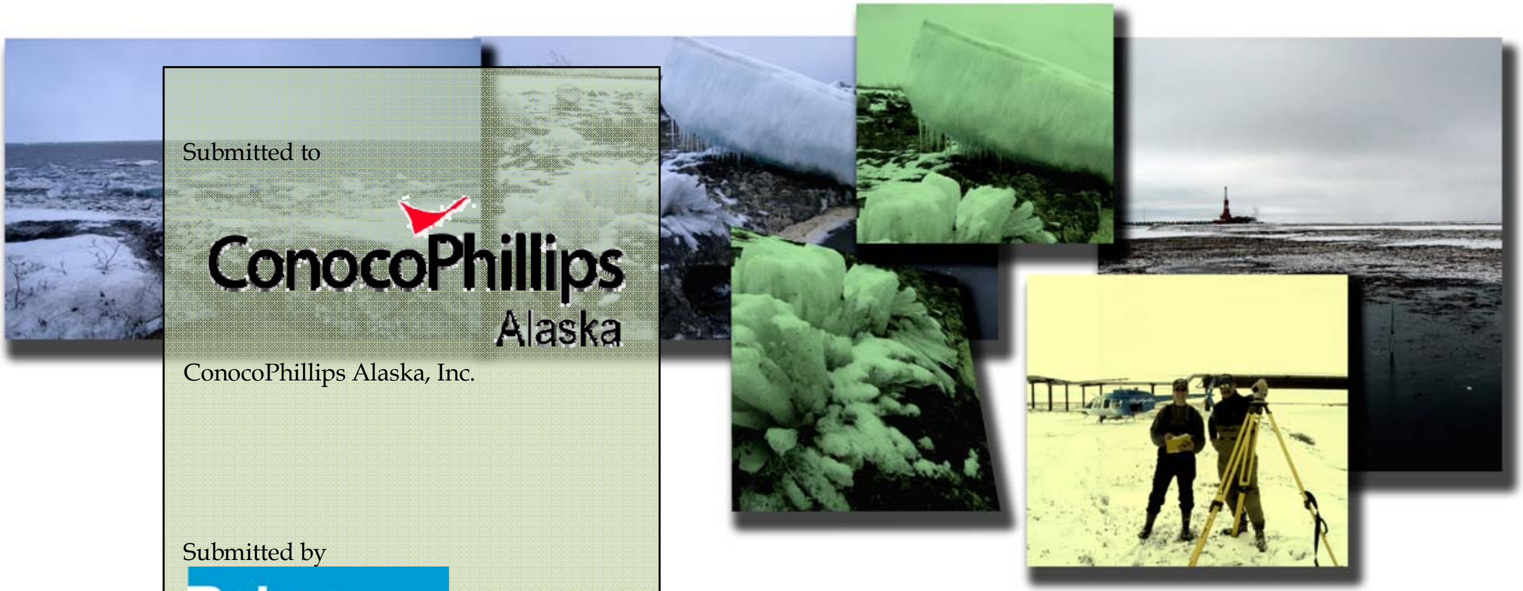
COLVILLE RIVER DELTA SPRING BREAKUP
2009 HYDROLOGIC ASSESSMENT



Submitted to

ConocoPhillips Alaska, Inc.

Submitted by

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117011-MBJ-RPT-001

EXECUTIVE SUMMARY

The 2009 Colville River Delta Spring Breakup Hydrologic Assessment, conducted by Michael Baker Jr., Inc. (Baker) at the request of ConocoPhillips Alaska (CPAI), supports the Alpine Development Project (ADP) and Alpine Satellite Development Plan (ASDP). 2009 was the eighteenth consecutive year of study in the region. The 2009 assessment is summarized below.

- *Locations.* Monitoring locations were the same as the 2008 locations, except three sites were added at proposed bridge crossings along the proposed CD5 pad access road.
- *Timing* of the Colville River breakup was earlier than average for both peak discharge (by nine days) and peak stage (by eight days) based on the historical record. The early timing of breakup may be attributed to an area-wide early warming period.
- *Water surface elevation (WSE).* The peak WSE at Monument 1 (MON1) at the head of the Delta occurred midday May 23. The peak water surface was measured at 17.65 feet (BPMSL), approximately 2.2 feet lower than the maximum peak WSE observed over the historic record. Peak water surface elevations around Alpine facilities had a recurrence interval of less than 5 years based on the stage frequency analysis.
- *Peak discharge.* The 2009 peak discharge of 266,000 cubic feet per second (cfs) was estimated to have occurred on May 23. The WSE at the time of peak discharge was estimated to be approximately 15.3 feet. The peak discharge has a recurrence interval of 3 years based on the Colville River flood frequency analysis.
- *Ice jamming.* Ice jamming was observed on May 22 at the Anaktuvuk confluence and upstream of the Itkillik confluence. Ribbon ice was also observed on this day in the vicinity of MON1 and Monument 9 (MON9). Ice jamming at the head of the Nigliq Channel occurred on May 23. Ice-free flow was not observed in the Colville until May 25. No adverse affect to the horizontal directional drilled (HDD) Colville River crossing site or Alpine facilities were observed as a result of ice jams.
- *Drinking water lakes recharge.* Floodwaters from the Sakoonang Channel recharged drinking water Lake L9313 to bankfull conditions. Lake L9312 did not receive floodwaters, and remained frozen for the majority of the monitoring period. Lake L9312 did not achieve bankfull recharge.
- *Drainage structures.* Conveyance through Alpine drainage structures was only observed along the CD2 access road at the Alpine swale bridges and at three neighboring culverts. No flow was observed in culverts along the CD4 road. Snow and ice had little impact on the hydraulic performance of the facilities drainage structures. No significant erosion was observed on any of the gravel structures subjected to floodwater.

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1.0 INTRODUCTION

Spring breakup flooding is the largest annual flooding event in the North Slope region. Monitoring of this event 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 annual flooding event.

Many areas on the North Slope of Alaska, including the Colville River Delta, share similar hydrologic and hydraulic characteristics common to the arctic climate and to the continuous presence of regional permafrost. Shallow groundwater is generally restricted to isolated zones beneath deep lakes and river channels. Groundwater influx is largely nonexistent. For much of the year, ponds, lakes, small streams and drainages remain frozen. After spring breakup, flow generally declines over the summer months, with temporary minor flow increases resulting from rainfall events. Figure 1.1 shows the Colville River Delta Drainage Basin Delineation.

The Alpine facilities are owned by ConocoPhillips Alaska Inc. (CPAI), in conjunction with Anadarko Petroleum Company, and are operated by CPAI. “Alpine facilities” refers to the existing facilities including the CD1 processing facility (Alpine); CD2, CD3, and CD4 drilling pads; access roads; and associated pipelines. Figure 1.2 shows the existing and proposed Alpine facilities within the extents of the monitoring region. Spring breakup monitoring activities have been conducted specifically for the Alpine Development Project (ADP) since 1992. Monitoring for the Alpine Satellite Development Plan (ASDP) facilities, including CD3 and CD4, has been conducted since 2004. The 2009 hydrologic field program is the 18th consecutive year of breakup investigations.

This report presents the results of the 2009 spring breakup monitoring activities conducted in the Colville River Delta (CRD) by Michael Baker Jr., Inc. (Baker). The gage monitoring locations at existing Alpine facilities, roads, pipeline bridge crossings, and at proposed CD5 road crossings are shown in Figure 1.3. The monument monitoring locations along the Colville River and Nigliq Channel are illustrated in Figure 1.4. The proposed CD5 drilling pad and access road locations, as presented in Figure 1.3 and Figure 1.4, were current as of the time of this study, and were provided by PND Engineers, Inc. The specific monitoring locations at the proposed CD5 crossings (Gage 21 [G21], G22, and G23) are shown in Figure 1.3.

Fieldwork began on May 7 and was completed on June 9, 2009. The report is organized into five sections and associated appendices as outlined below.

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

Section 2, 2009 Monitoring Locations: Outlines and discusses the 2009 monitoring sites.

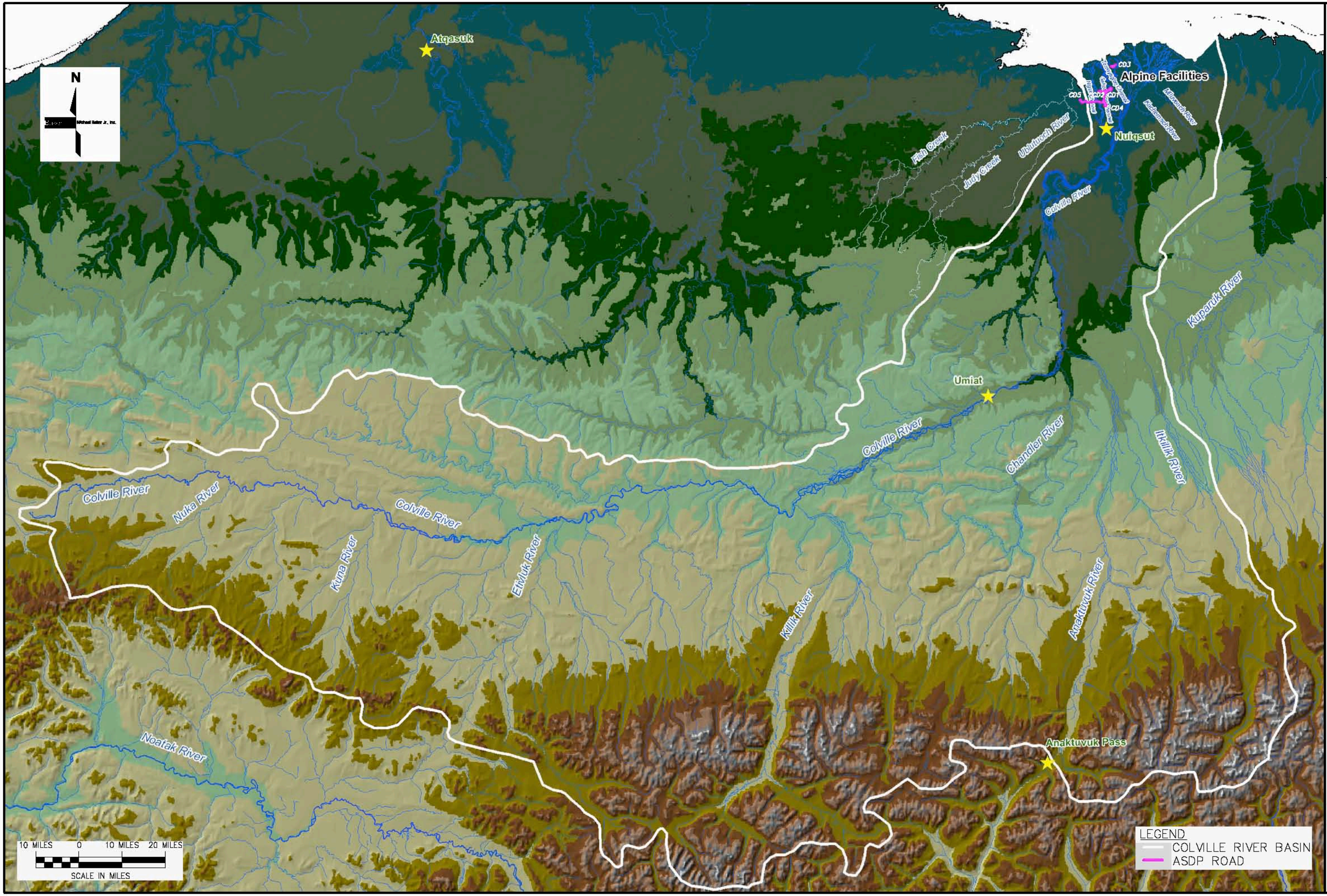
Section 3, Methods: Describes the methods of both the fieldwork and the data analyses.

Section 4, 2009 Spring Breakup: Presents the observations, stage, and discharge results including a two-dimensional hydrodynamic modeling analysis of the region as well as a discussion of the Alpine pad and erosion survey, and ice bridge breakup monitoring at the East Colville, Nigliq and Kachemach.

Section 5, References: Contains the references used in the development of this report. A list of Acronyms and a Glossary are also included to assist the reader.

Appendices: Includes survey control for monitoring gages and their geographic locations, acoustic Doppler current profiler (ADCP) discharge results, direct discharge results, and Lake L9312 water balance results.

We would like to thank Alaska Kuukpik/LCMF, Inc., and AirLogistics Helicopters for their assistance with the CRD breakup water resources field work. Their support and diligence contributed to a safe and productive breakup monitoring season and is greatly appreciated. Our thanks, as well, to the Alpine Environmental Coordinators, ACS, and others who assisted with ground travel logistics when tundra travel closed early this spring. We would also like to express our gratitude to CPAI for their continued trust in Baker to perform this work.



COLVILLE RIVER DELTA
DRAINAGE BASIN
DELINEATION

FIGURE 1.1
(SHEET 1 OF 1)

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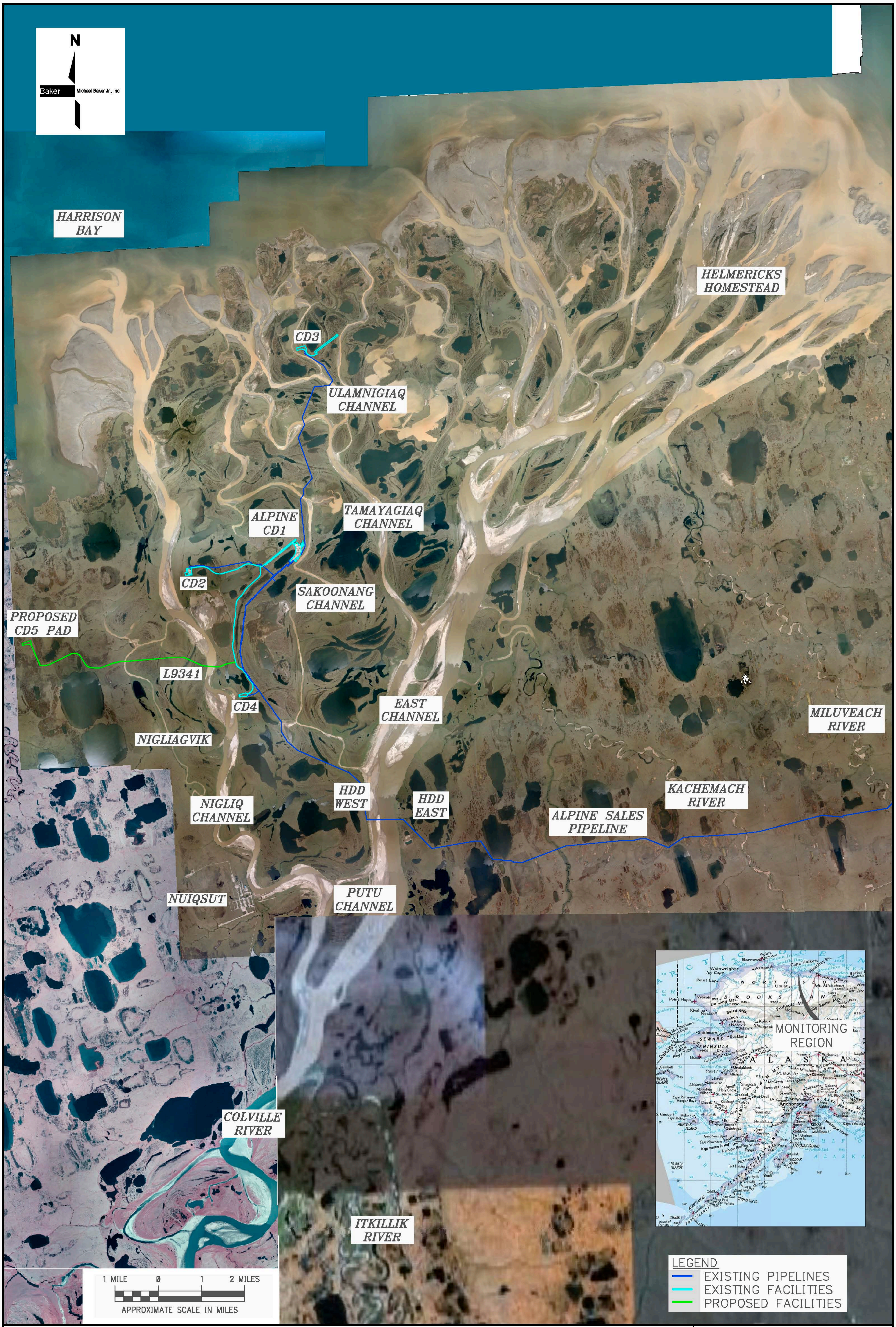

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2009 SPRING BREAKUP
COLVILLE RIVER DELTA
EXISTING & PROPOSED FACILITIES
FIGURE 1.2
(SHEET 1 OF 1)

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2009 SPRING BREAKUP
ALPINE AREA FACILITIES
GAGES

FIGURE 1.3
(SHEET 1 OF 1)

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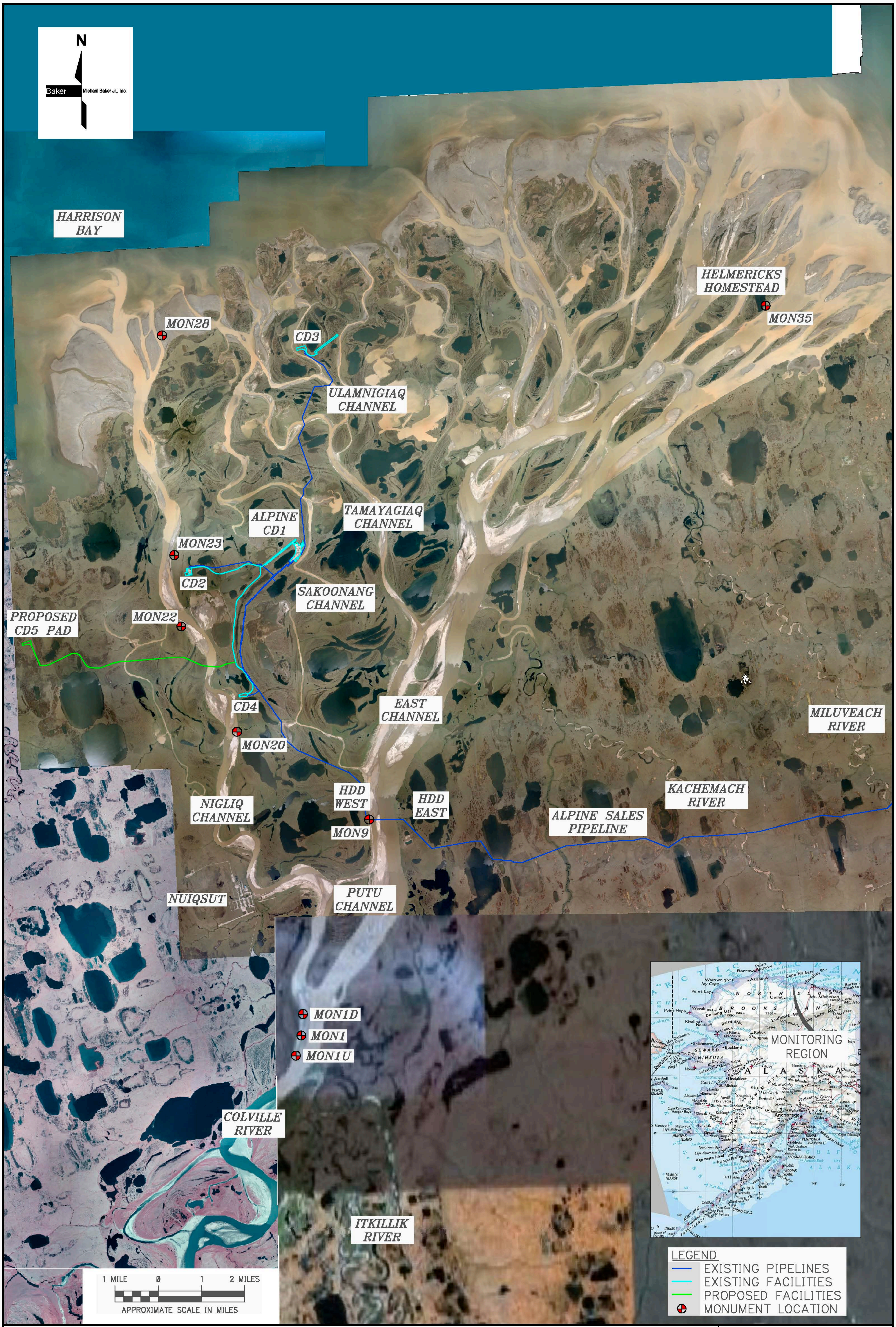

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2009 SPRING BREAKUP
COLVILLE RIVER DELTA
MONUMENTS
FIGURE 1.4
(SHEET 1 OF 1)

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1.1 MONITORING OBJECTIVES

Annual monitoring is conducted to evaluate the affect of breakup flooding events on existing facilities and infrastructure. It is also performed to collect data for analysis and design of proposed infrastructure projects.

The primary objective of the 2009 Colville River Delta Spring Breakup Hydrologic Assessment was to monitor and estimate the magnitude of breakup flooding. The effort included observation of breakup events, documentation of the distribution of floodwater, measurement of water levels throughout the project area, direct discharge measurement at Monument 1, and subsequent analysis of collected data.

Alpine facilities were monitored to satisfy 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. This included direct and indirect measurements of discharge through existing drainage structures, and documentation of pad and access road erosion caused by spring breakup.

Monitoring of recharge to Lakes L9312 and L9313 was completed to comply with State of Alaska Department of Fish and Game (ADF&G) permits FG99-III-0051-Amendment #7 and FG97-III-0190-Amendment #5, respectively. 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.

The 2009 spring breakup program also documented observations of effects to flow and channel morphology caused by the winter ice bridges across the East Channel of the Colville River at the HDD crossing, the Nigliq Channel, and the Kachemach River.

1.2 CLIMATIC REVIEW

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

Annual spring runoff in the Brooks Range contributes to rising stage in the Colville River and regionally related streams. The Brooks Range is located approximately 150 air miles south of MON1. MON1 is of particular interest for the CRD spring breakup assessment as it is the location farthest downstream on the Colville River where the majority of contributing flow in the Colville River is confined to a single channel.

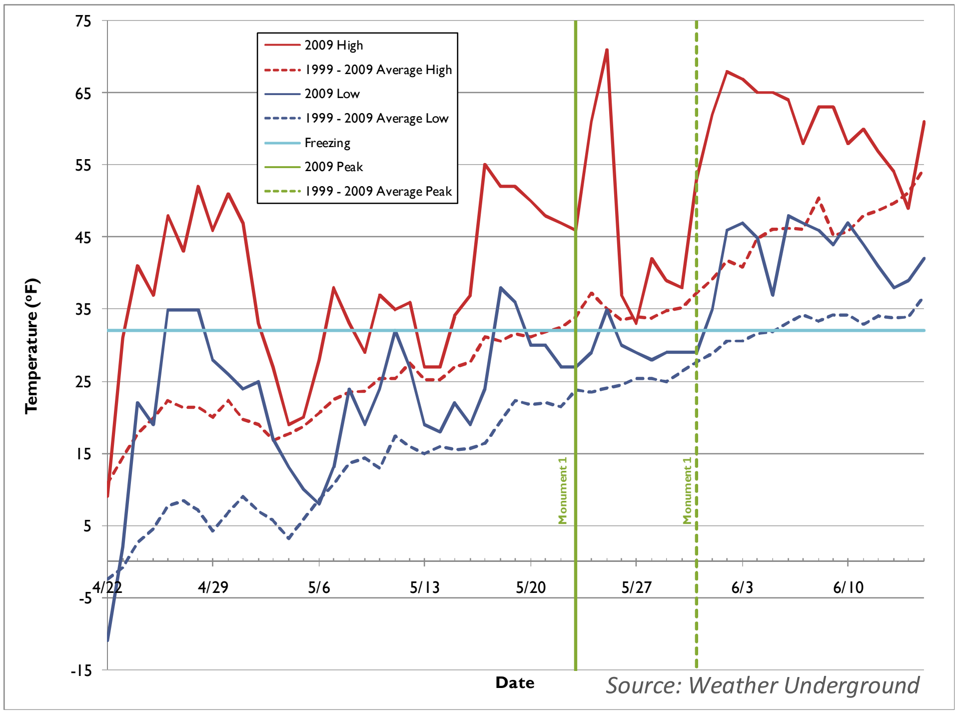
Breakup events historically coincide with increasing spring temperatures, particularly the rise of nightly low temperatures in the Brooks Range where the headwaters of the Colville River are located. As these nightly lows begin to approach and exceed freezing, breakup processes accelerate, melting snow in the area of the Colville River headwaters. This flow then progresses downstream towards the CRD.

Climate data for this region in the foothills of the Brooks Range are available from a monitoring station at Umiat, located approximately 60 air miles south of MON1. Review of daily high and low temperatures can be useful when evaluating breakup timing.

Graph 1.1 provides high and low temperatures for Umiat as recorded during the 2009 breakup monitoring period, from April 22 to June 15. Average highs and lows for the same late-April to mid-June time period for 1999 through 2009 are shown as dashed lines. Dates of 2009 peak stage and average peak stage from 1999 to 2009 from the centerline gage at Monument 1 (MON1C) are included for comparison.

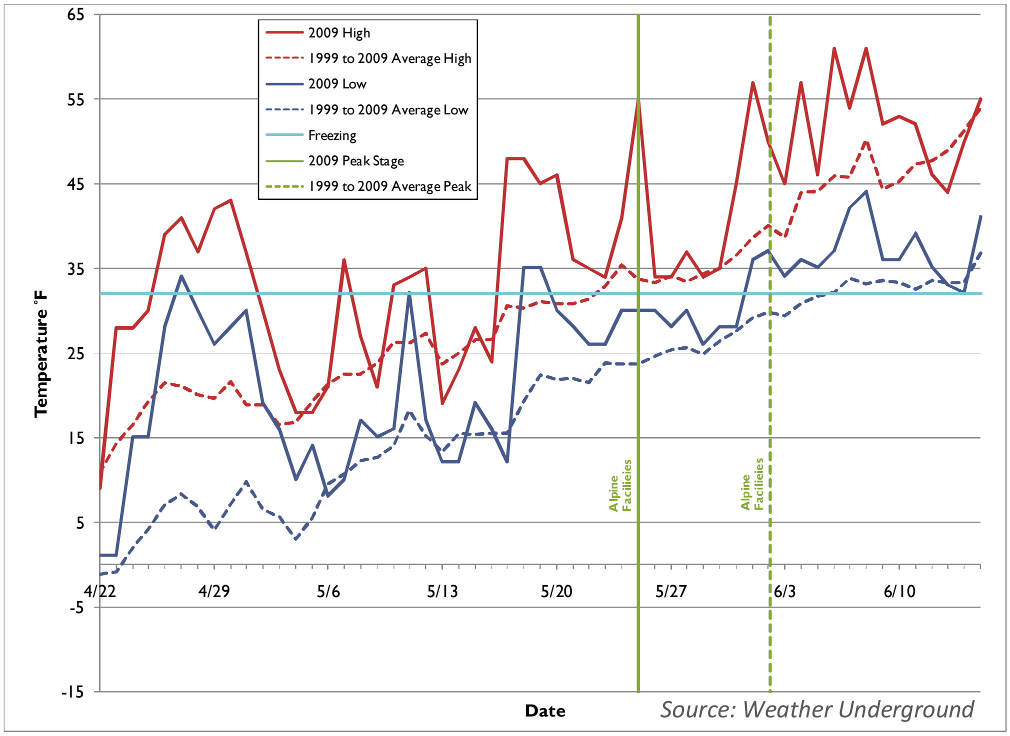
As shown in Graph 1.1, somewhat unseasonably warm weather throughout the region in late April appears to have affected the 2009 breakup cycle. Temperatures close to freezing at night may have set the stage for an earlier-than-typical peak stage at MON1 on the Colville River. This early warming trend contributed in part to an early arrival of flow at MON1. Peak stage at MON1 occurred on May 23, approximately eight days earlier than the historic average of May 31. This is further discussed in Section 1.3.

Graph 1.2 provides high and low temperatures for Nuiqsut as recorded during the same period. Nuiqsut is located approximately 3.5 air miles NW of MON1, and approximately 9 miles SW of the Alpine facilities. Local melting in the vicinity of Alpine facilities was initiated as daily highs and lows in the area, recorded in Nuiqsut, approached and exceeded freezing.



Source: Weather Underground

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



Source: Weather Underground

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

1.3 BREAKUP TIMING

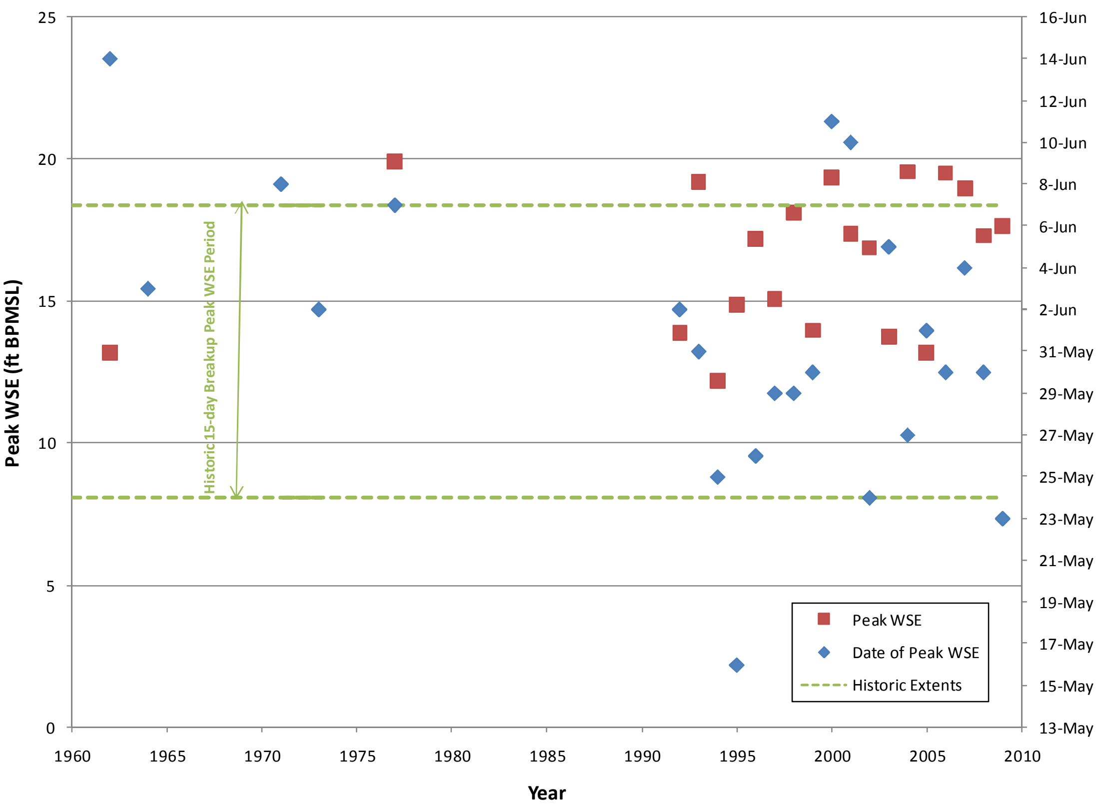
Breakup monitoring data for the Colville River have been intermittently collected at various locations since 1962. The most consistent historical record of breakup peak stage and discharge observations available for the CRD is at MON1. MON1 is located along the western bank of the Colville River approximately 3.5 air miles southeast of Nuiqsut. This location is the furthest downstream reach on the Colville River where all flow is confined to a single channel before entering the Delta (see Figure 1.4). Table 1.1 presents the annual peak discharge, peak stage, and the respective dates for the years that data are available for MON1.

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

	Discharge		Stage		
Year	Peak Discharge (cfs)	Date	Peak Stage (ft BPMSL)	Date	Reference
2009	266,000	23-May	17.65	23-May	This report
2008	221,000	28-May	17.29	30-May	Baker 2008b
2007	270,000	3-Jun	18.97	4-Jun	Baker 2007b
2006	281,000	30-May	19.83	30-May	Baker 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 15 recorded peak discharge dates, the average date of peak discharge is June 1. This year, peak discharge was estimated to have occurred on May 23, which is approximately nine days earlier than average. Based on the 23 recorded peak stage (peak water surface elevation or peak WSE) dates, the average date of peak WSE is May 31. In 2009, peak WSE occurred on May 23, eight days earlier than average.

Graph 1.3 presents the date and stage of peak WSE near MON1 for those years that data are available. All elevations presented in this report are in feet based on the BPMSL datum.



GRAPH 1.3: MONUMENT 1 ANNUAL PEAK WATER SURFACE ELEVATION AND DATES

Based on the dates available for the 23-year historical peak WSE record, nearly 75% of peak WSE for the CRD at MON1 have occurred during the 15-day period from May 24 to June 7. Eliminating the extreme peak WSE dates of May 16 and June 14, over 80% of the peak WSE dates fall within this 15-day window. This 15-day window is illustrated on Graph 1.3. The 2009 peak WSE at MON1 on May 23 occurred outside of the May 24 to June 7 peak WSE period.

The measured 2009 peak WSE value was 17.65 feet BPMSL. The maximum historical peak water surface elevation was in 2006 at 19.83 feet (Baker 2007b). The historical average peak WSE, based on the available 20 dates recorded is 16.53 feet. 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 and that pattern was consistent in 2009, with peak stage occurring around the facilities on or near May 25.

Section 4.0 further discusses the timing of spring breakup events within the CRD. Additional historic WSE information relating to flood and stage frequency is provided in Section 5.7.

2.0 2009 MONITORING LOCATIONS

Monitoring locations are based on topography, the proximity of existing and proposed facilities to relevant terrain features, and the historical hydrologic and hydraulic observation locations in the region.

The CRD 2009 monitoring locations were consistent with those presented in the *2008 Colville River Delta Spring Breakup and Hydrologic Assessment* (Baker 2008b), except for the addition of sites used to monitor conditions at three proposed bridge crossings along the proposed CD5 pad access road alignment. An overview of the 2009 facilities of interest is shown in Figure 1.2; gaging locations are presented graphically in Figure 1.3; monument locations are shown in Figure 1.4. Table 2.1 lists the gaging and monument monitoring sites and Table 2.2 presents the additional monitoring sites investigated during the 2009 breakup monitoring program. These locations are also presented with reference to survey control in Appendix A.

Locations are often identified in river miles (RM). Measurement of river miles commences at RM 0 at the mouth of the Delta at Harrison Bay. Measurement upstream is identified along the Nigliq (N) and East (E) channels of the Colville River. For example, RM N7.0 indicates a location 7.0 miles upstream from Harrison Bay on the Nigliq Channel.

2.1 MONUMENTS

PHOTO 2.1: COLVILLE RIVER REACH AT MON1, LOOKING SOUTH. MAY 18, 2009.

The Colville River Delta is bounded upstream by MON1, which serves as the head of the Delta. This is the location furthest downstream on the Colville River where the flow from all primary contributors is confined in a single channel prior to the Nigliq and East Channel bifurcation. Photo 2.1 shows the Colville River reach at MON1. MON1 is located at RM E27.1.

Approximately 1.0 miles downstream from MON1, the Colville River divides into the Nigliq and East Channels. The smaller Nigliq Channel flows past Nuiqsut west of the Alpine facilities. The larger East Channel flows east of the Alpine facilities. The mouth of the Delta lies at the end of a braided floodplain which empties into Harrison Bay.

TABLE 2.1: COLVILLE RIVER DELTA MONITORING PROGRAM LOCATIONS

Gaging Stations	
Location	**Notes**
Monuments - Colville East Channel	
MON1 (incl. MON1U & MON1D)	Entire Colville Flow confined to a single channel
MON9	HDD crossing
MON35	Helmricks Homestead
Monuments - Nigliq Channel	
MON20	S of CD4
MON22	S of CD2
MON23	N of CD2
MON28	At Harrison Bay
Alpine Facilities and Roads	CD1, CD2 & CD4; includes Alpine lakes
G1	CD1 betweeen Pad and Sakoonang Channel
G9	CD1 Pad area, Lake L9312
G10	CD1 Pad Area, Lake 9313
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
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 west end of Pad and Nigliq Channel
CD3 Pipeline River Crossings	
SAK	Sakoonang (Pipe Bridge #2)
TAM	Tamayagiaq (Pipe Bridge #4)
ULAM	Ulamnigiaq (Pipe Bridge #5)
Proposed CD5 Crossings	
G21	E Bank, Nigliq Channel
G22	W Bank, Lake L9341
G23	W Bank, Niglagvik

Bold font indicates a direct-read permanent staff gage.

TABLE 2.2: CRD ADDITIONAL MONITORING SITES

Additional Monitoring	
Location	**Notes**
Alpine Swale Bridges	
62-foot bridge	Along CD 2 Road
452-foot bridge	Along CD2 Road
Alpine Culverts	
CD2-22	Along CD2 Road
CD2-23	Along CD2 Road
CD2-24	Along CD2 Road
Alpine Roads	Erosion monitoring
CD2 Road	
CD4 Road	
East Channel Ice Bridge	Breakup monitoring HDD West

2.1.1 COLVILLE EAST CHANNEL

East Channel monitoring sites extend from MON1 downstream to Helmericks Homestead located near Monument 35 (MON35) at RM E3.0.

MON1 has been monitored annually since 1992. Three gaging stations are installed at MON1: one upstream (MON1U) at RM E27.6, one downstream (MON1D) at RM E26.6 and one between, often referred to as MON1 centerline (MON1C). Section 4.0 of this report includes a plan view and historical (2004) cross-sections at the MON1 gage locations.

MON35 was selected to monitor breakup events at the downstream reach of the East Channel. MON35 has been monitored intermittently since 1999.

In addition to gages at MON1 and MON35, a gaging station at Monument 9 (MON9 at RM E20.5) was selected to monitor the HDD crossing of the Alpine Sales Pipeline (ASP). This location is downstream of the Putu Channel and upstream of the Sakoonang Channel distributaries. MON9 has been monitored annually since 2005. All East Channel gages are located on the west bank. Repair and survey of all gages was completed between May 9 and May 15, 2009.

2.1.2 NIGLIQ CHANNEL

Nigliq Channel monitoring sites extend downstream from Monument 20 (MON20) at RM N13.1 to Monument 28 (MON28) at RM N0.8 at Harrison Bay.

MON20 gages are located on the east bank, just south of the CD4 pad. Photo 2.2 shows the proximity of CD4 from the MON20 gage location.

Monument 22 (MON22), the next site downstream from MON20, is located approximately midway between CD2 and CD4 at RM N9.7. Gages are located on the west bank.

PHOTO 2.2: NIGLIQ CHANNEL AT MON20 LOOKING TOWARD CD4. MAY 10, 2009.

Monument 23 (MON23), located north of CD2 at RM N7.6, is the next monitoring site downstream. The gages at MON23 are located on the east bank. Section 4.0 includes a plan view and historical cross-section at the MON23 gage location. Monument 28 (MON28) is located at RM N0.8, near the mouth of the Nigliq at Harrison Bay. MON28 is the northernmost gage on the Nigliq Channel.

All Nigliq Channel gages have been monitored intermittently since 1998 with the exception of MON28, which has been monitored intermittently since 1999. Repair and survey of all gages was completed between May 9 and May 16, 2009.

2.2 ALPINE AREA FACILITIES

Historically, gages were established between the Sakoonang and Nigliq Channels to monitor WSE and flow from major hydrologic features adjacent to existing Alpine pads and roads. In addition to facility stage (WSE) measurement, various locations are monitored for lake recharge, road prism erosion assessment, and ice bridge breakup.

2.2.1 GAGES

Alpine facility and lake gages include both direct-read permanent staff gages and indirect-read staff gages. Section 3.2.1 also discusses gage assemblies.

Direct-read gages are permanently mounted staff gages surveyed and assembled such that the gage faceplate corresponds to actual BPMSL elevation. For example, a high water mark (HWM) reading of 7.63 on gage G3 along the CD2 road indicates a HWM elevation of 7.63 feet BPMSL. Direct-read staff gages include G1, G3, G4, G6, G7, G9, G10, and G19. All direct-read permanent staff gages were surveyed and adjusted for elevation in May 2009 by LCMF.

PHOTO 2.3: G4 AND CULVERT CD2-22. MAY 22, 2009

Indirect-read staff gages are gages established with a faceplate that does not directly correspond to actual elevation. Baker surveys 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 1.24 on gage G20-B is corrected based on a Baker survey tying G20-B to local control. In this particular case, after adjustment is made, the indirect staff gage reading of 1.24 corresponds to a HWM elevation of 9.12 feet BPMSL. All indirect-read gages were surveyed by Baker.

Taken along the CD2 road, Photo 2.3 shows G4, culvert CD2-22 and the CD2 pipeline. Figures showing the facility gage locations in relation to drainage structures are provided in Section 4.0 of this report.

2.2.2 LAKES

Gages G9 and G10, installed at Lakes L9312 and L9313 respectively, were monitored to record recharge as per lake-use permit requirements discussed in Section 1.1. Photo 2.4 shows G10 at L9313 on the edge of the CD1 pad.

PHOTO 2.4: G10 AT LAKE L9313. MAY 22, 2009

2.2.3 DRAINAGE STRUCTURES

Various types of drainage structures, located along the Alpine pad access roads, were installed to allow passage of flood waters with associated sediment loads, and provide fish passage, as well as to maintain the structure and function of wetland habitats near the facilities. These drainage structures include culverts along both Alpine access roads as well as the 62-foot (short) and 452-foot (long) swale bridges along the CD2 access road.

PHOTO 2.5: SOUTH SIDE 452-FT (LONG) SWALE BRIDGE; SNOW DAM PRESENT BLOCKING FLOW. MAY 22, 2009.

PHOTO 2.6: NORTH SIDE OF 452-FT SWALE BRIDGE; SNOW DAM. MAY 22, 2009.

Discharge measurements were performed at the long bridge and at selected nearby culverts in addition to gaging WSE along the roads. Discharge measurements were not performed at all of the drainage structures because flow conditions were too low for meaningful measurements. Photo 2.5 and Photo 2.6 show the 452-ft swale bridge when an ice and snow dam temporarily blocked flow from south to north.

2.2.4 EROSION

Alpine access roads were evaluated post-breakup for evidence of erosion due to flooding. Data were collected from observations along the length of both shoulders of each gravel road and pad within the Alpine system.

PHOTO 2.7: EAST CHANNEL ICE BRIDGE. MAY 8, 2009.

2.2.5 ICE BRIDGES

Breakup monitoring of the ice bridges spanning the Colville River East Channel (near HDD), Nigliq Channel, and Kachemach River were performed by visual observation of each area. Photo 2.7 shows the eastern stretch of the Colville River East Channel ice bridge during the early stage of breakup.

2.3 CD3 PIPELINE RIVER CROSSINGS

Gaging stations were installed at the CD3 pipeline stream crossings to monitor breakup conditions at these facilities. These locations included Crossing #2 on the southwest bank of the Sakoonang (SAK), Crossing #4 on the south bank of the Tamayagiaq (TAM), and Crossing #5 on the northeast bank of the Ulamnigiaq (ULAM) Channels, all of which have been monitored intermittently since 2000. Repair and survey of all CD3 pipeline crossing gages was completed on May 9.

2.4 PROPOSED CD5 ROAD CROSSINGS

Gages were installed this spring to monitor flow at designated crossings along the proposed CD5 road alignment. These locations include Gage 21 (G21) on the east bank of the Nigliq Channel, Gage 22 (G22) on the west bank of Lake L9341, and Gage 23 (G23) on the east bank of the Nigliagvik.

Photo 2.8 and Photo 2.9 show installation of gages at the Nigliagvik. Photo 2.10, Photo 2.11, and Photo 2.12 show pre-breakup views of the CD5 crossing locations at the Nigliq Channel, L9341, and the Nigliagvik, respectively.

PHOTO 2.8: INSTALLATION OF GAGES AT THE NIGLIAGVIK. MAY 18, 2009.

PHOTO 2.9: INSTALLATION OF G23-A, NIGLIAGVIK. MAY 18, 2009.

PHOTO 2.10: NIGLIQ CHANNEL PROPOSED CD5 CROSSING. MAY 18, 2009.

PHOTO 2.11: LAKE L9341 PROPOSED CD5 CROSSING. MAY 18, 2009.

PHOTO 2.12: NIGLIAGVIK PROPOSED CD5 CROSSING. MAY 18, 2009.

3.0 METHODS

The primary methods used in the 2009 monitoring program were visual observations of melt water flow and distribution, measurement of WSE, and documentation of discharge. Field methods were based on standard techniques proven to be safe, reliable, efficient, and accurate for the conditions found on the North Slope of Alaska during spring breakup. Safety, logistics, and weather were the factors that most affected the collection of data.

3.1 VISUAL OBSERVATIONS

Visual observations of breakup events in the project area were conducted from the ground via Hägglund BV206 tracked vehicles from May 7 to May 10, 2009. Husky Air Boats were utilized on May 12, 2009. Observations were conducted by helicopter from May 14 to June 9, 2009. Ground travel ended earlier than is typical due to warmer than normal temperatures and the associated diminished ground snow cover.

All observations were recorded daily in field notebooks. Digital photographs were taken to document the progression of spring breakup prior to, during, and after peak flooding events. The geographic position of the camera in latitude and longitude (lat/long), date, and time were automatically imprinted onto each photo. Photo datum is WGS 84. Additional photographs were taken and their locations were manually geographically referenced, confirmed, and then imprinted onto each photograph to document the location of each image.

3.2 WATER SURFACE ELEVATION (WSE)

3.2.1 STAFF GAGES

Water surface elevations were monitored using permanent and temporary staff gages. The permanent, direct-read staff gages are located at CD1 and CD2 and consist of permanently-mounted metal gage faceplates attached to drill steel. The temporary, indirect-read gage sets consisted of between two and five staff gage assemblies. Each gage assembly consisted of a metal gage faceplate mounted on a two-by-four timber attached with U-bolts to 1.5-inch wide angle iron posts driven into the ground. Installation of the temporary staff gages was completed prior to the arrival of breakup floodwater.

Most often, WSE was recorded by viewing the water level on the gage faceplate. High water marks were recorded when floodwaters removed the chalk applied daily to the drill stem or angle iron, as noted during field visits. At those times when water levels were not sufficiently high to be recorded on the staff gage face plates, standard level loop survey techniques were used to measure WSE. The horizontal position of each gage was recorded using a handheld Garmin 60CSx GPSMAP in North American Datum of 1983 (NAD83). Photo 3.1 shows an example of a temporary staff gage after installation.

PHOTO 3.1: TEMPORARY STAFF GAGE G22-A AT LAKE L9341. MAY 18, 2009.

The elevation of each gage was surveyed from a local benchmark tied to BPMSL using standard level loop techniques. The basis of elevation for each gage, as well as the horizontal position of respective benchmarks and gages, is presented in Appendix A. The most recent basis of elevation of vertical control was used for each survey.

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

3.2.2 PRESSURE TRANSDUCERS (PT)

Pressure transducers (PT) were installed at five locations: MON1U, MON1C, MON1D, MON9, and MON23. In-Situ, Inc. Level TROLL® 500 pressure transducers were used.

The PT consists of a non-vented pressure sensor designed to collect and store pressure and temperature data at discrete intervals. The PT measures the absolute pressure imparted by the atmosphere and water at the sensor, allowing the depth of water above the sensor to be calculated. Variations in barometric pressure were taken into account using an independent In-Situ, Inc. BaroTROLL® barometric pressure logger. Resulting data yield a more complete record of the fluctuations in WSE than could be captured by visual measurements alone.

The measured pressure datum is the sum of the forces imparted by both the water column and atmospheric conditions. As a result, a correction of local barometric pressure was required and obtained from an In-Situ, Inc. BaroTROLL® sensor located at MON9. This BaroTROLL® location is considered to be representative of the entire CRD. MON9 is located approximately 6 miles north of MON1 and 8.5 miles southeast of MON23. See Appendix A for PT and BaroTROLL® basis of elevation and horizontal positions.

PHOTO 3.2: INSTALLATION OF PRESSURE TRANSDUCER, MON1D. MAY 12, 2009.

Prior to deployment, the PT were configured using Win-Situ LT 5.1.1.0®. Absolute pressure was set to zero. Each individual PT was housed in a segment of perforated galvanized steel pipe, clamped to angle iron, and placed in the active channel nearest the channel bottom. Photo 3.2 shows installation of a PT at MON1. The PT sensor was surveyed to establish a vertical datum using local control. Water depth was determined based on the recorded absolute pressure adjusted for barometric pressure. For 2009, the PT were programmed to collect absolute pressure and water temperature at 15-minute intervals from May 8, 2009, to June 30, 2009.

PT based WSE values were determined by summing the calculated water depth and the surveyed sensor elevation. A standard conversion using the density of water at 0°C was used to calculate all water depths from adjusted gage pressure. Fluctuations in water temperature during the sampling period were not significant enough to affect WSE calculations due to the limited range in temperature and observed water depths. Table 3.1 shows a comparison of sample temperatures and the resultant differences, demonstrating negligible differences attributed to temperature variation.

TABLE 3.1: COMPARISON OF TEMPERATURE FLUCTUATION ON WSE CALCULATION

Temp (°C)	Temp (°F)	Specific Volume (ft^3/lb)	Density (lb/ft^3)	PSI/1ft Depth	Calculated Depth (ft)*	Difference
-18	0	0.01743	57.3723	0.39842	0.9191	0.0021
-1	30	0.01747	57.2410	0.39751	0.9170	-0.0830
0.01	32.018	0.01602	62.4220	0.43349	1.0000	0.0000
2	35	0.01602	62.4220	0.43349	1.0000	0.0012
18	65	0.01604	62.3441	0.43295	0.9988	

*Calculated using the density of water at 0.01˚C (32.018°F)

3.3 DISCHARGE MEASUREMENTS

Discharge was measured directly and was indirectly calculated based on field observations. Standard U. S. Geological Survey (USGS) midsection methods were used to directly measure discharge. An ADCP was used to directly measure discharge on the Colville River at MON1. 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 long Alpine swale bridge and at the CD2 road culverts. A meaningful direct discharge measurement at the short Alpine swale bridge near peak flow was not possible due to intact channel-fast ice over the entire measurement section. The CD4 access road culverts did not have flow this year; water did not reach the culvert inlet elevations.

Depth and velocity measurements conducted at the long bridge were taken from the upstream side of the bridge deck using a sounding reel mounted on a boat boom. The velocity meter was attached to the sounding reel and stabilized with a 30-pound Columbus-type lead sounding weight. A tag line placed along the upstream bridge rail was used to define the cross section and to delineate measurement subsections within the channel. Velocity measurements at the Alpine culverts were conducted using a USGS wading rod.

The Price AA velocity meter was calibrated by the USGS at the Office of Surface Water (OSW) Hydraulic Laboratory in 2006. A spin test of the meter was successfully completed before and after the long bridge measurement.

3.3.2 ACOUSTIC DOPPLER CURRENT PROFILER (ADCP)

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 very difficult given such factors as the remote location, water depths and 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).

Direct discharge measurements on the Colville River 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 kHz Workhorse Sentinel broadband ADCP was used. The unit has a four-beam transducer with 20-degree beam. Power was supplied to the unit and supporting laptop (Panasonic Toughbook® CF-19) via a deep-cycle marine battery and 400-watt power inverter.

BBTalk v3.06, a DOS-based communication program, was used to perform pre-deployment tests. WinRiverII v1.01 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 according to 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. Pre-deployment tasks also included compass calibration and verification. Internal compass error was within the specified 2-degree limit. Additional diagnostic tests were performed using WinRiverII.

3.3.2.3 ADCP DEPLOYMENT AND DATA COLLECTION

The Sentinel ADCP was mounted to an Achilles SGX-132 inflatable raft powered by a 10 hp outboard motor using a fabricated aluminum tube framework spanning the boat's midsection gunwales. The aluminum framework provided a rigid and secure placement of the ADCP unit while allowing necessary adjustments as river conditions required.

A sampling cross section was identified at an established monitoring site (MON1). A minimum of four transects were completed such that measured discharges varied by less than 5% of their mean. Cross section end points were dependent on a minimum water depth to provide acceptable data, which was approximately 8 feet.

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 identified coordinates. An ADCP measurement is being taken in Photo 3.3.

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 was recorded by tracking the bottom of the channel with the ADCP unit.

PHOTO 3.3: ADCP MEASUREMENT ON THE COLVILLE. MAY 26, 2009.

In channels like the Colville, where the bed material is composed of fine-grained material and water velocities are sufficient to entrain bed materials, a moving bed can result. 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 if a moving bed is present, and if present to provide an approximate correction to the final discharge. The USGS recently established guidance for the Loop Method by outlining procedures for mean correction and distributed correction (USGS 2006a). Both procedures yield results within 2% 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 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

Physical characteristics obtained from field observations are used to calculate the indirect discharge for the access road culverts, the swale bridges, the Colville River, and the Nigliq Channel. These physical characteristics, including WSE and slope, are used as hydraulic equation input variables to calculate indirect discharge.

PHOTO 3.4: CULVERT CD2-24, CD2 ACCESS ROAD. MAY 22, 2009.

The software CulvertMaster® v1.0 was used to estimate discharge through the access road culverts; an example of culvert discharge can be seen in Photo 3.4. Recorded water surface elevations and times of peak stage observations were used to estimate the timing of peak discharge through the culverts. The average velocity and discharge through the culverts were estimated based on several variables, including:

- Headwater and tailwater elevations at each culvert;
- Culvert diameter and length (from Kuukpik/LCMF as-built surveys);
- Culvert upstream and downstream invert elevation (Kuukpik/LCMF surveys 2008); and
- Culvert Manning's roughness coefficient (0.012 for smooth steel and 0.024 for CMP).

Indirect calculation of peak discharge through the swale bridges was performed by correlating observed hydraulic depths during the direct discharge measurement at the 452-ft swale bridge, and observed peak discharge conditions. This method assumes that the average measured velocity varies little between when direct measurements were taken in the field, and actual conditions at peak discharge. The assumption is valid if the observed increase in stage and upstream-downstream stage differential is relatively low. For this reason, direct discharge measurements are collected as near to peak discharge as possible.

The slope-area method for a uniform channel (Benson and Dalrymple 1967) was also used to develop indirect estimates of peak discharge for the Colville River and the Nigliq Channel. Water surface elevation and slope data were obtained from observations made at nearby gages. Cross-sectional geometry was based on historic cross-sections surveyed by

Kuukpik/LCMF; in 2004 on the Colville River, 2005 near MON23, and 2008 near the proposed CD5 bridge crossing location on the Nigliq Channel. Adjustments were made to the cross-sectional flow area, wetted perimeter, and roughness coefficients to account for the presence and affect of ribbon ice in the Nigliq Channel before the time of peak discharge.

3.4 FLOOD AND STAGE FREQUENCY ANALYSIS

The estimate of observed peak discharge in the Colville River is analyzed each year in terms of flood frequency. Results of this analysis are the discharge magnitudes used in facilities 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. Section 5.7.1 discusses the flood frequency analysis in greater detail.

Flood frequency was analyzed using methods outlined in *Guidelines for Determining Flood Flow Frequency*, otherwise known as "Bulletin 17B" (USWRC 1981). PeakFQ hydrologic frequency analysis software (USGS 2007), based on Bulletin 17B, was used to statistically fit observed peak discharge data.

Observed peak WSE are analyzed each year in terms of stage frequency and compared to the predicted 2-dimensional (2D) surface water model elevations at select locations in the CRD. 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 2009). The stage frequency analysis is used to validate the results of the 2D model, and additionally provides returns for observed peak stage data.

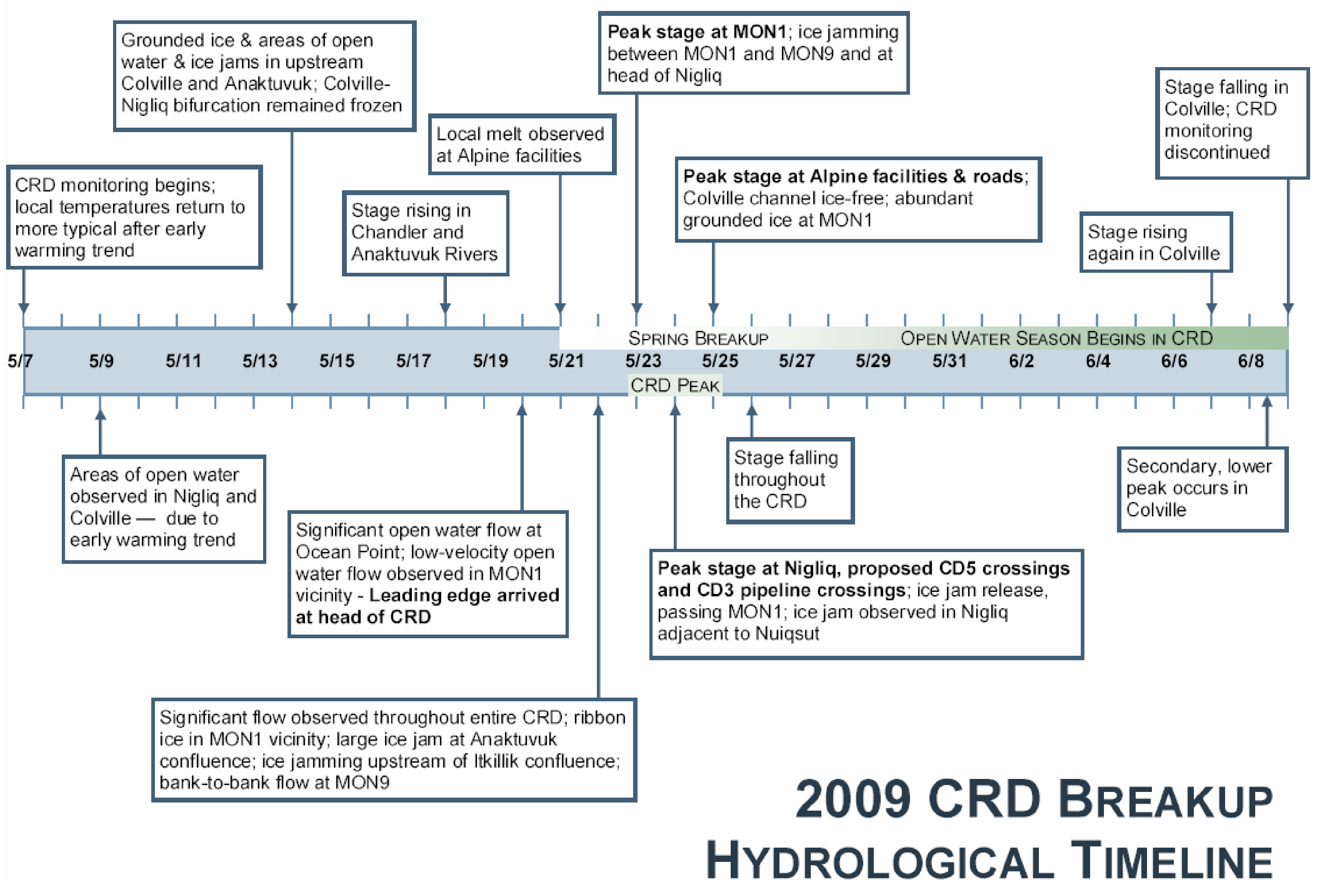
Stage frequency was analyzed using Federal Emergency Management Agency (FEMA 2003) and USACE (1991) guidelines. HYFRAN hydrologic frequency analysis software (INRS-ETE 2002) was used to statistically fit observed peak stage data.

4.0 2009 SPRING BREAKUP – HYDROLOGIC OBSERVATIONS

This chapter presents the images, data, and observations of the 2009 field program. Data and observations described in the following sections were documented between May 7 and June 9, 2009. Figure 4.1 provides a visual timeline summary addressing the major 2009 CRD breakup events.

As discussed in Section 1.2, the 2009 spring breakup event was affected by a period of unseasonably warm weather occurring in late April and early May. Air temperatures over a 5- to 7-day period spiked into the 30s and even low 40s locally at Nuiqsut, as seen in Graph 1.2. The timing of breakup in the study area was affected to some degree by the warm weather. An early warming trend can "set the stage" for breakup by pre-softening snow and ice such that when significant melt does occur, it occurs more rapidly and efficiently than if the early warming period had not occurred.

FIGURE 4.1: 2009 COLVILLE RIVER DELTA SPRING BREAKUP HYDROLOGICAL TIMELINE



4.1 COLVILLE RIVER DELTA

PHOTO 4.1: LOCAL MELT AND MON9. MAY 8, 2009.

As shown in Photo 4.1, localized melting of the Colville River was observed in the vicinity of MON 9 on May 8, likely due to local temperatures above freezing the previous day, as well as the sunshine. Connected open water, however, was not observed at this time. Leading edge did not arrive upstream at MON1 until May 20.

An initial aerial reconnaissance of pre-breakup conditions to the Anaktuvuk River confluence with the Colville River, which is located approximately 65 RM upstream of the head of the Delta (MON1) was conducted on May 14. Evidence of pre-breakup high water was observed; Photo 4.2 shows the presence of abundant grounded ice. Also present were large areas of open water and ice jams, as shown in Photo 4.3.

Rising stage at both the Chandler River confluence (approximately 70 RM upstream of MON1) and the Anaktuvuk River confluence was observed on May 18. Grounded ice was still present at this time. On May 20, the leading edge of water reached Ocean Point, located approximately 20 RM upstream of MON1. This represented the first significant open water seen near the head of the Delta.

PHOTO 4.2: GROUNDED ICE IN THE ANAKTUVUK RIVER. MAY 14, 2009.

PHOTO 4.3: OPEN WATER AND ICE JAM IN THE ANAKTUVUK RIVER. MAY 14, 2009.

Floodwaters entered the CRD on May 22. Ribbon ice was observed near MON1, and a large ice jam was noted at the confluence of the Anaktuvuk River.

4.2 MONUMENTS

On May 14, the East Channel and Nigliq bifurcation was frozen. Melt in this reach began on May 18, and low-velocity open water was first observed on May 20.

4.2.1 COLVILLE RIVER EAST CHANNEL

Daily monitoring of all East Channel gage locations began on May 22, when WSE had risen enough to be measurable on the gages. Photo 4.4 shows water on gage MON1U-A. Stage rapidly rose and peaked at MON1 (17.65 feet BPMSL) on May 23 and at MON9 the following day, May 24. Peak was not observed at MON35 (5.01 feet BPMSL) until May 26. Stage fell at a moderate rate until May 28, when stage dropped substantially and daily monitoring was discontinued at the Colville East Channel gages.

Monitoring was conducted briefly at MON1 and MON9 when WSE once again began rising in the Colville River on June 7, but the rise was not sustained and monitoring was discontinued on June 9. Data collected from pressure transducers installed at the East Channel gaging stations (MON1U, MON1C, MON1D and MON9) were consistent with recorded WSE measurements, except at MON1C, where the PT failed to correctly record data.

PHOTO 4.4: FIRST CRD MEASURABLE WSE ON MON1U-A. MAY 22, 2009.

Table 4.1 and Table 4.2 present the observations and WSE recorded for MON1C and MON1U and MON1D, respectively. Table 4.3 and Table 4.4 present the observations and WSE recorded for MON9 and MON35, respectively.

Ribbon ice was still present in the vicinity of MON1 on May 22, as shown in Photo 4.5. Significant ice jamming was also observed on May 22 in the area of the meander bends upstream of the Itkillik River confluence, located approximately 2.5 RM upstream of MON1 (see Photo 4.6). On May 22, ice jamming was also noted at the Anaktuvuk confluence. Breakup ice jams can be unstable events. Upon formation, water begins to back up behind the upstream edge of the ice jam. Upon release, often sudden and unpredictable, the stored water inundates downstream areas.

PHOTO 4.5: OPEN WATER AND RIBBON ICE IN MON1 VICINITY. MAY 22, 2009.

PHOTO 4.6: ICE JAM IN COLVILLE UPSTREAM OF ITKILLIK CONFLUENCE. MAY 22, 2009.

PHOTO 4.7: JUST AFTER PEAK STAGE AT MON1. MAY 23, 2009.

On May 23, the ribbon ice had dispersed and the ice jam at the Itkillik had failed (some time during the previous night). There was not a high water mark present at MON9 (located downstream of MON1) during a visit at 10:30 a.m. on May 23. However, there was a HWM at MON1D observed at 3:30 p.m. later that same day. A definite peak HWM was observed at MON1 during a site visit at 4:00 p.m. on May 23. Based on these gage observations, the peak stage likely occurred at MON1 sometime between 10:30 a.m. (when stage was still rising at MON9) and 3:30 p.m, (when a HWM was observed at MON1D). In support of the gage observations, PT data from MON1U and MON1D indicate peak stage at MON1 occurred between 12:00 p.m. and 12:30 p.m. on May 23. The rise was fairly substantial, an increase of nearly four feet over the water level observed on the afternoon of May 22. The sharp rise in water surface may have been the result of a combination of the release of the Itkillik jam, and the re-establishment of another minor ice jam as the released ice slowly migrated downstream.

Peak high water at MON9 was also affected by the ice jam release; however little to no effect was seen further downstream at MON35. Ice-grounding began along the western banks of the MON1-MON 9 reach as a result of the ice jam release and subsequent drop in stage. Photo 4.7 shows stranded ice at the Colville River at MON1 gaging station soon after peak stage on May 23.

PHOTO 4.8: GROUNDED ICE, MON1. MAY 25, 2009.

PHOTO 4.9: OPEN CHANNEL, MON9. MAY 28, 2009.

On May 24, the ice jam had moved past MON1. By May 25, ice had completely dispersed and was no longer present in the MON1 vicinity, leaving a relatively open, ice-free channel and abundant grounded ice (Photo 4.8).

The following day, a discharge measurement was taken at MON1. By this point the channel was sufficiently free of ice and debris to allow a safe discharge measurement by boat. The MON9 area was relatively ice-free by May 28, as seen in Photo 4.9. On May 27, channel ice began to break up and move out of the vicinity of Monument 35

TABLE 4.1: WSE DATA FOR GAGE MON1

Date and Time	WSE (feet BPMSL)	Observations
	MON1	
5/22/09 2:35 PM	13.93	Ribbon ice in vicinity; large ice jam upstream at Anaktuvuk confluence.
5/23/09 12:00 PM	17.65	High Water Mark. Peak occurred between 10:30am and 3:30pm.
5/23/09 4:02 PM	15.27	Ribbon ice gone; upstream ice jam gone.
5/24/09 10:22 AM	13.40	
5/25/09 4:40 PM	12.16	Abundant grounded ice; gage dry.
5/26/09 2:00 PM	11.42	Direct discharge 171,000 cfs 10:00 a.m.; Indirect discharge 181,000 cfs
5/27/09 4:55 PM	11.65	
5/28/09 3:03 PM	10.34	

Notes:

1. Elevations are based on Monument 1 at 27.93 feet BPMSL, surveyed by LCMF in 2006.
2. Indirect Peak Discharge 266,000 cfs based on a stage of 15.27 on May 23, 2009.
3. The PT at this location failed to correctly read WSE data.

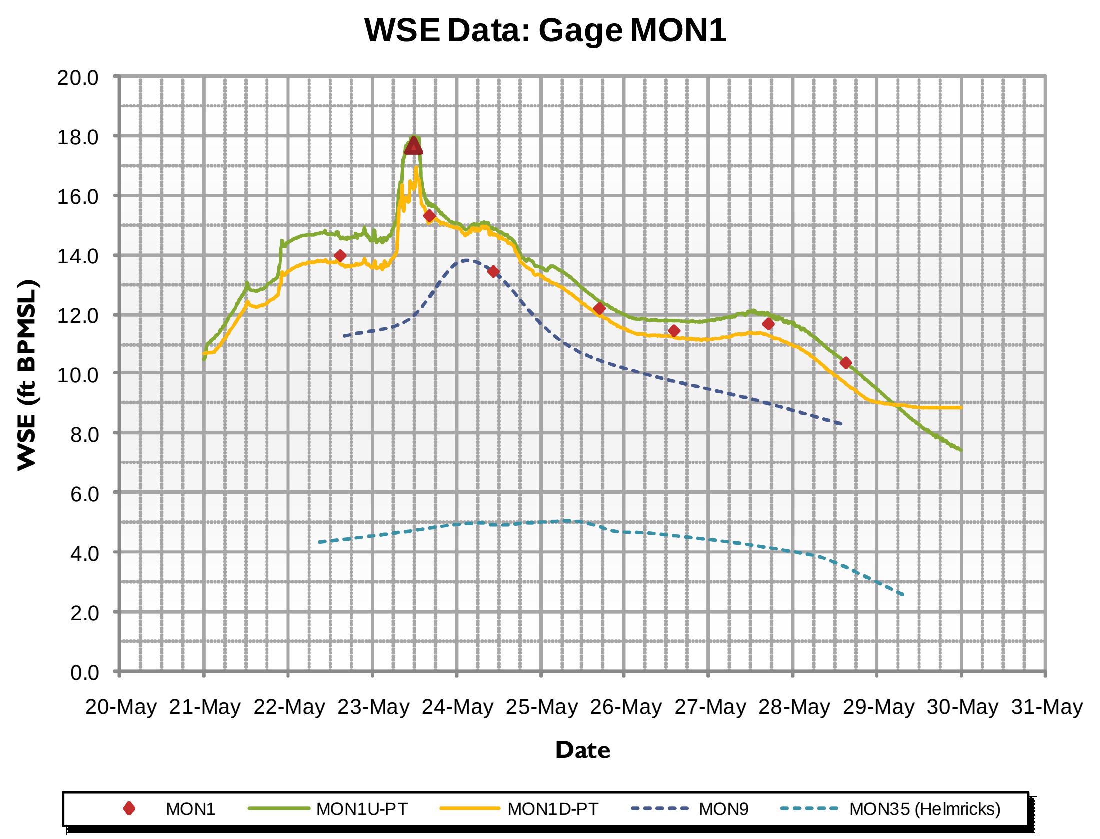


TABLE 4.2: WSE DATA FOR GAGES MON1U AND MON1D

Date and Time	WSE (feet BPMSL)		Observations
	MON1U	MON1D	
5/22/09 2:05 PM	14.47	13.62	Ribbon ice in vicinity; large ice jam upstream at Anaktuvuk confluence.
5/23/09 12:00 PM	17.92	17.07	High Water Mark. Peak occurred between 10:30am and 3:30pm.
5/23/09 3:33 PM	15.70	15.03	Ribbon ice gone; upstream ice jam gone.
5/24/09 10:22 AM	15.07	14.60	
5/25/09 4:09 PM	12.49	11.94	Abundant grounded ice; gage dry.
5/26/09 1:20 PM	11.70	11.21	
5/27/09 3:40 PM	11.95	-	No visit to MON1D due to weather.
5/28/09 2:39 PM	10.37	9.56	

Notes:

1. Elevations are based on Monument 1 at 27.93 feet BPMSL, surveyed by LCMF in 2006.

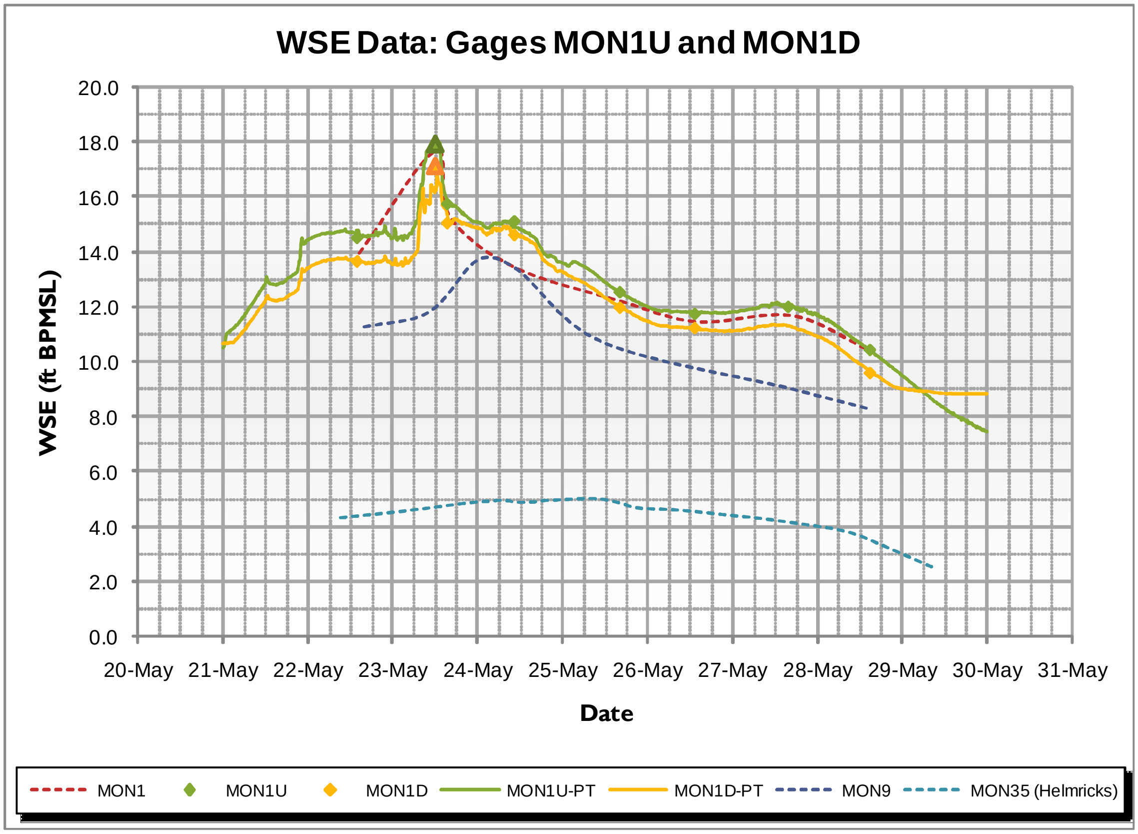


TABLE 4.3: WSE DATA FOR GAGE MON9

Date and Time	WSE (feet BPMSL)	Observations
	MON9	
5/22/09 3:52 PM	11.25	Ribbon ice in vicinity; large ice jam upstream at Anaktuvuk confluence.
5/23/09 10:11 AM	11.79	Abundant channel ice.
5/24/09 12:00 AM	13.69	High Water Mark
5/24/09 10:54 AM	13.36	
5/25/09 11:00 AM	10.70	
5/27/09 3:15 PM	9.03	
5/28/09 3:15 PM	8.24	Dug down to find water surface.

Notes:

1. Elevations are based on Monument 9 at 25.06 feet BPMSL, surveyed by LCMF in 2006.

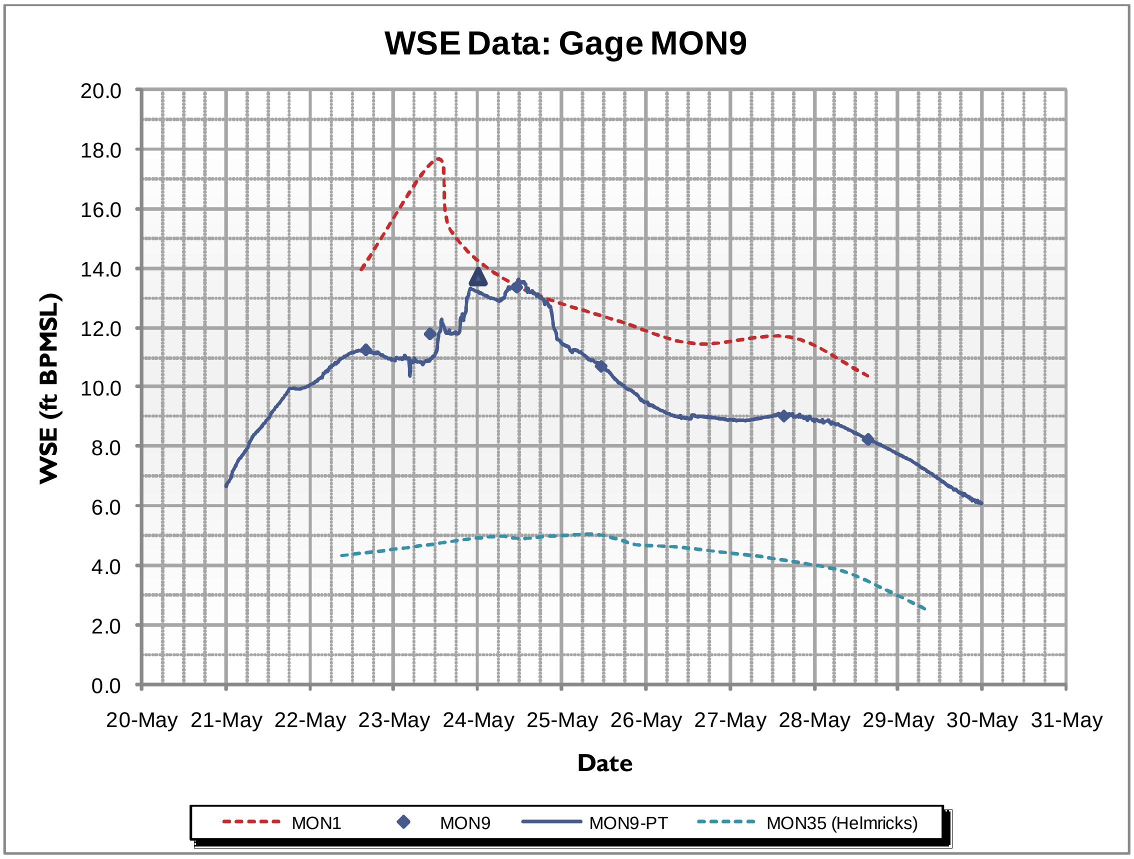
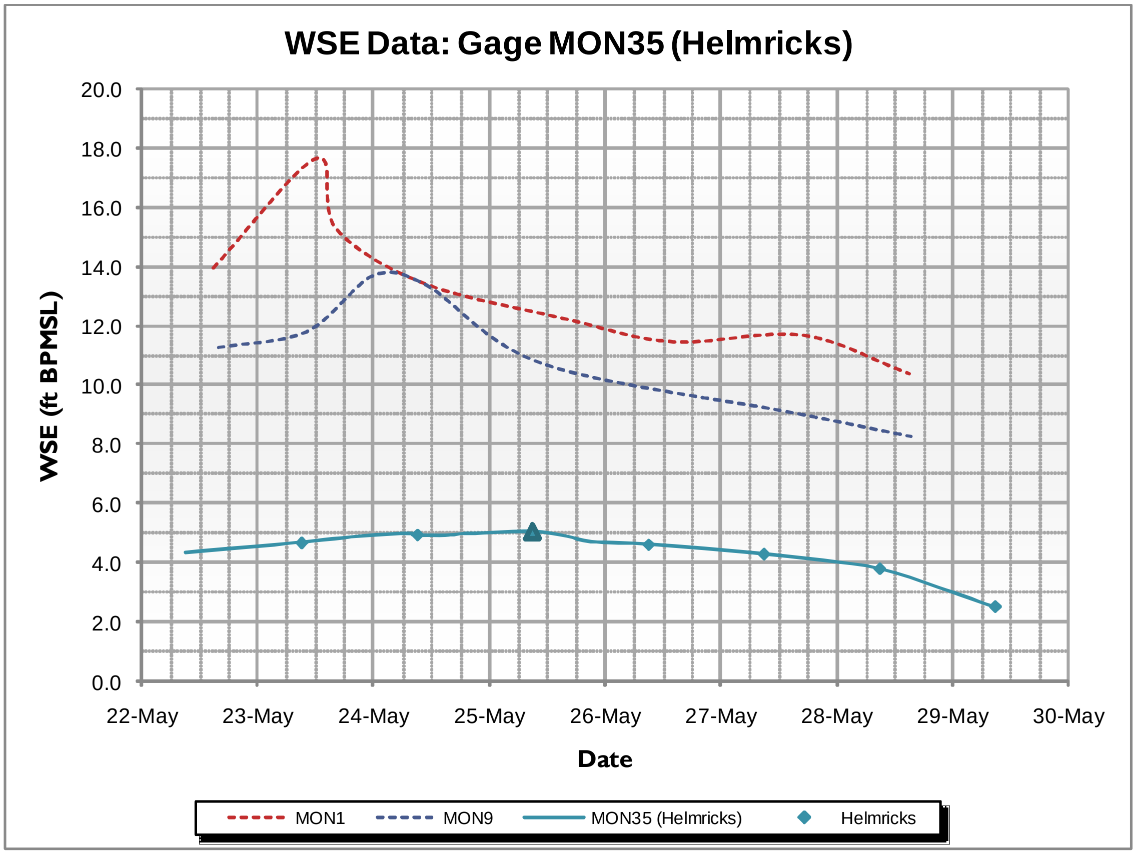


TABLE 4.4: WSE DATA FOR GAGE MON35 (HELMRICKS HOMESTEAD)

Date and Time	WSE (feet BPMSL) MON35 (Helmricks)	Observations
5/23/09 9:00 AM	4.65	
5/24/09 9:00 AM	4.92	
5/25/09 9:00 AM	5.01	
5/26/09 9:00 AM	4.59	
5/27/09 9:00 AM	4.27	
5/28/09 9:00 AM	3.77	
5/29/09 9:00 AM	2.47	

Notes:

1. Elevations are based on Monument 35 at 5.57 feet BPMSL, surveyed by Lounsbury in 1996.
2. These data were collected from Helmricks property by Jim Helmricks.



4.2.2 NIGLIQ CHANNEL

Daily monitoring of Nigliq Channel gages began on May 22 for MON 20, MON22, and MON23 gages. Monitoring began on May 23 at MON28. Stage rose and fell intermittently at all gages until peak occurred.

Peak occurred sometime between late afternoon May 24 and mid-morning on May 25 at MON20 (9.61 feet BPMSL).

Peak occurred sometime between late afternoon May 23 and late afternoon May 24 at MON 22 (7.76 feet BPMSL); at mid-day on May 23 at MON23 (7.09 feet BPMSL); and sometime between mid-morning May 23 and mid-morning May 24 at MON28 (3.65 feet BPMSL). Stage began falling consistently at all Nigliq Channel gages after May 25, and daily monitoring was discontinued on May 28.

PHOTO 4.10: RIBBON ICE IN VICINITY OF MON20. MAY 22, 2009.

Table 4.5, Table 4.6, Table 4.7, and Table 4.8 present the observations and WSE recorded for MON20, MON22, MON23 and MON28, respectively.

Erratic stage fluctuation was most likely due to small, local ice jams in the Nigliq Channel. Ribbon ice was present throughout the entire Nigliq Channel on May 22, as shown in Photo 4.10, taken in the vicinity of MON20. As discussed in previous sections in this chapter, significant ice jamming occurred upstream in the Colville River at this time.

PHOTO 4.11: ICE JAM IN COLVILLE RIVER DIVERTING INTO NIGLIQ. MAY 23, 2009.

On May 23, part of the Colville River ice jam diverted into the Nigliq Channel, as seen in Photo 4.11. By May 24, the bulk of the ice jam had moved down the Nigliq, settling temporarily in the channel adjacent to Nuiqsut, coming into contact with ribbon ice still present throughout the channel.

Photo 4.12 was taken at MON20, downstream from Nuiqsut, approximately 12 hours before peak stage. Significant channel ice is visible in the background. The Nigliq Channel in the vicinity of the Alpine facilities was mostly ice-free by May 28, as shown in Photo 4.13 (visible ice in channel is accumulation from a recent snowfall). Channel ice was still present in the vicinity of MON28 gages on May 28 (see Photo 4.14).

PHOTO 4.12: MON20 GAGE READING. MAY 24, 2009.

PHOTO 4.13: NIGLIQ CHANNEL AND CD4. MAY 28, 2009.

PHOTO 4.14: MON28 GAGE READING. MAY 28, 2009.

TABLE 4.5: WSE DATA FOR GAGE MON20

Date and Time	WSE (feet BPMSL)	Observations
	MON20	
5/22/09 4:31 PM	8.54	
5/23/09 12:00 AM	9.11	
5/23/09 4:52 PM	8.57	Ice jam at head of Nigliq Channel
5/24/09 12:00 AM	9.08	
5/24/09 4:52 PM	8.99	Ice jam moved downstream to bend adjacent to Nuiqsut
5/25/09 12:00 AM	9.61	High Water Mark
5/25/09 10:40 AM	8.95	
5/27/09 2:47 PM	7.57	Gage dry
5/28/09 1:52 PM	5.75	

Notes:

1. Elevations are based on CP-08-12-61 at 11.956 feet BPMSL, updated by LCMF in 2009.

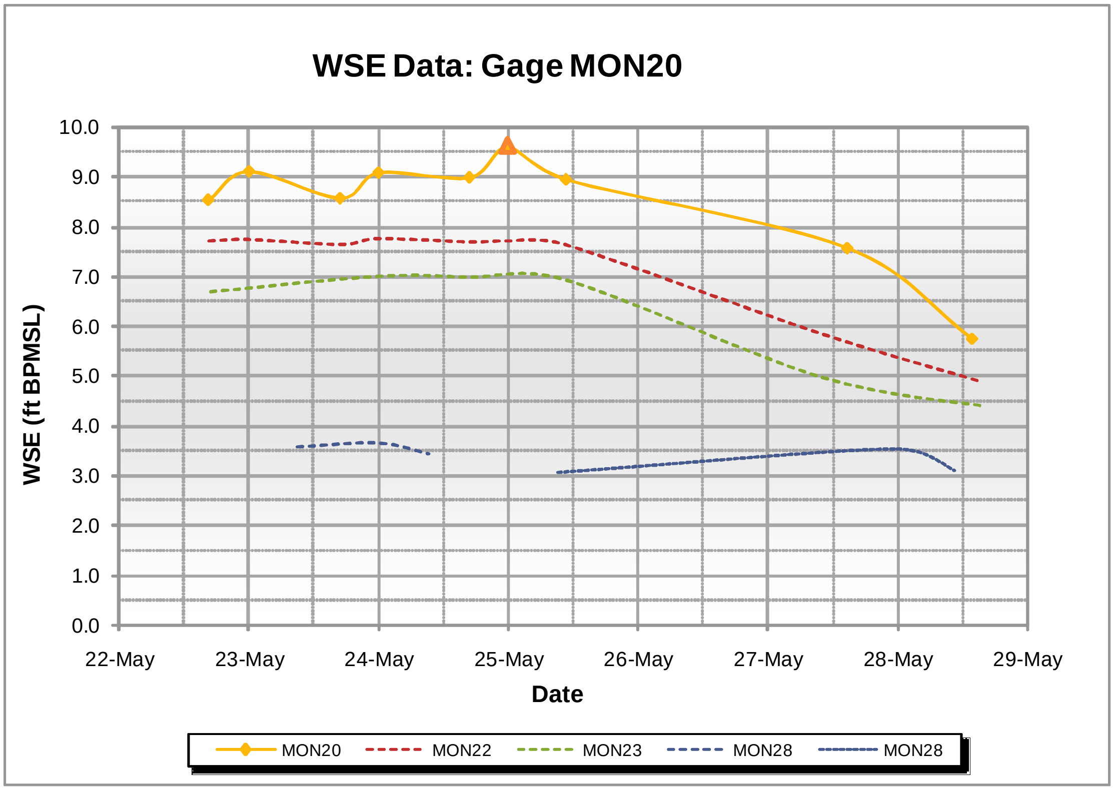


TABLE 4.6: WSE DATA FOR GAGE MON22

Date and Time	WSE (feet BPMSL)	Observations
	MON22	
5/22/09 4:43 PM	7.71	
5/23/09 12:00 AM	7.74	
5/23/09 5:22 PM	7.64	
5/24/09 12:00 AM	7.76	High Water Mark
5/24/09 5:02 PM	7.69	
5/25/09 12:00 AM	7.71	
5/25/09 10:35 AM	7.64	
5/27/09 10:00 AM	5.85	
5/28/09 4:02 PM	4.87	

Notes:

1. Elevations are based on Monument 22 at 10.13 feet BPMSL, updated by LCMF in 2003.

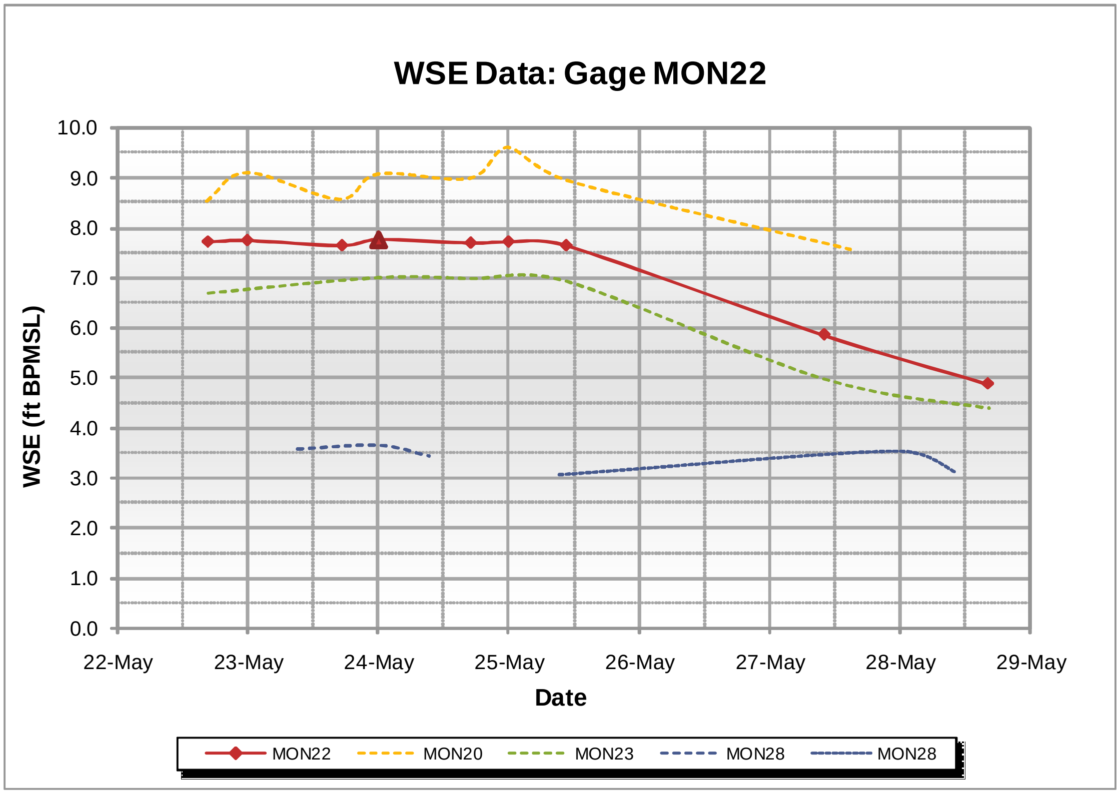


TABLE 4.7: WSE DATA FOR GAGE MON23

Date and Time	WSE (feet BPMSL)	Observations
	MON23	
5/22/09 4:53 PM	6.70	
5/23/09 10:45 AM	7.25	High Water Mark
5/23/09 5:10 PM	6.67	
5/24/09 12:00 AM	7.01	
5/24/09 5:11 PM	6.99	
5/25/09 10:30 AM	6.94	
5/27/09 9:47 AM	4.98	
5/28/09 4:12 PM	4.39	Gage dry

Notes:

1. Elevations are based on Monument 23 at 9.523 feet BPMSL, updated by LCMF in 2005.
2. The timing and elevation of the High Water Mark was adjusted to match PT data.

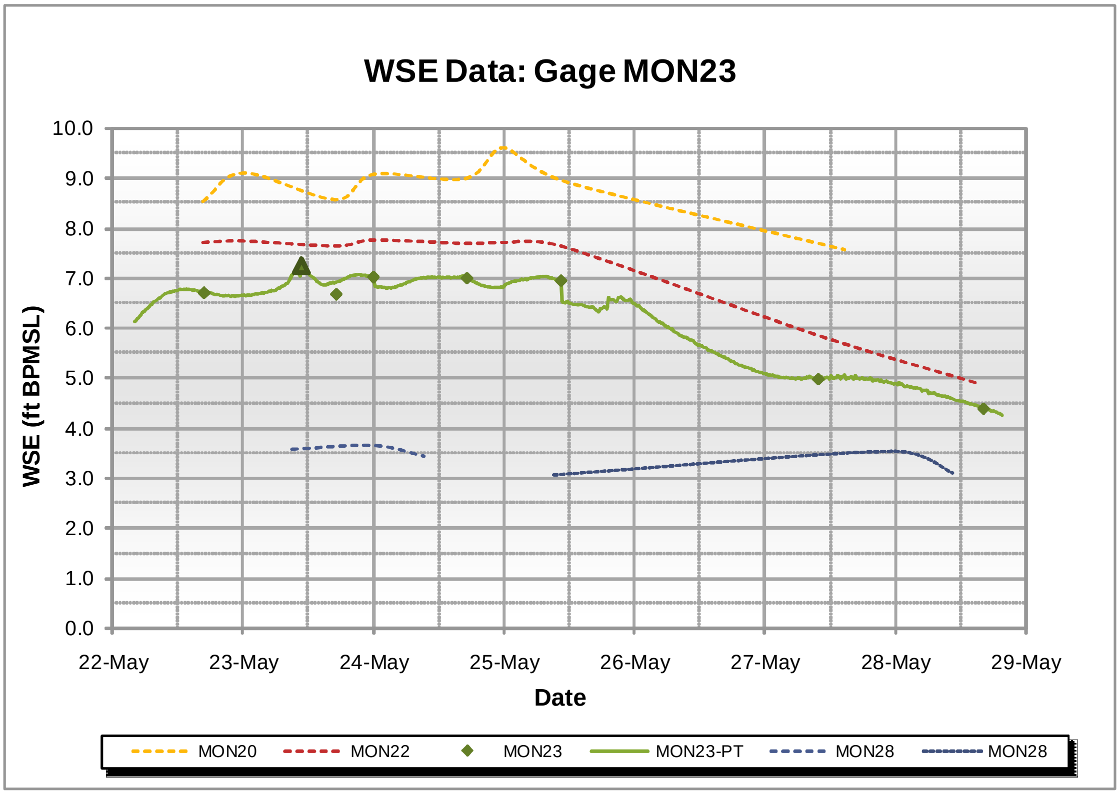
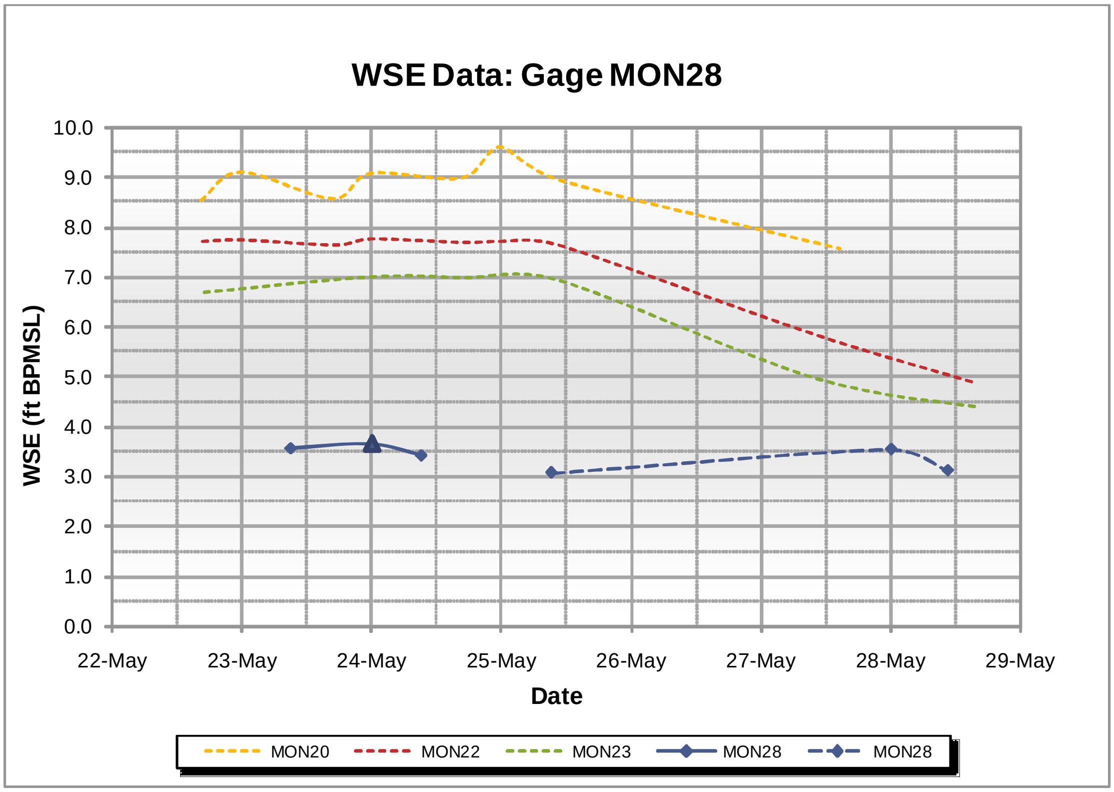


TABLE 4.8: WSE DATA FOR GAGE MON28

Date and Time	WSE (feet BPMSL)	Observations
	MON28	
5/22/09 5:00 PM	-	Unable to visit gage location due to weather
5/23/09 9:00 AM	3.57	
5/24/09 12:00 AM	3.65	High Water Mark
5/24/09 9:14 AM	3.42	
5/25/09 9:20 AM	3.07	Estimated WSE
5/27/09 9:30 AM	-	Unable to land helicopter on dry land, no reading
5/28/09 12:00 AM	3.53	Estimated WSE
5/28/09 10:29 AM	3.11	Estimated WSE

Notes:

1. Elevations are based on Monument 28 at 3.66 feet BPMSL, updated by Lounsbury in 1996.



4.3 ALPINE FACILITIES AND ROADS

Flooding events around Alpine facilities were rather mild in 2009, in terms of quantity of water and ice, when compared to historical observations. Localized melt was first observed in the vicinity of Alpine facilities on May 19. Daily monitoring of all Alpine gages began May 22.

4.3.1 GAGES

PHOTO 4.15: CD2 AND CD4 ACCESS ROADS. MAY 24, 2009.

With the exception of WSE at gages G3 and G4, stage rose steadily around Alpine facilities and roads at those locations which saw floodwaters in 2009. Water did not reach gages G8, G17 and G19. Peak WSE at all but two facility and road gages occurred on May 25. Peak at G12 was recorded on May 24; at G18 on May 23 with local melt only. WSE decreased quickly at all Alpine gaging stations after peak. Floodwaters did not remain around facilities for an extended period; the average duration of measureable water on a gage during 2009 breakup was 4 days. By May 28, most Alpine gages were dry and daily monitoring was discontinued. WSE data and observations for the Alpine gages are located at the end of this section (Table 4.9 through Table 4.14).

PHOTO 4.16: CD2 AND CD4 ACCESS ROADS. MAY 25, 2009.

Photo 4.15 is an aerial view looking south towards the CD2 access road, both swale bridges, and the CD4 road, taken on May 24. Photo 4.16 is an aerial view taken on May 25 looking north along a portion of the CD4 road and pipeline; the CD2 road and Alpine are in the background.

TABLE 4.9: WSE DATA FOR GAGE 1

Date and Time	WSE (feet BPMSL) Gage 1	Observations
5/22/09 8:45 AM	3.96	Water and ice present, no flow velocity.
5/22/09 6:30 PM	4.48	
5/23/09 2:20 PM	5.52	
5/23/09 5:00 PM	5.66	
5/24/09 9:45 AM	6.28	
5/24/09 4:40 PM	6.48	
5/25/09 9:10 AM	6.65	High water observed the morning of May 25.
5/25/09 4:10 PM	6.60	
5/26/09 8:50 AM	6.19	
5/27/09 9:55 AM	5.96	
5/28/09 9:45 AM	5.51	

Notes:

1. Elevations are based on Monument 21 at 13.277 feet BPMSL, updated by LCMF in 2008.
2. Gage 1 is a permanent staff gage surveyed and set by LCMF in 2008.

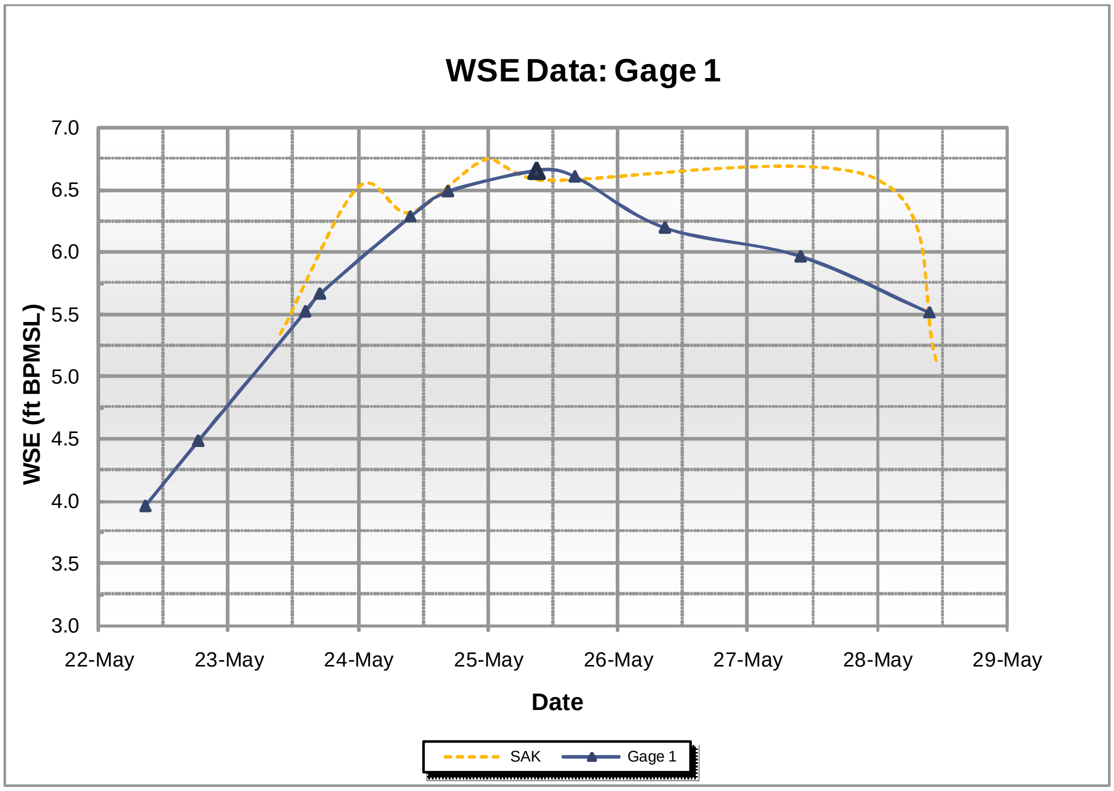


TABLE 4.10: WSE DATA FOR GAGE 3 AND GAGE 4

Date and Time	WSE (feet BPMSL)		Observations
	Gage 3	Gage 4	
5/22/09 9:05 AM	7.38	6.45	Significant flow under swale bridges and through nearby culverts
5/23/09 9:50 AM	7.37	6.85	
5/23/09 2:35 PM	7.01	6.72	
5/24/09 8:30 AM	7.45	7.01	
5/24/09 3:25 PM	7.45	7.11	
5/25/09 9:35 AM	7.46	7.13	
5/25/09 1:00 PM	7.63	7.18	High Water Marks, peak occurred between 9:35am and 4:40pm
5/25/09 4:40 PM	7.25	6.98	
5/26/09 9:15 AM	5.99	5.90	
5/26/09 11:24 AM	5.89	5.80	
5/26/09 1:40 PM	5.88	5.80	

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 May of 2009.

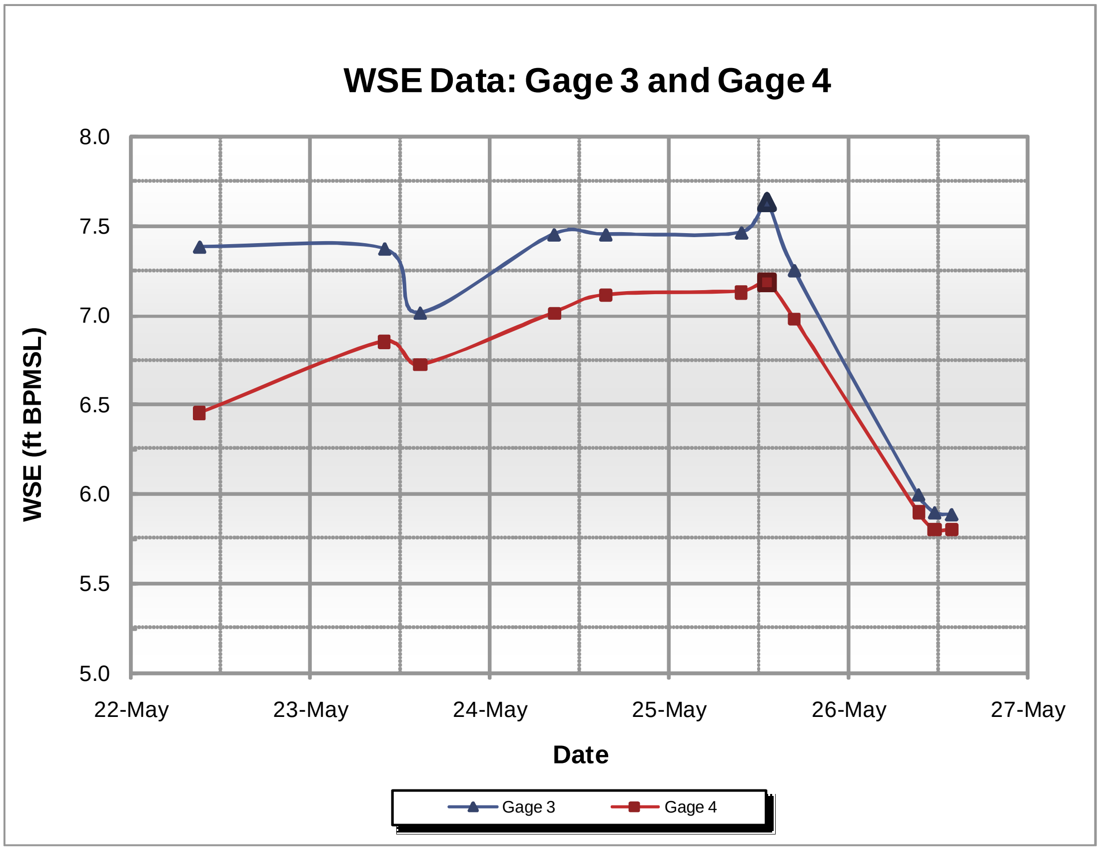


TABLE 4.11: WSE DATA FOR GAGE 6 AND GAGE 7

	WSE (feet BPMSL)		
Date and Time	**Gage 6**	**Gage 7**	**Observations**
5/23/09 2:50 PM	-	-	Both gages dry
5/24/09 8:15 AM	7.38	-	
5/24/09 3:35 PM	7.47	-	
5/25/09 9:50 AM	7.66	7.48	
5/25/09 12:00 PM	7.67	-	High Water Mark
5/25/09 5:00 PM	7.55	7.50	
5/26/09 9:30 AM	7.50	7.46	

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 May 2009.

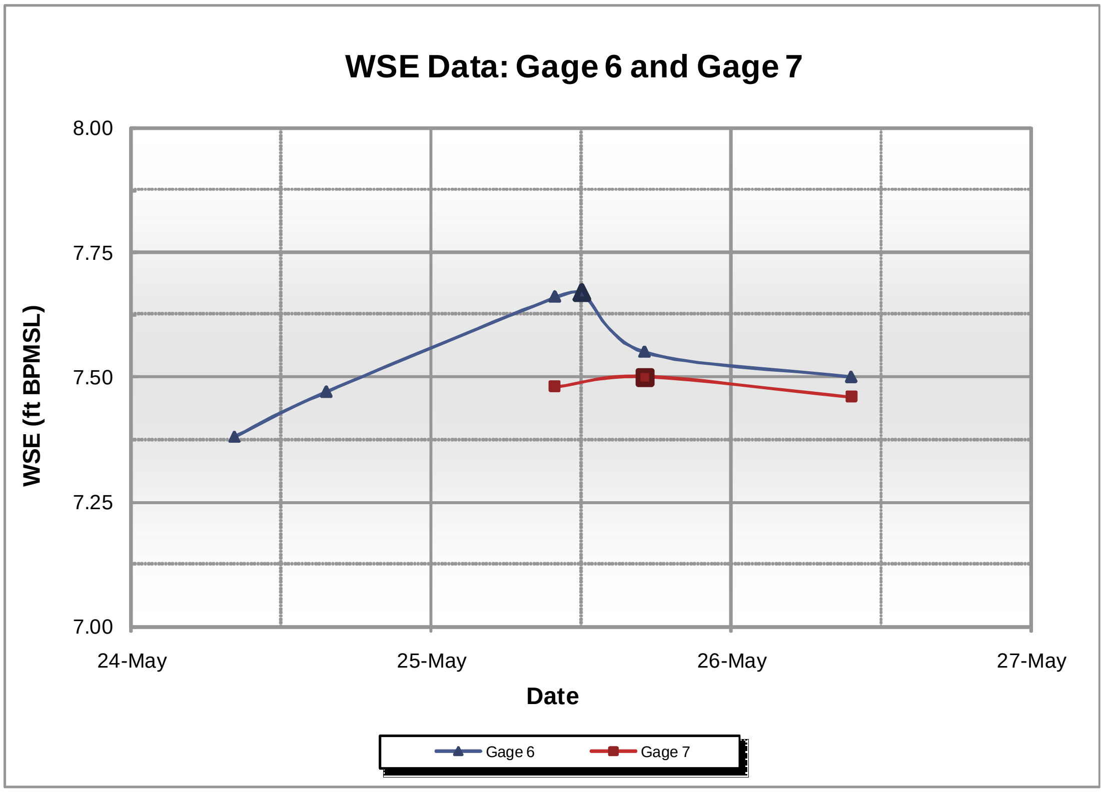


TABLE 4.12: WSE DATA FOR GAGE 12 AND GAGE 13

Date and Time	WSE (feet BPMSL)		Observations
	Gage 12	Gage 13	
5/22/09 5:20 PM	-	-	Both gages dry
5/23/09 9:40 AM	-	7.28	
5/23/09 2:45 PM	-	7.29	
5/24/09 8:20 AM	7.76	7.30	
5/24/09 3:30 PM	7.83	7.46	
5/25/09 9:45 AM	7.76	7.61	
5/25/09 4:45 PM	7.56	7.50	
5/26/09 9:25 AM	-	-	

Notes:

1. Elevations are based on CD2 access road culvert CD2-14 north and south inverts at 11.03 and 11.04 feet BPMSL, respectively, confirmed by LCMF in 2008.

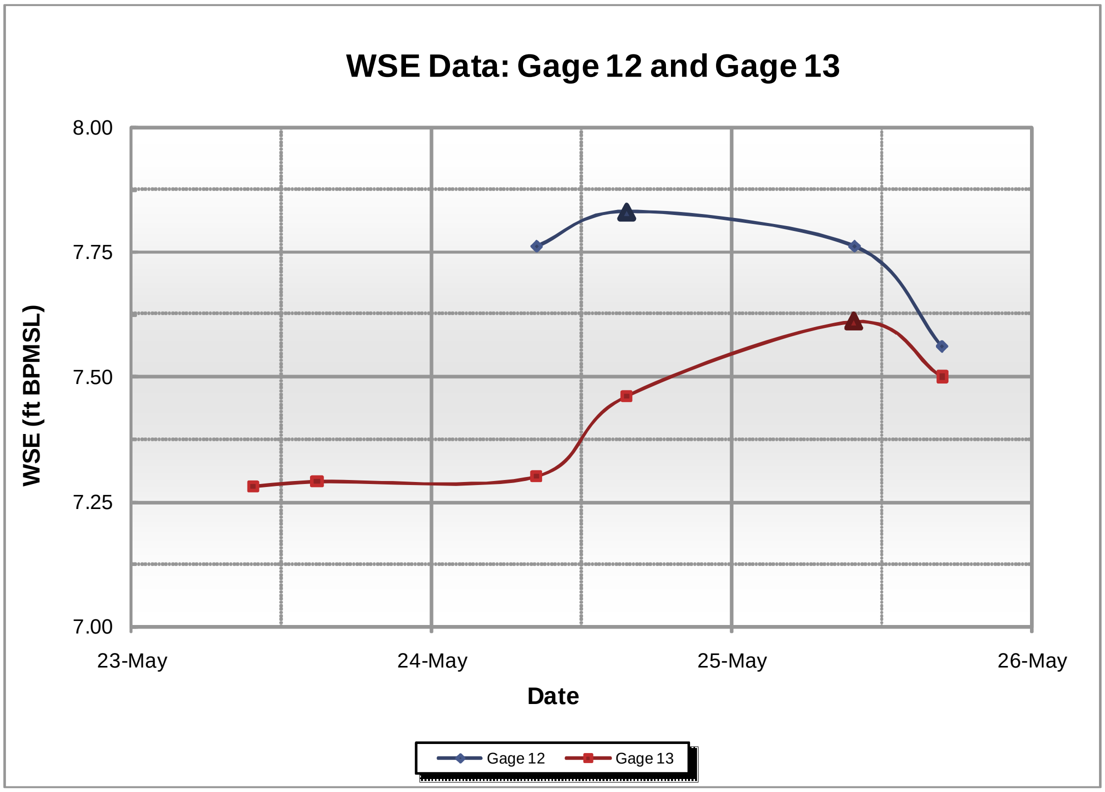


TABLE 4.13: WSE DATA FOR GAGE 15, GAGE 16, GAGE 17 AND GAGE 18

	WSE (feet BPMSL)				
Date and Time	Gage 15	Gage 16	Gage 17	Gage 18	Observations
5/23/09 3:35 PM	-	-	-	11.34	Local melt only
5/24/09 8:50 AM	6.39	6.39	-		
5/24/09 3:55 PM	6.72	6.74	-	-	
5/25/09 10:10 AM	7.22	7.17	-	-	
5/25/09 5:20 PM	7.28	7.26	-	-	
5/26/09 10:10 AM	7.20	7.24		-	
5/27/09 10:35 AM	7.10	7.08	-	-	
5/28/09 10:45 AM	6.52	6.53	-	-	

Notes:

1. Elevation for Gage 15 is based on culvert CD4-21N at 8.92 feet BPMSL, updated by LCMF in 2009.
2. Elevation for Gage 16 is based on culvert CD4-21N at 8.05 feet BPMSL, updated by LCMF in 2009.
3. Elevation for Gage 17 is based on culvert CD4-29N at 13.08 feet BPMSL, updated by LCMF in 2009.
4. Elevation for Gage 18 is based on culvert CD4-29S at 13.23 feet BPMSL, updated by LCMF in 2009.
5. Water did not reach Gage 17 in 2009.

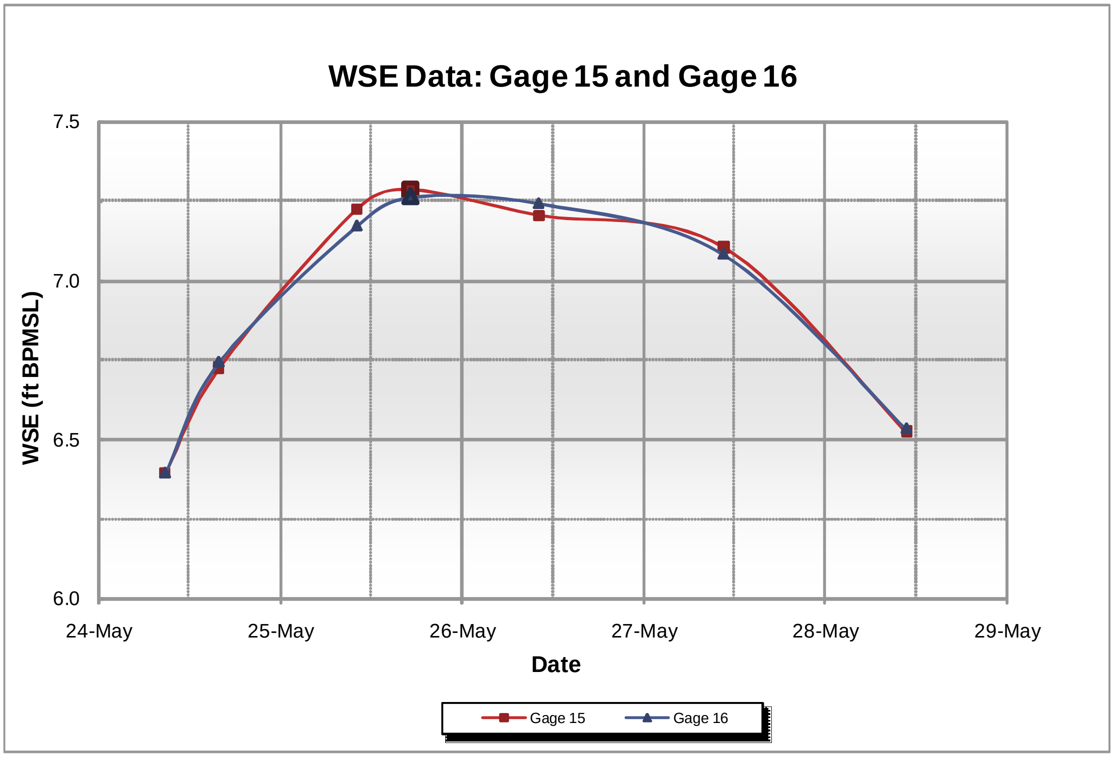
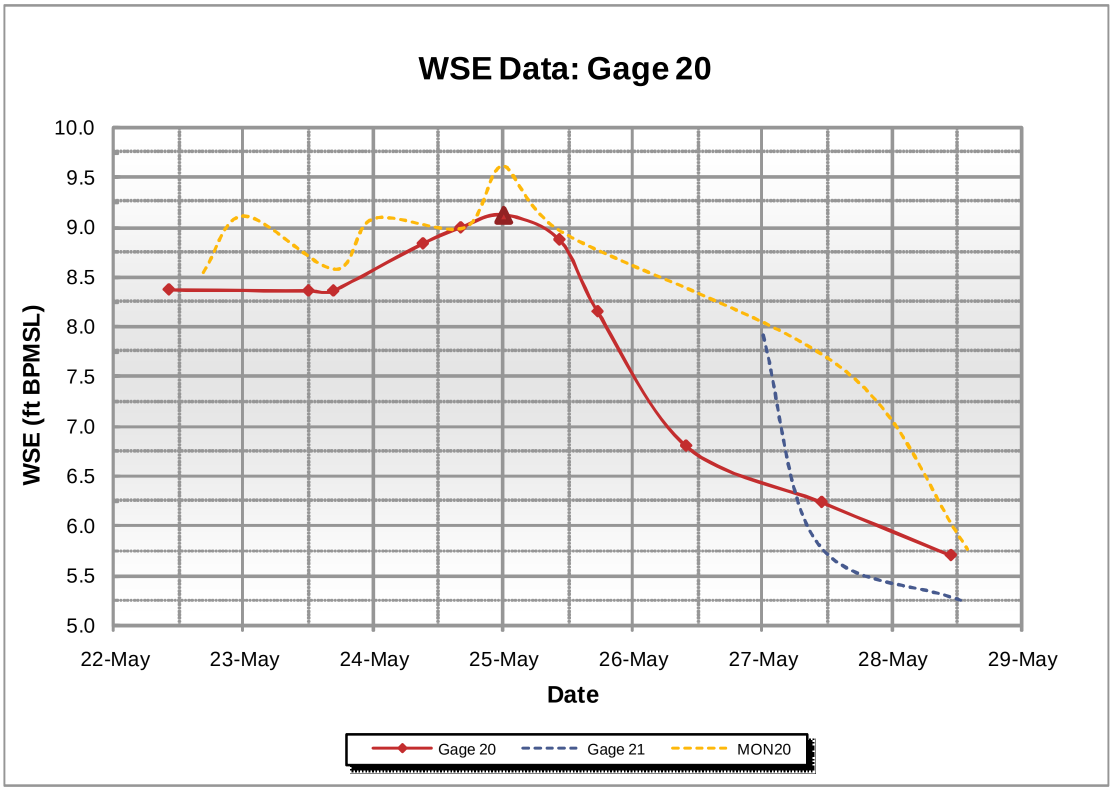


TABLE 4.14: WSE DATA FOR GAGE 20

Date and Time	WSE (feet BPMSL) Gage 20	Observations
5/22/09 10:00 AM	8.37	Channel ice downstream from gage
5/23/09 11:55 AM	8.36	
5/23/09 4:30 PM	8.36	Ice jam at head of Nigliq
5/24/09 9:05 AM	8.83	
5/24/09 4:05 PM	8.99	Ice jam moved downstream adjacent to Nuiqsut
5/25/09 12:00 AM	9.12	High Water Mark
5/25/09 10:25 AM	8.87	
5/25/09 5:30 PM	8.15	
5/26/09 9:55 AM	6.80	
5/27/09 11:00 AM	6.23	
5/28/09 11:00 AM	5.70	

Notes:

1. Elevations are based on TBM-05-20-01A at 25.734 feet BPMSL, updated by LCMF in 2007.



4.3.2 ALPINE DRINKING WATER LAKES RECHARGE

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. 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 as well as by direct observed measurements of water surface elevations at each lake during breakup. Water level surveys and water surface elevation observations of gages G9 (L9312) and G10 (L9313) were the primary references used to evaluate the water surface elevations.

Aerial observations generally document the presence of floodwater inflow. These observations were recorded with geo-referenced photographs. L9313 received floodwater recharge from the Sakoonang Channel and reached a bankfull condition. L9312 did not receive overland recharge of floodwater. Both L9312 and L9313 received recharge from snowmelt. At both lakes, stage dropped quickly after peak WSE was recorded.

PHOTO 4.17: LAKES L9312 & L9313. JUNE 1, 2009.

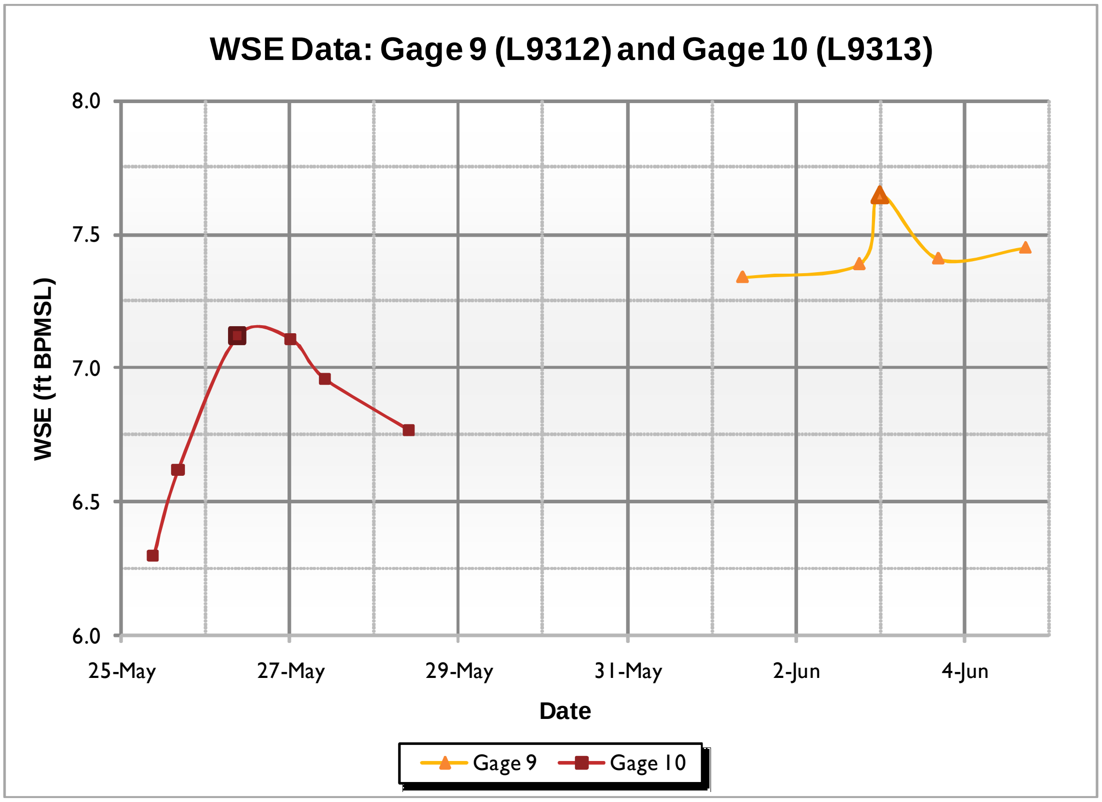
WSE data and observations for the Alpine lakes are provided in Table 4.15. Photo 4.17 shows an aerial view of L9313 and L9312 on June 1, after breakup flooding receded, but before peak stage was recorded at L9312.

TABLE 4.15: WSE DATA FOR ALPINE LAKES L9312 AND L9313 (GAGES G9 AND G10)

Date and Time	WSE (feet BPMSL)		Observations
	Gage 9 L9312	Gage 10 L9313	
5/25/09 9:10 AM	-	6.30	L9313 recharge initiated by Sakoonang; L9312 frozen
5/25/09 4:10 PM	-	6.62	
5/26/09 9:05 AM	-	7.12	High water observed the morning of May 26.
5/27/09 12:00 AM	-	7.11	
5/27/09 9:55 AM	-	6.96	
5/28/09 9:40 AM	-	6.77	L9312 still frozen
6/1/09 9:00 AM	7.34	-	LCMF survey WSE
6/2/09 6:07 PM	7.39	-	
6/3/09 12:00 AM	7.65	-	High Water Mark
6/3/09 4:32 PM	7.41	-	
6/4/09 5:19 PM	7.45	-	

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 02-01-39-P of 11.46 feet BPMSL, established by LCMF in 2005.
3. Elevations for Gage 10 are based on Monument 22 of 11.27 feet BPMSL, established by LCMF in 2005.
4. Gages surveyed and set by LCMF in 2009.



4.3.2.1 LAKE L9312 RECHARGE

Gage G9 at Lake L9312 remained frozen until after May 31. Photo 4.18 shows G9 on May 31.

Initial water readings were taken at gage G9 on June 1. The 2009 peak floodwater stage was not high enough to reach L9312. Recharge of L9312 began on June 1 and was a result of local melt.

Peak WSE at L9312 occurred on June 2, and was measured at 7.65 feet BPMSL. The recorded peak was likely due to local melt which pooled around the gage, and then dissipated as snow continued to melt.

PHOTO 4.18: GAGE G9, LAKE L9312. GAGE REMAINED FROZEN THROUGHOUT MAY. MAY 31, 2009.

The final recorded WSE for L9312 was documented on June 4 at 7.45 feet BPMSL. Daily monitoring at L9312 was discontinued after June 4.

Bankfull conditions were not achieved at L9312. Based on the historical record, bankfull elevation for is 7.8 feet BPMSL (Baker 2000 and 2001). The water surface elevations observed during the monitoring period are presented in Table 4.15.

PHOTO 4.19: LAKE L9313. MAY 18, 2009.

4.3.2.2 LAKE L9313 RECHARGE

Floodwater was not present in Lake L9313 until May 25, coinciding with the approximate time of peak stage around facilities and roads. Daily monitoring of both Alpine lake gages began on May 25, when L9313 began recharging as a result of overland flow from the Sakoonang Channel.

Between May 25 and May 26, the WSE of L9313 increased from 6.30 feet to a peak WSE of 7.12 feet BPMSL. Bankfull conditions were reached on May 26. Daily monitoring was discontinued at L9313 after May 28.

Observed WSE and field notes are provided in Table 4.15. Photo 4.19 shows L9313 prior to breakup. Photo 4.20 shows floodwaters from the Sakoonang approaching L9313 on May 24. Photo 4.21 shows L9313 on May 25 with floodwaters reaching the lake. High water was observed in L9313 on May 26. In the background of Photo 4.21, behind L9313, L9312 remained frozen and not connected to floodwater.

PHOTO 4.20: LAKE L9313 AND LAKE L9312 WITH SAKOONANG FLOODWATERS APPROACHING L9313. MAY 24, 2009.

PHOTO 4.21: LAKE L9313. RECHARGE BY SAKOONANG FLOODWATERS. MAY 25, 2009.

4.3.3 DRAINAGE STRUCTURES

By May 22 significant flow was observed in the Sakoonang Channel at Gage G1, passing south to north under the CD2 access road 62-ft swale bridge and through nearby culverts. Flow was not observed under the 452-ft swale bridge the morning of May 22 due to a large ice and snow dam, as can be seen in Photo 2.5 and Photo 2.6. The dam held until the evening of May 22 (Photo 4.22). Photo 4.23 and Photo 4.24 show flow on the south and north sides of the CD2 access road in the vicinity of the smaller bridge on May 22. Direct discharge measurements were taken on May 26 at the 452-ft swale bridge and at selected culverts.

PHOTO 4.22: FAILURE OF ICE DAM UNDER THE 452-FT SWALE BRIDGE. MAY 22, 2009.

Discharge data for the 452-ft swale bridge is provided in Table 5.4; discharge data for selected culverts is shown in Table 5.5 through Table 5.8. Photo 4.25 shows a portion of CD2 and CD4 access roads, as well as a section of the 452-ft swale bridge just before peak stage at the facilities.

PHOTO 4.23: FLOW UNDER 62-FT SWALE BRIDGE, SOUTH SIDE. MAY 22, 2009.

PHOTO 4.24: FLOW UNDER 62-FT SWALE BRIDGE, NORTH SIDE. MAY 22, 2009.

PHOTO 4.25: AERIAL VIEW, 452-FT SWALE BRIDGE. MAY 24, 2009.

4.3.4 EROSION

The peak stage of floodwater passing by Alpine roads and facilities was relatively low in 2009, based on comparison with the historical record. In addition, no significant ice floes were observed throughout the area. Breakup affect on gravel pads, roads, and drainage structures was negligible.

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 recorded on June 1 and June 2. Floodwater did not inundate the gravel pad embankments at the CD1, CD2, CD3, or CD4 pads. Floodwater also did not inundate the CD4 gravel road prism.

PHOTO 4.26: SOUTH SIDE OF CD2 ROAD BETWEEN THE SWALE BRIDGES. JUNE 1, 2009.

PHOTO 4.27: CD2 ROAD SOUTHEAST OF THE 62-FT SWALE BRIDGE. JUNE 1, 2009.

Floodwater was observed along the CD2 road in the vicinity of the swale bridges. Visual inspection of the CD2 road near the swale bridges revealed high water marks where breakup flows reached the lower portions of the gravel road prism. Photo 4.26, Photo 4.27, and Photo 4.28 show representative photos taken on June 1 along the CD2 access road. Photo 4.29, Photo 4.30, and Photo 4.31 show representative photos taken on June 2 along the CD4 access road.

High water marks along the CD2 Access Road were identified by debris stranded on the gravel side slopes or by noting where silts and fine-grained sands were washed from the road prism. Orange-topped lath in the photos were placed to better show the location and elevation of high water. All lath placed to indicate erosion limits was removed after photos were taken. No indications of significant erosion due to breakup floodwater were observed anywhere on the Alpine gravel facilities.

PHOTO 4.28: CD2 ROAD NEAR THE 62-FT SWALE BRIDGE. JUNE 1, 2009.

PHOTO 4.29: CD4 ACCESS ROAD NEAR CULVERT CD4-24. JUNE 2, 2009.

PHOTO 4.30: CD4 ACCESS ROAD CULVERT BATTERY CD4-29 THROUGH -32. JUNE 2, 2009.

PHOTO 4.31: CD4 ACCESS ROAD. JUNE 2, 2009.

4.3.5 ICE BRIDGES

Ice bridge melt progressed smoothly throughout the breakup period at all monitored crossing locations; no significant erosion or scour as a result of the ice bridges was observed.

PHOTO 4.32: COLVILLE EAST CHANNEL ICE BRIDGE, LOOKING SOUTH. MAY 18, 2009.

The first visual evidence of melt at the Colville East Channel ice bridge was recorded on May 8, after early warm temperatures initiated pre-breakup conditions throughout the CRD. Open water was first seen at that location on May 18. By May 28, the majority of the channel was open, with only the ice road transitions on either side of the channel remaining.

Photo 4.32 and Photo 4.33 show conditions at the Colville East Channel ice bridge crossing on May 18. Photo 4.34 shows the remnants of the western ramp on May 28.

PHOTO 4.33: COLVILLE EAST CHANNEL ICE BRIDGE, LOOKING NORTH. MAY 18, 2009.

PHOTO 4.34: REMNANTS OF COLVILLE ICE BRIDGE, WEST BANK. MAY 28, 2009.

Breakup of the Nigliq Channel ice road and ice bridge occurred without event. No significant erosion or scour was observed along the Nigliq between the Putu Channel and Nuiqsut.

An aerial reconnaissance to the Kachemach River ice bridge crossing location was performed on May 31. Breakup processes were progressing smoothly. Melting conditions of the ice bridge at the Kachemach crossing are shown in Photo 4.35. No evidence of scour or erosion was observed at the Kachemach River during or after breakup.

PHOTO 4.35: REMNANTS OF KACHEMACH ICE BRIDGE. MAY 31, 2009.

4.4 CD3 PIPELINE CROSSINGS

Data collection at the Sakoonang (SAK), Tamayagiaq (TAM) and Ulamnigiaq (ULAM) Channel gages began on May 9; daily monitoring began on May 23, when all streams were open and flowing well. WSE rose and fell between peak and near-peak levels at the SAK and TAM gages between May 23 and May 25. Peak WSE occurred on May 24 at the ULAM gage site, which coincided with the first event of measureable water. Stage did not fall significantly at any of the three CD3 pipeline crossing gages until after May 28, when stage dropped off quickly.

Table 4.16 presents the observations and WSE recorded for the SAK, TAM and ULAM.

Stage at all gages, the SAK and TAM gages in particular, was most likely affected by ice jamming both in channel and from the Colville. Photo 4.36 shows ice from the released Colville ice jam diverting into the Sakoonang Channel. Photo 4.37 is an aerial view of the Ulamnigiaq pipe bridge during peak stage. Photo 4.38 shows gage TAM-B on May 28, 2009. Photo 4.39 shows an aerial view of the Tamayagiaq on June 2.

PHOTO 4.36: ICE DIVERTING INTO THE SAKOONANG CHANNEL. MAY 24, 2009.

PHOTO 4.37: ULAMNIGIAQ PIPE BRIDGE. MAY 24, 2009.

PHOTO 4.38: TAMAYAGIAQ PIPE BRIDGE AND GAGE TAM-B. MAY 28, 2009.

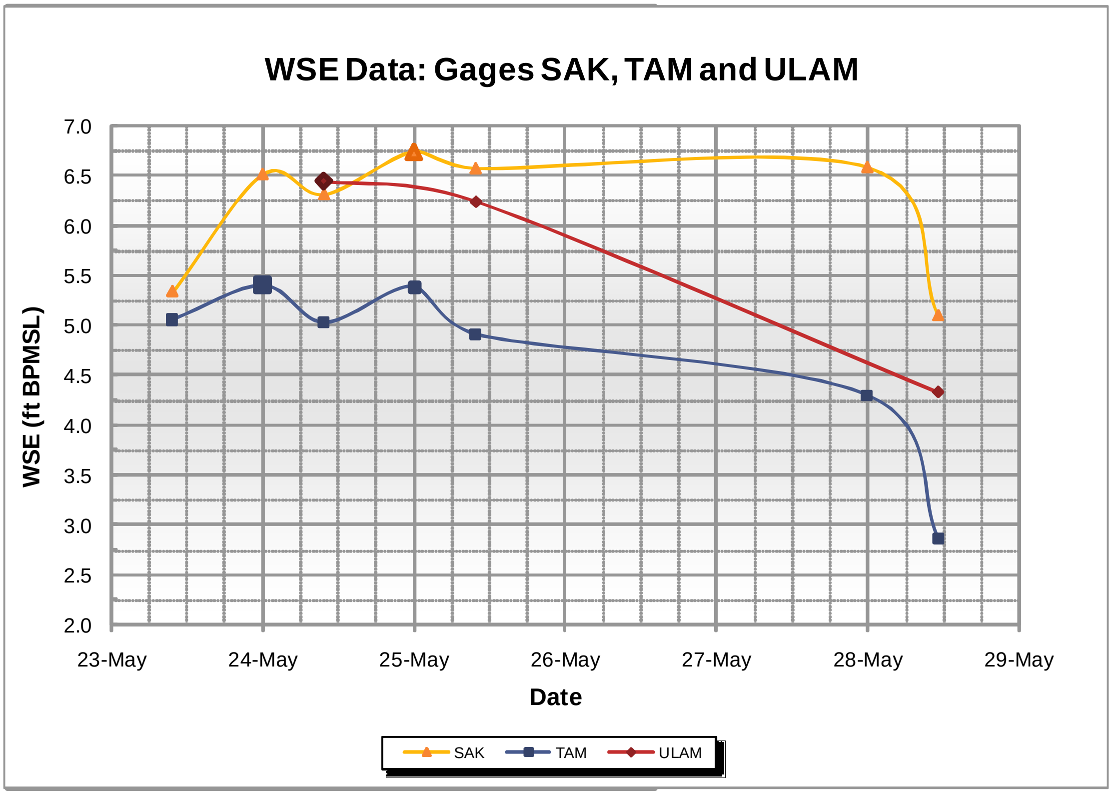
PHOTO 4.39: TAMAYAGIAQ PIPE BRIDGE. JUNE 2, 2009.

TABLE 4.16: WSE DATA FOR GAGE SAK, GAGE TAM AND GAGE ULAM

Date and Time	WSE (feet BPMSL)			Observations
	SAK	TAM	ULAM	
5/23/09 9:40 AM	5.34	5.06	-	All streams open and flowing well.
5/24/09 12:00 AM	6.51	5.40	-	High Water Mark
5/24/09 9:45 AM	6.31	5.03	6.44	
5/25/09 12:00 AM	6.74	5.39	-	High Water Mark
5/25/09 9:50 AM	6.57	4.91	6.24	
5/28/09 12:00 AM	6.58	4.30	-	High Water Mark
5/28/09 11:15 AM	5.10	2.86	4.33	

Notes:

1. Elevations for SAK are based on CP-08-11-12 of 7.365 feet BPMSL established by LCMF in 2008.
2. Elevations for TAM are based on CP-08-11-23 of 8.524 feet BPMSL established by LCMF in 2008.
3. 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 4.40: PROPOSED NIGLIQ CD5 ROAD CROSSING. MAY 28, 2009.

Initial observations of the proposed CD5 road crossing gages were recorded from May 8 to May 18. Daily monitoring began on May 27. High water marks were noted on the gages at each of the three proposed CD5 road crossing locations. Because water levels in the CRD were observed to be dropping, and observed WSE was dropping at each of the three crossing locations, monitoring of the three crossing gage sites was discontinued May 28. General observation continued until June 2.

PHOTO 4.41: WEST SIDE PROPOSED CD5 NIGLIQ CROSSING. JUNE 2, 2009.

Gage G21 is located between MON20 and MON22 on the Nigliq Channel, at the proposed CD5 crossing location. The G21 location experienced similar breakup events, including discharge, stage and ice effects, as the other Nigliq Channel gages in the area (see Section 4.2.2). Peak WSE at G21 was 7.91 feet BPMSL. Photo 4.40 and Photo 4.41 show an open Nigliq Channel at the proposed bridge crossing location after floodwaters began to recede. WSE data and observations for Nigliq Channel G21 can be found in Table 4.17.

As shown in Photo 4.42, open water was observed in L9341 on May 22. However, measureable water did not reach gage G22 until several days later. A high water mark was observed on May 27. Peak WSE at G22 was 8.00 feet BPMSL based on an observed HWM. Photo 4.43 shows a survey to determine below-gage water surface elevation. Photo 4.44 shows an aerial view of the CD5 road proposed L9341 bridge crossing location after peak stage. WSE data and observations are provided in Table 4.18.

PHOTO 4.42: PROPOSED LAKE L9341 CD5 CROSSING. MAY 22, 2009.

PHOTO 4.43: WSE SURVEY AT LAKE L9341. MAY 28, 2009.

PHOTO 4.44: PROPOSED L9341 CD5 CROSSING. JUNE 2, 2009.

A considerable amount of snow remained in-channel and along the banks of the Nigliagvik throughout the duration of the breakup period. The majority of the snow was in place along the steeper west bank. The 2009 breakup flow was contained within the channel banks and did not extend into the floodplain to the east. Peak WSE at G23 was 7.71 feet BPMSL.

Photo 4.45 shows the CD5 road proposed Nigliagvik bridge crossing location on May 27. Photo 4.46 shows an aerial view of the same location, with an open channel after recession of breakup floodwaters. Table 4.19 presents the observations and WSE recorded for G23.

PHOTO 4.45: NIGLIAGVIK PROPOSED CD5 CROSSING. MAY 27, 2009.

PHOTO 4.46: NIGLIAGVIK PROPOSED CD5 ROAD CROSSING. JUNE 2, 2009.

TABLE 4.17: WSE DATA FOR GAGE 21 (NIGLIQ CHANNEL)

Date and Time	WSE (feet BPMSL)	Observations
	Gage 21	
5/25/09 12:00 AM	7.91	High Water Mark
5/27/09 10:09 AM	5.82	
5/28/09 12:41 PM	5.25	

Notes:

1. Elevations are based on CP 08-11-53A at 7.787 feet BPMSL, confirmed by LCMF in 2008.
2. Peak WSE likely occurred May 25 based on peak observed at MON20 (upstream) and MON22 (downstream).

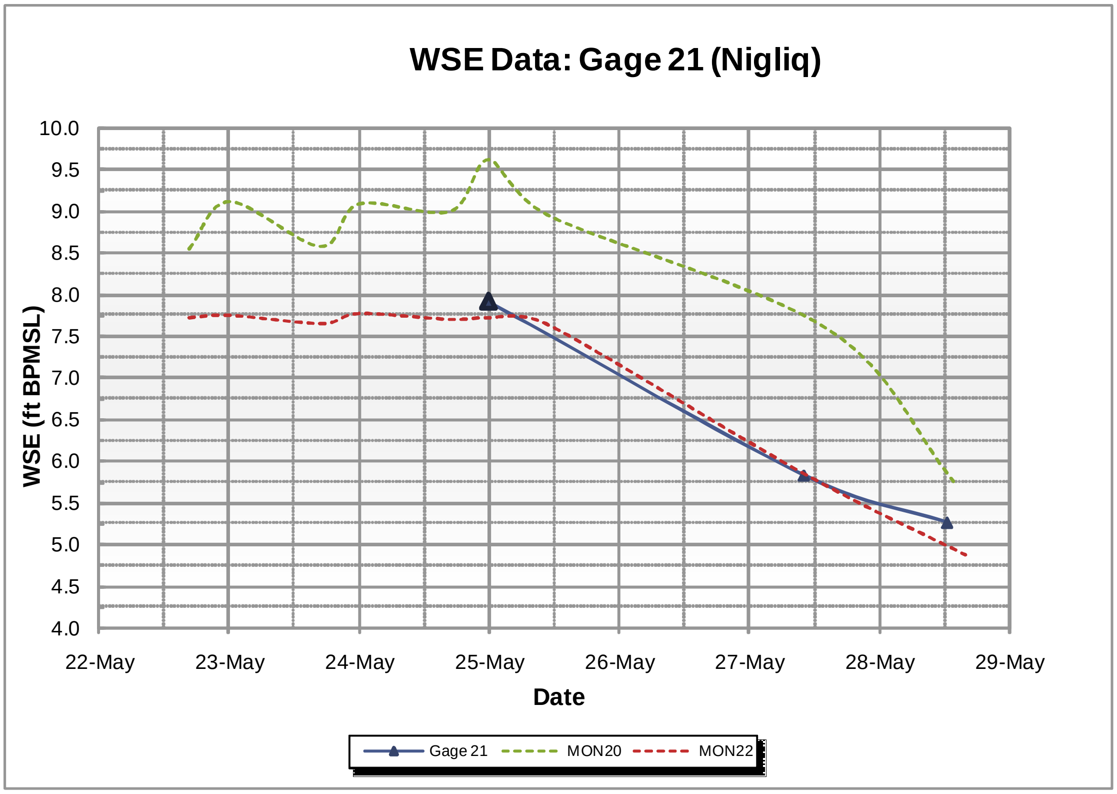


TABLE 4.18: WSE DATA FOR GAGE 22 (L9341)

Date and Time	WSE (feet BPMSL)	Observations
	Gage 22	
5/25/09 12:00 AM	7.98	High Water Mark
5/27/09 10:25 AM	5.19	
5/28/09 12:55 PM	4.94	

Notes:

1. Elevations are based on CP 08-11-64A at 12.305 feet BPMSL, confirmed by LCMF in 2008.
2. Peak WSE likely occurred based on peak observed at MON20 (upstream) and MON22 (downstream).

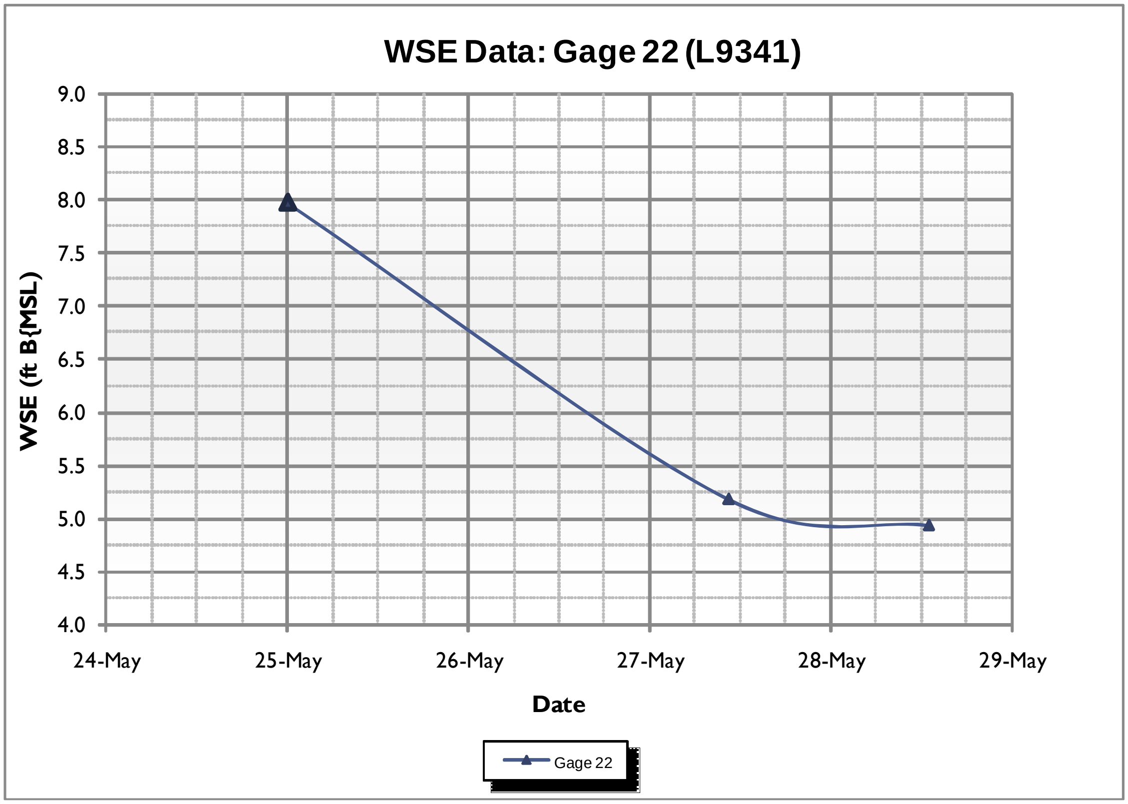
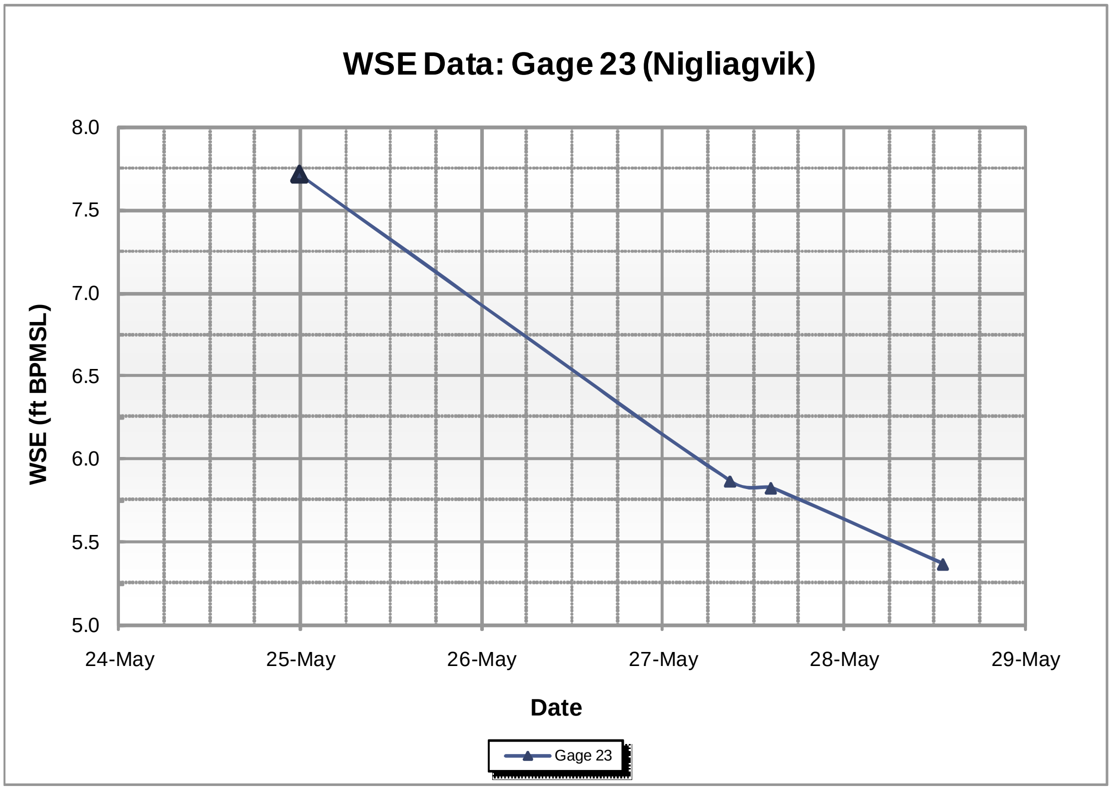


TABLE 4.19: WSE DATA FOR GAGE 23 (NIGLIAGVIK)

Date and Time	WSE (feet BPMSL)	Observations
	Gage 23	
5/25/09 12:00 AM	7.71	High Water Mark
5/27/09 9:00 AM	5.86	
5/27/09 2:25 PM	5.82	
5/28/09 1:14 PM	5.36	

Notes:

1. Elevations are based on CP 08-11-66C at 10.418 feet BPMSL, confirmed by LCMF in 2008.
2. Peak WSE likely occurred based on peak observed at MON20 (upstream) and MON22 (downstream).



5.0 2009 DISCHARGE

Direct discharge measurements were made at MON1, the 452-ft swale bridge, and all culverts conveying flow along the CD2 gravel access road. Indirect calculations were performed for MON1, MON23, both swale bridges, the culverts conveying flow, and the Nigliq Channel proposed CD5 crossing location.

5.1 MON1 DISCHARGE

5.1.1 DIRECT DISCHARGE

On May 26, a direct discharge measurement was completed on the Colville River at MON1 using standard ADCP techniques. Discharge was approximately 171,000 cfs having an average velocity of 4.0 feet per second (fps) with a maximum measured velocity of 7.9 fps and an associated stage of 11.42 feet. A summary of direct discharge measurements and the WinRiver output windows for each transect are presented in Appendix B. Figure 5.1 shows the location of the discharge measurement, as well as the cross-sectional geometry at the MON1 gage locations.

Six transects and one loop test were completed during the direct discharge measurement. Measurements could not be completed prior to May 26 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. After May 26, the Colville River stage was too low for a safe and accurate ADCP measurement. The direct discharge is plotted against the MON1 stage-discharge rating curve in Graph 5.1. The direct discharge plots off the rating curve. The shift is likely due to backwater from downstream ice jamming and/or sediment deposition in the channel resulting from low flow velocities. Backwater can raise water surface elevations without the normal associated increase in discharge while sediment deposition can change the bedform geometry, thus changing the relationship between stage and discharge.

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DRAWN:	MDM	FILE:	FIGURE 5.1-1.DWG
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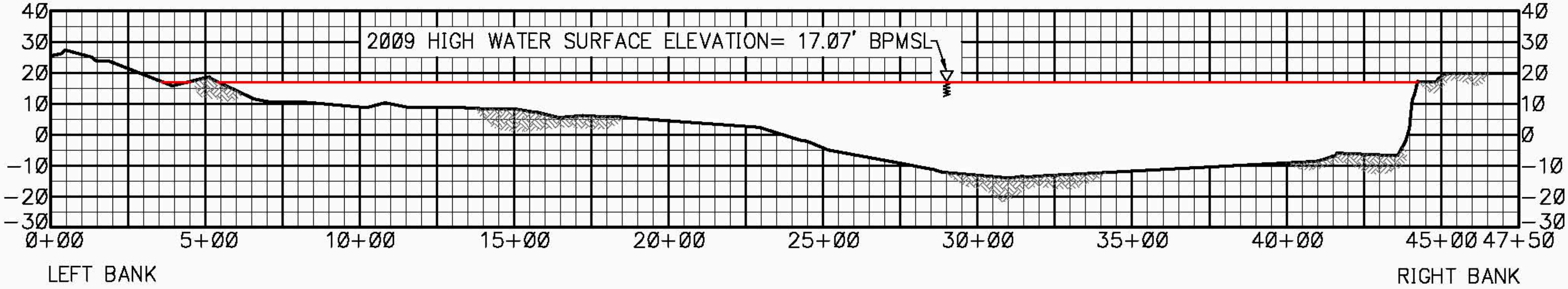
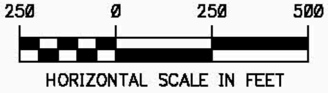
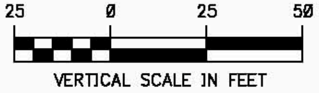
2009 SPRING BREAKUP
MONUMENT 1
PLAN
FIGURE 5.1
(SHEET 1 OF 4)

NOTES
1. BASIS OF ELEVATION, MONUMENT MON 01.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY KUUKPIK/LCMF INC.



(1D) COLVILLE RIVER CROSS SECTION AT MONUMENT 1 DOWNSTREAM





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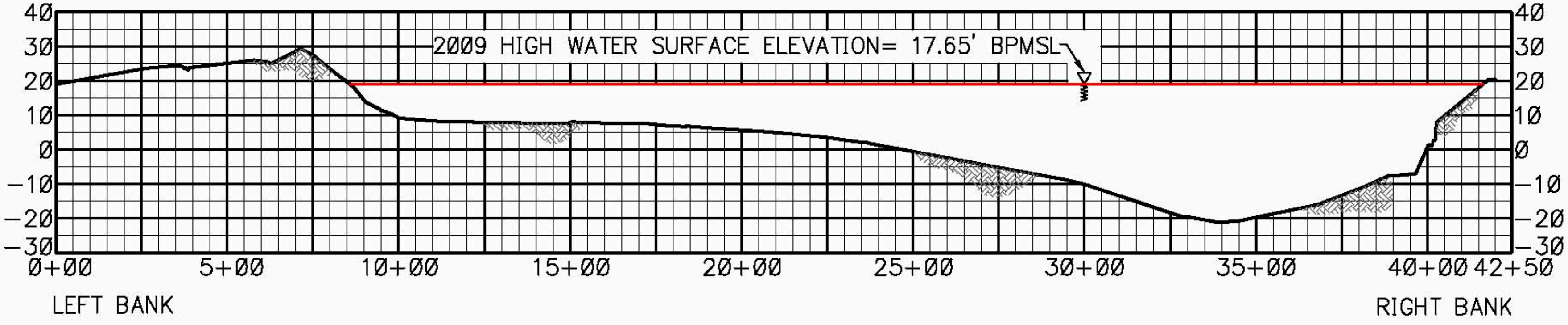
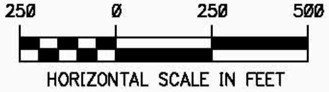
2009 SPRING BREAKUP
MONUMENT 01 DOWNSTREAM
2004 CROSS SECTION

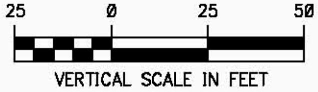
FIGURE 5.1
(SHEET 2 OF 4)

NOTES
1. BASIS OF ELEVATION, MONUMENT MON 01.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY KUUKPIK/LCMF INC.



① COLVILLE RIVER CROSS SECTION AT MONUMENT 1





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DATE:	10/7/09	PROJECT:	117011
DRAWN:	SMC	FILE:	FIGURE 5.1-2.DWG
CHECKED:	JMS	SCALE:	AS SHOWN

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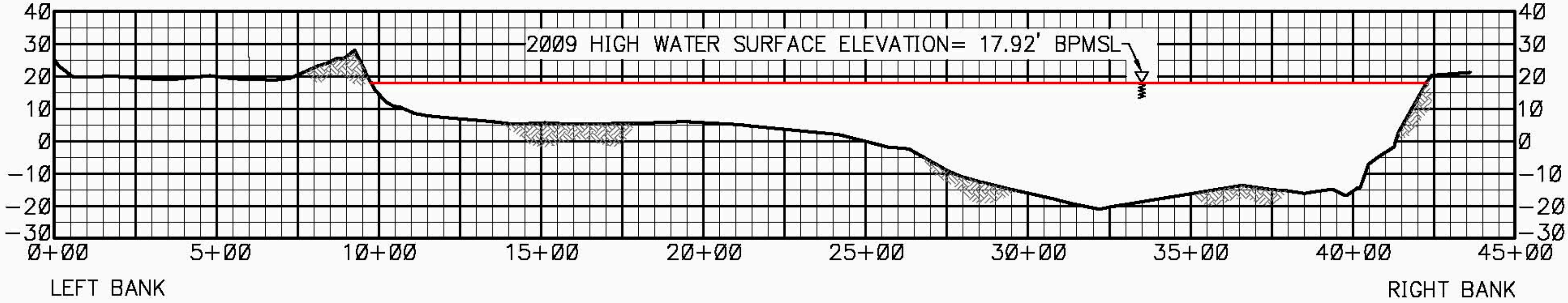
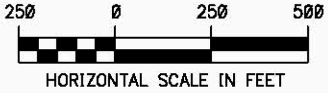
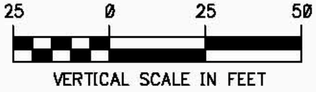
2009 SPRING BREAKUP
MONUMENT 01
2004 CROSS SECTION
FIGURE 5.1
(SHEET 3 OF 4)

NOTES
1. BASIS OF ELEVATION, MONUMENT MON 01.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY KUUKPIK/LCMF INC.



(1U) COLVILLE RIVER CROSS SECTION AT MONUMENT 1 UPSTREAM





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DATE:	10/7/09	PROJECT:	117011
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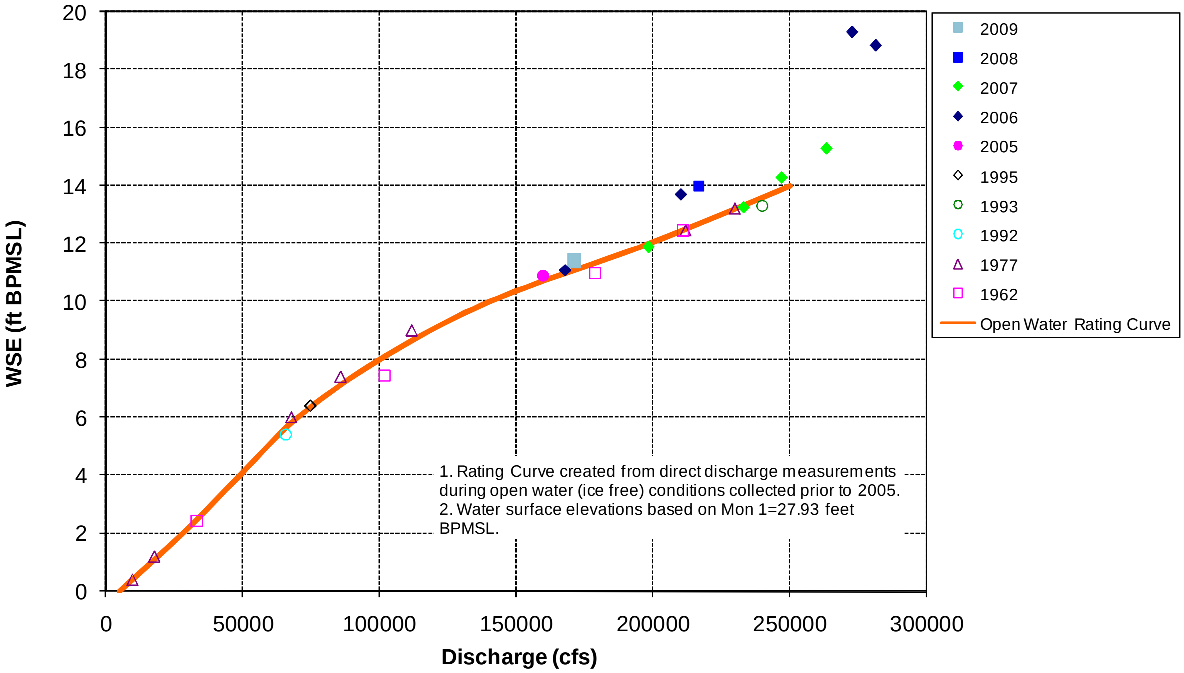
2009 SPRING BREAKUP
MONUMENT 01 UPSTREAM
2004 CROSS SECTION

FIGURE 5.1
(SHEET 4 OF 4)



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.

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

5.1.2 INDIRECT DISCHARGE

Indirect calculations used 2004 topographic survey data provided by LCMF and presented in Figure 5.1. Estimated discharge was calculated using the slope-area method and stage at MON1U, MON1 and MON1D.

Indirect calculations at the time of peak stage (May 23) were largely skewed by ice jams at the Nigliq and East Channel bifurcation immediately downstream of MON1. Ice jamming of this magnitude and proximity causes significant backwater effects that are not accounted for when using indirect calculations. Resulting estimates cannot be presented with any level of confidence and are thus not considered as the peak annual discharge. Additional errors associated with changes in bedform geometry can skew indirect calculations made evident when compared to direct measurements, as was done on May 26. Indirect calculations estimated a discharge of 181,000 cfs, whereas the corrected direct discharge measurement was 171,000 cfs.

Peak discharge at the head of the CRD was estimated to be 266,000 cfs on May 23 using indirect discharge methods at a stage of 15.27 feet. A peak stage of 17.65 feet occurred approximately 12 hours prior. The energy grade-line slope, approximated by the water surface slope from MON1U to MON1D, and water surface elevation at MON1 were used to calculate indirect discharge.

Table 5.1 presents a historic tabulation of published peak annual discharge and peak stage between 1992 and 2009.

TABLE 5.1: COLVILLE RIVER BREAKUP PEAK ANNUAL DISCHARGE (1992-2009)

Year	Monument 1 Peak Discharge (cfs)			Monument 1 Peak Water Surface Elevation (feet-BPMSL)	
	Discharge	Method	Reference	Mon 1	Reference
2009	266,000	Estimated-Indirect Calculation	This Report	17.65	This Report
2008	221,000	Estimated-Indirect Calculation	Baker 2008b	17.29	Baker 2008b
2007	270,000	ADCP Measurement	Baker 2007b	18.97	Baker 2007b
2006	281,000	ADCP Measurement	Baker 2007b	19.83	Baker 2007b
2005	195,000	Estimated-Mon 1 Rating Curve	Baker 2005b	13.18	Baker 2005b
2004	360,000	Estimated-Indirect Calculation	Baker 2005a	19.54	Baker 2005a
2003	232,000	Estimated-Mon 1 Rating Curve	Baker 2006a	13.76	Baker 2003
2002	249,000	Estimated-Mon 1 Rating Curve	Baker 2006a	16.87	Baker 2002a
2001	255,000	Estimated-Mon 1 Rating Curve	Baker 2006a	17.37	Baker 2001
2000	580,000	Estimated-Indirect Calculation	Baker 2000	19.33	Baker 2000
1999	203,000	Estimated-Indirect Calculation	Baker 1999	13.97	Baker 1999
1998	213,000	Estimated-Indirect Calculation	Baker 1998a	18.11	Baker 1998a
1997	177,000	Estimated-Indirect Calculation	Baker 2002b	15.05	Baker 1999
1996	160,000	Estimated-Indirect Calculation	Shannon & Wilson 1996	17.19	Shannon & Wilson 1996
1995	233,000	Estimated-Indirect Calculation	ABR 1996	14.88	ABR 1996
1994	159,000	Estimated-Indirect Calculation	ABR 1996	12.20	ABR 1996
1993	379,000	Estimated-Indirect Calculation	ABR 1996	19.20	ABR 1996
1992	188,000	Estimated-Indirect Calculation	ABR 1996	13.90	ABR1996

5.2 MON23 DISCHARGE

A direct discharge measurement was not performed at MON23 due to prohibitive weather conditions and the presence of in-channel ice. Indirect calculations used 2005 topographic survey data provided by LCMF. Location and cross-section of the area is presented in Figure 5.2. Estimated discharge was calculated based on the slope-area method and observed stage at MON22 and MON23.

PHOTO 5.1: RIBBON ICE IN THE VICINITY OF MON23. MAY 22, 2009.

Photographic evidence, as shown in Photo 5.1, indicates ribbon ice remained in the vicinity of MON23 on May 22. As a result, indirect calculations based on stage for May 22 were performed by subtracting estimated ice dimensions to account for the ribbon ice remaining in the vicinity. Calculations, based on stage from May 23 and May 24, were performed assuming an ice-free channel.

Indirect calculations are to be considered a conservative estimate based on the probability of bottom-fast ice remaining in-channel, morphology of the channel bed due to sediment transport, and assumptions based on the presence and dimensions of in-channel ice, or lack thereof.

Peak discharge at MON23 was estimated to have occurred on the evening of May 23, approximately 12 hours before peak stage at MON22 and approximately 12 hours after peak stage at MON23. Peak discharge was calculated to be 59,000 cfs at a MON23 with a WSE of 6.67 ft BPMSL. A historic record of peak discharge at MON23 is presented in Table 5.2.

TABLE 5.2: NIGLIQ CHANNEL BREAKUP PEAK ANNUAL DISCHARGE (2005 – 2009)

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

LEGEND
- ● GAGES
- ┼ CROSS SECTION ALIGNMENT

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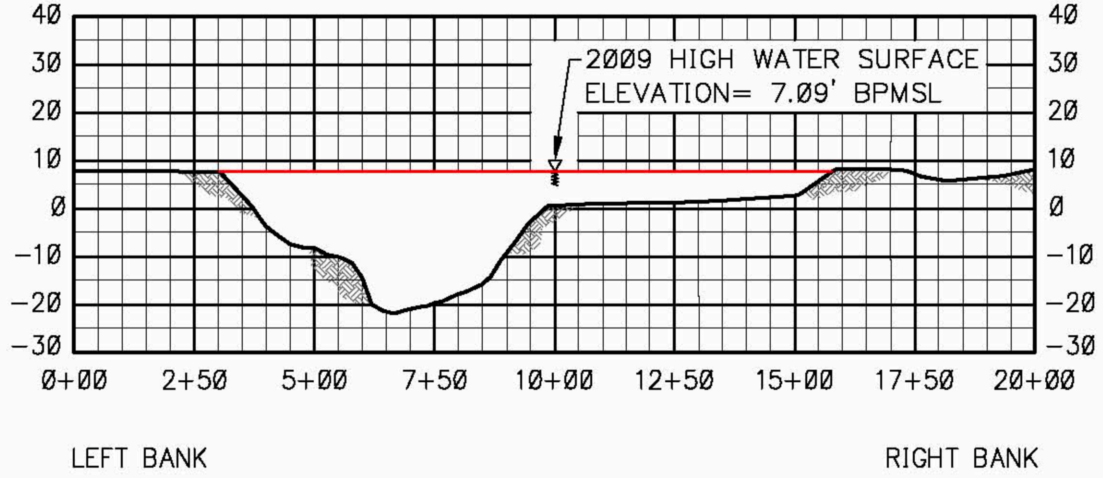
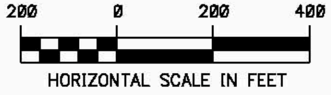
2009 SPRING BREAKUP
MONUMENT 23
PLAN

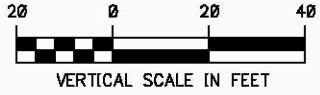
FIGURE 5.2
(SHEET 1 OF 2)

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



1 MONUMENT 23 CROSS SECTION





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2009 SPRING BREAKUP
MONUMENT 23
2005 CROSS SECTION

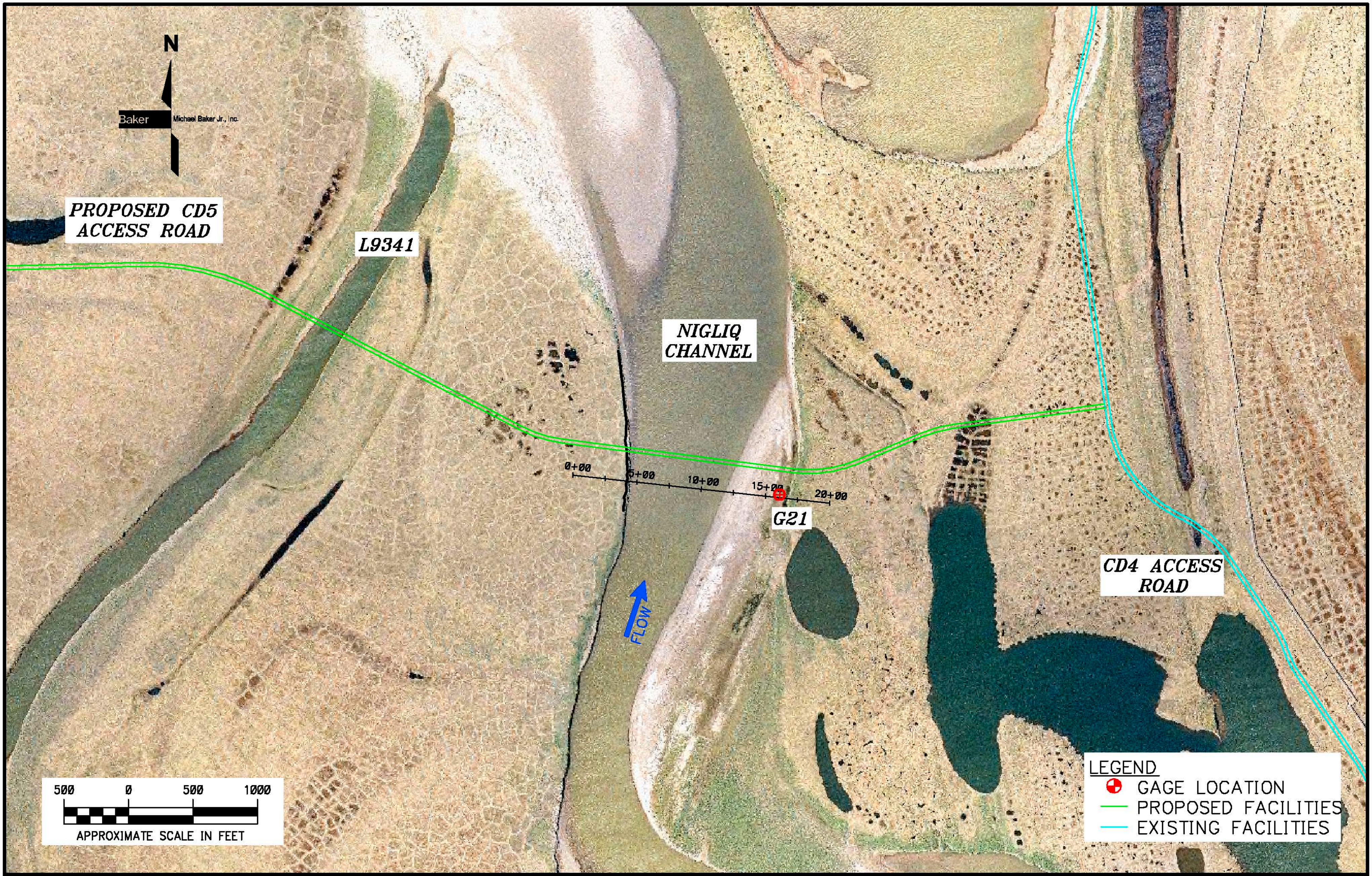
FIGURE 5.2
(SHEET 2 OF 2)

5.3 NIGLIQ BRIDGE SITE DISCHARGE

A direct discharge measurement was not performed at the proposed Nigliq Channel CD5 bridge crossing location due to the prohibitive weather conditions and the presence of channel ice. Indirect calculations were completed using July 2008 topographic survey data provided by LCMF, presented in Figure 5.3. Estimated discharge was calculated based on the slope-area method and stage at MON20 and MON22. Indirect calculations were based on stage from May 23 through May 25 and were performed assuming an ice-free channel.

Indirect calculations are considered to be a reasonable estimate of actual discharge based on the possibility of in-channel ice, change in channel bed morphology due to sediment transport, assumptions regarding channel and overbank roughness, and the assumption that the WSE differential is instantaneous at gaging stations.

Peak discharge, based on the indirect calculations at gage G21, was estimated to have occurred in the evening of May 24, approximately 12 hours before peak stage at MON20 and approximately 12 hours after peak stage at MON22. Peak discharge at G21 was calculated to be approximately 57,000 cfs with an estimated WSE of 8.3 ft BPMSL. The WSE during peak discharge at G21 was calculated based on the slope of the flood water between MON20 and MON22; the WSE of MON20 and MON22; and the distance of G21 from MON20.



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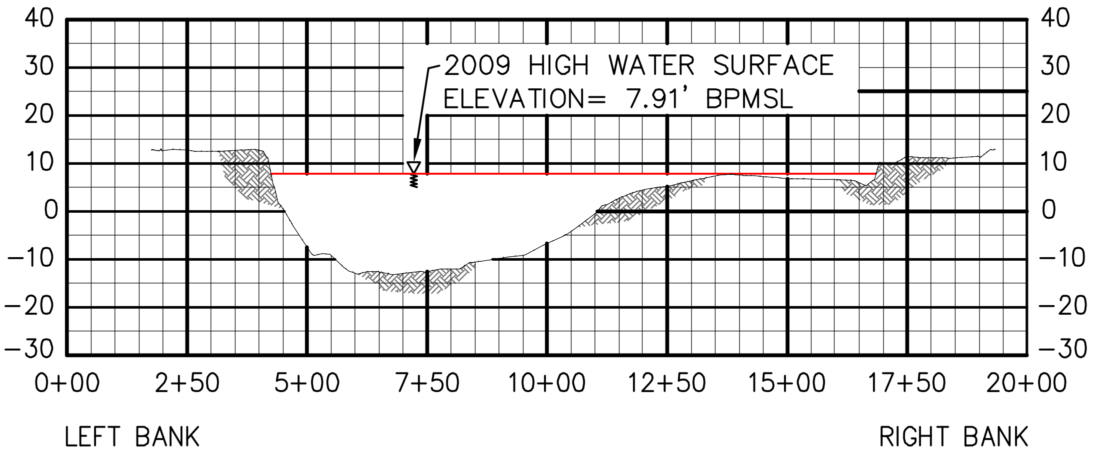
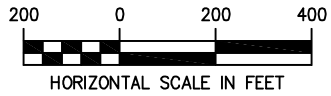
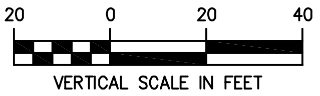
2009 SPRING BREAKUP
GAGE 21
NIGLIQ CHANNEL PLAN
FIGURE 5.3
(SHEET 1 OF 2)

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



① GAGE 21 CROSS SECTION





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2009 SPRING BREAKUP
GAGE 21
NIGLIQ CHANNEL PROFILE

FIGURE 5.3
(SHEET 2 OF 2)

5.4 ALPINE SWALE BRIDGES DISCHARGE

5.4.1 DIRECT DISCHARGE

A direct discharge measurement at the 62-ft swale bridge was not conducted in 2009 due to initial flow obstruction by snow and ice, followed by unsafe channel icing conditions. One direct discharge measurement at the 452-ft swale bridge was conducted on May 26 at 12:00 PM. Discharge was measured to be 728 cfs, and was not performed at the time of peak flow due to the presence of abundant ice in the channel bottom.

A summary of the 2009 direct discharge measurement at the 452-ft swale bridge is presented in Table 5.3, which includes a summary of historic discharge measurements. Complete notes for the discharge measurement are in Appendix C.

TABLE 5.3: HISTORIC DIRECT DISCHARGE SUMMARY: ALPINE SWALE BRIDGES (2000 – 2009)

Site Name	Date	WSE (ft)	Measurement Performed By	Width (ft)	Area (ft^2)	Mean Vel (ft/s)[1]	Discharge (cfs)	MMT Rating[2]	Number of Sections	MMT Type	Reference
62-foot Bridge	**–[3]**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**This report**
	05/29/08	6.35	JPM, OOO, MDM	55	211	0.58	123	P	14	Cable	Baker 2008b
	06/05/07	7.83	JPM, OOO, MDM	55	292	1.18	345	F	20	Cable	Baker 2007b
	05/31/06	8.49	JPM, SLB, EJK	55	615	1.59	980	F	20	Cable	Baker 2007a
	–[3]	–	–	–	–	–	–	–	–	–	Baker 2005b
	05/29/04	8.34	JWW, MTA	55	451	1.60	720	F	17	Cable	Baker 2005a
	–[3]	–	–	–	–	–	–	–	–	–	Baker 2003
	05/25/02	6.74	JWW, HA	56.0	283	1.52	430	G	17	Cable	Baker 2002a
	06/11/01	7.64	JWW, CD	56	336	1.79	600	G	15	Cable	Baker2001
	06/10/00	7.87	JA, JA, JC	47	175	3.30	580	F	13	Cable	Baker2000
452-foot Bridge	**05/26/09**	**5.89**	**JPM, JWW**	**445**	**1592**	**0.82**	**728**	**F**	**27**	**Wading**	**This report**
	05/29/08	6.35	JPM, OOO, MDM	445	949	2.03	1930	F	21	Wading	Baker 2008
	06/05/07	7.76	JPM, OOO, MDM	447	1670	0.74	1240	F	20	Cable	Baker 2007b
	05/31/06	8.42	JPM, SLB, EJK	409	1730	1.89	3260	F	29	Cable	Baker 2007a
	06/02/05	6.13	JPM, MDC, EJK	445	841	1.37	1100	G	20	Wading	Baker 2005b
	05/29/04	8.34	JWW, MTA	446	1700	1.40	2400	F	18	Cable	Baker 2005a
	06/08/03	5.48	JWW, HA	444	478	0.88	420	G	16	Wading	Baker 2003
	05/25/02	6.74	JWW, HA	445	930	3.47	3200	G	17	Cable	Baker 2002a
	06/11/01	7.64	JWW, CD	460	1538	2.4	3700	G	16	Cable	Baker2001
	06/09/00	7.34	JA, JA	437	1220	3.27	4000	F	15	Cable	Baker2000

Notes:
1. Mean velocities adjusted with angle of flow coefficient
2. 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
3. Bridge obstructed with snow or ice, no measurement made

5.4.2 INDIRECT DISCHARGE

The 2009 peak discharge though the 452-ft swale bridge likely occurred at the time of peak stage and high water surface differential, as determined by comparison of gages G3 and G4 readings. The peak stage at G3, 7.63 feet BPMSL, occurred on the afternoon of May 25 (see Table 4.10). The headwater-tailwater differential at that time was 0.45 feet, the third highest calculated during the spring breakup flow period. The high differentials are considered inflated, occurring during and just after the ice and snow dam under the bridge was present, restricting south to north flow. Peak discharge through the swale bridge was estimated based on the assumption that the measured average adjusted velocity was representative of the average velocity at peak stage, approximately 24 hours earlier.

Peak discharge was estimated to have been 1,400 cfs though the 452-ft swale bridge. Table 5.4 summarizes the estimated peak annual discharge data at the Alpine swale bridges between 2000 and 2009.

TABLE 5.4: ESTIMATED PEAK DISCHARGE SUMMARY: ALPINE SWALE BRIDGES (2000 - 2009)

Date & Time	Peak WSE (ft)[1]	452-Foot Bridge		62-Foot Bridge		References
		Discharge (cfs)[2]	Mean Vel (ft/s)	Discharge (cfs)[2]	Mean Vel (ft/s)	
5/25/09 1:00 PM	**7.63**	**1400**	**0.82**	**– [3]**	**-**	**This report**
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	– [3]	–	Baker 2005b
5/27/04 1:30 PM	9.97	3400	1.38	900	1.59	Baker 2005a
06/07/2003[4]	6.31	700	0.88	– [3]	–	Baker 2003
05/26/2002[4]	7.59	4000	3.47	500	1.52	Baker 2002a
06/11/2001[4]	7.95	3900	2.40	600	1.79	Baker2001
06/12/2000[4]	9.48	7100	3.60	1000	4.30	Baker2000

Notes:
1. Gage 3 high water mark
2. Estimated peak discharge
3. Bridge obstructed with snow or ice, no measurement made
4. Unknown time of peak stage

5.5 ALPINE CULVERT DISCHARGE

Stage, velocity, and discharge are measured and estimated at the CD2 and CD4 culverts to monitor the performance of the drainage structures and to comply with stipulated monitoring requirements outlined in USACE Permit Number POA-2004-253 and the State of Alaska Fish Habitat Permit FH04-III-0238. The location and naming convention of the CD2 and CD4 culverts are presented in Figure 5.4.

Water surface elevation data and culvert dimensions are used to perform indirect culvert discharge calculations for a variety of conditions. CD2 and CD4 culvert invert elevations were surveyed by LCMF in May and June 2008, while culvert length and diameter was obtained using as-built surveys conducted by LCMF in 2002 and 2005, respectively.

Floodwater was observed flowing through three CD2 road culverts (CD2-20, CD2-23, and CD2-24) and standing backwater was observed in eight CD4 culverts (CD4-20A through CD4-23D). This standing backwater resulted in no discernable flow through the CD4 culverts. Though snow and ice were present in the vicinity of Alpine during breakup, its presence had limited impact on the hydraulic performance and discharge of the CD2 and CD4 culverts.

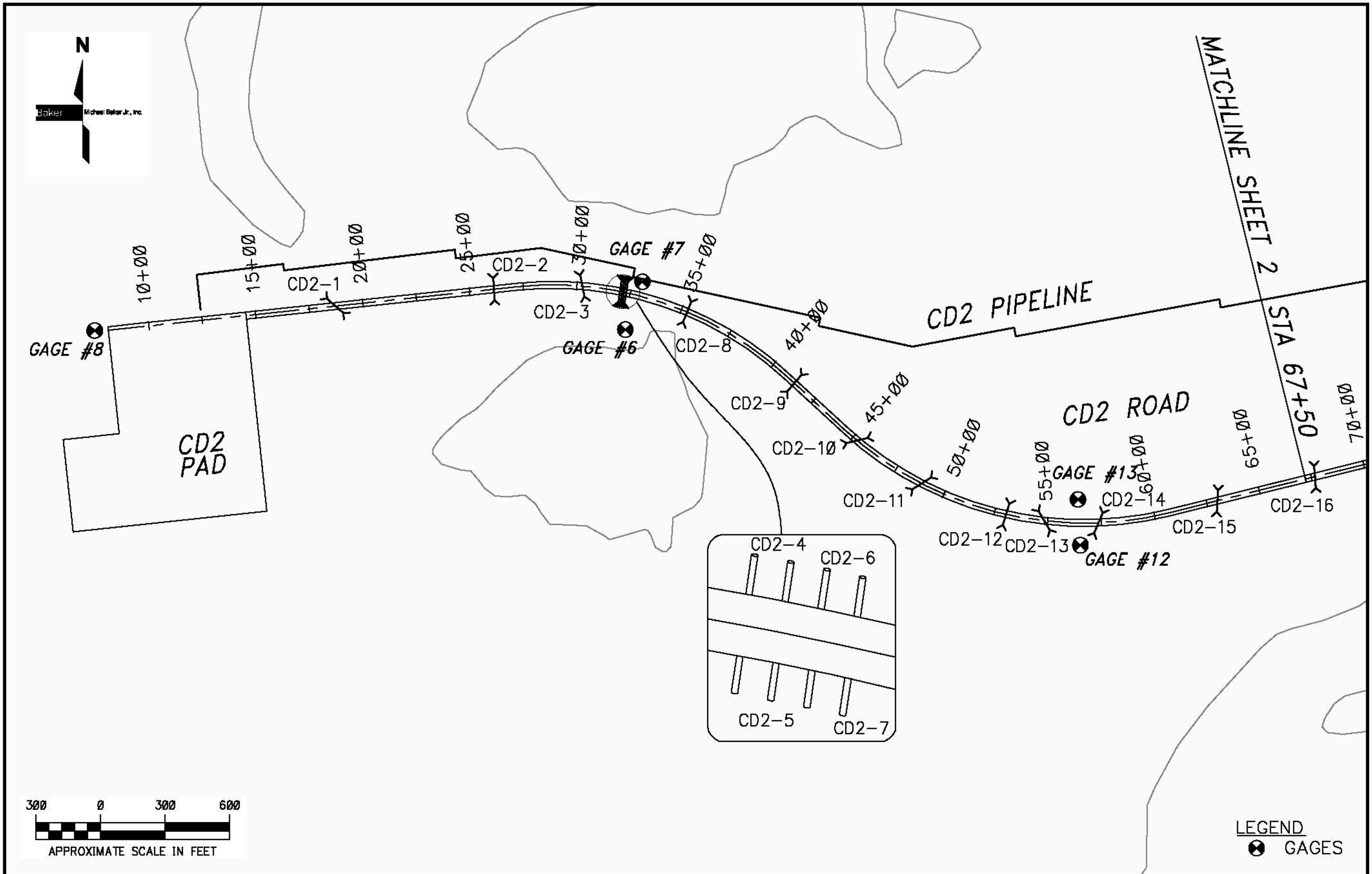
5.5.1 INDIRECT ESTIMATED DISCHARGE AND VELOCITY

5.5.1.1 ALPINE CULVERTS INDIRECT DISCHARGE

Flow through the CD2 access road culverts was estimated to have first occurred on May 22, 2009. The peak discharge through CD2 culverts did not coincide with peak stage. Peak discharge ranged from 2.1 cfs to 39.7 cfs through culverts CD2-22 and CD2-24, respectively. The indirectly calculated maximum total discharge through all CD2 culverts at a given time during breakup was approximately 96.8 cfs. The calculated indirect discharge of the CD2 road culverts is presented in Table 5.5.

TABLE 5.5: CD2 ROAD CULVERTS ESTIMATED DISCHARGE SUMMARY (CFS)

Culvert	5/22/09 9:05 AM	5/23/09 9:50 AM	5/23/09 2:35 PM	5/24/09 8:30 AM	5/24/09 3:25 PM	5/25/09 9:35 AM	5/25/09 1:00 PM	5/25/09 4:40 PM	5/26/09 9:15 AM	5/26/09 11:26 AM	5/26/09 1:42 PM
CD2-22	21.8	21.1	14.0	21.7	20.3	20.2	24.5	16.5	2.7	2.2	2.1
CD2-23	34.7	32.3	22.5	32.0	29.3	29.1	34.8	24.7	7.0	6.3	5.9
CD2-24	39.7	35.6	25.0	34.9	31.8	31.5	37.5	26.9	8.4	7.7	7.2
Discharge	96.2	89.0	61.5	88.6	81.4	80.9	96.8	68.1	18.0	16.2	15.2



ConocoPhillips
Alaska, Inc.

DATE:	12/14/09	PROJECT:	117011
DRAWN:	SMC	FILE:	FIGURE 5.4
CHECKED:	EJK	SCALE:	AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
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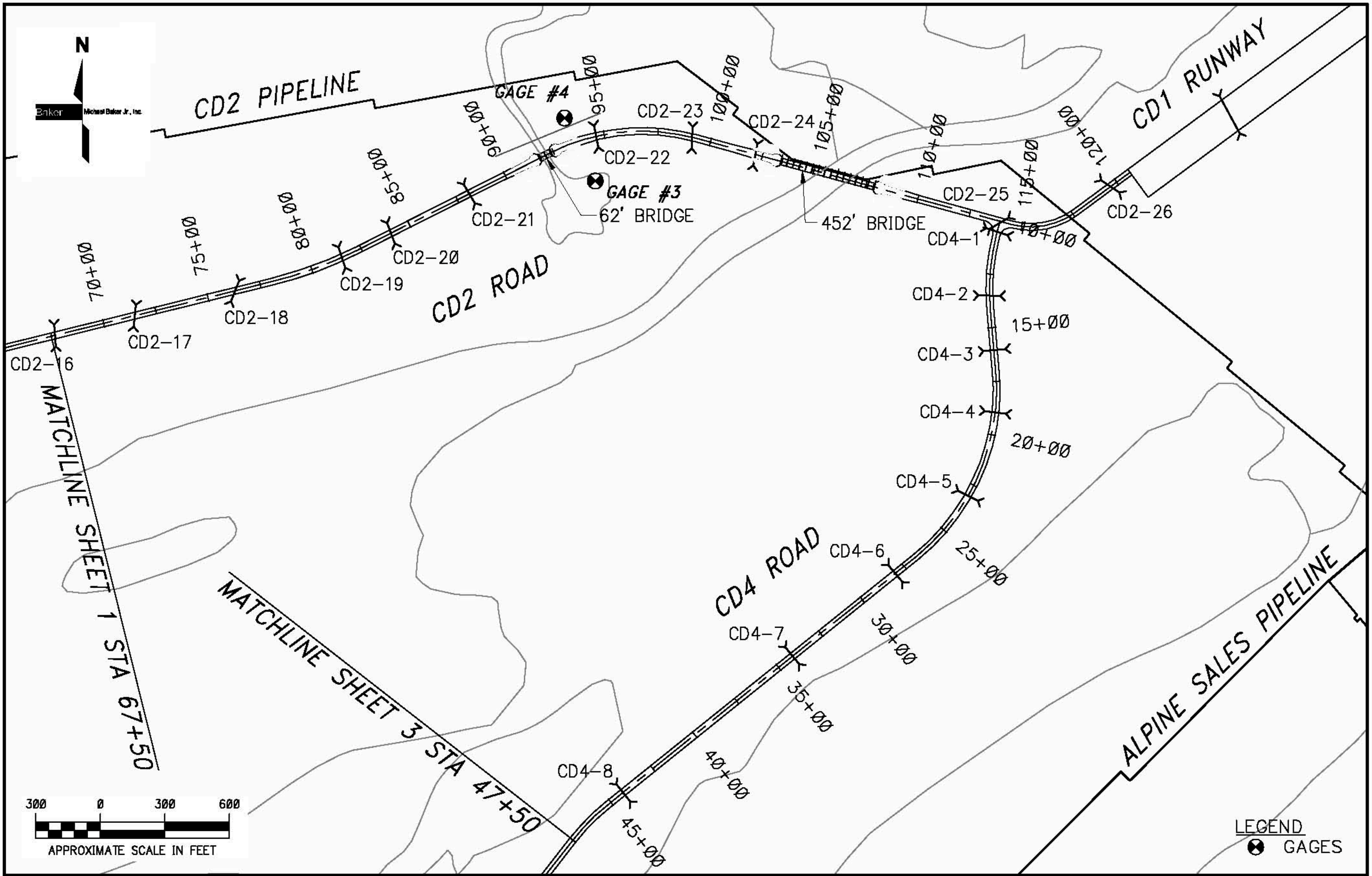
2009 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 1 OF 6)



ConocoPhillips
Alaska, Inc.

DATE:	12/14/09	PROJECT:	117011
DRAWN:	SMC	FILE:	FIGURE 5.4
CHECKED:	EJK	SCALE:	AS SHOWN

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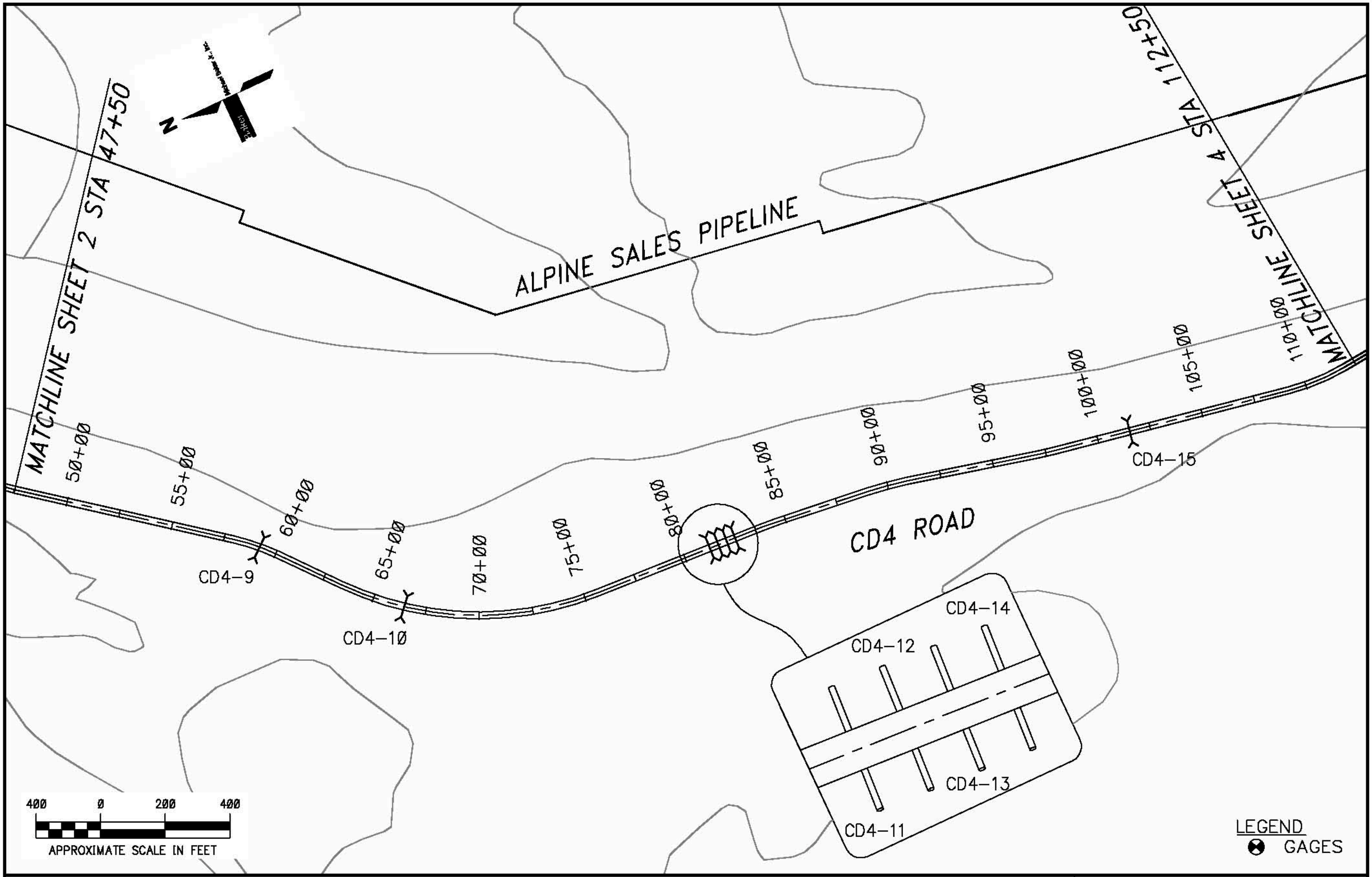
2009 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 2 OF 6)



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Alaska, Inc.

DATE:	12/14/09	PROJECT:	117011
DRAWN:	SMC	FILE:	FIGURE 5.4
CHECKED:	EJK	SCALE:	AS SHOWN

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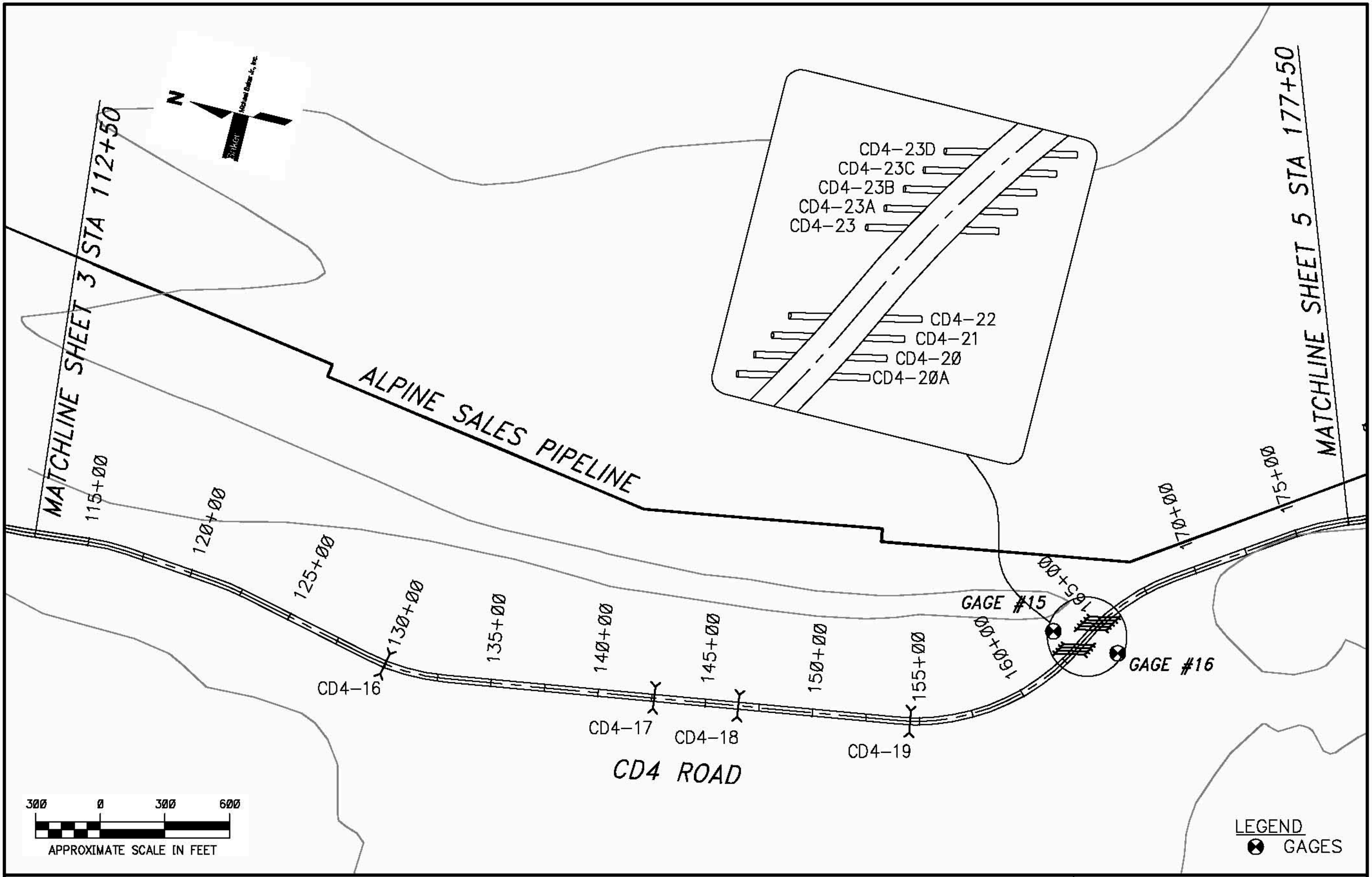
2009 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 3 OF 6)



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DATE:	12/14/09	PROJECT:	117011
DRAWN:	SMC	FILE:	FIGURE 5.4
CHECKED:	EJK	SCALE:	AS SHOWN

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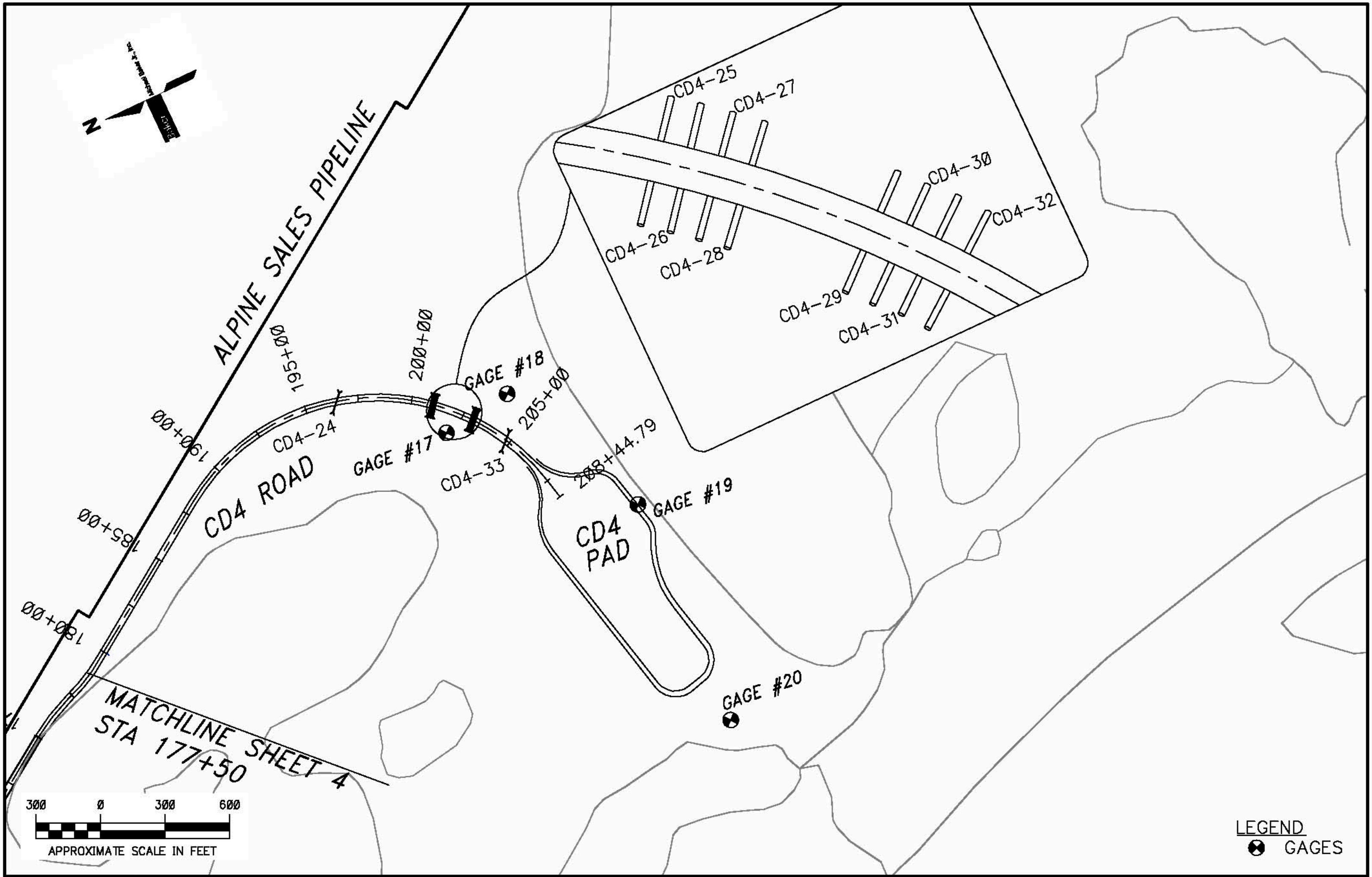
2009 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 4 OF 6)



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DATE:	12/14/09	PROJECT:	117011
DRAWN:	SMC	FILE:	FIGURE 5.4
CHECKED:	EJK	SCALE:	AS SHOWN

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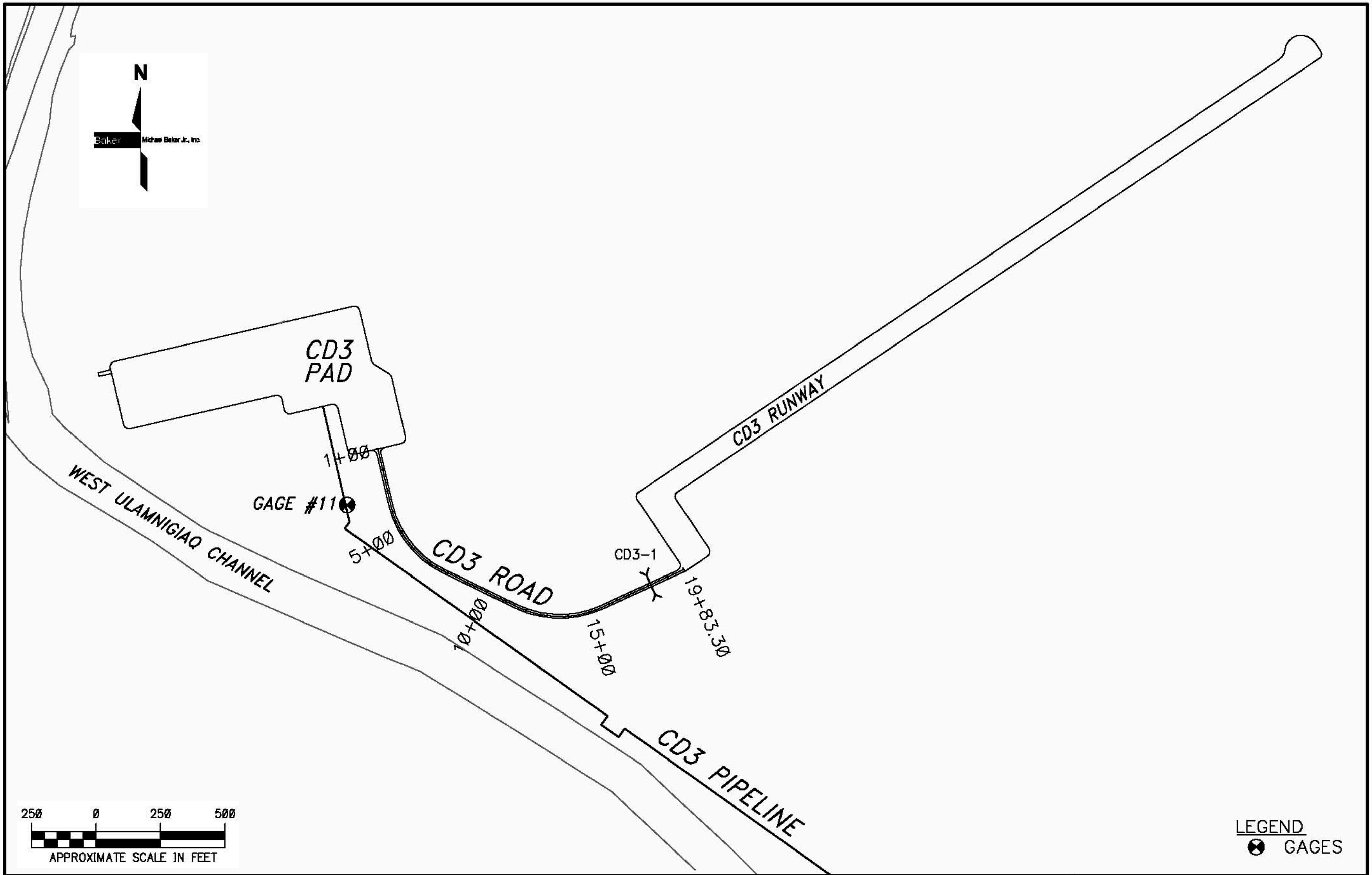
2009 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 5 OF 6)



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DATE:	12/14/09	PROJECT:	117011
DRAWN:	SMC	FILE:	FIGURE 5.4
CHECKED:	EJK	SCALE:	AS SHOWN

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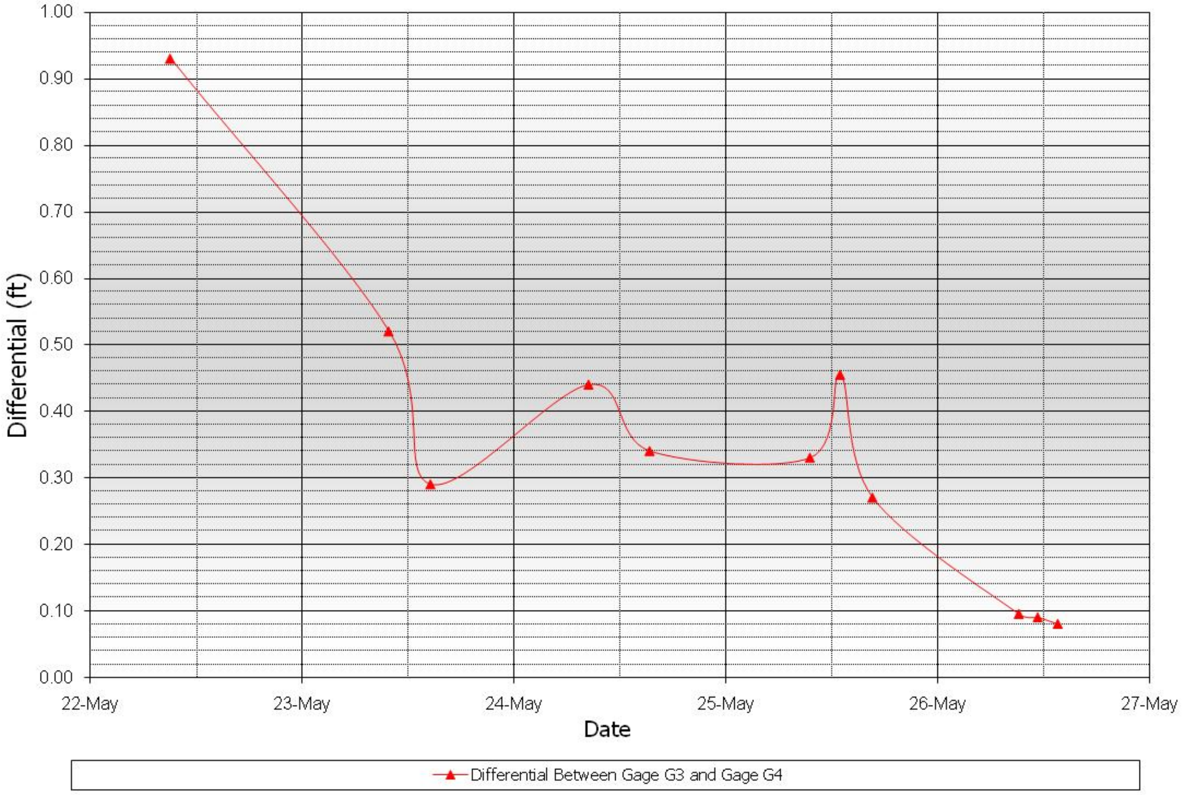
2009 SPRING BREAK-UP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 6 OF 6)

5.5.1.2 ALPINE CULVERTS HEADWATER AND TAILWATER DIFFERENTIAL

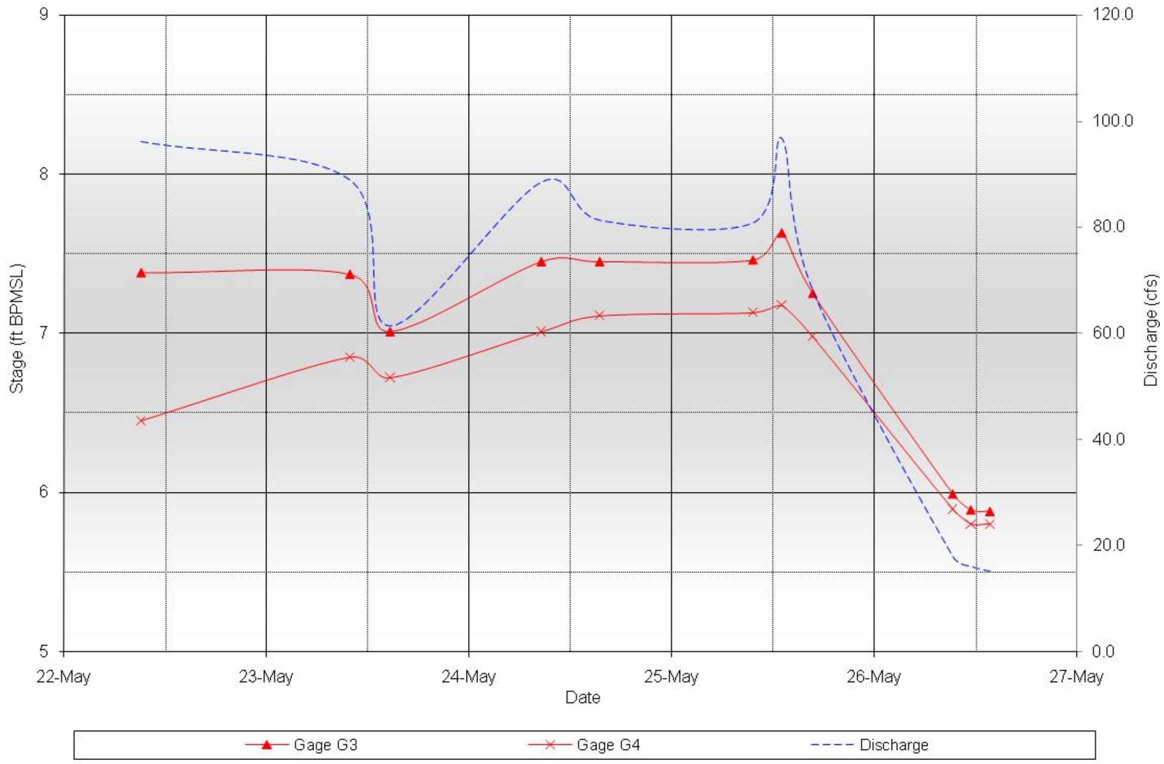
For 2009, the differential between headwater and tailwater elevations for the CD2 culverts that passed water is based on the water surface elevation observed at gages G3 and G4, given the proximity to the culverts. The maximum differential between G3 and G4 occurred simultaneously with the initial flow of water through the CD2 road culverts on May 22. A maximum slope differential between G3 and G4 of 0.93 feet occurred on May 22 (Graph 5.2) but this is due to the presence of a snow and ice dam on the upstream side of both swale bridges (Photo 5.2 and Photo 5.3). Flow through the CD2 culverts is estimated to have stopped in the late evening of May 26 or in the early morning of May 27 when water receded below the gages, and below culvert inverts. A comparison of stage and discharge during breakup for CD2 culverts is presented in Graph 5.3.



GRAPH 5.2: DIFFERENTIAL BETWEEN GAGE G3 AND GAGE G4 ALONG CD2 ROAD

PHOTO 5.2: SNOW/ICE DAM ON UPSTREAM SIDE OF 62-FT SWALE BRIDGE. MAY 22, 2009.

PHOTO 5.3: SNOW/ICE DAM ON UPSTREAM SIDE OF 452-FT SWALE BRIDGE. MAY 22, 2009.



GRAPH 5.3: CD2 ROAD CULVERTS AND ESTIMATED DISCHARGE VS. STAGE

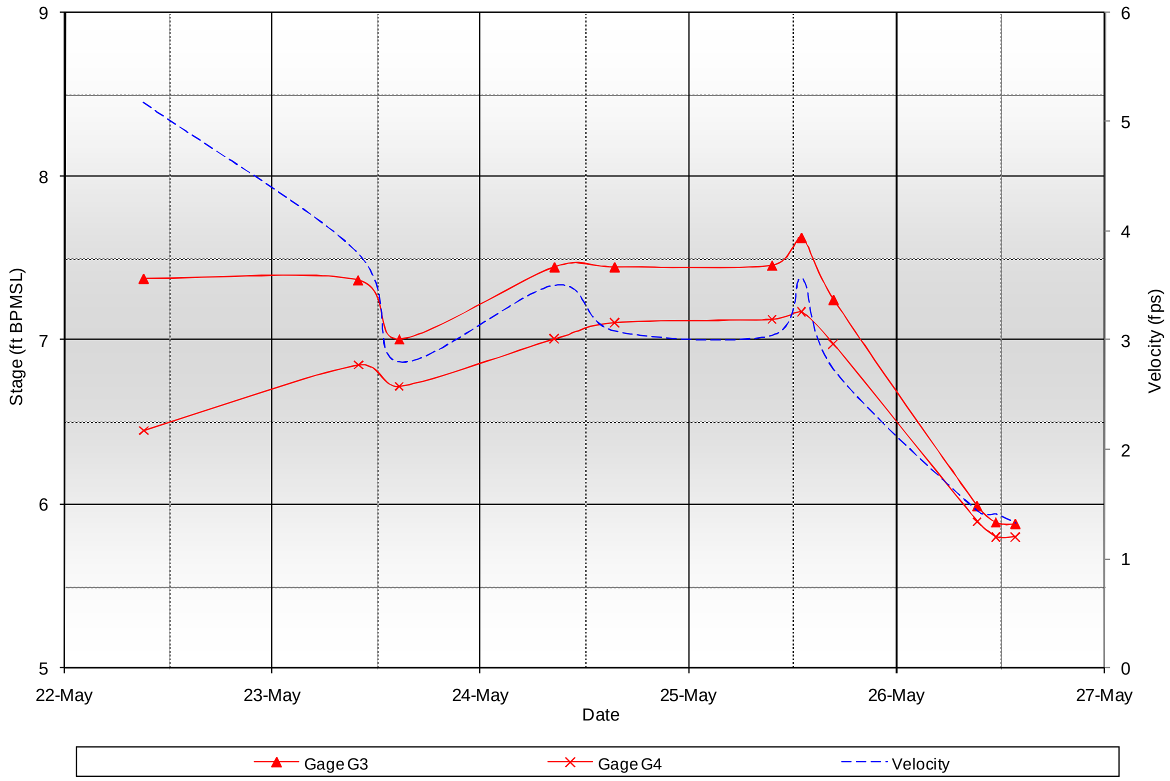
5.5.1.3 ALPINE CULVERTS INDIRECT VELOCITY

Peak velocities for the CD2 road culverts were estimated to have occurred in the early morning of May 25 with a maximum velocity of 5.52 fps through CD2-22. During peak discharge, the average velocities through the culverts ranged from 3.54 fps to 3.59 fps. A summary of average velocities for each culvert is presented in Table 5.6.

TABLE 5.6: CD2 ROAD CULVERTS ESTIMATED VELOCITY SUMMARY (FPS)

Culvert	5/22/09 9:05 AM	5/23/09 9:50 AM	5/23/09 2:35 PM	5/24/09 8:30 AM	5/24/09 3:25 PM	5/25/09 9:35 AM	5/25/09 1:00 PM	5/25/09 4:40 PM	5/26/09 9:15 AM	5/26/09 11:26 AM	5/26/09 1:42 PM
CD2-22	5.52	3.82	2.79	3.52	3.09	3.05	3.58	2.73	1.36	1.32	1.24
CD2-23	4.92	3.75	2.78	3.47	3.06	3.02	3.54	2.71	1.44	1.41	1.33
CD2-24	5.12	3.83	2.84	3.53	3.11	3.07	3.59	2.76	1.50	1.49	1.40
Average Velocity	**5.19**	**3.80**	**2.80**	**3.51**	**3.09**	**3.05**	**3.57**	**2.73**	**1.43**	**1.41**	**1.32**

The velocity estimates for the CD2 culverts are related to water surface differentials between the culvert headwater and the tailwater elevations. The velocity for each culvert was greatest on May 22, which had the largest differential between headwater and tailwater. A comparison of stage and velocity for the CD2 culverts is presented in Graph 5.4.



GRAPH 5.4: CD2 ROAD CULVERTS ESTIMATED VELOCITY VS. STAGE

5.5.2 DIRECT DISCHARGE AND VELOCITY MEASUREMENTS

Direct water depth and velocity measurements were conducted at the CD2 (CD2-22, CD2-23, and CD2-24) road culverts to validate indirect culvert calculations. Velocity measurements were taken at the downstream side of the culvert. A calibrated Price AA velocity meter and graduated USGS wading rod were used to measure a single at-point velocity at six-tenths of the culvert's total water depth. This velocity was used as a representative average cross-sectional velocity in the culvert.

On May 26, water depth and velocities were measured at the CD2 road culverts. These measurements, provided in Table 5.7, represent conditions at culverts approximately 24 hours after peak stage occurred at gages G3 and G4. The measured velocities ranged from 1.26 to 2.00 fps, averaging 1.70 fps. The total measured discharge flowing through CD2 culverts was 11.6 cfs, ranging from 0.8 cfs to 5.8 cfs at culverts CD2-22 and CD2-24 respectively. The timing of the data collection suggests that direct measurements were not a fair representation of the near-peak flow conditions at the CD2 culverts; in this case, indirect estimates better capture peak flow conditions.

TABLE 5.7: CD2 ROAD CULVERTS – MAY 26 DISCHARGE MEASUREMENTS

Culvert #	Date Time	Made By	Depth (ft)	Area (ft²)	Mean Vel (ft/s)	Discharge (cfs)	Number of Sections	MMT Type
CD2-1	– (1)	–	–	–	–	–	–	–
through	– (1)	–	–	–	–	–	–	–
CD2-21	– (1)	–	–	–	–	–	–	–
CD2-22	5/26/09 4:15 PM	JPM, JWW	0.40	0.65	1.26	0.8	1	Wading
CD2-23	5/26/09 4:05 PM	JPM, JWW	1.00	2.46	2.00	4.9	1	Wading
CD2-24	5/26/09 4:00 PM	JPM, JWW	1.20	3.17	1.84	5.8	1	Wading
CD2-25	– (1)	–	–	–	–	–	–	–
CD2-26	– (1)	–	–	–	–	–	–	–
Notes: 1. No water flowing through culvert, no measurement made					Average Measured Velocity (ft/s)			1.70
					Total Measured Discharge (cfs)			11.6

5.5.3 ALPINE CULVERTS INDIRECT/DIRECT DISCHARGE ESTIMATES COMPARISON

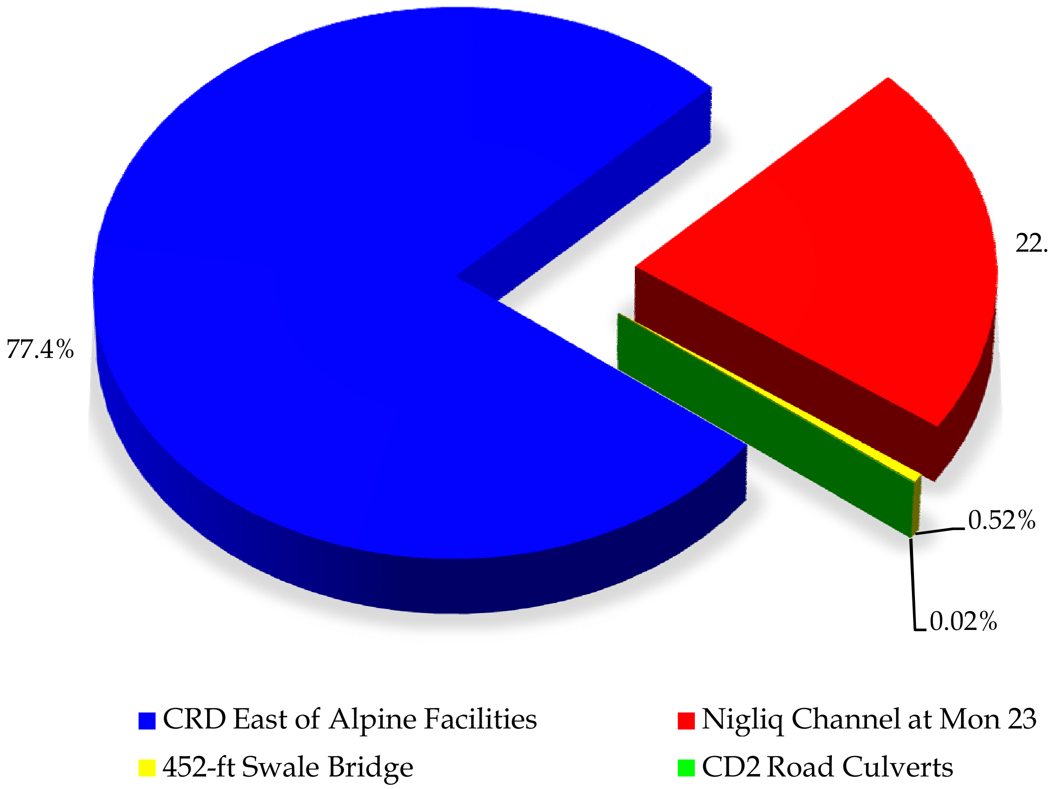
Indirect calculations were used to estimate peak discharge values. The indirect estimates were compared with the respective direct velocity measurements and associated discharge estimates to get a sense of relative accuracy of the indirect calculations. The comparison between the May 26 CD2 culverts direct and indirect measurements are presented in Table 5.8. The percent difference between measured and calculated mean velocity and total discharge was 22% and -32%, respectively.

TABLE 5.8: CD2 ROAD CULVERTS – DISCHARGE COMPARISON

Culvert	Time of Direct Measurement	Mean Velocity (ft/s)	Direct Measured Discharge (cfs)	Time of Indirect Measurement	Indirect Calculated Velocity (ft/s)	Indirect Calculated Discharge (cfs)	Percent Difference (1)	
							Velocity	Discharge
CD2-22	5/26/09 4:15 PM	1.26	0.8	5/26/09 1:40 PM	1.24	2.1	2%	-150%
CD2-23	5/26/09 4:05 PM	2.00	4.9	5/26/09 1:40 PM	1.33	5.9	34%	-21%
CD2-24	5/26/09 4:00 PM	1.84	5.8	5/26/09 1:40 PM	1.40	7.2	24%	-24%
Average Measured Velocity (ft/s)		**1.70**	**Average Calculated Velocity (ft/s)**			**1.3**	**V Difference**	**22%**
Total Measured Discharge (cfs)		**11.6**	**Total Calculated Discharge (cfs)**			**15.2**	**Q Difference**	**-32%**
Notes: 1. Percent difference is computed using direct to indirect velocity and discharge values.								

5.6 CRD PEAK DISCHARGE FLOW DISTRIBUTION

Approximately 77% of the flow in the CRD passed through the East Channel during the 2009 spring breakup peak discharge event, which was estimated to have occurred on the evening of May 23, 2009. Twenty-two percent of the flow passed down the Nigliq Channel at MON23. The remaining 1% of flow was calculated to have gone through the CD2 road culverts combined with the 452-ft swale bridge. The 62-ft swale bridge was obstructed with snow and ice during peak discharge and it is assumed that the structure saw little of the peak flow. Flood waters were not observed flowing through CD4 road culverts due to low stage. Graph 5.5 presents the 2009 estimated peak flow distribution within the CRD.



GRAPH 5.5: 2009 CRD ESTIMATED PEAK FLOW DISTRIBUTION

5.7 FLOOD AND STAGE FREQUENCY ANALYSES

5.7.1 COLVILLE RIVER FLOOD FREQUENCY

Since 1992, annual peak discharges have been recorded at the head of the Delta (at MON1, specifically). Thus, eighteen years of continuous observed data is now available. These observed data are fitted to a Weibull distribution, which assigns recurrence intervals to each recorded peak discharge. This method requires a continuous data record, and is performed as an analysis of observed data only. The Weibull distribution does not predict flood events for a recurrence interval greater than one year beyond the observed data period. For example, with the 18 years of observed peak discharge values for the Colville River, a Weibull distribution will generate up to a 19-year return interval. In short, the Weibull distribution ranks the observed discharges, and assigns a return period to those observed discharges with a maximum return period equal to the number of years' continuous data available plus one.

To predict design flood recurrence intervals, such as a 50-year or 200-year event, alternate analysis methods are used. The U.S. Water Resources Council Bulletin 17B (USWRC 1981) outlines the industry standard for flood frequency analysis utilizing the Log-Pearson Type III method. The Log-Pearson Type III method is a statistical technique using observed data to determine the probability of floods, with the advantage that the method allows for extrapolation of design events with return periods beyond the observed data.

Table 5.9 provides a list of observed discharge for the 18-year continuous record. Discharge is sorted from greatest to least magnitude. The assigned Weibull return period for each observed discharge is provided, with a maximum return period of 19 years assigned to the event with the largest peak discharge. The Weibull plot of the observed data is shown on Graph 5.6.

In 2002, a design-magnitude flood frequency analysis was performed for the Colville River at MON1 (Baker and Hydroconsult 2002). Because the data record was fairly limited for the Colville River at that time, the 2002 analysis used extrapolated peak discharge data, based on recorded observations of peak discharge for the Kuparuk and Sagavanirktok Rivers, in order to estimate peak discharge values for the Colville River. The 2002 analysis also used estimated historic peaks for the Colville River. These estimated peaks for large flood events relied on personal memories, as well as what surviving physical evidence remained, to estimate peak discharge values. Based on this extrapolated and estimated data, a body of "continuous" data extending back to 1971 was developed and utilized to conduct the 2002 flood frequency analysis. Due to the nature of the developed data, the 2002 analysis was believed to be reasonably conservative. The 2002 Log-Pearson Type III analysis is also shown on Graph 5.6. It is important to note, while the Weibull plot ends at 19 years, the Log-Pearson Type III analysis extends to much greater return intervals.

The 2002 analysis was revisited in 2006 (Baker 2007a). The 2006 analysis was based entirely on observed data from 1992 through 2006 at MON1 and did not include the estimated historic peaks that were based on memories and surviving evidence. This 2006 analysis supported the accuracy of the 2002 flood frequency discharge estimates, which were, on average, 15% more conservative than the 2006 values. While the 2002 values are recognized to be somewhat conservative, the 2002 flood peak discharge design estimates have remained the accepted design criteria values.

TABLE 5.9: COLVILLE RIVER PEAK ANNUAL DISCHARGE AND RECURRENCE INTERVAL COMPARISON (1992-2009)

Year	Discharge (cfs)	Weibull Return Period (years)	Log-Pearson Type III Return Period (years)	Difference
2000	580,000	19.0	23.8	25.3%
1993	379,000	9.5	5.9	37.9%
2004	360,000	6.3	5.0	20.6%
2006	281,000	4.8	2.9	39.6%
2007	270,000	3.8	2.6	31.6%
2009	**266,000**	**3.2**	**2.5**	**21.9%**
2001	255,000	2.7	2.3	14.8%
2002	249,000	2.4	2.2	8.3%
1995	233,000	2.1	2.0	4.8%
2003	232,000	1.9	1.9	0%
2008	221,000	1.7	1.8	5.9%
1998	213,000	1.6	1.7	6.2%
1999	203,000	1.5	1.6	6.7%
2005	195,000	1.4	1.5	7.1%
1997	177,000	1.3	1.4	7.7%
1994	165,000	1.2	1.3	8.3%
1992	164,000	1.1	1.3	18.2%
1996	160,000	1.1	1.2	9.1%

In 2009, a design-magnitude flood frequency analysis was again performed based on the observed data from 1992 through 2009, and the extrapolated data extending back to 1971. With less than 50-years' worth of observed data, use of the extrapolated data is recommended for the analysis. The 2009 data, similar to the 2006 and 2002 data, were fitted to a Log-Pearson Type III (station skew) distribution. The 2009 results were then compared to the results of the 2002 analysis. On average, the discharge estimates from the 2002 analysis are 3% more conservative than those derived from the 2009 analysis. Values are presented in Table 5.10. The flood frequency curve is shown in Graph 5.6. The flood frequency curve includes both the 2002 design values and the 95% confidence interval based on the 2009 analysis.

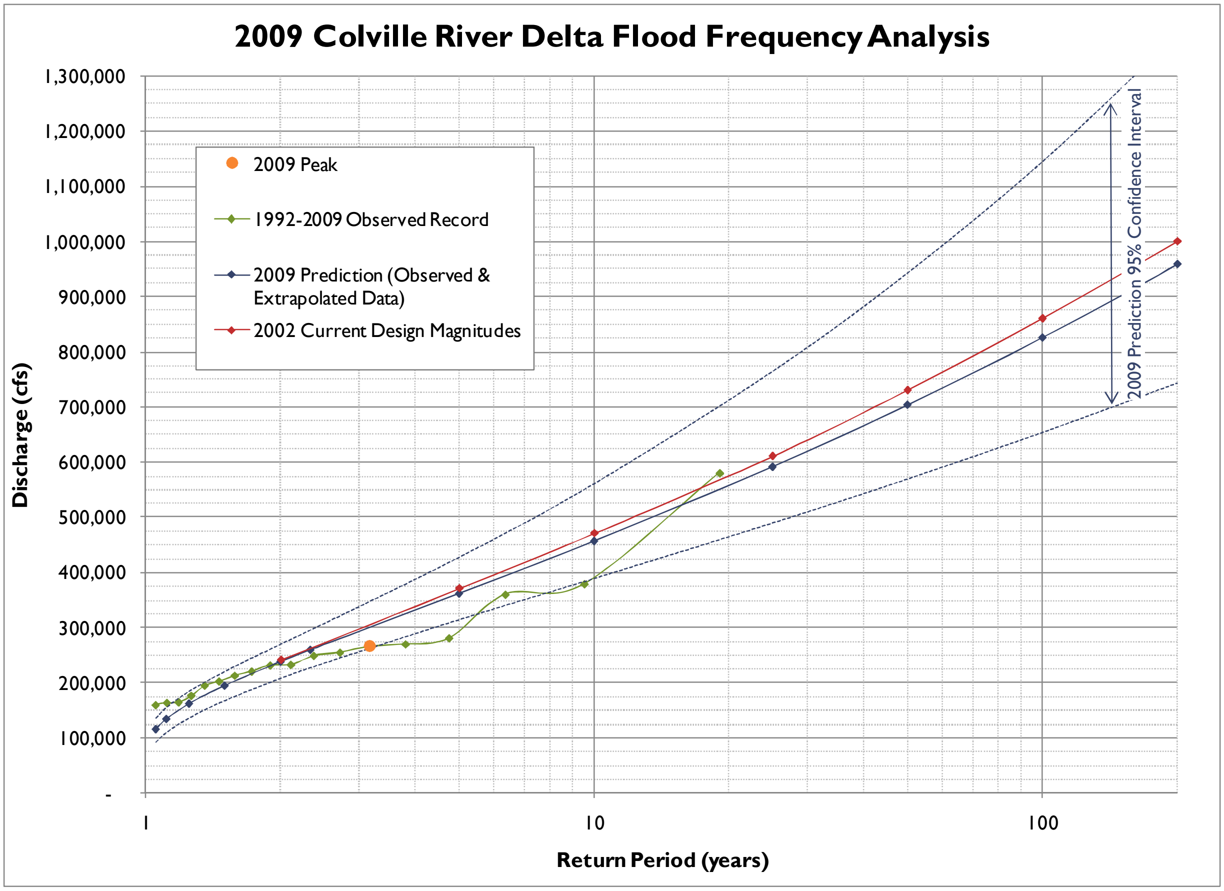
Graph 5.6 provides a visual comparison of the 2009 Weibull plot and the 2002 and the 2009 flood frequency analyses. Interestingly, when comparing the 2009 Weibull plot to the 2009 flood frequency analysis, the calculated return period for the discharge values are fairly close for small return periods. However, as the magnitude of the discharge event increases, the Weibull plot underestimates the return period because of the inherent limitation of the

Weibull analysis. As noted, the Weibull analysis limits the return period to the number of record years plus one. For example, the 2009 peak discharge of 266,000 cfs at MON1 was considered to be a fairly small magnitude, high frequency event. As shown in Graph 5.6 and Table 5.9, the 2009 Weibull plot assigned the 2009 peak discharge a return period of 3.2 years, corresponding closely to the 2009 flood frequency analysis return period of 2.5 years for the same discharge. However, for a large magnitude event, such as the 580,000 cfs in 2000, the Weibull assigns a 19-year return period for the event, which is somewhat less than the 23.8 year return period assigned by the 2009 flood frequency analysis.

The 2002 analysis, the current basis for existing design criteria, falls within the 95% confidence interval of the 2009 analysis. This supports maintaining existing design criteria based on the 2002 analysis.

TABLE 5.10: COLVILLE RIVER DELTA COMPARISON OF 2009 AND 2002 FLOOD FREQUENCY ANALYSIS RESULTS

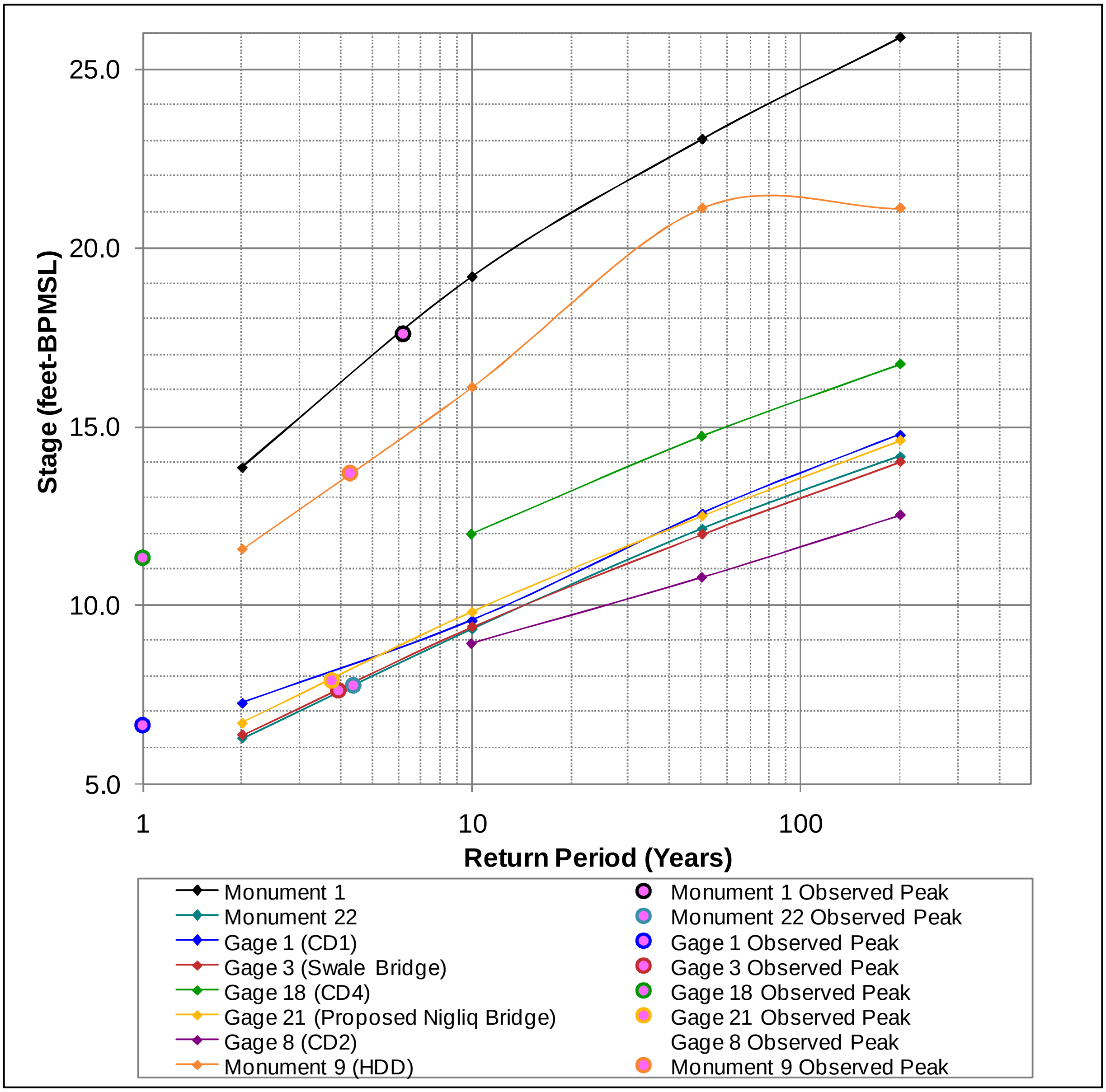
2009 Results		2002 Results (Basis for Current Design Criteria)	
Return Period	Flood Peak Discharge (cfs)	Return Period	Flood Peak Discharge (cfs)
2-year	240,000	2-year	240,000
5-year	360,000	5-year	370,000
10-year	460,000	10-year	470,000
25-year	590,000	25-year	610,000
50-year	700,000	50-year	730,000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



GRAPH 5.6: COLVILLE RIVER DELTA FLOOD FREQUENCY ANALYSIS DISTRIBUTION

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

The Colville River 2-dimensional (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 again modified to include as-built alignment conditions along the CD4 access road and pad and 2004/2005 survey data of the Nigliq Channel near MON23 (Baker 2006b). The model was completely reconstructed in 2009 (Baker 2009). Graphical representation of the 2009 observed peak stage and predicted WSE for 2-, 10-, 50-, and 200-year floods are shown in Graph 5.7. The current 2D surface water model predictions and the 2009 observations are presented in Table 5.11.



GRAPH 5.7: CRD 2009 OBSERVED AND 2D MODEL PREDICTED WSE

TABLE 5.11: 2009 CRD 2D MODEL PREDICTED AND 2009 OBSERVED WATER SURFACE ELEVATIONS

Monitoring Sites	2D Model Predicted Water Surface Elevation [based on open water conditions] (feet BPMSL)				2009 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	13.9	19.2	23.0	25.9	17.6	6
Monument 9 (HDD)	11.5	16.1	21.1	21.1	13.7	4
Monument 35 (Helmericks)	4.3	5.4	6.1	6.5	5.0	6
Monuments - Nigliq Channel						
Monument 20	7.8	11.4	14.6	16.8	9.6	4
Monument 22	6.3	9.3	12.1	14.2	7.8	4
Monument 23	5.1	7.4	10.2	12.0	7.0	7
Monument 28	3.1	3.4	3.9	4.3	3.7	24
CD1 Pad						
Gage 1	7.2	9.6	12.6	14.8	6.7	<2
Gage 9	8.3	10.8	13.4	15.7	7.7	<2
Gage 10	\	10.9	13.4	15.8	7.1	<10
CD2 Pad						
Gage 8	\	8.9	10.8	12.5	-	-
CD2 Road						
Gage 3	6.4	9.4	12.0	14.0	7.6	4
Gage 4	6.2	8.5	10.1	11.7	7.2	4
Gage 6	\	9.6	12.2	14.2	7.7	<10
Gage 7	\	8.4	10.0	11.6	7.5	<10
Gage 12	\	9.5	12.1	14.1	7.8	<10
Gage 13	\	8.4	10.0	11.6	7.6	<10
CD4 Pad						
Gage 19	\	11.9	14.6	16.6	-	-
Gage 20	\	11.1	14.2	16.3	9.1	<10
CD4 Road						
Gage 15	\	10.9	13.5	15.9	7.3	<10
Gage 16	\	11.2	14.2	16.1	7.3	<10
Gage 17	\	11.2	14.2	16.2	-	-
Gage 18	\	12.0	14.7	16.7	11.3	<10
CD3 Pipeline Crossings						
Sakoonang (Crossing #2) Gage	6.4	8.9	11.1	12.8	6.7	2
Tamayagiaq (Crossing #4) Gage	6.7	8.6	9.1	9.9	5.4	<10
Ulamnigiaq (Crossing #5) Gage	5.5	7.1	7.8	8.7	6.4	5
Proposed CD5 Road Crossings						
Gage 21 (Nigliq Channel)	6.7	9.8	12.5	14.6	7.9	4
Gage 22 (L9341)	\	\	12.8	14.9	8.0	<10
Gage 23 (Nigliagvik)	6.9	10.0	12.7	14.9	7.7	3

Notes:
1. Sites having dry ground in 2D model are denoted with a backward slash "\"
2. Sites having no observed WSE in 2009 are denoted with a dash "-"

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 snow, channel ice, or ice jams.

In general, the 2D model under-predicts stage for lower return periods (approximately 10 years and less), as can be seen in Table 5.12. This is to be expected as the 2D model does not account for ice- and snow-related events, which have a large impact on lower-magnitude flood events and less of an impact on higher-magnitude flood events. With an extended period of record, a stage frequency analysis can be performed to better estimate low flood stage within the delta impacted by recurrent ice jamming. Discussion of the 2009 analysis is continued in the following section.

TABLE 5.12: AVERAGE DIFFERENCES BETWEEN 2D OPEN WATER MODEL PREDICTIONS AND OBSERVED WSE

Range of Return Period (years)	MON1	MON22	Gage 1	Gage 3	Gage 18
	(feet)				
Greater than 10	0.50	-0.24	-0.48	-0.01	-2.06
Between 2 and 10	-3.01	-1.95	-0.74	-1.49	-2.23
Less than 2	-1.10	-0.86	1.84	-0.48	-1.06
	Note: Negative sign "-" indicates a lower 2D model prediction				

5.7.3 COLVILLE RIVER DELTA STAGE FREQUENCY

A systematic record of water surface elevations at most 2009 CRD monitoring locations exists back to 1998. A continuous record does not exist at all locations since distribution of monitoring sites has varied annually based on the objectives of the field program each year. At MON1, the systematic record exists back to 1992. Locations were selected for stage frequency analysis based on completeness of observed historic record and/or proximity to major existing or proposed facilities. Annual peak stages at selected locations throughout the CRD were estimated or extrapolated back to 1992, based on MON1 data. The annual observed record of each location's peak WSE was compared to the annual observed record at MON1, and an independent best-fit line was developed for each set. The linear equations were used to calculate extrapolated peak stages. Values were linearly extrapolated for those years when peak stage was known, and the differences between the data were compared. In all cases except at G18, for which the average difference was less than one and one-half feet, the average difference was one foot or less. Observed, estimated and extrapolated peak annual stage data from 1992 through 2009 for locations used in the stage frequency analysis are presented in Table 5.13.

TABLE 5.13: CRD PEAK ANNUAL STAGE FOR SELECTED LOCATIONS (1992-2009)

Year	Monument 1	Monument 22	Gage 1	Gage 3	Gage 18
	(Head of Delta)	(Nigliq/CD2)	(CD1)	(Swale Bridge)	(CD4)
2009	17.60	7.76	6.65	7.63	11.34
2008	17.30	6.78	5.61	8.60	8.60
2007	19.00	9.04	8.64	6.49	10.98
2006	19.49	9.95	9.29	9.72	14.67
2005	13.18	7.65	4.46	6.48	*8.17*
2004	19.54	10.17	8.88	9.97	*11.58*
2003	13.76	7.02	6.07	6.31	*8.03*
2002	16.87	7.94	7.68	7.59	*9.60*
2001	17.37	8.80	6.95	7.95	*10.16*
2000	19.33	9.58	*9.10*	*9.48*	*10.44*
1999	13.97	5.89	*4.64*	*5.79*	*7.10*
1998	18.11	**10.20**	**9.51**	**8.02**	**11.39**
1997	15.05	**7.37**	**5.85**	**6.84**	**8.65**
1996	17.19	**8.43**	**7.33**	**7.87**	**10.22**
1995	14.88	**7.29**	**5.73**	**6.75**	**8.53**
1994	12.20	**5.96**	**3.88**	**5.46**	**6.56**
1993	19.20	**9.42**	**8.72**	**8.84**	**11.69**
1992	13.90	**6.80**	**5.06**	**6.28**	**7.81**
Average:	16.55	8.11	6.89	7.56	9.75
Linear Equations:	-	y = 0.4943x - 0.0667	y = 0.6919x - 4.5605	y = 0.4821x - 0.4205	y = 007334x - 2.3879

Notes:

1. Italicized values were estimated based on linear comparison to peak stage at proximal monitoring locations.

2.Bold values were linearly extrapolated based on peak stage at Monument 1.

These stage data are fitted to a Weibull distribution, which assigns recurrence intervals to each peak stage. This method is performed as an analysis of observed and extrapolated data only, and does not predict stage events for a recurrence interval greater than one year beyond the observed/extrapolated data period. Alternate analysis methods must instead be used to predict peak stages in orders required for design magnitudes.

It is generally considered risky to extrapolate stage data for a river impacted by ice and ice jamming beyond the observed record (USACE 2002 and FEMA 2003). This is true not only due to the inherently unpredictable nature of ice jams in general, but also since the quantity of water in large-magnitude flood events will naturally be less affected by ice than smaller-magnitude floods. In the case of the CRD, the observed record is 18 years for the MON1 reach and stage has been demonstrated to be impacted by ice during each spring breakup event.

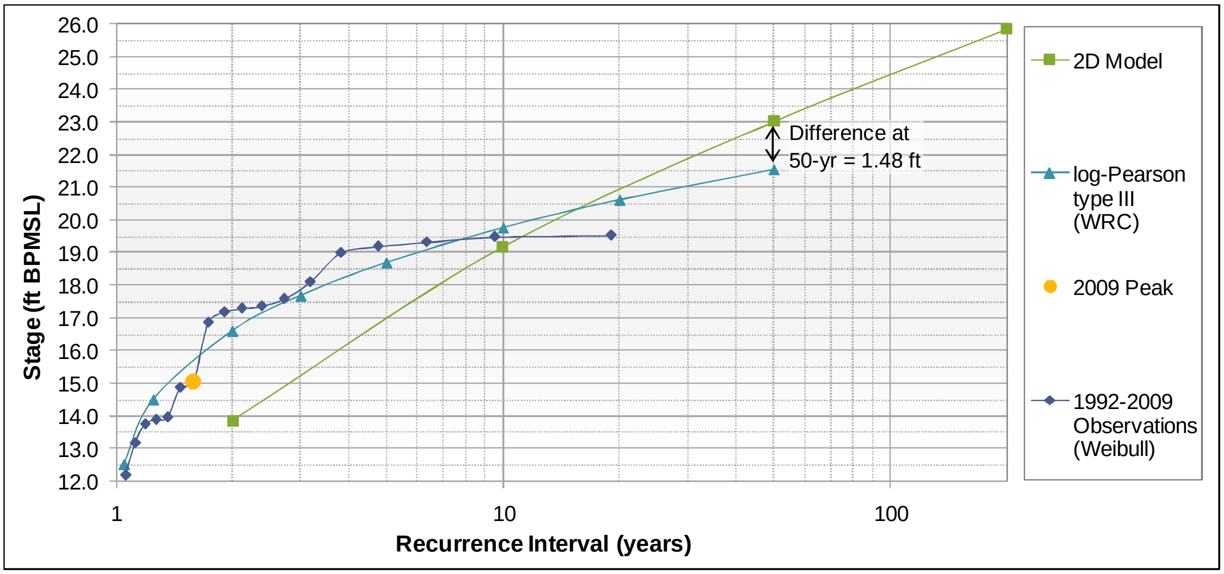
For the purpose of comparing the observations between 1992 and 2009 with the 2D open water model, extreme value statistical analysis was used to extend the record to 50 years, 2.8 times the record length. The objective of this analysis is not to redefine the Alpine design criteria which were established based on the 2D open water model; rather, this analysis is intended to supplement these criteria specifically for low-magnitude ice-impacted flood events similar to the events observed between 1992 and 2009.

A design-magnitude stage frequency analysis for the CRD was performed in 2006 (Baker 2007a). In 2009, a design-magnitude stage frequency analysis was again performed. The 2009 data, like the 2006 data, were fitted to a log-Pearson type III (station skew) distribution. The results were then compared to the stage frequency data generated by the 2D model, the observed data as fit to the Weibull distribution, and the 2006 stage frequency analysis results. Table 5.14 presents the log-Pearson type III stage frequency analysis results at selected locations. Graph 5.8 through Graph 5.12 compare visually the stage frequency analysis and 2D model results to the observed record for each selected location.

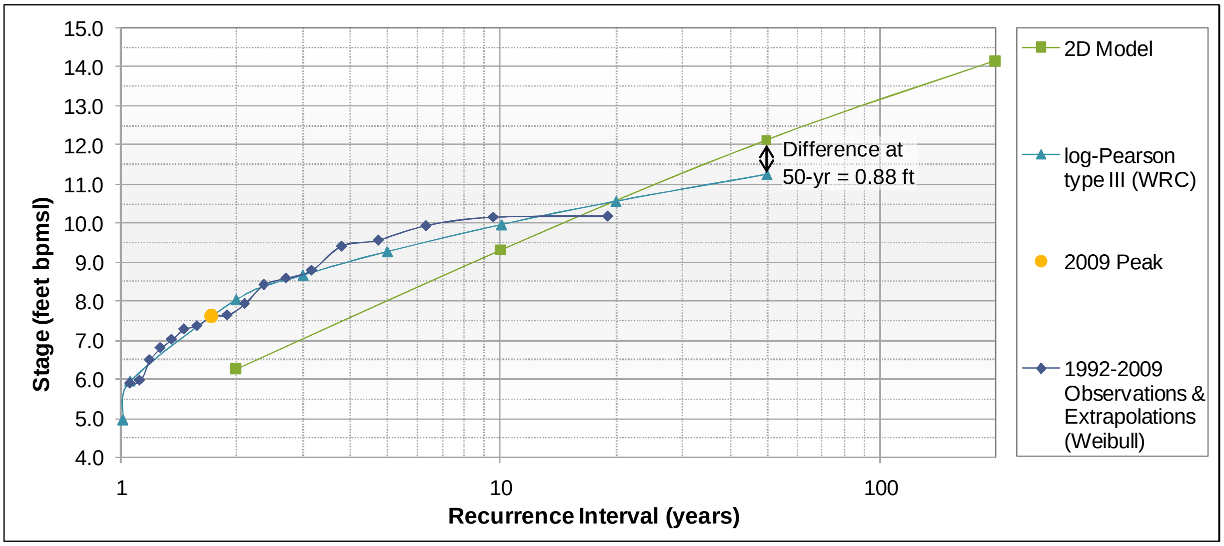
TABLE 5.14: CRD 2009 STAGE FREQUENCY ANALYSIS RESULTS

Monitoring Sites	Stage Frequency - Log-Pearson Type III (feet BPMSL)						2009 Observed 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	17.6	3
Monument 22	8.1	8.7	9.2	9.9	10.5	11.2	7.6	<2
Gage 1	6.8	7.6	8.4	9.4	10.2	11.2	6.7	<2
Gage 3	7.3	7.9	8.5	9.2	9.8	10.5	7.6	2
CD4 Pad (Gage 18)	9.5	10.4	11.4	12.5	13.4	14.7	11.3	5

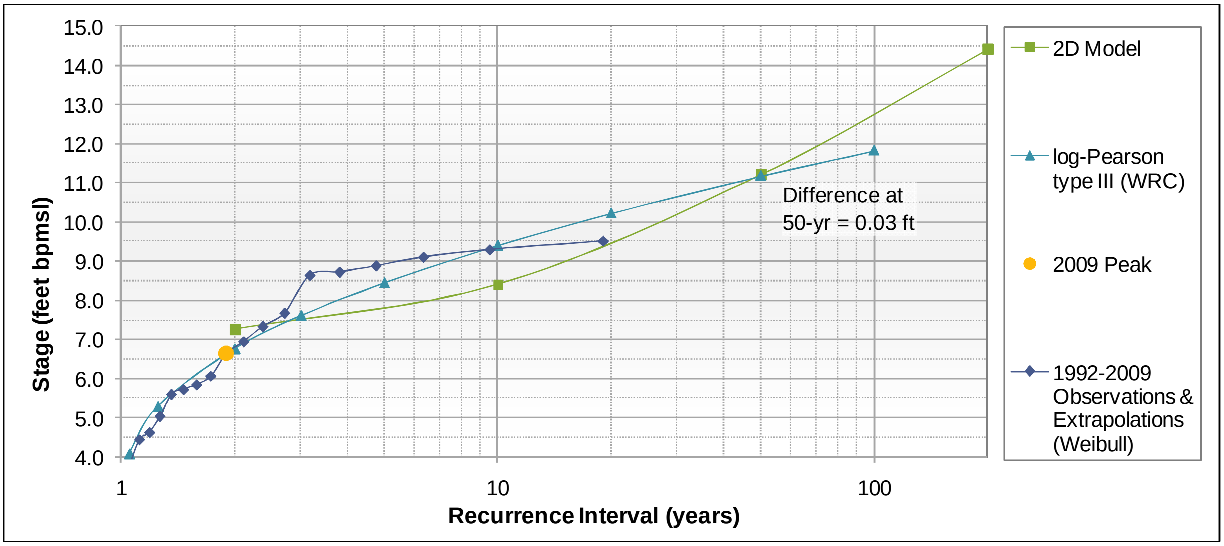
GRAPH 5.8: MON1 STAGE FREQUENCY ANALYSIS, 2D MODEL RESULTS AND 2009 OBSERVED DATA



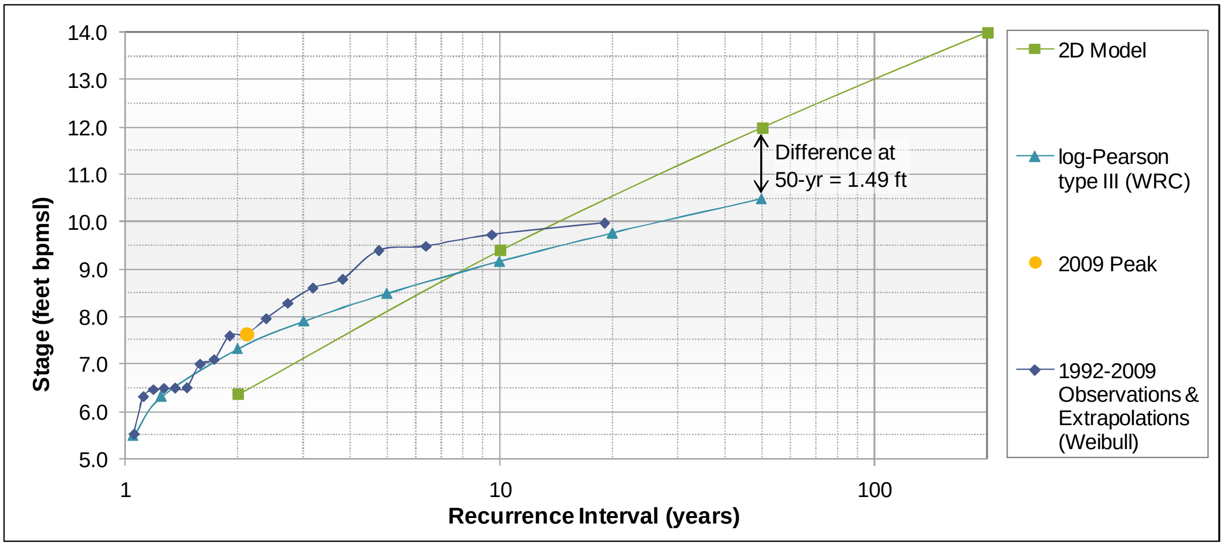
GRAPH 5.9: MON22 STAGE FREQUENCY ANALYSIS, 2D MODEL RESULTS AND 2009 OBSERVED DATA



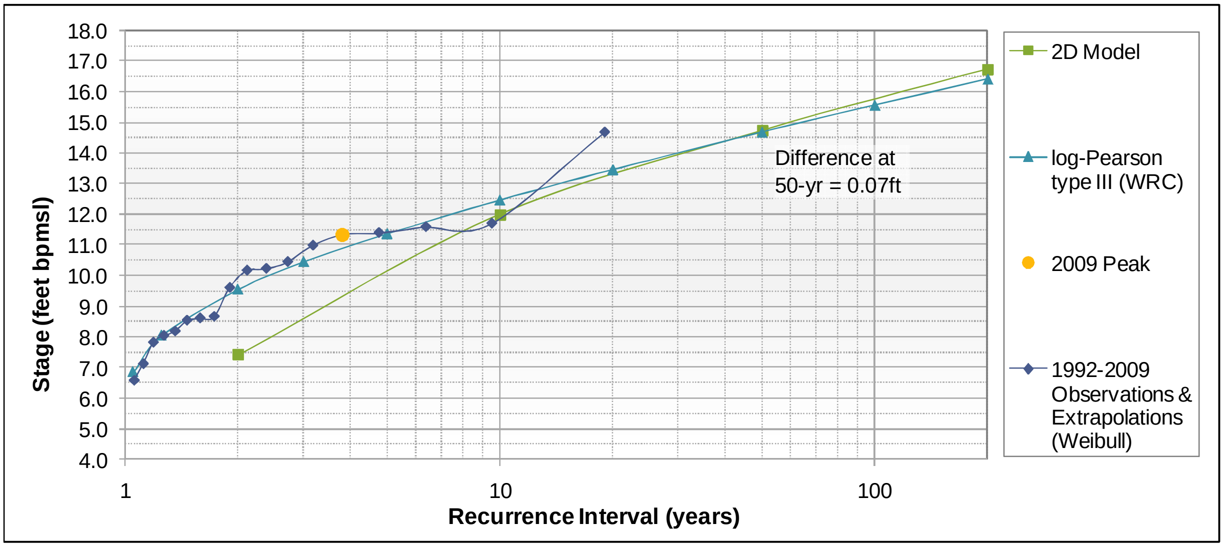
GRAPH 5.10: GAGE 1 STAGE FREQUENCY ANALYSIS, 2D MODEL RESULTS AND 2009 OBSERVED DATA



GRAPH 5.11: GAGE 3 STAGE FREQUENCY ANALYSIS, 2D MODEL RESULTS AND 2009 OBSERVED DATA



GRAPH 5.12: GAGE 18 STAGE FREQUENCY ANALYSIS, 2D MODEL RESULTS AND 2009 OBSERVED DATA



The recurrence intervals for peak stage at all locations were comparatively lower for 2009, the maximum being 5 years at G18 (which is likely inaccurate, since water present at that location was considered to be local melt). The log-Pearson type III model accurately predicted peak stage for all selected locations, within 0.5 feet, maximum. The difference in the relationship between analyses methods that include ice events (log-Pearson type III) and those that do not (2D model) are obvious, as can be seen in the above graphs. In most cases, significant deviation between the 2D model and the log-Pearson type III in the high-magnitude flood region becomes apparent at return intervals greater than 50 years. Based on comparison of these analyses, it is recommended that the log-Pearson type III fit be consulted for stage frequency for the lower return intervals (1 to 10 years, generally) and that the 2D model be consulted for stage frequency for the higher return intervals (greater than 10 years, generally). For those return intervals where a discrepancy occurs, the model analysis that produces the more conservative prediction is recommended.

5.7.4 2009 DISCHARGE AND STAGE SUMMARY

The 2009 peak discharge in the Colville River Delta is expected to be exceeded once every 3 years, based on PeakFQ (log-Pearson type III) analysis results. The 2009 peak stage throughout the CRD is expected to be exceeded once every 5 years, based on HYFRAN (log-Pearson type III) analysis results.

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6.2 ACRONYMS AND ABBREVIATIONS

2D	Two-Dimensional
ACS	Alaska Clean Seas
ADCP	Acoustic Doppler Current Profiler (see Glossary for definition)
ADF&G	Alaska Department of Fish and Game
ADP	Alpine Development Project
ASDP	Alpine Satellite Development Plan
ASP	Alpine Sales Pipeline
BPMSL	British Petroleum Mean Sea Level
Baker	Michael Baker Jr. Inc.
CD#	Colville Delta (facility number)
cfs	cubic feet per second
CMP	Corrugated Metal Pipe
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
DGPS	Differentially corrected Global Positioning System
DNR	Alaska Department of Natural Resources
FEMA	Federal Emergency Management Agency
fps	feet per second
GPS	Global Positioning System
HDD	Horizontal Directional Drilled
HWM	High Water Mark
LCMF	Kuukpik-LCMF
MMT	Measurement
NAD83	North American Datum of 1983
OSW	Office of Surface Water
PT	Pressure Transducer
RM	River Mile
SONAR	Sound navigation ranging
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USWRC	United States Water Resources Council
WAAS	Wide Area Augmentation System
WGS84	World Geodetic System of 1984
WSE	Water Surface Elevation

6.3 GLOSSARY

ADCP
Acoustic Doppler Current Profiler is a SONAR hat attempts to produce a record of water current velocities for a range of depths. ADCPs can be configured in many ways: side-listening, into rivers and canals for long term continuous discharge measurements, downward-listening and mounted on boats for instantaneous surveys in the ocean or rivers, and mounted on moorings, or the seabed for long term current & wave studies.

Alpine
CD1 pad

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

Bankfull
Refers to a water body that has water at the top of its banks

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

Breakup
Period of disintegration of ice cover in rivers and lakes

Confluence
A flowing together of two or more streams

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

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

Headwater
The water level upstream of the point of interest

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

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

Pressure Transducer
Measurement device converting pressure-induced mechanical changes to an electrical signal

Spring Breakup
See Breakup

Staff Gage
See Gage

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

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

Wide Area Augmentation System
WAAS uses a network of ground-based reference stations to measure small variations in the GPS satellites' signals in the western hemisphere. Measurements from the reference stations are routed to master stations, which queue the received Deviation Correction (DC) and send the correction messages to geostationary WAAS satellites in a timely manner (5 seconds or less). Those satellites broadcast the correction messages back to Earth, where WAAS-enabled GPS receivers use the corrections while computing their positions to improve accuracy

Water Surface Elevation
See Stage

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Appendix A 2009 GAGE LOCATIONS AND VERTICAL CONTROL

TABLE A. 1: SUMMARY OF 2009 GAGE LOCATIONS

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Monuments - Colville East Channel				
Monument 1 Upstream	MON1U-A-2	N 70° 09' 29.5"	W 150° 56' 32.6"	MONUMENT 1
	MON1U-A-1	N 70° 09' 30.3"	W 150° 56' 42.6"	
	MON1U-A	N 70° 09' 30.5"	W 150° 56' 44.6"	
	MON1U-B	N 70° 09' 30.6"	W 150° 56' 45.6"	
	MON1U-C	N 70° 09' 30.6"	W 150° 56' 46.1"	
	MON1U-D	N 70° 09' 30.7"	W 150° 56' 46.5"	
	MON1U-E	N 70° 09' 30.6"	W 150° 56' 47.0"	
	MON1U-F	N 70° 09' 30.6"	W 150° 56' 47.3"	
	MON1U-PT[2]	N 70° 09' 29.5"	W 150° 56' 32.2"	
Monument 1	MON1-A-1	N 70° 09' 56.2"	W 150° 56' 09.7"	MONUMENT 1
	MON1-A	N 70° 09' 56.8"	W 150° 56' 18.5"	
	MON1-B	N 70° 09' 57.0"	W 150° 56' 20.0"	
	MON1-C	N 70° 09' 57.0"	W 150° 56' 21.3"	
	MON1-D	N 70° 09' 57.0"	W 150° 56' 20.6"	
	MON1-E	N 70° 09' 56.9"	W 150° 56' 23.3"	
	MON1-F	N 70° 09' 57.0"	W 150° 56' 22.9"	
	MON1-Z[1]	N 70° 09' 56.9"	W 150° 56' 20.2"	
	MON1-PT[2]	N 70° 09' 56.2"	W 150° 56' 09.0"	
Monument 1 Downstream	MON1D-A-2	N 70° 10' 26.5"	W 150° 55' 57.7"	MONUMENT 1
	MON1D-A-1	N 70° 10' 25.9"	W 150° 56' 06.3"	
	MON1D-A	N 70° 10' 25.8"	W 150° 56' 09.4"	
	MON1D-B	N 70° 10' 25.7"	W 150° 56' 11.4"	
	MON1D-C	N 70° 10' 25.7"	W 150° 56' 14.1"	
	MON1D-D	N 70° 10' 25.5"	W 150° 56' 14.4"	
	MON1D-Z_a[1]	N 70° 10' 25.9"	W 150° 56' 7.4"	
	MON1D-Z_b[1]	N 70° 10' 25.4"	W 150° 56' 14.6"	
	MON1D-PT[2]	N 70° 10' 26.6"	W 150° 55' 57.5"	

[1] angle iron without gage

[2] pressure transducer

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Monuments - Colville East Channel (continued)				
Monument 9	MON9-A	N 70° 14' 40.8"	W 150° 51' 24.4"	MONUMENT 9
	MON9-B	N 70° 14' 40.7"	W 150° 51' 27.1"	
	MON9-C	N 70° 14' 40.7"	W 150° 51' 28.0"	
	MON9-D	N 70° 14' 40.7"	W 150° 51' 28.4"	
	MON9-E	N 70° 14' 40.7"	W 150° 51' 28.6"	
	MON9-F	N 70° 14' 40.7"	W 150° 51' 28.7"	
	MON9-G	N 70° 14' 41.0"	W 150° 51' 29.8"	
	MON9-PT[2]	N 70° 14' 40.8"	W 150° 51' 25.0"	
	MON9-BARO[3]	N 70° 14' 39.3"	W 150° 51' 37.6"	
Monument 35 (Helmricks)	MON35-A	N 70° 25' 33.5"	W 150° 24' 20.6"	MONUMENT 35
	MON35-B	N 70° 25' 33.7"	W 150° 24' 20.5"	
	MON35-C	N 70° 25' 33.8"	W 150° 24' 20.8"	
	MON35-D	N 70° 25' 34.0"	W 150° 24' 20.9"	
Monuments - Nigliq Channel				
Monument 20	MON20-A	N 70° 16' 42.8"	W 150° 59' 55.8"	CP08-12-61
	MON20-B	N 70° 16' 43.0"	W 150° 59' 55.9"	
	MON20-C	N 70° 16' 42.8"	W 150° 59' 55.0"	
	MON20-D	N 70° 16' 42.8"	W 150° 59' 54.5"	
	MON20-E	N 70° 16' 42.8"	W 150° 59' 53.8"	
Monument 22	MON22-A	N 70° 19' 07.1"	W 151° 03' 16.3"	MONUMENT 22
	MON22-B	N 70° 19' 06.5"	W 151° 03' 17.5"	
	MON22-C	N 70° 19' 06.5"	W 151° 03' 18.1"	
	MON22-D	N 70° 19' 05.9"	W 151° 03' 19.7"	
Monument 23	MON23-A	N 70° 20' 37.1"	W 151° 03' 58.9"	MONUMENT 23
	MON23-B	N 70° 20' 37.0"	W 151° 03' 56.1"	
	MON23-C	N 70° 20' 37.0"	W 151° 03' 55.0"	
	MON23-D	N 70° 20' 37.0"	W 151° 03' 54.1"	
	MON23-PT[2]	N 70° 20' 36.3"	W 151° 03' 59.1"	
Monument 28	MON28-A	N 70° 25' 33.0"	W 151° 04' 11.0"	MONUMENT 28
	MON28-Z[1]	N 70° 25' 32.0"	W 151° 04' 1.0"	
Alpine Facilities and Roads				
CD 1	**G1**	N 70° 20' 34.0"	W 150° 55' 15.0"	*
	G9	N 70° 20' 01.0"	W 150° 57' 07.0"	*
	G10	N 70° 20' 33.0"	W 150° 55' 58.0"	*

GX - direct-read permanent staff gage

* direct-read gages are surveyed and adjusted for elevation by LCMF

[1] angle iron without gage

[2] pressure transducer

[3] BaroTROLL barometer

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Alpine Facilities and Roads (continued)				
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' 21.2"	W 151° 02' 56.5"	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"	CD2-14N
CD 4	G15-A	N 70° 18' 08.1"	W 150° 59' 34.4"	CD4-21N
	G15-B	N 70° 18' 08.8"	W 150° 59' 38.0"	
	G16-A	N 70° 18' 06.0"	W 150° 59' 36.0"	CD4-21S
	G16-B	N 70° 18' 06.3"	W 150° 59' 39.5"	
	G17	N 70° 17' 35.9"	W 150° 58' 57.8"	CD4-29N
	G18-A	N 70° 17' 34.9"	W 150° 58' 54.6"	CD4-29S
	G19	N 70° 17' 30.0"	W 150° 59' 18.0"	*
	G20-A-1	N 70° 17' 29.7"	W 150° 59' 49.3"	CP05-20-01A
	G20-A	N 70° 17' 30.2"	W 150° 59' 48.5"	
	G20-B	N 70° 17' 30.0"	W 150° 59' 48.1"	
Pipeline River Crossings				
Sakoonang Pipe Bridge	SAK-A	N 70° 21' 52.6"	W 150° 55' 18.0"	CP08-11-12
	SAK-B	N 70° 21' 52.3"	W 150° 55' 19.1"	
	SAK-C	N 70° 21' 52.2"	W 150° 55' 19.4"	
Tamayagiaq Pipe Bridge	TAM-A	N 70° 23' 30.5"	W 150° 54' 42.9"	CP08-11-23
	TAM-B	N 70° 23' 29.1"	W 150° 54' 40.3"	
	TAM-Z[1]	N 70° 23' 29.3"	W 150° 54' 40.6"	
Ulamnigiaq Pipe Bridge	ULAM-A	N 70° 24' 24.5"	W 150° 53' 00.4"	CP08-11-35
	ULAM-B	N 70° 24' 24.8"	W 150° 52' 59.6"	
	ULAM-Z[1]	N 70° 24' 25.1"	W 150° 52' 59.2"	
Proposed CD5 Crossings				
Nigliq Channel	G21-A	N 70° 18' 10.6"	W 151° 01' 21.6"	CP08-11-53A
	G21-B	N 70° 18' 10.4"	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' 07.7"	
Lake L9341	G22-A	N 70° 18' 21.5"	W 151° 02' 59.6"	CP08-11-64A
	G22-B	N 70° 18' 22.0"	W 151° 03' 02.7"	
Nigliagvik	G23-A	N 70° 18' 19.9"	W 151° 07' 07.3"	CP08-11-66C
	G23-B	N 70° 18' 19.9"	W 151° 07' 05.5"	

GX - direct-read permanent staff gage

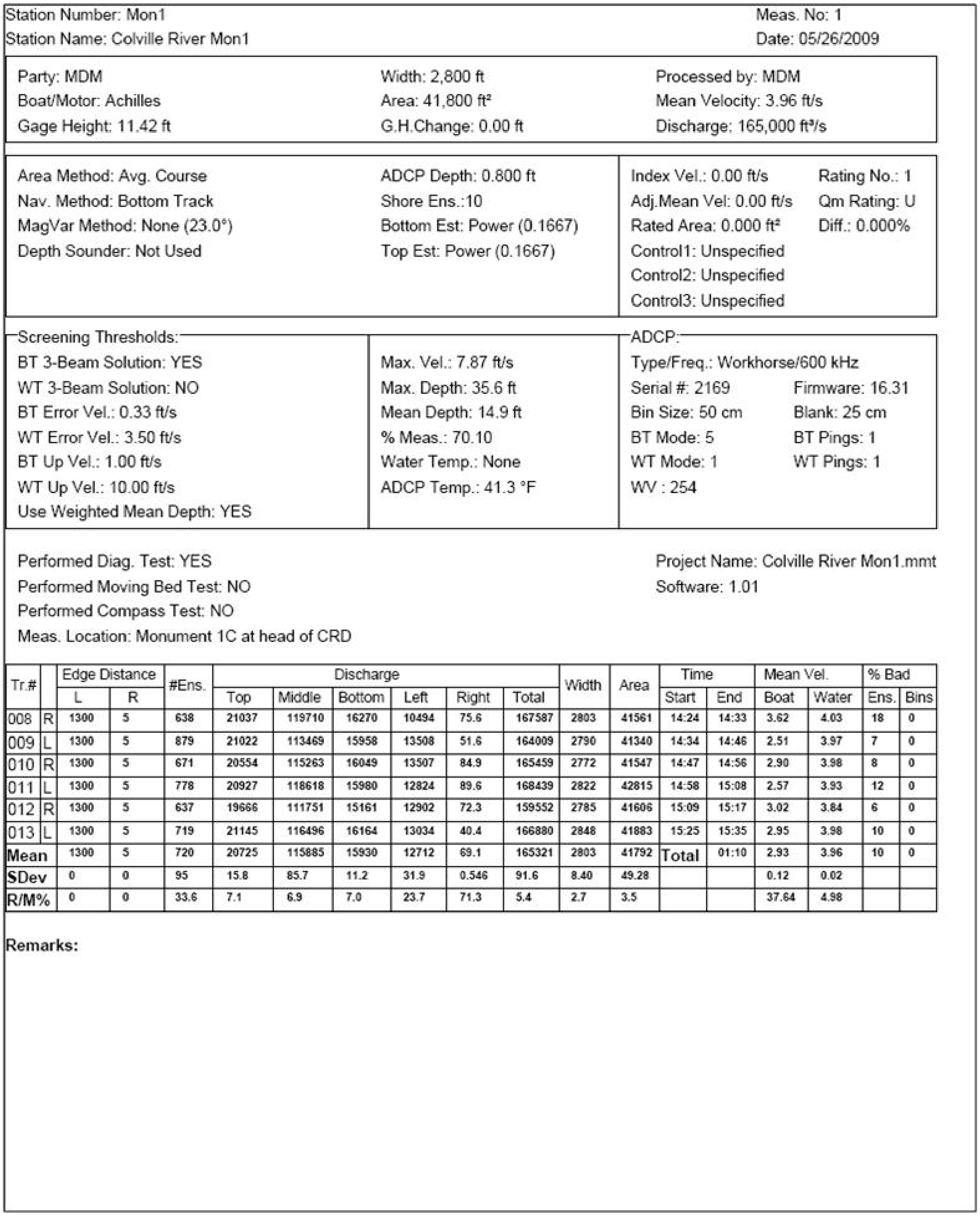
* direct-read gages are surveyed and adjusted for elevation by LCMF

[1] angle iron without gage

TABLE A. 2: SUMMARY OF 2009 CRD VERTICAL CONTROL

Control	Elevation (BPMSL - Feet)	Latitude (NAD 83)	Longitude (NAD83)	Control Type	Reference
CD2-14N	11.033	N 70° 20' 13.7"	W 150° 00' 39.5"	Culvert	LCMF 2008
CD2-14S	11.038	N 70° 20' 12.9"	W 150° 00' 40.4"	Culvert	LCMF 2008
CD4-21N	8.918	N 70° 18' 07.7"	W 150° 59' 36.1"	Culvert	LCMF 2008
CD4-21S	8.050	N 70° 18' 06.6"	W 150° 59' 35.6"	Culvert	LCMF 2008
CD4-29N	13.084	N 70° 17' 35.2"	W 150° 58' 58.6"	Culvert	LCMF 2008
CD4-29S	13.225	N 70° 17' 34.6"	W 150° 58' 57.1"	Culvert	LCMF 2008
CP05-20-01A	25.734	N 70° 17' 30.3"	W 150° 59' 32.9"	HSM	LCMF 2008
CP08-11-12	7.365	N 70° 21' 50.2"	W 150° 55' 13.7"	Alcap	LCMF 2008
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
CP08-12-61	11.956	N 70° 16' 39.9"	W 150° 59' 36.5"	Alcap	LCMF 2009
MONUMENT 1	27.930	N 70° 09' 57.2"	W 150° 56' 23.8"	Alcap	LCMF 2006
MONUMENT 21	13.277	N 70° 20' 32.7"	W 150° 55' 25.0"	Drill Stem	LCMF 2008
MONUMENT 22	10.100	N 70° 19' 05.2"	W 151° 03' 21.9"	Alcap	LCMF 2003
MONUMENT 23	9.523	N 70° 20' 40.0"	W 151° 03' 40.7"	Alcap	LCMF 2005
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

Appendix B ADCP DISCHARGE RESULTS COLVILLE RIVER MONUMENT 1



Station Number: Mon1
Station Name: Colville River Mon1
Meas. No: 1
Date: 05/26/2009

Party: MDM
Boat/Motor: Achilles
Gage Height: 11.42 ft
Width: 2,800 ft
Area: 41,800 ft^2
G.H.Change: 0.00 ft
Processed by: MDM
Mean Velocity: 3.96 ft/s
Discharge: 165,000 ft^3/s

Area Method: Avg. Course
Nav. Method: Bottom Track
MagVar Method: None (23.0°)
Depth Sounder: Not Used
ADCP Depth: 0.800 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.: 3.50 ft/s
BT Up Vel.: 1.00 ft/s
WT Up Vel.: 10.00 ft/s
Use Weighted Mean Depth: YES

Max. Vel.: 7.87 ft/s
Max. Depth: 35.6 ft
Mean Depth: 14.9 ft
% Meas.: 70.10
Water Temp.: None
ADCP Temp.: 41.3 °F

ADCP:
Type/Freq.: Workhorse/600 kHz
Serial #: 2169
Firmware: 16.31
Bin Size: 50 cm
Blank: 25 cm
BT Mode: 5
BT Pings: 1
WT Mode: 1
WT Pings: 1
WV : 254

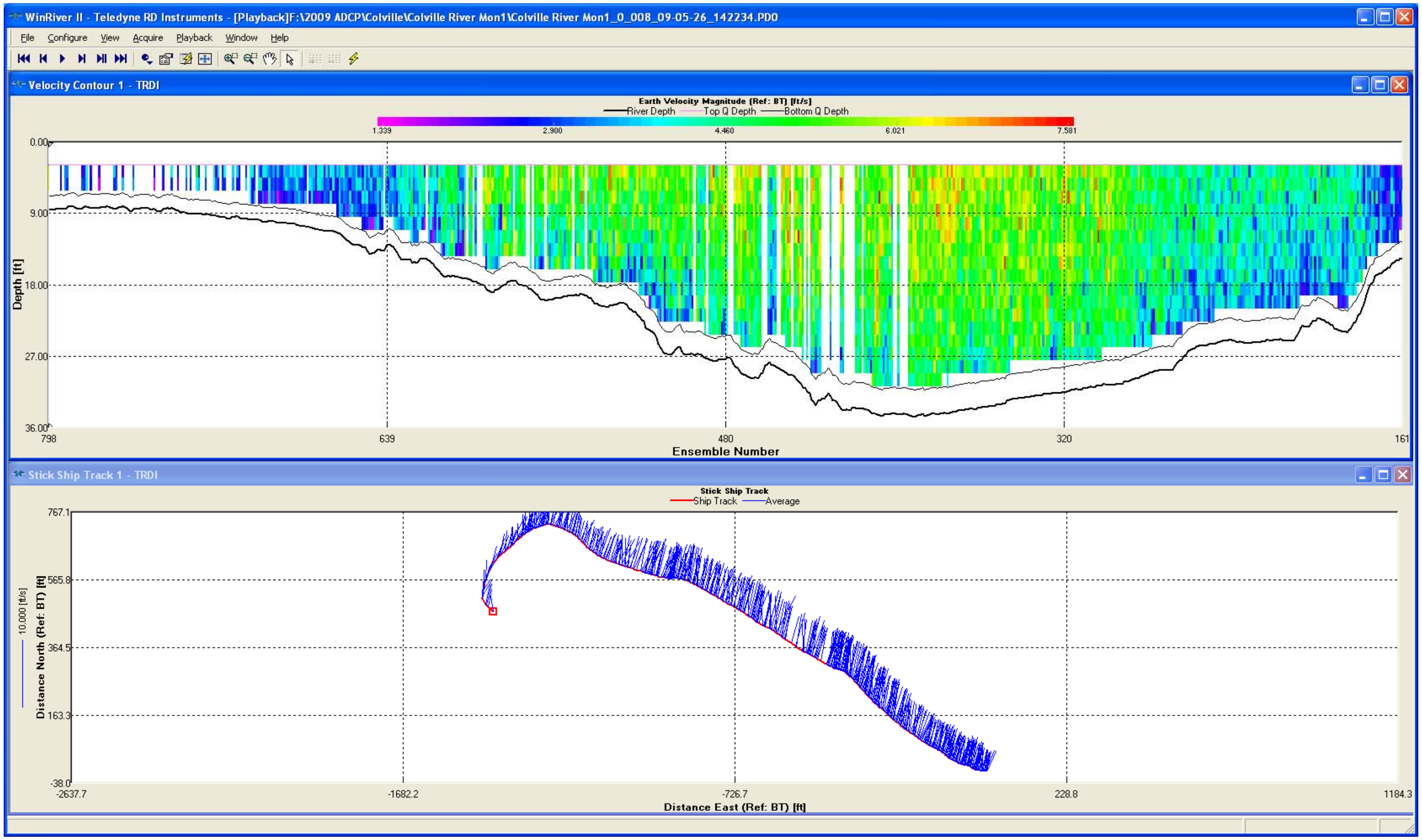
Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Test: NO
Meas. Location: Monument 1C at head of CRD

Project Name: Colville River Mon1.mmt
Software: 1.01

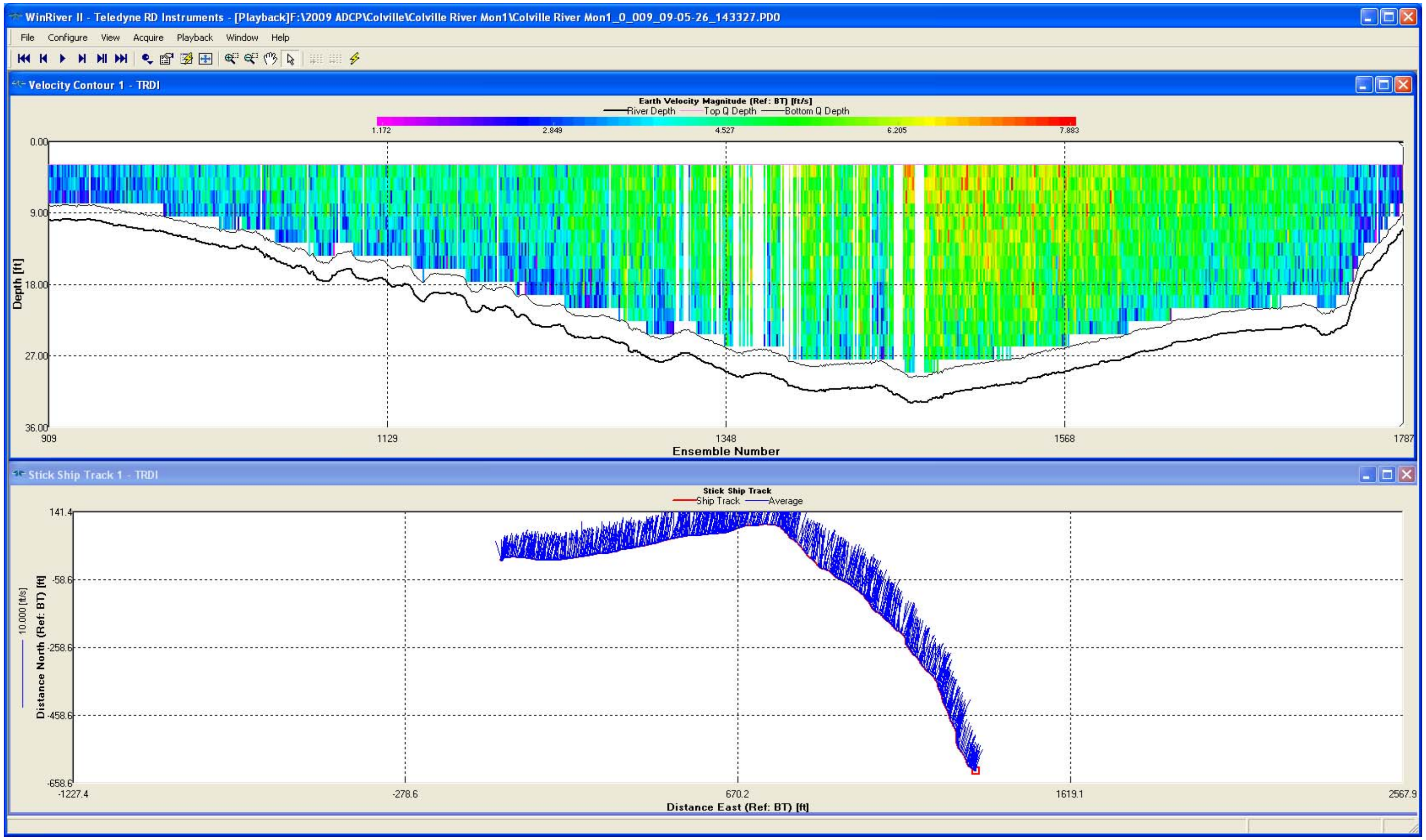
Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
008	R	1300	5	638	21037	119710	16270	10494	75.6	167587	2803	41561	14:24	14:33	3.62	4.03	18	0
009	L	1300	5	879	21022	113469	15958	13508	51.6	164009	2790	41340	14:34	14:46	2.51	3.97	7	0
010	R	1300	5	671	20554	115263	16049	13507	84.9	165459	2772	41547	14:47	14:56	2.90	3.98	8	0
011	L	1300	5	778	20927	118618	15980	12824	89.6	168439	2822	42815	14:58	15:08	2.57	3.93	12	0
012	R	1300	5	637	19666	111751	15161	12902	72.3	159552	2785	41606	15:09	15:17	3.02	3.84	6	0
013	L	1300	5	719	21145	116496	16164	13034	40.4	166880	2848	41883	15:25	15:35	2.95	3.98	10	0
Mean		1300	5	720	20725	115885	15930	12712	69.1	165321	2803	41792	Total	01:10	2.93	3.96	10	0
SDev		0	0	95	15.8	85.7	11.2	31.9	0.546	91.6	8.40	49.28			0.12	0.02		
R/M%		0	0	33.6	7.1	6.9	7.0	23.7	71.3	5.4	2.7	3.5			37.64	4.98		

Remarks:

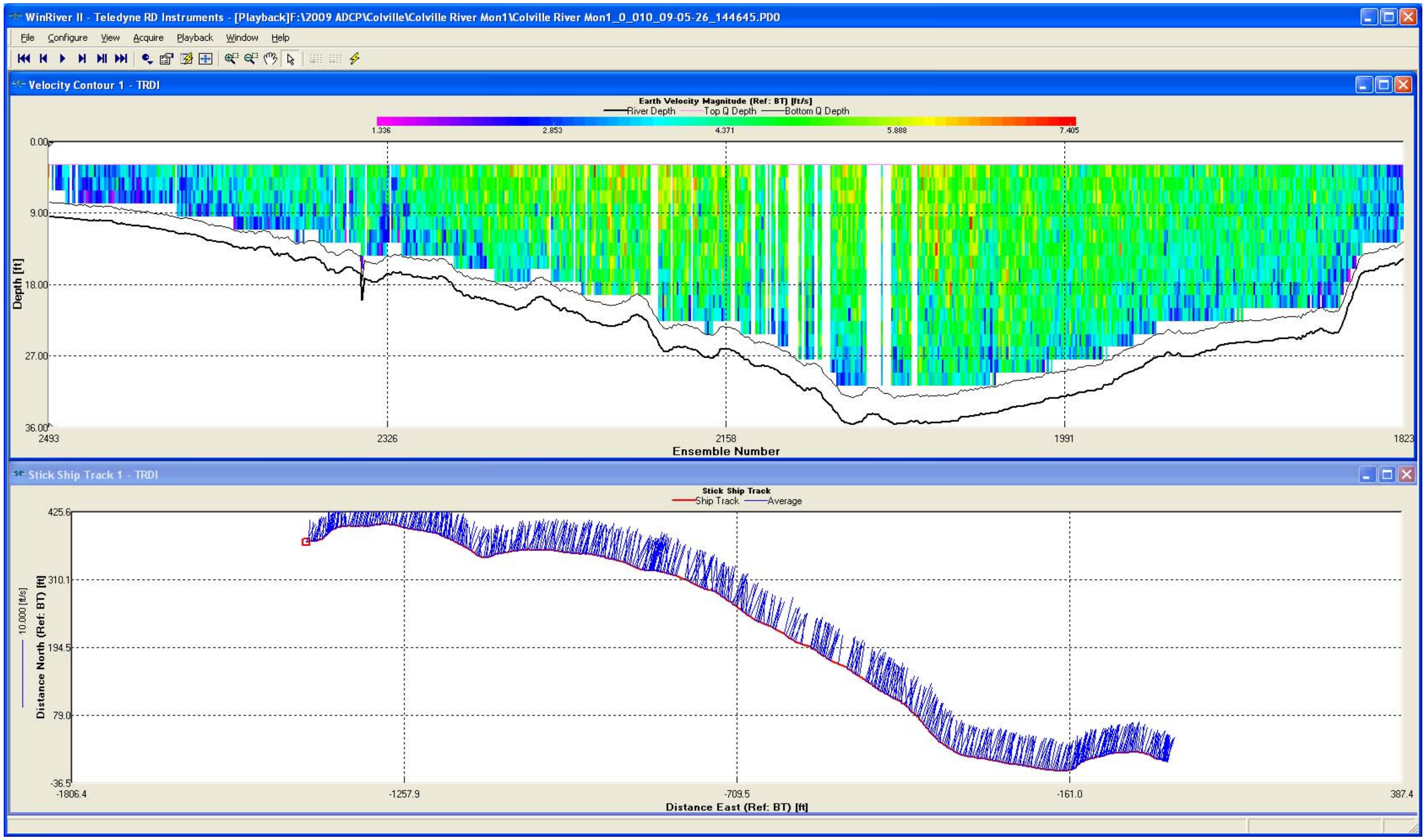
Monument 1 Colville River Direct Discharge Transect 1, WinRiverII Velocity and Ship Track Plots May 26, 2009



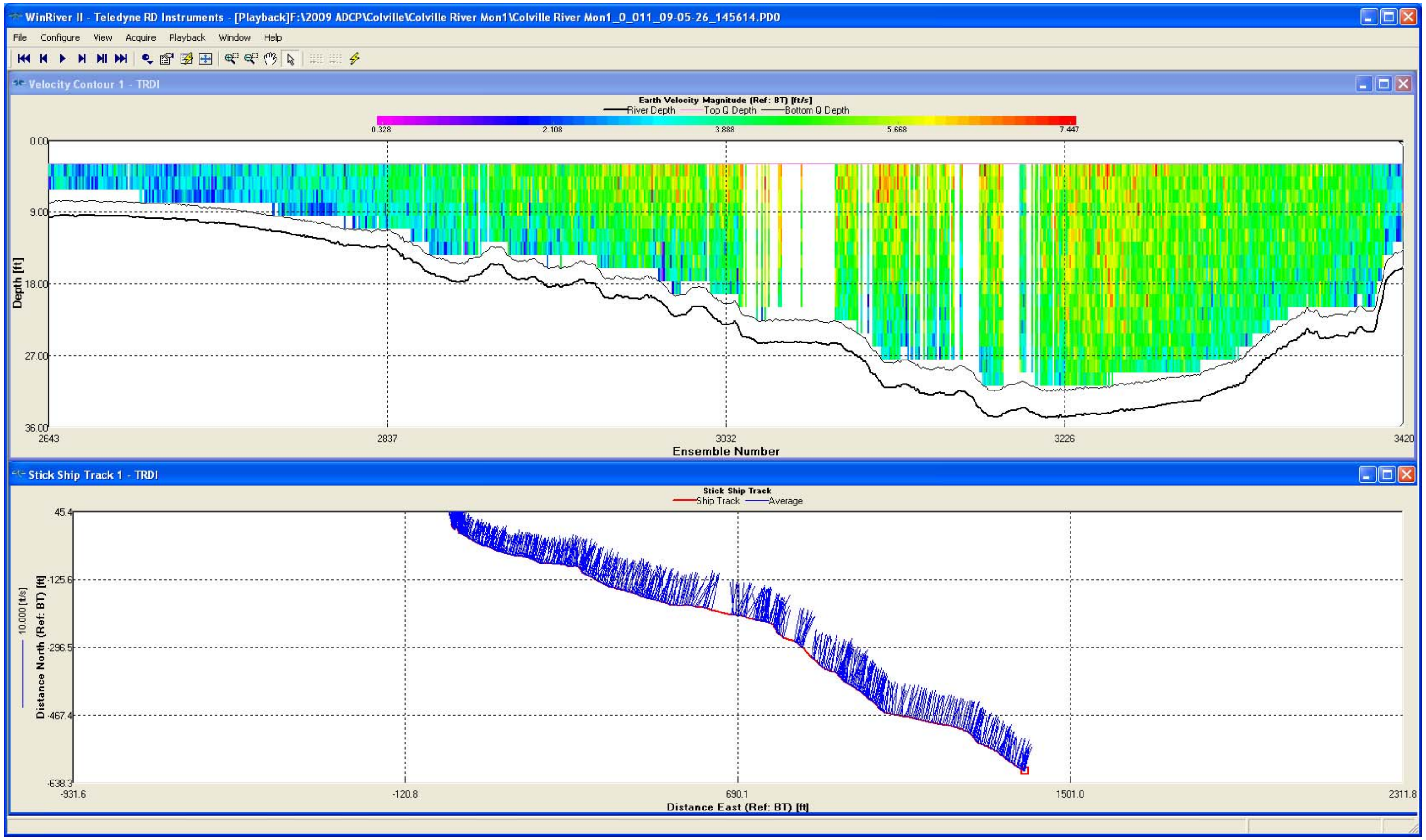
Monument 1 Colville River Direct Discharge Transect 2, WinRiverII Velocity and Ship Track Plots May 26, 2009



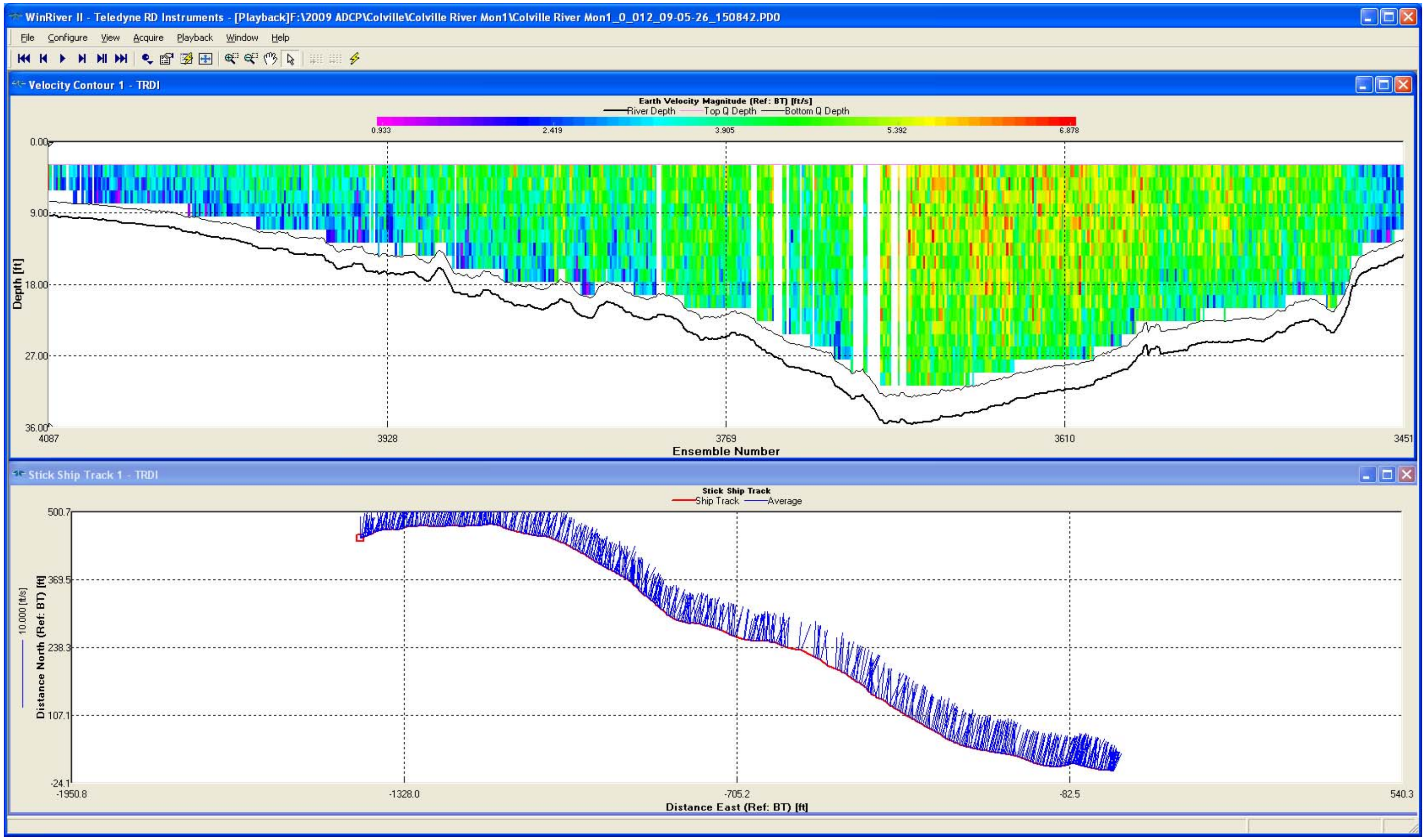
Monument 1 Colville River Direct Discharge Transect 3, WinRiverII Velocity and Ship Track Plots May 26, 2009



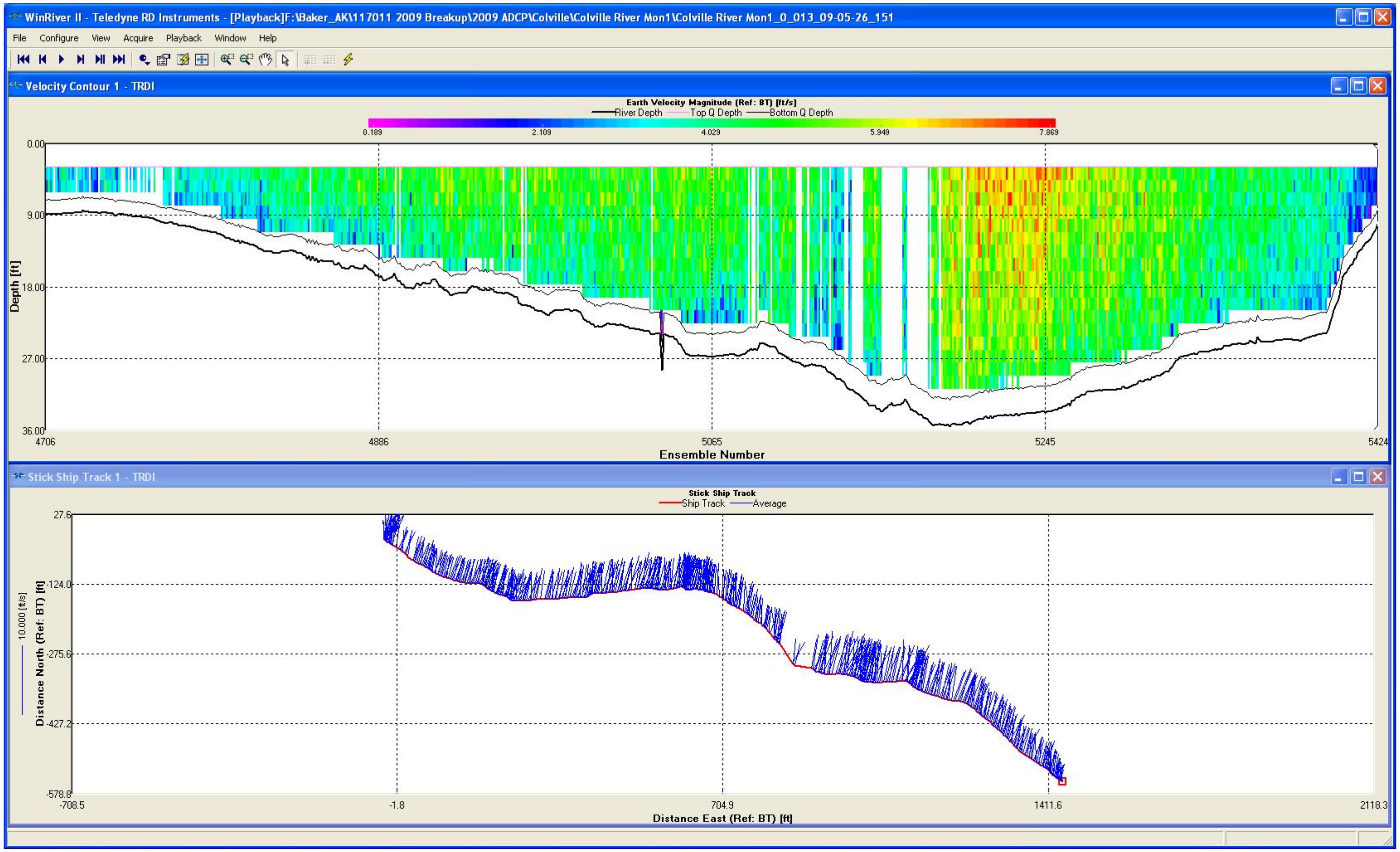
Monument 1 Colville River Direct Discharge Transect 4, WinRiverII Velocity and Ship Track Plots May 26, 2009



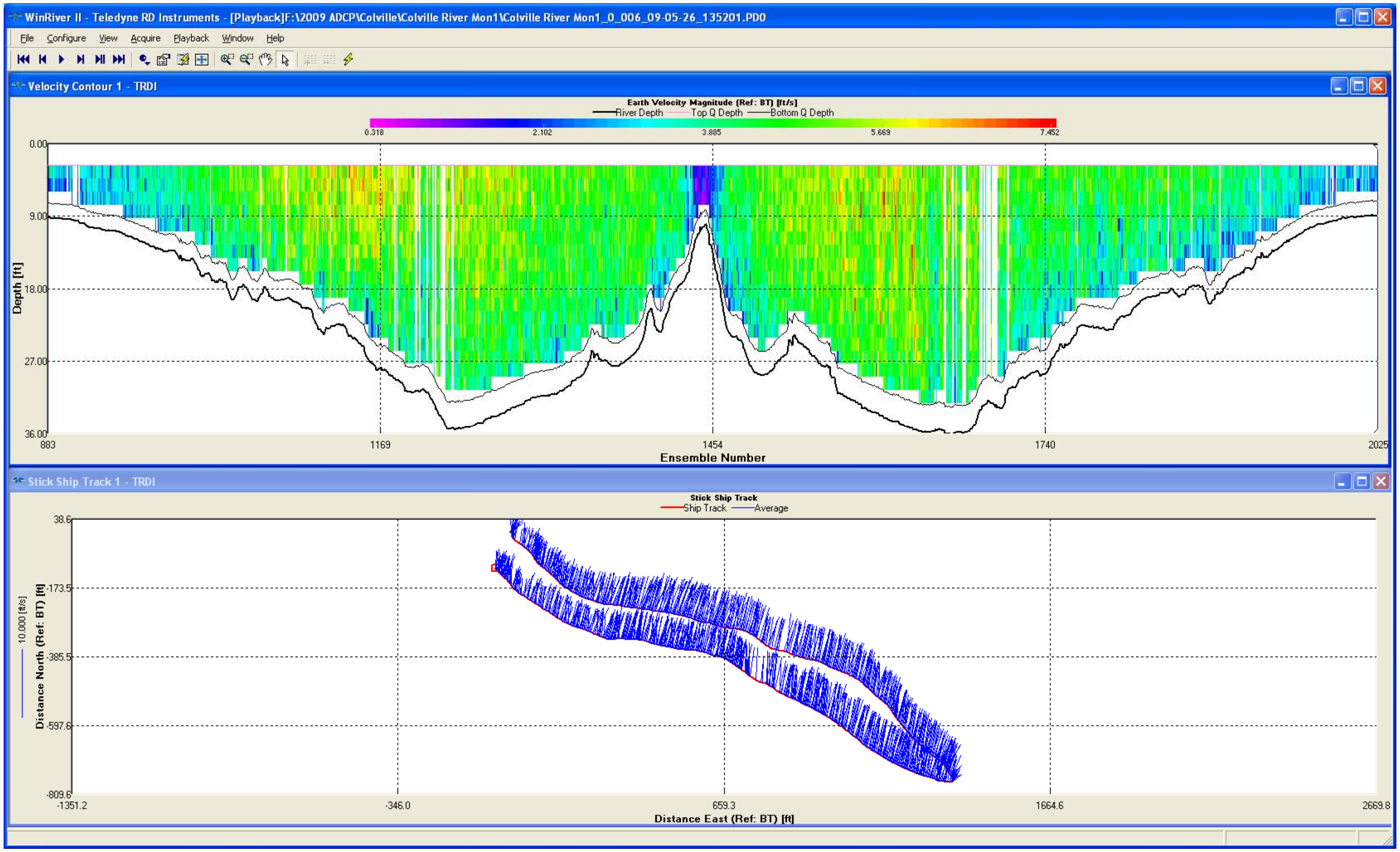
Monument 1 Colville River Direct Discharge Transect 5, WinRiverII Velocity and Ship Track Plots May 26, 2009


WinRiver II - Teledyne RD Instruments - [Playback]F:\2009 ADCP\Colville\Colville River Mon1\Colville River Mon1_0_012_09-05-26_150842.PD0

Monument 1 Colville River Direct Discharge Transect 6, WinRiverII Velocity and Ship Track Plots May 26, 2009



Monument 1 Colville River Direct Discharge Loop Test, WinRiverII Velocity and Ship Track Plots May 26, 2009



Appendix C 452-FT SWALE BRIDGE DIRECT DISCHARGE NOTES

452-Foot Bridge Direct Discharge Notes

2009 Michael Baker Jr., Inc. Comp. By JPM
Check By HLR

Discharge Measurement Notes

Station No. Long Bridge Start: 1200 Finish: 1322

Date 5/26/2009 Party JWW, JPM

Width 445 ft Area 889 sq ft Vel. 0.822 fps Disch. 728 cfs

Method 0.6 No. Secs. 27 Count Audio

GAGE READINGS			
Gage	Start	Finish	Change
U/S	5.89	5.88	-0.01
D/S	5.80	5.80	0.00

Wading, cable, ice, boat

Upstrm or Dwnstrm side of bridge

Meter 0.6 ft above bottom of weight

Weight 30 lbs

Spin Test 2.5 min after ok Meter Type/No. Price AA/MJBA01

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

Cross Section: Uniform, firm, variable horizontal angles, snow on left pier

Flow: Steady Weather: P.C., 8-10 mph winds

Other: Temp: 30°F

Gages:

Remarks: Control - Large pond, no ice in tailwater

Site/Date: 452-foot Bridge 5/26/2009

							VELOCITY				
Angle Coeff.	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	At Point (fps)	Mean in Vertical (fps)	Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
LEW @ 1200											
	17	0.5	1.00	6/10				0.20	0.00	0.5	0.10
0.98	18	4.0	1.80	6/10	11	40	0.63		0.62	7.2	4.44
0.92	25	8.5	1.80	6/10	9	40	0.52		0.47	15.3	7.3
0.96	35	12.5	1.60	6/10	20	50	0.91		0.87	20.0	17.4
0.98	50	17.5	2.00	6/10	15	40	0.85		0.83	35.0	29.2
0.99	70	20.0	2.00	6/10	15	56	0.61		0.61	40.0	24.3
0.99	90	20.0	1.60	6/10	15	40	0.85		0.84	32.0	27.0
1.00	110	20.0	1.60	6/10	15	40	0.85		0.85	32.0	27.2
1.00	130	20.0	1.90	6/10	15	45	0.76		0.76	38.0	28.8
1.00	150	20.0	1.70	6/10	15	40	0.85		0.85	34.0	28.9
1.00	170	20.0	1.60	6/10	15	43	0.79		0.79	32.0	25.4
1.00	190	20.0	2.00	6/10	15	48	0.71		0.71	40.0	28.5
0.99	210	20.0	1.70	6/10	20	46	0.98		0.97	34.0	33.1
0.99	230	20.0	2.20	6/10	15	49	0.70		0.69	44.0	30.4
0.99	250	20.0	2.50	6/10	15	43	0.79		0.79	50.0	39.3
0.99	270	20.0	2.20	6/10	15	40	0.85		0.84	44.0	37.1
0.99	290	20.0	2.70	6/10	20	43	1.05		1.04	54.0	56.2
0.97	310	20.0	2.10	6/10	20	42	1.08		1.04	42.0	43.8
0.94	330	20.0	1.80	6/10	20	42	1.08		1.01	36.0	36.4
0.96	350	20.0	2.10	6/10	20	46	0.98		0.94	42.0	39.7
0.90	370	20.0	2.20	6/10	20	50	0.91		0.82	44.0	35.9
0.92	390	20.0	2.10	6/10	20	44	1.03		0.95	42.0	39.7
0.94	410	20.0	2.50	6/10	20	51	0.89		0.84	50.0	41.8
0.92	430	20.0	2.00	6/10	10	47	0.49		0.45	40.0	18.0
0.99	450	15.0	1.70	6/10	15	49	0.70		0.69	25.5	17.6
0.99	460	6.0	2.30	6/10	15	46	0.74		0.74	13.8	10.1
1.00	462	1.0	2.00	6/10			0.30		0.30	2.0	0.6
		445.0								**889.3**	**728.2**
			Estimated values								
REW @ 1322											