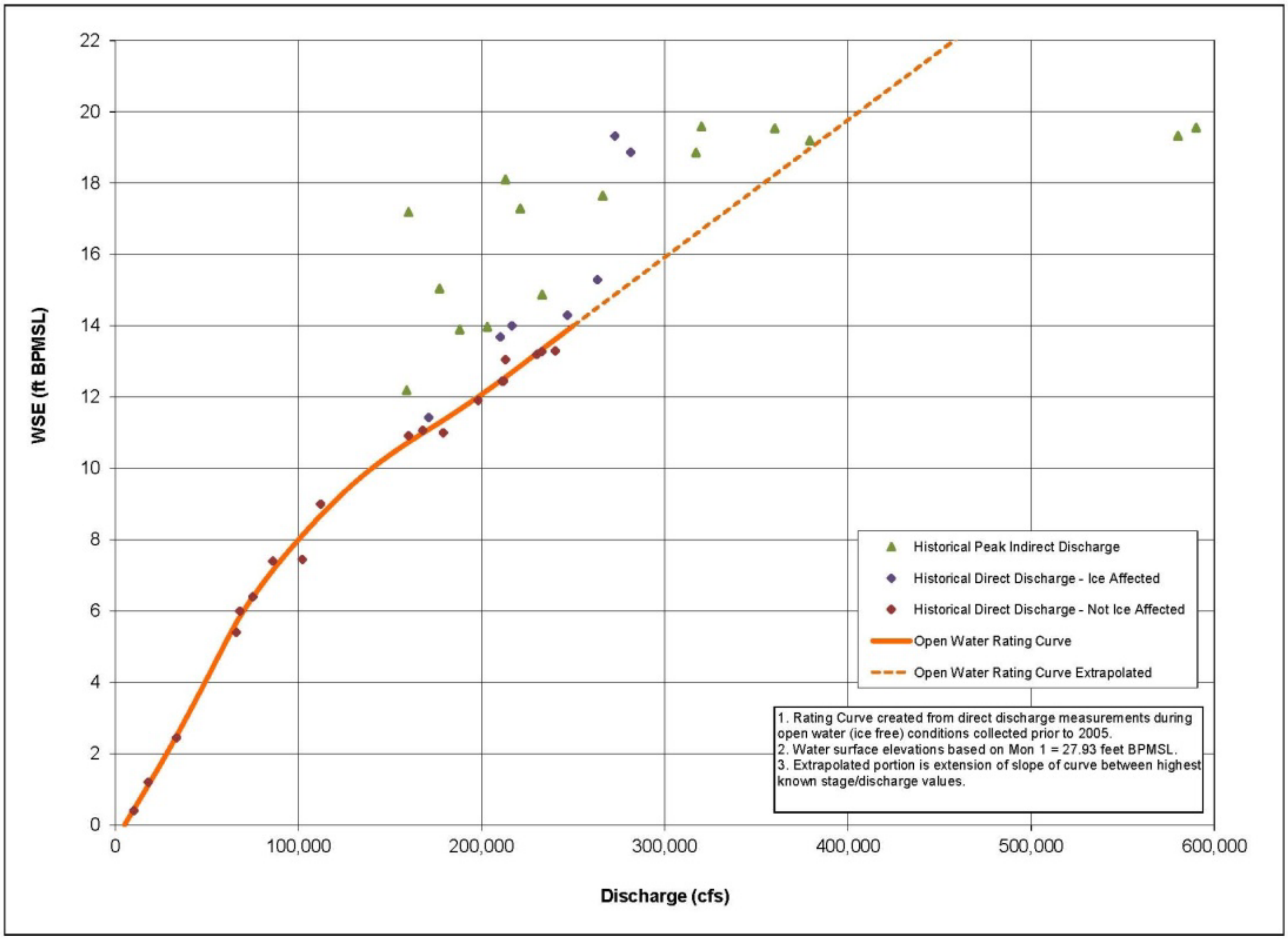
The MON1 stage-discharge rating curve, provided below in Graph D-1 represents a comparison between ice-affected and non-ice-affected direct discharge measurements and historical peak indirect discharge values. As stated in Section 5.1.2, these values fairly accurately represent the relationship between stage and discharge at lower-stage values when ice-free direct discharge measurements are possible. The stage-discharge rating curve may be used as a basis of comparison for accuracy of indirect-discharge-calculated values. The limitations of this curve are the ice effects on stage and discharge that are common during peak flow periods, as open-water conditions rarely occur at or near recorded historical peak stage levels. This rating curve was extrapolated beyond known values; those values at lower stage-discharge periods. For the purpose of extrapolation, the slope is based on the highest known values. This section of the curve is used as a general reference only.



1. Rating Curve created from direct discharge measurements during open water (ice free) conditions collected prior to 2005.
2. Water surface elevations based on Mon 1 = 27.93 feet BPMSL.
3. Extrapolated portion is extension of slope of curve between highest known stage/discharge values.

GRAPH D-1: MON1 HISTORIC STAGE AND DISCHARGE DATA V. RATING CURVE

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2011 Colville River Delta Spring Breakup Hydrological Assessment

124033-MBJ-RPT-001

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