2013 Colville River Delta Spring Breakup Monitoring & Hydrologic Assessment

ConocoPhillips Alaska

Submitted by:

Baker

Michael Baker, Jr., Inc.
1400 West Benson Blvd.,
Suite 200
Anchorage, Alaska 99503

135141-MBJ-RPT-001 | November 2013

CONTENTS

TABLES

FIGURES

GRAPHS

PHOTOS

ACRONYMS AND ABBREVIATION

2D	Two-dimensional
ADF&G	Alaska Department of Fish & Game
ADP	Alpine Development Project
ADCP	Acoustic Doppler Current Profiler
ASDP	Alpine Satellite Development Plan
Baker	Michael Baker Jr., Inc.
BPMSL	British Petroleum mean sea level
CD	Colville Delta (facility names CD1, CD2)
cfs	Cubic feet per second
CMP	Corrugated metal pipe
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
DGPS	Differential global positioning system
E	East Channel
fps	Feet per second
GPS	Global positioning systems
HDD	horizontal directionally drilled
HWM	High water mark
LCMF	Umiaq, LLC
MON	Monument
N	Nigliq Channel
NUC	Non-uniform channel
OSW	Office of Surface Water
PT	Pressure transducer
RM	River mile
UC	Uniform channel
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WSE	Water surface elevation

1. INTRODUCTION

This 2013 Colville River Delta Spring Breakup Hydrologic Assessment supports the ConocoPhillips Alaska, Inc. (CPAI) Alpine Development Project (ADP) and the Alpine Satellite Development Plan (ASDP). Michael Baker Jr., Inc. (Baker) conducted spring breakup monitoring to determine the extent and magnitude of this annual flooding event within the Colville River Delta (CRD). Primary tasks included documentation of the distribution of floodwater and the measurement of water levels and discharge quantities. Observations of lake recharge, ice jam activities, ice road crossing degradation, and post-breakup floodwater effects were collected. Measurements and observations were used to determine peak discharge and stage at key CRD locations, and are evaluated and compared to current flood and stage frequency values and the CRD two-dimensional (2D) surface water model results. Hydrologic observations were collected at the Colville East Channel, Nigliq Channel, Alpine facilities and roads, Colville Delta (CD) 3 pipeline crossings, and the proposed CD5 road crossings. The results of the 2013 spring breakup monitoring activities are presented in this report.

Spring breakup on Alaska's North Slope typically occurs during a three-week period in May and June. The Colville River is the largest river on the North Slope. It is an approximately 23,500 square mile drainage basin that includes a significant portion of the western and central areas north of the Brooks Range. CRD breakup is generally considered to be the largest annual flooding event in the region. Breakup monitoring is integral to understanding regional hydrology and ice effects, establishing appropriate design criteria for proposed facilities, and maintaining the continued safety of the environment, oilfield personnel, and existing facilities during the flooding event.

In many areas of the North Slope, including the CRD, similar hydrologic and hydraulic characteristics are created in part by the arctic climate and presence of continuous regional permafrost. Groundwater is shallow and is generally restricted to isolated zones beneath deep lakes and river channels. Groundwater influx is largely nonexistent. After breakup, flow generally declines during the summer months with some temporary increases from rainfall events until winter freeze up begins. Surface water is frozen for much of the year. In deeper channels, velocities tend to approach zero where water remains under the ice during winter months with no contributing flow. Nearer to the coast, under-ice flows are influenced by tidal flux and oceanic storm surges.

Spring breakup monitoring activities have been conducted in the CRD since 1992. Monitoring was expanded to include ASDP facilities in 2004 and CD5 proposed development area in 2009. The 2013 hydrologic field program is the 22nd consecutive year of CRD spring breakup investigations.

Operated by CPAI, the Alpine facilities are owned by CPAI and Anadarko Petroleum Company. The existing Alpine facilities are the CD1 processing facility (Alpine), CD2, CD3, and CD4 drilling pads, access roads, and associated pipelines. Alpine facilities CD1 and CD2 were built for the ADP. Alpine facilities CD3, CD4, and proposed CD5 facilities are part of the ASDP.

This report is organized as outlined below.

Section 1 – Introduction: Discusses the objectives of the monitoring program, and presents climatic and breakup timing information and the 2013 monitoring sites.

Section 2 – Methods: Describes the methods of the fieldwork and the data analyses.

Section 3 –2013 Spring Breakup Monitoring & Analysis: Presents the 2013 hydrologic observations and stage (or water surface elevation [WSE]) in the CRD. Additional breakup observations include drinking water lakes recharge, drainage structure assessment, pad and road erosion investigations, and ice bridge degradation. Section 2 also presents the 2013 CRD direct (measured) and peak indirect (calculated) discharge results.

Section 4 –2013 Results and Historical Data: Presents the results of the 2013 Spring Breakup Monitoring event with historical data.

Section 5 – References: Contains the references used in the development of this report.

Appendix A – 2013 Vertical Control and Gage Locations: Includes survey control for monitoring gages and the geographic locations for gages and control.

Appendix B – 2013 MON1 ADCP Direct Discharge Data: Presents a summary of direct discharge measurements at Monument (MON) 1 and the WinRiverII output for each transect.

Appendix C –MON1 Stage-Discharge Rating Curve with Indirect Discharge: Presents a rating curve comparing both ice-affected and non-ice-affected direct discharge measurements to historical indirect discharge values.

Appendix D – 2013 Alpine Swale Bridges Direct Discharge Notes: Contains discharge notes for measurements performed at the Alpine swale bridges.

UMIAQ, LLC (LCMF), the Alpine environmental coordinators, and Bristow Helicopters provided support during the 2013 CRD spring breakup field work and contributed to a safe and productive monitoring season.

1.1 MONITORING OBJECTIVES

The primary objective of the Colville River Delta Spring Breakup 2013 Hydrologic Assessment is to monitor and estimate the magnitude of breakup flooding within the CRD in relation to the CPAI Alpine facilities.

Annual monitoring data is used to evaluate the effect of breakup flooding events and associated ice activities on existing Alpine and ASDP roads, pads, and pipelines. Flood stage, discharge data, and observations are also used for planning and design of proposed infrastructure, including the CD5 facilities. Flood data collection supports refinement of the Delta's flood frequency analysis and CRD 2D surface water model, as well as stage frequency analyses across the Delta.

The 2013 spring breakup program documented observations of effects to flow and channel morphology caused by the construction of winter ice bridges across the Colville East Channel near the Horizontal Directionally Drilled (HDD) crossing and the Kachemach River. Additional ice road crossing locations were observed during breakup for any significant impacts.

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 Fish Habitat Permit FH04-III-0238 require monitoring of the Alpine facilities during spring breakup. Permit requirements include direct and indirect measurements of discharge through drainage structures and documentation of pad and access road erosion caused by spring breakup flooding. For the CD5 road and bridge, under USACE Permit No. POA-2005-1576, similar requirements for breakup monitoring will be implemented post construction.

Culvert inlets and outlets are surveyed annually by LCMF to compare structure elevations on either side of the road to satisfy Alaska Department of Fish and Game (ADF&G) permit FH04-III-0328. Observations on functionality and flooding effects to the swale bridges are recorded to satisfy ADF&G permit FG97-III-0260.

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

1.2 2013 MONITORING LOCATIONS

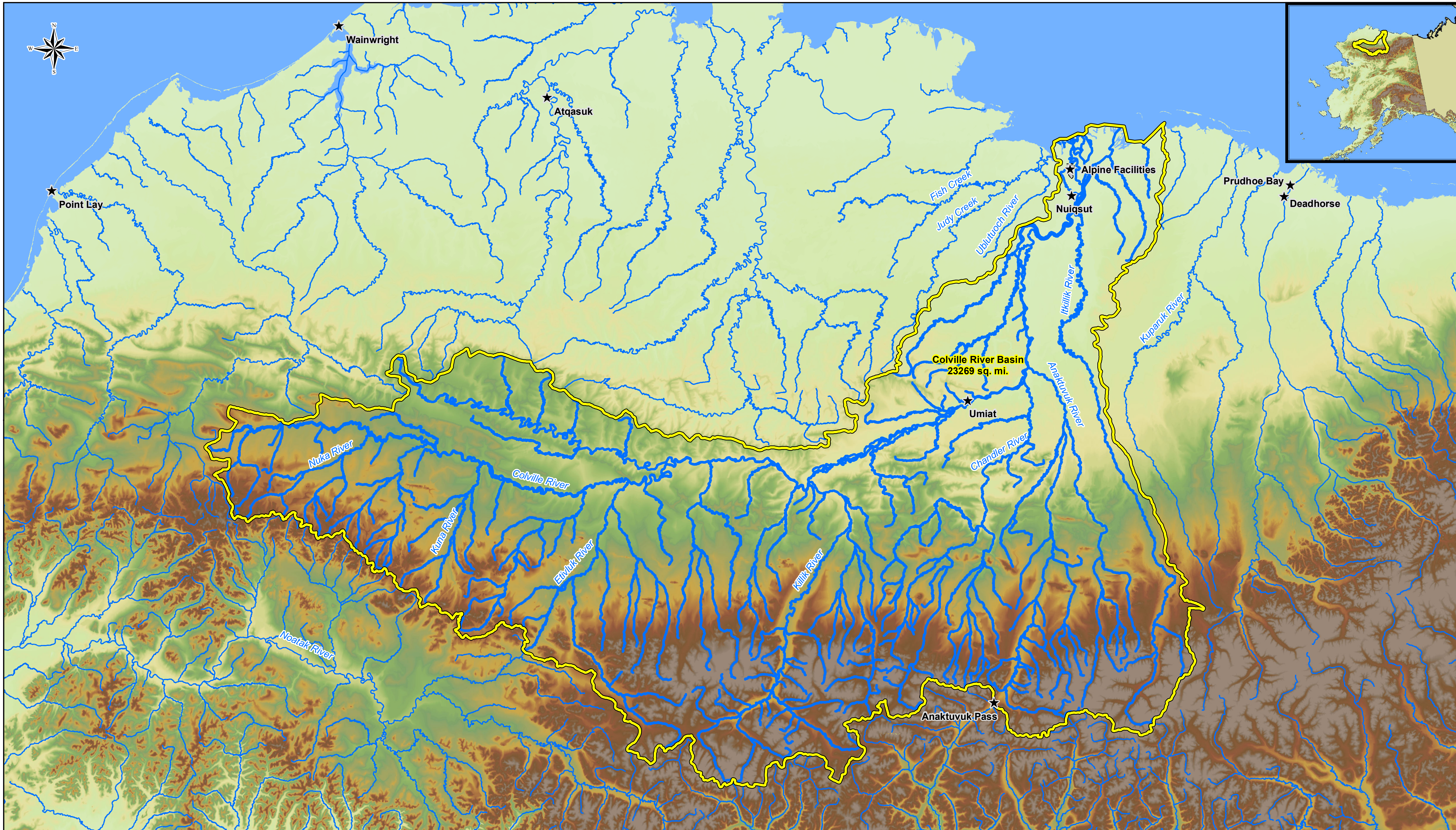
Observations of significant breakup flooding and ice effects near existing and proposed Alpine infrastructure were collected throughout the CRD. The monitoring locations in the CRD are consistent with those studied in 2012 (Baker 2012b). The CRD drainage basin delineation is shown in Figure 1.1. Figure 1.2 shows the existing Alpine facilities, the proposed CD5 facilities, the Colville River and Nigliq Channel monitoring locations, and the locations of the ice road crossings. Monitoring locations specific to the Alpine facilities area are shown in Figure 1.3. The proposed CD5 facilities presented in Figure 1.3, and Figure 3.7 to Figure 3.10 were provided by PND Engineers, Inc. and CPAI (PND 2012). Gaging and monitoring sites are also listed in Table 1.1 and Table 1.2.

Stage monitoring is accomplished using a network of established hydrologic gages. The majority of monitoring locations are adjacent to major hydrologic features and are selected based on topography; proximity, and hydraulic significance to existing or proposed facilities, temporary infrastructure and relevant terrain features; and their importance to the historical record.

Gages are used to monitor WSE and flow at major hydrologic features adjacent to Alpine facility roads and pads. Observations are recorded for water source lake recharge, drainage structure performance, gravel road prism erosion, and breakup of ice bridges. Stage data and breakup observations are collected at pipeline channel crossings between CD3 and Alpine, and the Colville River HDD crossing.

Geographic reference for all locations is provided in Appendix A.

In this report, locations are identified in river miles (RM) with RM 0 indicating the terminus of the river. The terminus is where smaller stream channels converge with larger channels or other water bodies. The terminus of the Colville East and Nigliq channels of the Colville River is at Harrison Bay. From the terminus at Harrison Bay, the RM increases in the southern direction (moving upstream). Measurement upstream is identified along the Colville East Channel (E) and Nigliq Channel (N). RM locations in this report are based on the following assumptions: MON35 is located at RM E3.0 and MON28 is located at RM N0.8.



ConocoPhillips
Alaska

Miles
0 12.5 25 50

Date:	11/01/2013	Project:	135141
Drawn:	BTG	File:	Figure 1.1
Checked:	SME	Scale:	1 in = 25 miles

Legend

★ Place Name

Stream

Colville River Basin

Baker

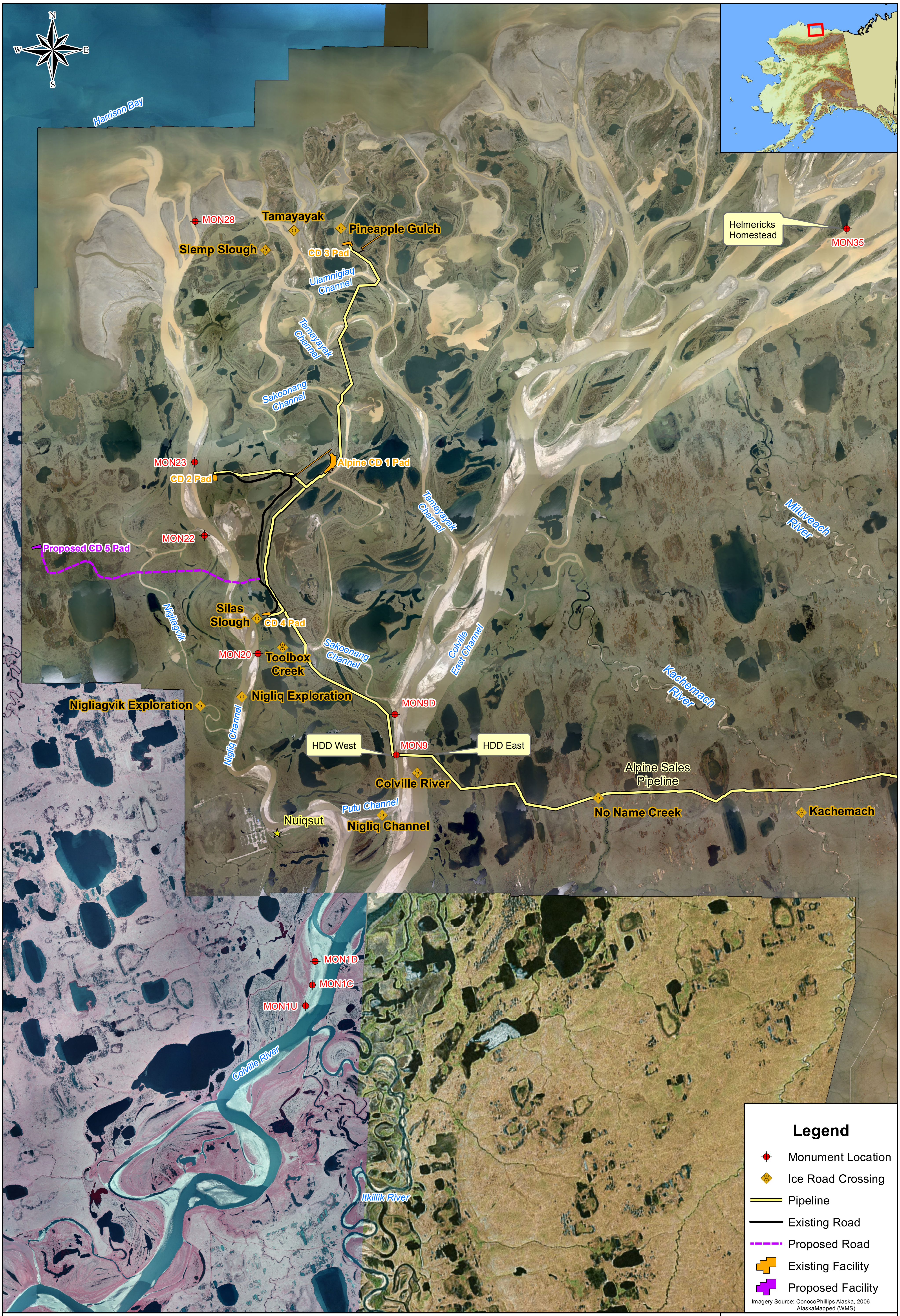
Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
COLVILLE RIVER

Drainage Basin

FIGURE: 1.1

(SHEET 1 of 1)



ConocoPhillips Alaska

Miles
0 1 2

Date: 11/01/2013	Project: 135141
Drawn: BTG	File: Figure 1.2
Checked: SME	Scale: 1 in = 2 miles

Baker

Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
COLVILLE RIVER DELTA

Monitoring Locations

FIGURE: 1.2

(SHEET 1 of 1)

ConocoPhillips Alaska

Miles
0 0.5 1

Date:	11/01/2013	Project:	135141
Drawn:	BTG	File:	Figure 1.3
Checked:	SME	Scale:	1 in = 1 miles

Baker

Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
ALPINE AREA FACILITIES

Monitoring Locations

FIGURE: 1.3

(SHEET 1 of 1)

Table 1.1: Colville River Delta Primary Monitoring Locations

Monitoring Area	
Location	**Notes**
Monuments - Colville East Channel	
MON1 (MON1U, MON1C & MON1D)	Entire Colville flow confined to a single channel
MON9	HDD crossing
MON35	Helmericks Homestead
Monuments - Nigliq Channel	
MON20	South of CD4
MON22	South of CD2
MON23	North of CD2
MON28	At Harrison Bay
Alpine Facilities and Roads	
G1	CD1 betweeen pad and Sakoonang Channel
G9	Lake L9312
G10	Lake L9313
G3/G4	CD2 access road, swale bridge vicinity
G12/G13	CD2 access road
G6/G7	CD2 access road
G8	CD2 between pad and Nigliq Channel
G11	CD3 pad area
G15/G16	CD4 access road
G17/G18	CD4 access road
G19	CD4 between southeast corner of pad and Lake L9324
G20	CD4 between west end of pad and Nigliq Channel
CD3 Pipeline Stream Crossings	
SAK	Sakoonang (Pipe Bridge #2)
TAM	Tamayayak (Pipe Bridge #4)
ULAM	Ulamnigiaq (Pipe Bridge #5)
Proposed CD5 Crossings	
G24/G25	Lake L9323
G26/G27	East bank, Nigliq Channel adjacent to crossing - formerly known as G21 (2009-2011)
G28/G29	East bank/west bank, Nigliq Channel
G30/G31	Small drainage area
G32/G33	Lake L9341 - formerly known as G22 (2009-2011)
G34/G35	Small drainage area
G36/G37	Small drainage area
G38/G39	West bank, Nigliagvik - formerly known as G23 (2009-2011)

Table 1.2: Colville River Delta Additional Monitoring Locations

Additional Monitoring Areas	
Location	**Notes**
Alpine Swale Bridges	
62-foot bridge	Along CD2 access road
452-foot bridge	Along CD2 access road
Alpine Culverts	
CD2 Road	26 culverts
CD4 Road	38 culverts
Alpine Roads	
CD2 Access Road	Access road from CD1 to CD2
CD4 Access Road	Access road from CD1 to CD4
Ice Road Stream Crossings	
Colville East Channel	North of HDD
Kachemach River	South of pipeline crossing to 2L Pad - Kuparuk
Downstream Nigliq Channel	
FWR1	Small drainage in the western Nigliq overbank area
FWR2	Small drainage in the western Nigliq overbank area

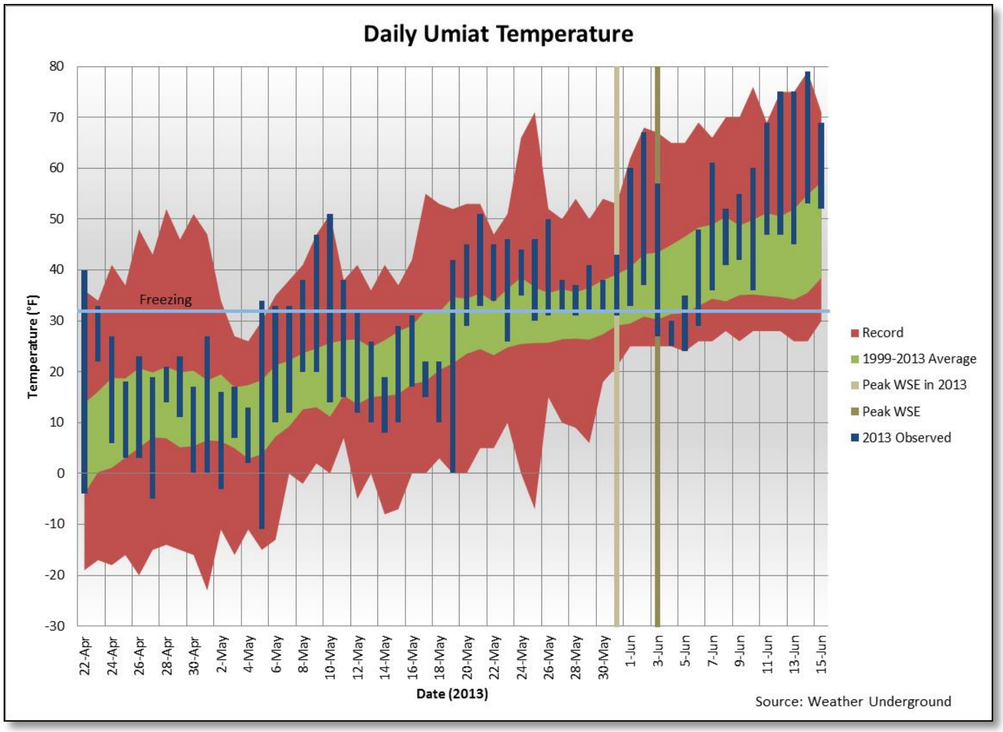
1.3 CLIMATIC REVIEW

Breakup flooding dominates the Alaska North Slope landscape for approximately three weeks each spring. The open water season, a four-month period generally from June through September, follows shortly after breakup. Factors contributing to the breakup cycle include snow pack, sustained cold or warm temperatures, ice thickness, wind speed and direction, precipitation, and solar radiation.

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

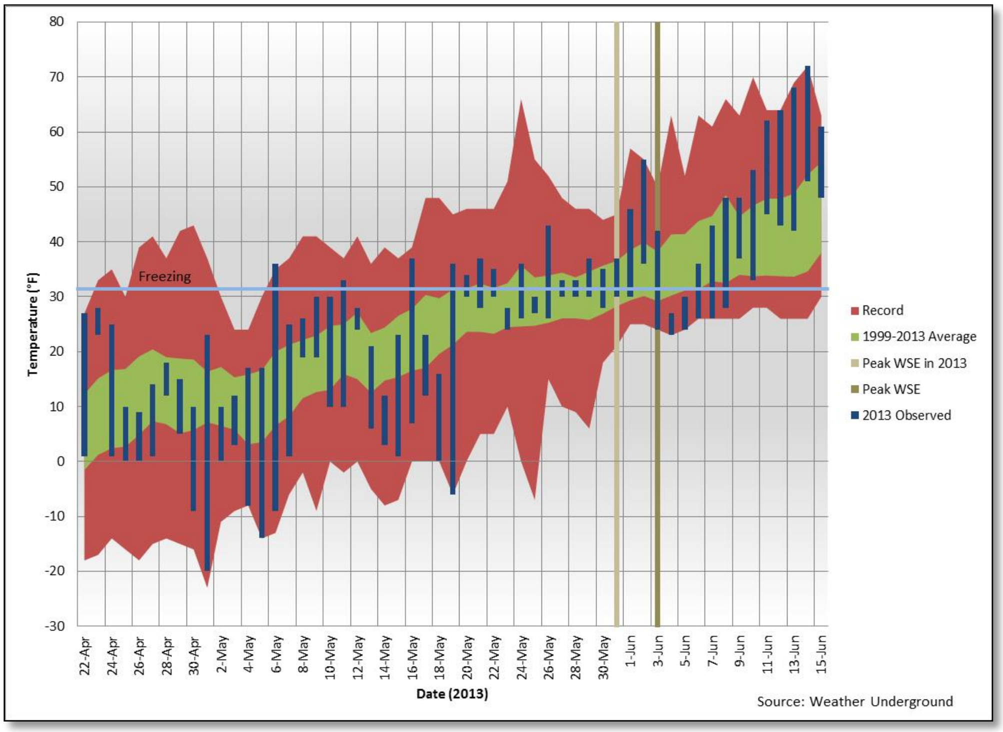
Increasing spring temperatures initiate the breakup processes. The rise of daily high ambient air temperatures in the Brooks Range, where the headwaters of the Colville River originate is important, but not solely responsible for initiation of the breakup process. As the daily highs begin to approach and exceed freezing, the breakup processes accelerate, with subsequent snow melt progressing downstream towards the CRD. The daily high and low ambient air temperatures are used in the evaluation of breakup timing.

Climate data upstream of the CRD is available from the Umiat weather station. Umiat (shown in Figure 1.1) is located approximately 60 air miles south of MON1 at the northern extent of the Brooks Range foothills. The 2013 ambient air temperatures at Umiat were generally at or above historical averages; however, cooler temperatures in mid-May prolonged the initiation of breakup processes. Nighttime ambient air temperatures in Umiat did not stay above freezing until late May. Two near record temperature days on June 1 and June 2 accelerated melting of the snowpack. Graph 1.1 illustrates high and low ambient air temperatures recorded for Umiat from April 22 to June 15 during the breakup monitoring period (Weather Underground 2013). Average highs and lows for the same period for 1999 through 2013 are shown shaded in green. Dates of 2013 peak stage and average peak stage from 1999 to 2013 from the centerline gage at MON1 (MON1C) are included for comparison.



Graph 1.1: Daily High and Low Breakup Ambient Air Temperatures at Umiat and Peak Stage at MON1

Temperatures for the Alpine area were obtained from the Nuiqsut weather station. Nuiqsut is located on the west bank of the Nigliq Channel, approximately 3.5 air miles northwest of MON1, and approximately 9 air miles south of the Alpine facilities, as shown in Figure 1.2. Ambient air temperatures at Nuiqsut had minimal influence on the progression of breakup. Nighttime ambient air temperatures in the CRD remained below freezing until the second week of June. Graph 1.2 provides high and low ambient air temperatures recorded for Nuiqsut from April 22 to June 15 (Weather Underground 2013). Dates of the 2013 peak stage and average peak stage from 1999 to 2013 at Alpine facilities are included for comparison.



Graph 1.2: Daily High and Low Breakup Ambient Air Temperatures at Nuiqsut and Peak Stage at Alpine Facilities

2. METHODS

The field program consists of setup and monitoring activities. Prior to breakup, field crews rehabilitate existing gages, install new gages, and survey gages to tie into a control elevation. Setup was completed between May 6 and May 15, 2013. LCMF provided personnel with Hägglund BV206 tracked vehicles for overland transportation.

Photo 2.1: Breakup monitoring at MON22 with Bristow helicopter support; June 6, 2013

The 2013 spring breakup monitoring activities included documenting observations of floodwater flow, distribution, and ice conditions; recording stage at gage locations; and measuring discharge at channels and drainage structures. Spring breakup monitoring was performed between May 27 and June 9. CPAI contracted Bristow to provide helicopter support to access remote sites (Photo 2.1), and a CPAI pickup truck was used to access local sites.

The following field methodologies have been proven to be safe, efficient, and accurate for the conditions encountered on the North Slope of Alaska during spring breakup. Data collection is affected by conditions related to safety, weather, and logistics.

2.1 VISUAL OBSERVATIONS

Field data collection and observations of breakup progression, flow distribution, bank erosion, ice events, lake recharge, and interactions between floodwaters and infrastructure were recorded in field notebooks. Digital cameras with integrated global positioning systems (GPS) were used for photographic documentation of spring breakup prior to, during, and after peak conditions. The geographic position of the camera in latitude and longitude, the date, and time were automatically imprinted onto each photo. The photo location is based on the World Geodetic System of 1984 datum.

Photo 2.2: Reading the water level off a staff gage at G29; June 1, 2013

2.2 WATER SURFACE ELEVATION

Stage or WSE monitoring of spring breakup flooding conditions is key to understanding CRD regional hydrology. Stage data was collected using hydrologic gages and pressure transducers (PTs). Daily site visits were performed as conditions allowed (Photo 2.2).

2.2.1 HYDROLOGIC STAFF GAGES

Both permanent and temporary staff gages are located throughout the CRD. Permanent, direct-read staff gages are located at CD1 and CD2. These consist of metal gage faceplates attached to drill stems driven into the ground or attached to pipeline supports and assembled so the gage faceplate corresponds directly to British Petroleum Mean Sea Level (BPMSL) elevation (Photo 2.3). The faceplates were surveyed prior to breakup in May 2013 by LCMF. The pre-breakup survey is used to determine if correction factors must be applied to adjust elevation during flooding conditions. Adjustments are made annually by LCMF during ice-free conditions to correct for jacking or settlement induced by the freeze-thaw cycle.

Temporary, indirect-read gage sets (Photo 2.4) are designed to measure floodwater levels and consist of one to multiple staff gage assemblies. Each gage assembly includes a metal gage faceplate marked to indicate water levels between 0.00 to 3.33 feet mounted on a two-by-four timber. The timber is attached with U-bolts to a 1.5-inch-wide angle iron post driven into the ground.

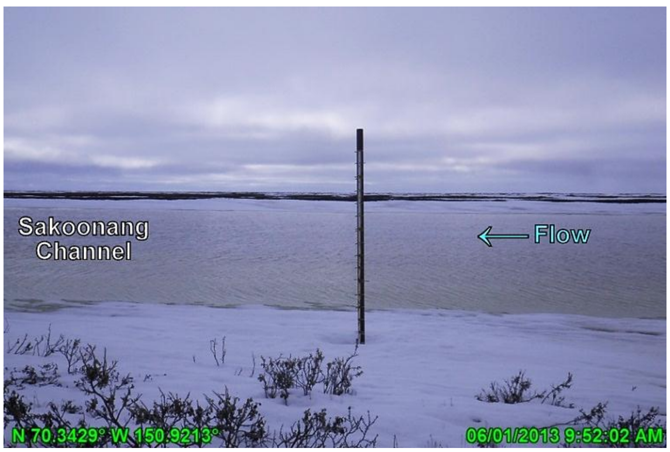


Photo 2.3: Permanent, direct-read staff gage near CD1; June 1, 2013

Photo 2.4: Temporary, indirect-read gage set at MON9; May 29, 2013

Indirect-read staff gages are established with a faceplate that does not directly correspond to a BPMSL elevation. The gages are surveyed relative to a known benchmark elevation to determine a correction factor. The correction factor is then applied to the faceplate reading to obtain the elevation in feet BPMSL. For example, a high water mark (HWM) reading of 2.40 on G20-A is corrected by 5.92 feet, based on survey tie-in to local control. After the correction factor is applied, the HWM elevation is 8.32 feet BPMSL.

Rehabilitation or installation and survey of the temporary staff gages were completed prior to the arrival of breakup floodwater.

Extreme stage, thaw, and ice effects during breakup can require re-installation, rehabilitation, and re-survey of affected gages and is performed as needed in the fall.

The quantity of gage assemblies per set depends on site specific conditions, primarily slope of the channel bank and overbank. In locations where terrain elevation varied by more than three feet or where the loss of gages due to ice impacts was considered to be likely, multiple gages were installed linearly from the edge of the low water channel up to the overbank. The elevations overlapped by approximately one foot. Individual gage assemblies were identified with alphabetical designations beginning with “A” representing the location nearest to the stream centerline.

Chalk was applied to the iron gage supports during each site visit. Subsequent HWMs were recorded when floodwaters removed the chalk. Peak WSEs, often occurring between site visits, were captured as HWMs.

2.2.2 PRESSURE TRANSDUCERS

Pressure transducers (PTs) measure the absolute pressure of the atmosphere and water, allowing the depth of water above the sensor to be calculated. Resulting data yield a comprehensive record of the fluctuations in stage. PTs supplement gage measurements and are used to validate and adjust data. Each PT consists of an unvented pressure sensor designed to collect and store pressure and temperature data at discrete pre-set intervals. For 2013, the PTs were programmed to collect gage pressure and water temperature at 15-minute intervals from May 10 to July 15, 2013.

In-Situ® Level TROLL® 500 PTs were installed at G3 and G4. Solinst® Levelogger® Model 3001 PTs were installed at twenty locations: MON1U, MON1C, MON1D; MON9 and MON9D; MON20, MON23, MON28, G1, G24, G25, G28, G29, G32, G33, G38, and G39; and at SAK, TAM, and ULAM.

The reported pressure datum is the sum of the forces imparted by the water column and atmospheric conditions. Variations in local barometric pressure are taken into account, using two independent barometric pressure loggers: In-Situ BaroTROLL® (primary) and Solinst Barologger® (secondary). A correction of barometric pressure was obtained from the BaroTROLL sensor installed at CD4 and the Barologger installed at MON9. See Appendix A for PT and barometric pressure logger elevation and horizontal positions.

Baker tested the PTs before field mobilization to Alpine. The PTs were configured using Win-Situ® LT 5.6.21.0 (for the Level TROLL 500s) or Solinst Levelogger v4.0.3 (for the Solinst Leveloggers) software prior to placement in the field. Absolute pressure was set to zero. Each PT was housed in a segment of perforated galvanized steel pipe and clamped to the angle iron or the base of the gage assembly nearest to the bed of the active channel. The PT sensor was surveyed during setup to establish a vertical datum using local control.

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

2.3 DISCHARGE

Direct discharge was measured at MON1 (MON1C, MON1D, MON1U) and Alpine drainage structures as close to the observed peak stage as possible. Peak indirect discharge was calculated based on direct discharge measurements and observed WSEs. Standard U. S. Geological Survey (USGS) techniques were used for direct discharge measurements at Alpine drainage structures. Direct discharge was measured at MON1 using an Acoustic Doppler Current Profiler (ADCP). Direct discharge was measured at the long and short swale bridges using Standard USGS midsection techniques. Industry standard methods were used to indirectly calculate peak discharge for MON1, MON9, MON23, Alpine drainage structures, the proposed Nigliq Channel CD5 crossing (G26), the proposed Lake L9341 CD5 crossing (G32), and the proposed Nigliagvik CD5 crossing (G38).

In open channel conditions, peak discharge typically occurs at the same time as peak stage. This is not always the case in the arctic where peak annual flow is typically affected by ice and snow conditions. Ice-affected channels often produce backwater effects and can temporarily inflate stage, or can reduce stage and velocity to quantities not representative of actual discharge.

2.3.1 USGS TECHNIQUES

Standard USGS midsection techniques (USGS 1982) were used to directly measure velocities and determine discharge at the two CD2 road swale bridges.

Swale bridge depth and velocity measurements were taken from the upstream side of each bridge deck using a sounding reel mounted on a wooden boom. A Price AA velocity meter was attached to the sounding reel and stabilized with a 30-pound Columbus-type lead sounding weight. Photo 2.5 shows the Price AA velocity meter in use. A tag line was placed along the bridge rail to define the cross section and to delineate measurement subsections within the channel. The Price AA velocity meter was rated by the USGS Office of Surface Water (OSW) Hydraulic Laboratory in 2011. A spin test of the meter was successfully completed before and after the swale bridge measurements. To ensure accurate performance of meters, procedures outlined in OSW Technical Memorandum No. 99.06 (OSW 1999) were followed.

Velocity measurements at the outlets of those CD2 and CD4 road culverts experiencing flow were conducted using a wading rod and Price AA velocity meter, as shown in Photo 2.6. Discharge was determined based on velocity and culvert geometry. Visual observations of culvert performance and overall condition were also recorded.

Photo 2.5: Price AA velocity meter in use at an Alpine facility bridge; June 5, 2013

Photo 2.6: Measuring velocity at a culvert along the CD2 access road using a wading rod and Price AA velocity meter; June 6, 2013

2.3.2 ACOUSTIC DOPPLER CURRENT PROFILER

A direct discharge measurement of the Colville River during the breakup season presents unique challenges. Implementation of accurate USGS midsection techniques are challenging because of water depths, flow velocities, channel ice movement, and weather conditions. The Acoustic Doppler Current Profiler (ADCP) is a good alternative for collecting repeatable and accurate direct river discharge measurements in challenging conditions. The ADCP discharge measurement system can be faster than traditional methods and provides equivalent levels of accuracy (USGS 2009).

With the exception of 2010 and 2012, a direct discharge measurement has been taken at MON1 using an ADCP each year since 2005. In 2010, a direct discharge measurement was not possible because of weather and helicopter transportation. The 2012 measurement was also aborted because of weather-related logistics. For 2013, direct discharge measurements at MON1 were performed using ADCP techniques and procedures following the USGS *Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers* (USGS 2005). The following sections outline the standard procedures used for collecting direct discharge measurements at MON1.

1) Hardware and Software

A Teledyne RD Instruments 600-kilohertz Workhorse Sentinel broadband ADCP was used. The unit has a phased array, Janus four-beam transducer with a 20-degree beam angle. The ADCP unit and supporting laptop (Panasonic Toughbook® CF-19) were self-powered via internal batteries.

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

2) Pre-Deployment Testing

Prior to deployment of the ADCP unit, a full suite of tests were run in accordance with the manufacturer's instructions using BBTalk.® The tests confirmed 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 the transducer beams were connected and operational. Additional diagnostic tests were performed using WinRiverII.® Pre-deployment tasks also included compass calibration and verification. Internal compass error was within the specified five-degree limit.

3) ADCP Deployment and Data Collection

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

A cross section was identified at an established monitoring site (MON1C). A minimum of four transects were completed so the measured discharges varied by less than five percent of their mean. Cross section end points were dependent on a minimum water depth of approximately eight feet to provide acceptable data.

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

4) ADCP Background and Data Processing

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

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

The loop method is a technique to determine whether a moving bed is present and, if present, to provide an approximate correction to the final discharge. The USGS established guidance for the loop method by outlining procedures for mean correction and distributed correction (USGS 2006a). Both procedures yield results within two percent of the actual discharge, as measured using DGPS. Baker applied the mean correction procedure to the Colville River discharge calculations because of the simple geometry of the channel cross section. The results of the loop test, performed immediately following discharge measurements, was used to estimate the mean velocity of the moving bed. The 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.

2.3.3 INDIRECT DISCHARGE

Indirect discharge for the Colville River at MON1 and MON9, the Nigliq Channel at MON23, the CD2 and CD4 road culverts, Alpine swale bridges, and proposed CD5 crossings at the Nigliq Channel, Lake L9341, and Nigliagvik were calculated using physical characteristics obtained during field observations. These physical characteristics, including measured stage and velocity data, culvert dimensions, and channel cross sections, are used as hydraulic equation input variables to calculate indirect discharge to determine peak discharge at each location.

Industry accepted engineering methods and Bentley CulvertMaster® software were used to estimate discharge through the CD2 and CD4 road culverts. Time and magnitude of peak discharge through the culverts was determined based on recorded WSE and peak stage observations on both sides of the road prism.

Average velocity and discharge through the culverts assumes ice-free open-water conditions and were estimated based on several variables, including:

- Headwater and tailwater elevations at each culvert (hydraulic gradient)
- Culvert diameter and length from LCMF as-built surveys (UMIAQ 2002); as-built information is not available for the slip-lined culverts – field measurements and approximations for slip-lined culverts were used.
- Culvert upstream and downstream invert elevation (UMIAQ 2012)
- Culvert Manning's roughness coefficient (0.012 for smooth steel and 0.024 for corrugated metal pipe [CMP])

Results are evaluated in terms of culvert functionality based on visual inspection.

The calculation for peak discharge through the swale bridges was performed by correlating the hydraulic depths and velocities measured during the direct discharge measurements with peak stage using the velocity-area method.

The slope-area method (Benson and Dalrymple 1967) for a uniform channel (UC) and non-uniform channel (NUC) was used to develop the estimates of peak discharge at MON1. This method is based on channel cross section geometry and stage differential between gage sites as an estimate for hydraulic gradient. The UC and NUC methods differ by the number of cross sections used in the calculations. The NUC method uses all three cross sections at MON1 (cross section geometry current as of 2004, [UMIAQ 2004]) and the UC method uses a single cross section at MON1C. Accuracy of each method depends on conditions at the time of calculation, particularly the presence of ribbon and bottom fast ice, ice jam activity, and backwater effects. The average of the UC and NUC results were used to compute the peak indirect discharge at MON1.

Lacking additional cross sections, the UC method was used to estimate peak discharge at all other locations. Cross sectional geometry for MON9 is the result of data from the 2009 HDD survey by LCMF for the Alpine Pipelines Monitoring report (Baker 2009c). Cross sectional geometry at MON23 is current as of 2005 (UMIAQ 2005) and at the proposed CD5 crossing locations as of 2008 (UMIAQ 2008). The Lake L9323 crossing was surveyed by LCMF in 2012. Because of channel bed morphology, cross sectional geometry becomes less accurate with time, particularly for those CRD channels that are predominantly comprised of fine grained soils or have bottom-fast ice. Stage and hydraulic gradient data were obtained from observations made at nearby gages and PT results.

2.4 FLOOD AND STAGE FREQUENCY ANALYSIS

Flood and stage frequency statistical analyses are performed using historic annual peak discharge and stage data to determine recurrence in terms of years. Analyses assume open channel conditions. CRD breakup flood conditions are usually characterized by channel ice and ice jams. Even though these analyses are not representative of peak spring breakup flooding conditions, it provides the most accurate results possible.

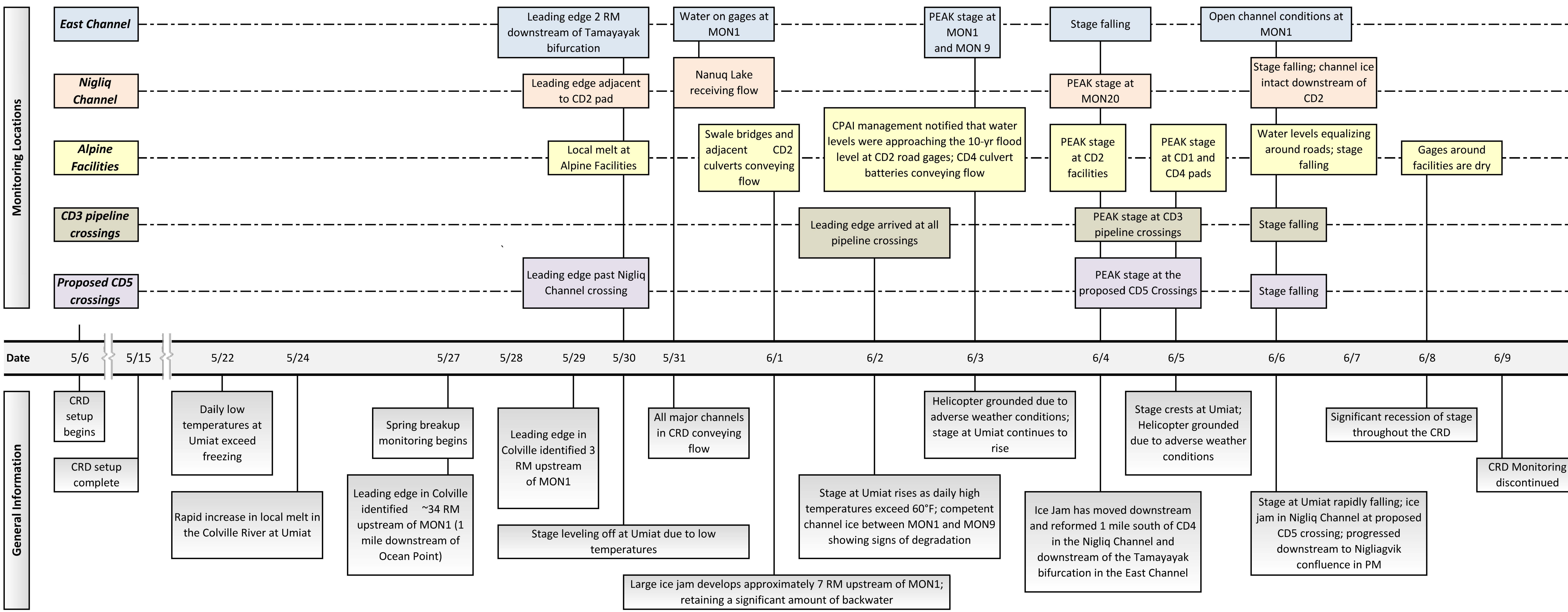
Peak discharge at select locations in the CRD is analyzed every three years in terms of flood frequency. The last flood frequency analysis for the CRD was performed in 2012. The results of these analyses are used in facility designs. The basis for comparison is the 2002 design-magnitude flood frequency analysis for the Colville River at MON1 (Baker and Hydroconsult 2002). The 2002 values continue to be the recommended design magnitudes. The 2013 peak discharge value is compared to results from 2002, 2009, and 2012.

Similarly, WSE at select locations in the CRD are analyzed every three years in terms of stage frequency. The last stage frequency analysis for the CRD was performed in 2012. Peak stage values are compared annually to the most current stage frequency analysis results and to the 2D surface water model elevations. The 2D model was developed during the original design of Alpine and has been updated throughout the life of the Alpine facilities, most recently in 2012 (Baker 2012b).

3. 2013 SPRING BREAKUP MONITORING AND ANALYSIS

The images, data, and observations of the 2013 field program are presented in this chapter. Setup was completed between May 6 and May 15, 2013. Data and observations described in the following sections were documented between May 27 and June 9, 2013. The General Observations of the 2013 Spring Breakup Conditions (Section 3.1) provides an overview of the progression of breakup events. A more detailed analysis of the breakup events are broken down by location (Section 3.2 through Section 3.8). Figure 3.1 provides a visual timeline summarizing the major 2013 CRD breakup events.

2013 Colville River Delta Spring Breakup Hydrologic Timeline



Date:	10/18/2013	Project:	135141
Drawn:	GYC	File:	Figure 3.1
Checked:	SME	Scale:	N/A

ConocoPhillips Alaska

Baker

Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
COLVILLE RIVER DELTA
HYDROLOGIC TIMELINE
FIGURE: 3.1
(SHEET 1 of 1)

3.1 GENERAL OBSERVATIONS OF THE 2013 SPRING BREAKUP CONDITIONS

Breakup floodwaters entering the CRD originate upstream in the Brooks Range. This melt accumulates along the base of the mountains and flows into the Colville River via a network of smaller drainages before the Colville branches out into a delta terminating at Harrison Bay (Figure 1.1 through Figure 1.3). MON1, located at the head of the delta, is the farthest downstream confined reach, conveying approximately 22,500 square miles worth of runoff in a single channel. Breakup events are initially monitored upstream of this location as floodwaters progress downstream toward the CRD.

A USGS gaging station and live camera is located on the Colville River at Umiat approximately 93 RM upstream of MON1. The stage and discharge data from this station represents conditions upstream of the CRD and is used for forecasting peak conditions, having a typical flood routing time of 24 hours before reaching MON1. The Umiat station data are presented as preliminary and do not account for melt contribution from the Chandler or Anaktuvuk rivers. These are larger drainages that join the Colville River upstream of MON1 and downstream of Umiat. Figure 3.2 presents the stage data from the USGS gage at Umiat during the CRD breakup monitoring period.

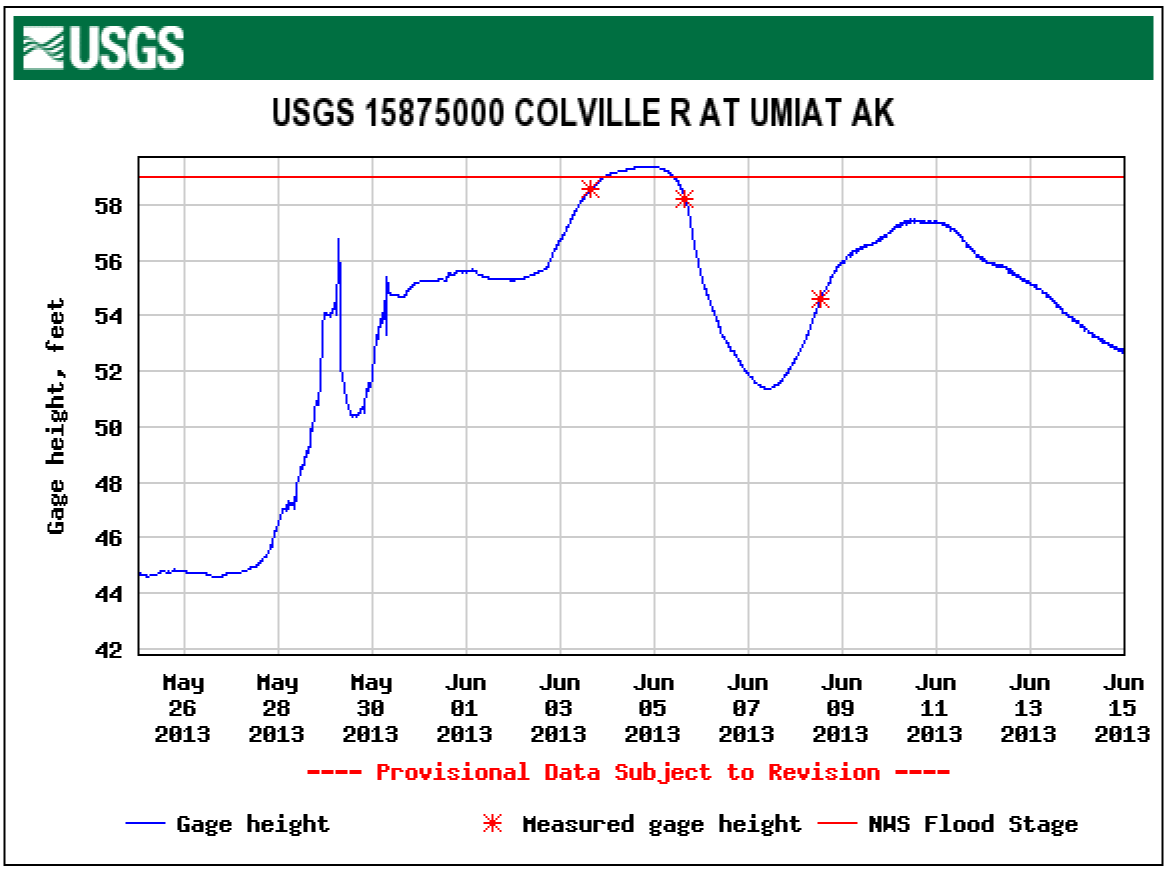


Figure 3.2: USGS Gage at Umiat Stage Data for the CRD Monitoring Period (USGS 2013a); May 25 through June 15, 2013

Cold mid-May temperatures in the northern Brooks Range and foothills delayed the onset of spring breakup flooding in the CRD. Overnight freezing temperatures at Umiat persisted until May 22 inhibiting local snow melt and prolonging the progression of melt water in the drainage basin. A rapid increase in local melt in the Colville River at Umiat was recorded by the live camera on May 24 (Photo 3.1).

On May 27, field personnel performed a reconnaissance flight on the Colville River upstream of MON1. The leading edge of the melt water in the Colville River was identified approximately 1 mile downstream of Ocean Point. Ocean Point is 35 RM upstream of MON1. Flow was predominantly below the ice, with intermittent pockets of visible open water flow (Photo 3.2).

Photo 3.1: Local melt in the Colville River at Umiat; May 24, 2013 at 8:00 AM (USGS 2013b)

Photo 3.2: Melt water emerging from below the ice cover and flowing over remnants of an ice bridge near Ocean Point; May 27, 2013

On May 29 at 10:30 AM, the leading edge of breakup flow in the Colville River had progressed to the large channel bend approximately 3.0 RM upstream of MON1.

On May 30 at 3:30 PM, the leading edge in the Colville East Channel was 2 RM downstream of the Tamayayak bifurcation (Photo 3.3). At 6:00 PM, May 30, the leading edge in the Nigliq Channel was adjacent to CD2, and no overbank flow was observed in the vicinity of the facilities (Photo 3.4). Channel ice remained intact in both the Colville East Channel and the Nigliq Channel. The stage at Umiat had leveled off in response to lower daily high temperatures.

By May 31, all major channels in the CRD were conveying flow. Channel ice remained intact along the east bank of the Colville River at MON1 (Photo 3.5). Nigliq Channel floodwater was observed flowing into Nanuq Lake (Photo 3.6) and L9324 was hydraulically connected to the Sakoonang Channel.

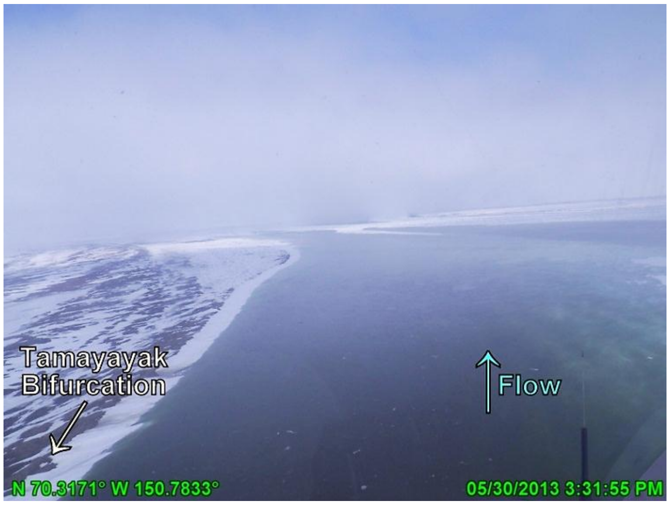


Photo 3.3: Leading edge in the Colville East Channel 2 RM downstream of the Tamayayak bifurcation, looking north; May 30, 2013

Photo 3.4: Leading edge in the Nigliq Channel near CD2, looking north; May 30, 2013

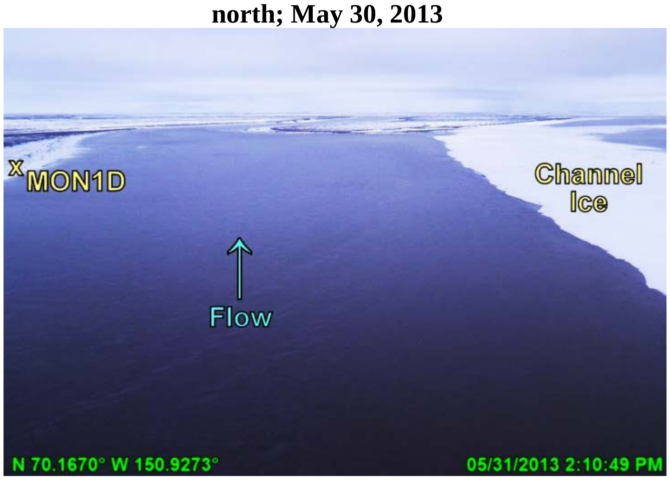


Photo 3.5: Intact channel ice along the east bank of the Colville River at MON1, looking north; May 31, 2013

Photo 3.6: Nigliq Channel flood water entering Nanuq Lake, looking southeast; May 31, 2013

On June 1, flood water had reached facilities. Nanuq Lake and Lake M9524 had recharged over bankfull, and consequently both swale bridges and adjacent culverts along the CD2 road were observed conveying flow (Photo 3.7). Floodwater was also observed in the vicinity of the CD4 road and pad as Lake L9324 continued recharging from the Sakoonang and Nigliq channels (Photo 3.8). An ice jam was developing in the Colville River at the series of bends 7 RM upstream of MON1 (Photo 3.9). Ice floes obstructed by intact channel ice were observed accumulating in the channel bends. Backwater was contained within the active channel banks. The Colville River was free of intact channel ice upstream of the ice jam.

On June 2, high temperatures, over 60 degrees Fahrenheit observed at Umiat, accelerated melting of the snowpack and intensified flow in the Colville River and its tributaries. The ice jam upstream of MON1 remained in place and was retaining a large amount of backwater causing widespread inundation (Photo 3.10). Water levels around facilities continued to increase.

Photo 3.7: Floodwater passing through the CD2 swale bridges and adjacent culverts, looking southwest; June 1, 2013

Photo 3.8: Lake L9324 recharging from the Sakoonang and Nigliq channels, looking south; June 1, 2013

Photo 3.9: Ice jam upstream of MON1, looking southwest; June 1, 2013

Photo 3.10: Ice jam upstream of MON1 with widespread inundation, looking south; June 2, 2013

Adverse weather conditions grounded the helicopter on June 3 preventing aerial observations. Initial hydraulic connections between Lake L9323, Lake L9324, and Lake M9525 via the CD4 culvert batteries were observed. The ice jam was estimated to have released on June 3 from its location upstream of MON1 and by June 4 had reformed one mile south of CD4 in the Nigliq Channel and in the Colville East Channel near the Tamayayak Channel bifurcation. On June 4, water levels were receding at MON1 and MON9 and continued to increase around facilities. Additional floodwater was diverted down the Nigliq, Sakoonang, and Tamayayak channels as backwater accumulated behind the Colville East Channel ice jam. Diverted flood water around the Nigliq Channel ice jam inundated surrounding floodplains resulting in flooding around facilities (Photo 3.11). Backwater from the Colville East Channel ice jam flooded the Sakoonang Channel and contributed to flood water south of the CD4 pad, increasing flow through the CD4 culvert batteries into Lake M9525.

By the afternoon of June 4, floodwater had peaked near the CD2 facilities (Photo 3.12) and by June 5, had peaked near the CD4 and CD1 facilities. Stage crested at the Umiat gage on the morning of June 5 and was rapidly falling by June 6. The ice jam in the Nigliq Channel continued to slowly advance downstream as resilient intact channel ice persisted late into the flood event; however, backwater flooding diminished as water levels dropped below bankfull stage. By June 8, significant recession of stage throughout the CRD was observed. Monitoring in the CRD was discontinued on June 9.

Photo 3.11: CD4 with diverted floodwater around the Nigliq Channel ice jam, looking southeast; June 4, 2013

Photo 3.12: CD2 facility during peak; June 4, 2013

3.2 MONUMENTS

All Colville River, Colville East Channel, and Nigliq Channel monument locations are shown in Figure 1.2. Indirect discharge measurements were calculated for MON1, MON9, and MON23. Direct discharge measurements were conducted at MON1.

3.2.1 MONUMENT 1

MON1 has been monitored annually since 1992 and periodically since 1962. Because of its location at the head of the delta and long historical record, MON1 is the primary spring breakup monitoring site. Three gaging stations are installed at MON1 along the west bank; one upstream (MON1U) at RM E23.5, one at the centerline (MON1C) at RM E22.9, and one downstream (MON1D) at RM E22.3.

1) SPRING BREAKUP OBSERVATIONS

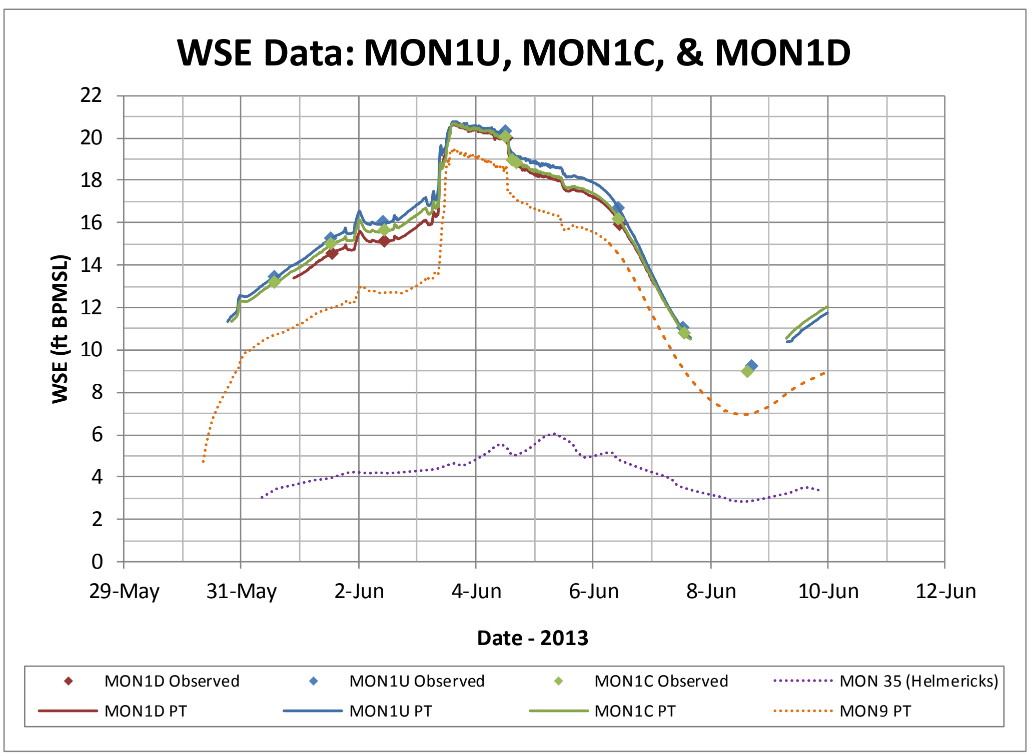
The leading edge passed MON1 sometime between May 29 and May 30. Stage was first measureable on the MON1 gages on May 31. The ice jam located 7 RM upstream of MON1 is estimated to have released on June 3. On June 3, recorded PT data at MON1 captured the surge of water accompanying the ice jam release. As the surge of water moved through MON1, a peak WSE of 20.77, 20.69, and 20.63 feet BPMSL was recorded at MON1U, MON1C, and MON1D, respectively at around 3:00 PM (Table 3.1 and Graph 3.1). All intact channel ice was cleared from the Colville River at MON1 once the jam had passed, though some ice floes remained. On June 4, floodwater was observed in the swales and paleochannels west of the MON1 gages. The channel was free of ice by June 6.

Table 3.1: 2013 Stage Data for MON1

Date and Time	WSE (feet BPMSL)			Observations
	MON1U	MON1C	MON1D	
5/31/13 1:45 PM	13.42	13.16	-	
6/1/13 1:00 PM	15.27	14.96	14.56	Early signs of developing ice jam observed approximately 7 RM upstream from MON1
6/2/13 10:40 AM	16.00	15.61	15.13	Ice jam holding and increasing in size, backwater flooding is evident upstream of the jam
6/3/13 3:15 PM	-	20.69	-	Peak Stage at MON1C - based on PT data
6/3/13 3:30 PM	20.77	-	-	Peak Stage at MON1U - based on PT data
6/3/13 3:00 PM	-	-	20.63	Peak Stage at MON1D - based on PT data
6/4/13 12:30 PM	20.28	20.06	19.99	Floodwater observed in swales and paleochannels west of MON1 gages
6/4/13 3:15 PM	-	18.93	-	
6/4/13 4:55 PM	-	18.82	-	
6/6/13 10:30 AM	16.70	16.17	15.87	Ice free conditions in Colville River at MON1
6/7/13 12:45 PM	11.05	-	-	
6/7/13 1:30 PM	-	10.79	-	
6/8/13 3:15 PM	-	8.95	-	
6/8/13 5:00 PM	9.23	-	-	

Note:

1. Elevations based on MONUMENT 1 at 27.930 ft BPMSL, surveyed by LCMF in 2006

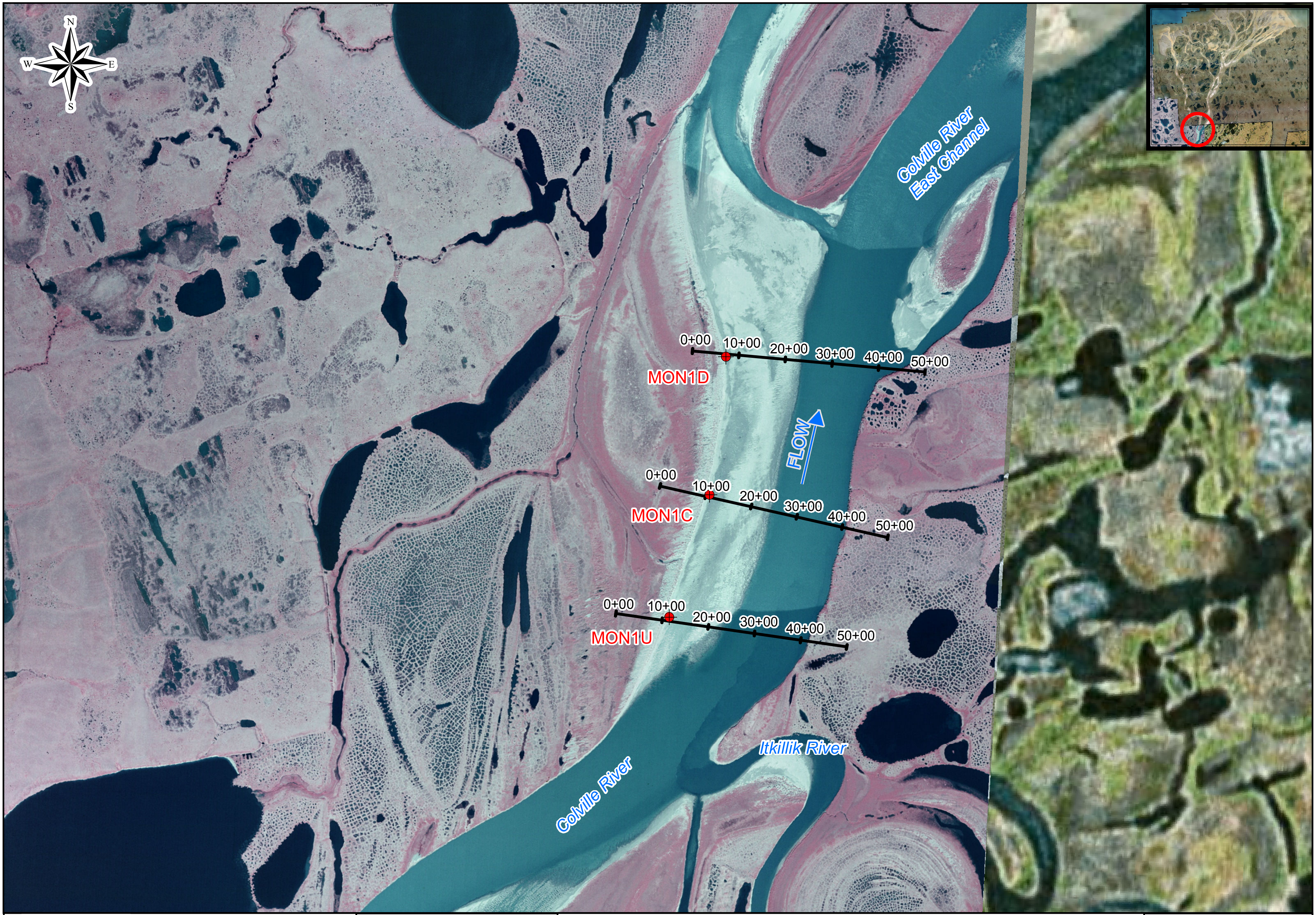


Graph 3.1: 2013 Stage Data for MON1 (including MON9 PT and MON35 Observed)

2) Direct Discharge

On June 8, direct discharge measurements were conducted on the Colville River at MON1. At the time of measurements, the channel was clear of ice. The corrected discharge, accounting for the moving bed condition, was approximately 117,000 cubic feet per second (cfs), having an average velocity of 3.2 feet per second (fps) with a maximum measured velocity of 6.5 fps, and an associated stage of 9.13 feet BPMSL. A summary of direct discharge measurements and the WinRiverII output for each transect are presented in Appendix B. The direct discharge measurement was 114,000 cfs without considering ice and bed conditions. Figure 3.3 shows the location of the discharge measurement and the cross-sectional geometry at the MON1 gage locations.

Four transects and one loop test were completed during the direct discharge measurement. A moving bed was noted and direct discharges were adjusted accordingly. An indirect discharge calculation was also completed for the Colville at MON1, using WSE collected at the time of the direct discharge measurement. Indirect calculations yield a discharge of 105,000 cfs, approximately ten percent lower than the direct discharge measurement.



ConocoPhillips
Alaska

Miles
0 0.25 0.5

Date:	11/01/2013	Project:	135141
Drawn:	BTG	File:	Figure 3.3
Checked:	SME	Scale:	1 in = .5 miles

Legend

Gage Location

2004 Cross Section Alignment

Imagery Source: AlaskaMapped (WMS)

Baker

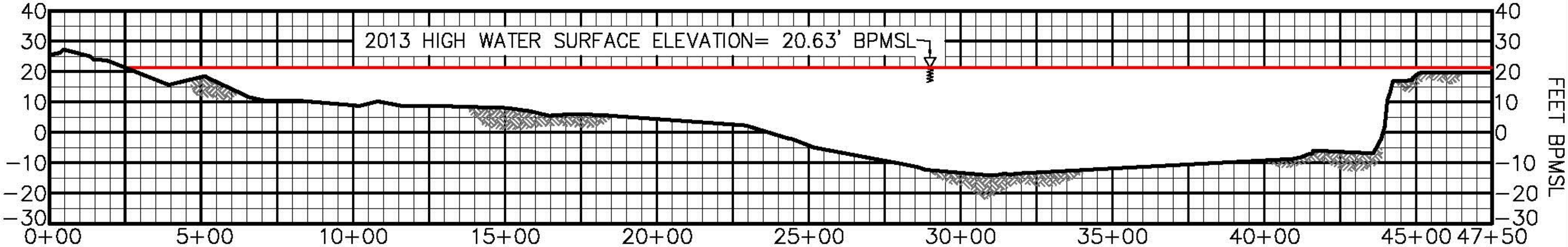
Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
MONUMENT 1
PLAN

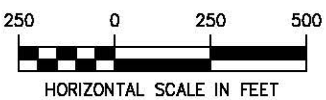
FIGURE: 3.3

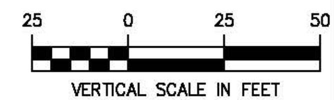
(SHEET 1 of 4)

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



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





ConocoPhillips Alaska, Inc.

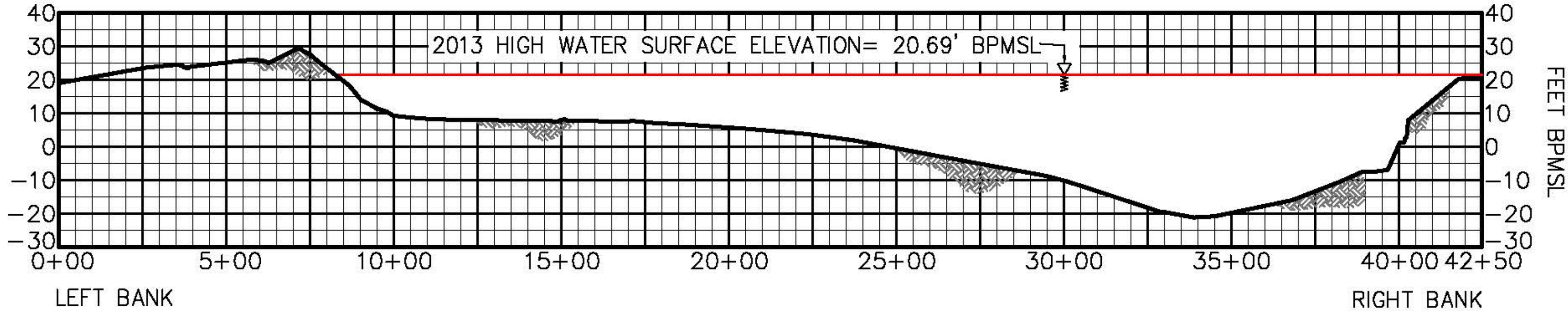
DATE:	10/17/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.3.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Baker
Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
COLVILLE RIVER MONUMENT 1
DOWNSTREAM CROSS SECTION

FIGURE 3.3
(SHEET 2 OF 4)

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



1C COLVILLE RIVER CROSS SECTION AT MONUMENT 1 CENTERLINE

250 0 250 500
HORIZONTAL SCALE IN FEET

25 0 25 50
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/17/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.3.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Baker

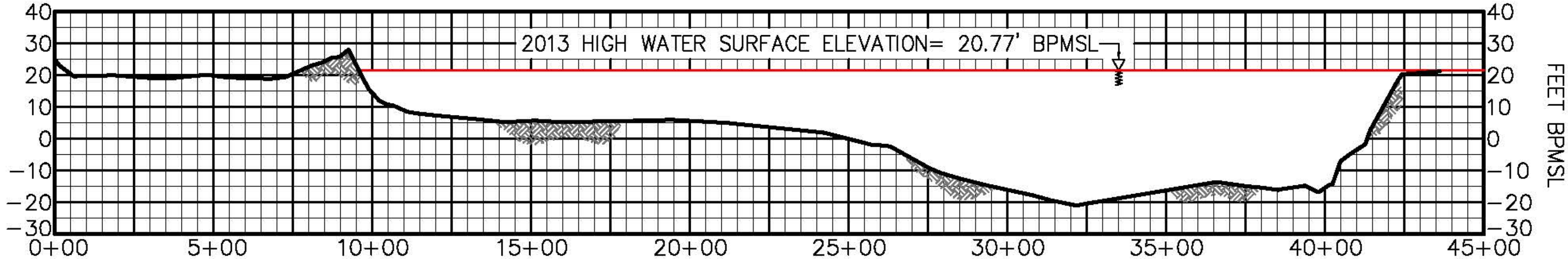
Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
COLVILLE RIVER MONUMENT 1
CENTERLINE CROSS SECTION

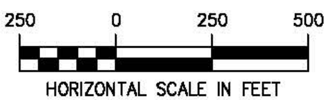
FIGURE 3.3

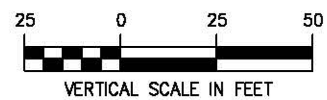
(SHEET 3 OF 4)

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



1U COLVILLE RIVER CROSS SECTION AT MONUMENT 1 UPSTREAM





ConocoPhillips Alaska, Inc.

DATE:	10/17/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.3.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

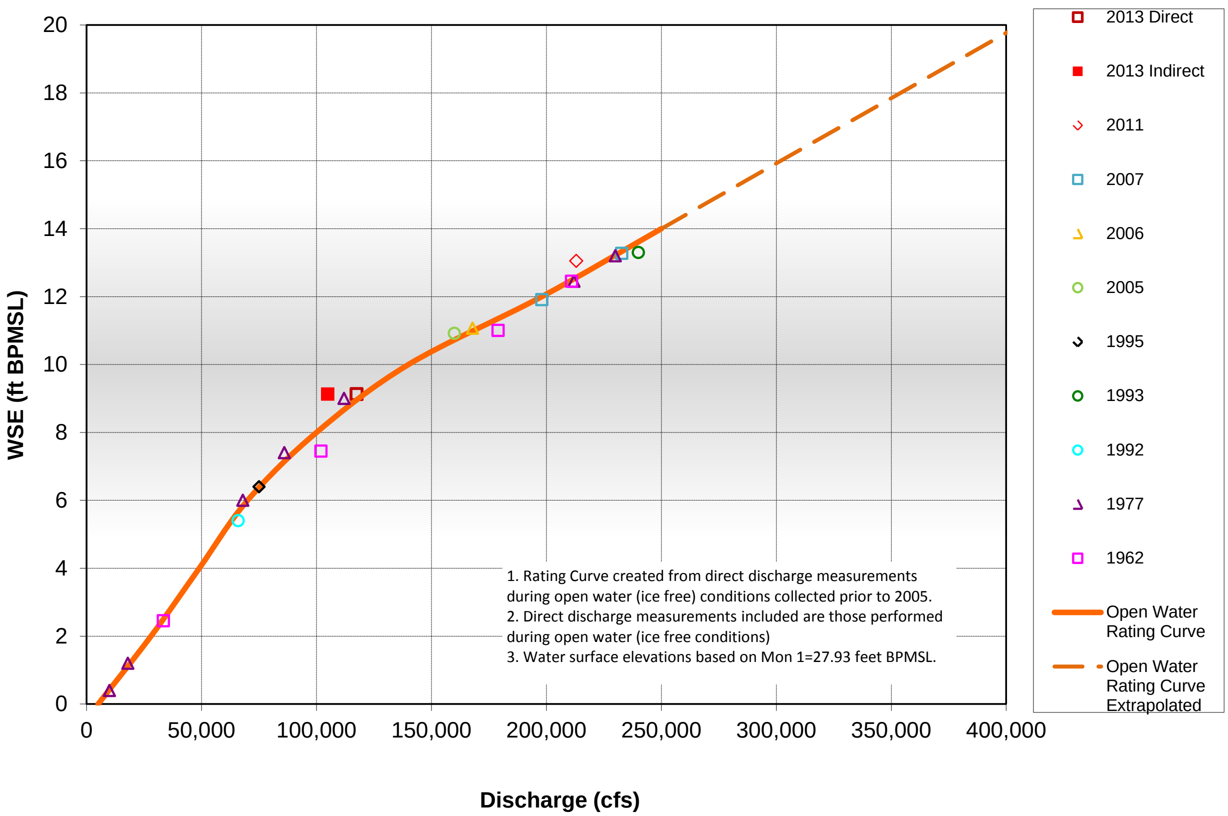
Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
COLVILLE RIVER MONUMENT 1
UPSTREAM CROSS SECTION

FIGURE 3.3
(SHEET 4 OF 4)

Direct and indirect discharges are plotted against the MON1 stage-discharge rating curve in Graph 3.2. The percent differences from measured direct discharge and computed indirect discharge to the stage-discharge rating curve were -4 percent and -17 percent, respectively. The shift is likely because of sediment deposition in the channel resulting from low flow velocities. Sediment deposition can change the bedform geometry, affecting indirect calculations and changing the relationship between stage and discharge of the rating curve. The overall quality of the direct discharge measurement is considered good based on site conditions and the similarity to the stage discharge rating curve.

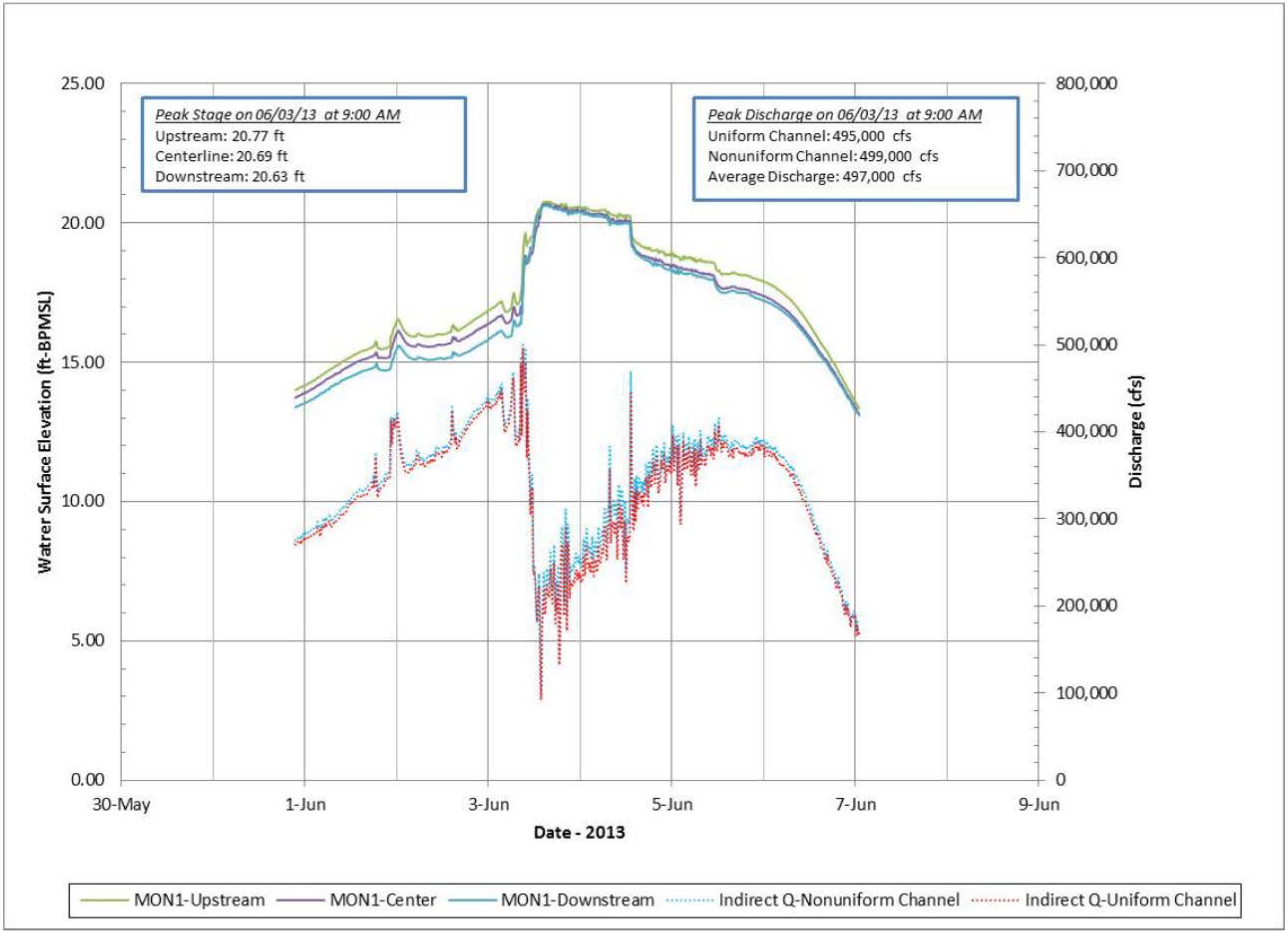


Graph 3.2: MON1 Stage Discharge Rating Curve with Direct Discharge

3) Indirect Discharge

The slope-area method for a UC and NUC was used to calculate the indirect discharge at MON1. Indirect discharge is calculated using the following: 1) energy grade-line slope approximated using the water surface slope as measured by the gages and pressure transducers at MON1U, MON1C, and MON1D; 2) WSE at MON1U, MON1C, and MON1D at the time of estimated peak discharge; and 3) 2004 topographic survey data provided by LCMF (Figure 3.3). Changes in the channel bed morphology are likely to have occurred since this cross section was surveyed, which can introduce error and skew indirect discharge calculations. The channel bed morphology and cross sections have likely changed in the 9 years since this data was last collected.

The most accurate peak indirect discharge values would be calculated at or near peak stage, during a time when the channel is relatively ice-free and with current-year channel topographic cross-sections. Under ideal open channel conditions, peak discharge would coincide with peak stage. Discharge in the CRD during spring break up is typically ice affected, so these two events will not necessarily occur simultaneously. Graph 3.3 presents the UC and NUC method discharge results plotted versus time. The WSE recorded by the PTs at 15-minute intervals for the three MON1 locations are included as a reference. The difference in peak discharge between using the UC and NUC methods was less than 1%. Averaging the maximum values for both methods resulted in a peak discharge at MON1 of 497,000 cfs with corresponding WSE of 18.59, 17.58, and 17.47 feet BPMSL at MON1U, MON1C and MON1D, respectively. Peak stage and peak discharge were separated by approximately 6 hours. Peak stage occurred in the afternoon of June 3 and peak discharge occurred in the morning of June 3. Both were likely affected by the surge of water accompanying the upstream ice jam release. Conditions were not observed at MON1 on June 3; therefore, the amount of channel ice and ice floes during peak indirect discharge is unknown. On June 2, channel ice remained intact along the east bank and had cleared by June 4. A large amount of snow and ice was observed along the west bank.



Graph 3.3: 2013 MON1 WSE and Indirect Discharge Results versus Time

3.2.2 MONUMENT 9

MON9, positioned on the west bank at RM E16.8, is the first gaging station on the Colville East Channel downstream of MON1. It is used to monitor the HDD crossing of the Alpine Sales Pipeline and is in the downstream vicinity of the Colville River ice bridge crossing. MON9 is downstream of the Putu Channel, connecting the Nigliq and Colville East channels, and upstream of the Sakoonang Channel distributary which flows past Alpine facilities. MON9 has been monitored annually since 2005.

1) SPRING BREAKUP OBSERVATIONS

The leading edge passed MON9 sometime between the evening of May 29 and the morning of May 30. Stage was first measureable on the MON9 gages on May 30. The ice jam located 7 RM upstream of MON1 is estimated to have released on June 3. On June 3, recorded PT data at MON9 captured the surge of water accompanying the ice jam release. However, the PT at MON9D malfunctioned and did not accurately record measurements until June 4. As the surge of water moved through MON9, a peak WSE of 19.47 feet BPMSL was recorded at around 2:45 PM (Table 3.2 and Graph 3.4). On June 4, floodwaters were observed to have reached, but not overtopped the west bank of the channel. The east bank had extensive flooding, inundating the overbank areas and surrounding the HDD East gravel pad (Photo 3.13). The gravel pad was not overtopped. All intact channel ice was cleared from the Colville River at MON9 once the jam had passed, though some ice floes remained. The Colville East Channel at MON9 was free of ice by June 6.

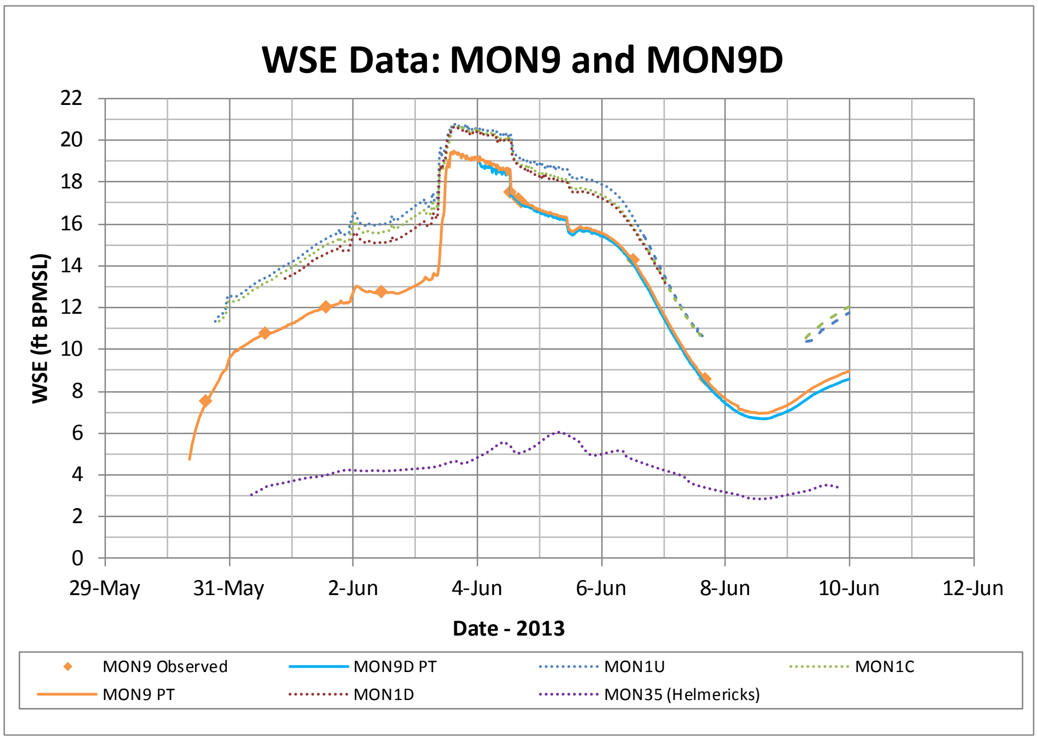
Photo 3.13: Extensive flooding near HDD East gravel pad; June 4, 2013

Table 3.2: 2013 Stage Data for MON9

Date and Time	WSE (feet BPMSL)		Observations
	MON9	MON9D	
5/30/13 3:30 PM	7.514	PT Malfunction	
5/30/13 12:00 PM	-		Leading edge 2 RM downstream of Tamayayak bifurcation
5/31/13 2:15 PM	10.73		
6/1/13 1:30 PM	12.02		
6/2/13 11:15 AM	12.72		The Colville East Channel ice remains intact
6/3/13 2:45 PM	19.52		
6/3/13 2:45 PM	19.47		Peak Stage at MON9 - based on PT data
6/4/13 12:45 AM	-	18.92	MON9D PT operational
6/4/13 1:00 PM	17.47	-	Significant flooding on the east bank of the Colville East Channel and at HDD East.
6/4/13 3:45 PM	17.18	-	
6/4/13 5:00 PM	17.05	-	
6/6/13 12:15 PM	14.23	-	Ice free conditions in the East Channel at MON9
6/7/13 3:45 PM	8.59	-	

Note:

1. Elevations based on MONUMENT 9 at 25.060 ft BPMSL, surveyed by LCMF in 2008
2. MON9D PT data prior to June 4, 2013 was erroneous and not considered in analysis



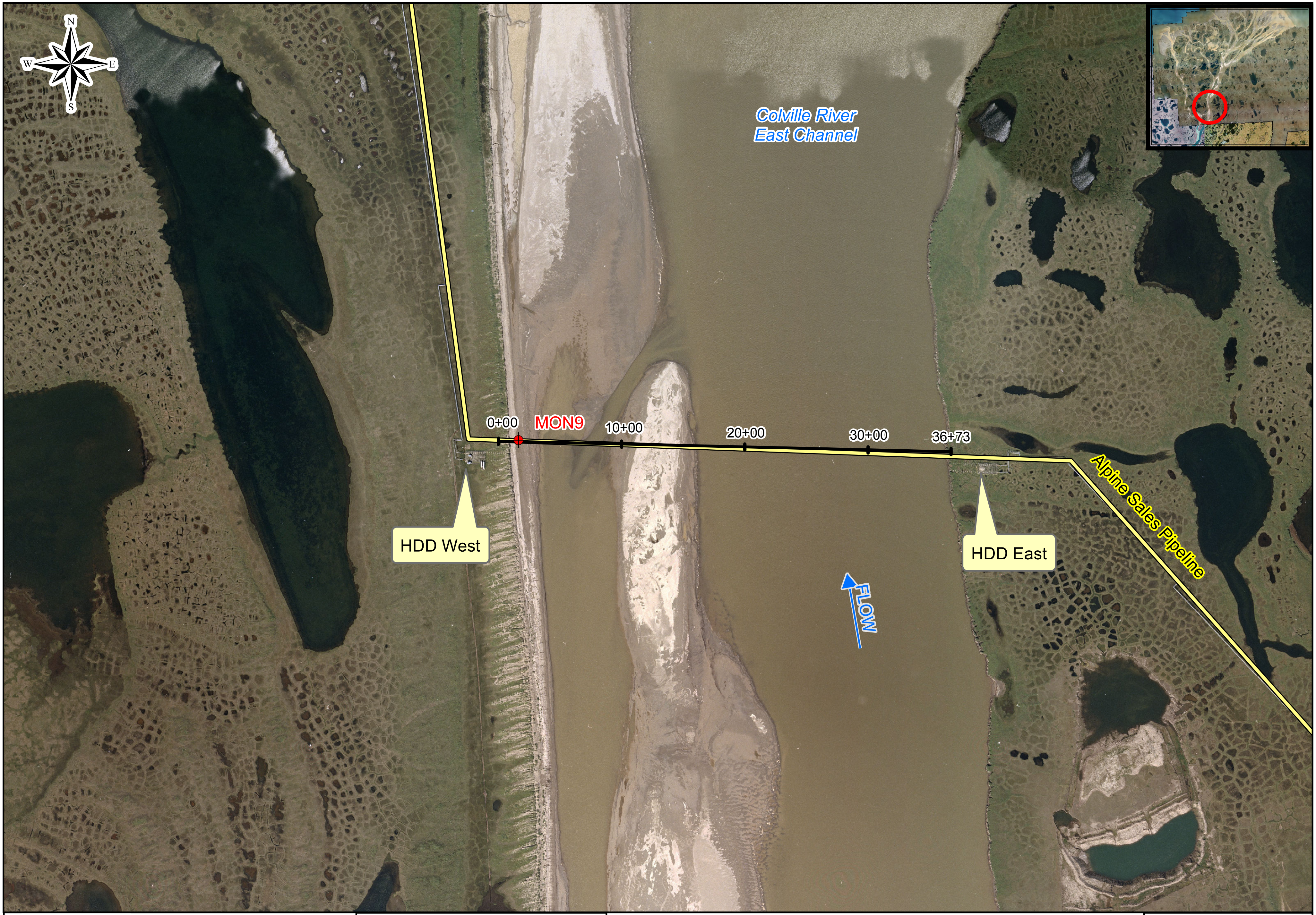
Graph 3.4: 2013 Stage Data for MON9 (including MON1 PT and MON35 Observed)

2) Indirect Discharge

The slope-area method was used to calculate the indirect discharge at MON9. Discharge was calculated using the energy grade-line slope as approximated by the water surface slope from MON9 to MON9D, WSE at MON9, and the 2009 LCMF topographic channel cross-sectional survey. Location and cross-section of the area is presented in Figure 3.4.

Indirect discharge calculations were performed assuming an ice-free channel and are considered to be a conservative estimate.

The actual peak discharge at MON9 likely occurred on June 3. The PT malfunction at MON9D prevented indirect discharge calculations prior to June 4. Actual peak discharge was likely influenced by the ice jam release above MON1. The calculated discharge on June 4 was approximately 320,000 cfs at MON9 with a corresponding WSE of 19.21 feet BPMSL at MON9 and 18.92 feet BPSML at MON9D. The rapid drop in stage at MON9 suggests the June 4 peak was the result of the nearby ice jam and subsequent backwater release.



ConocoPhillips Alaska	Feet 0 500 1,000		
Date: 11/01/2013	Project: 135141		
Drawn: BTG	File: Figure 3.4		
Checked: SME	Scale: 1 in = 1000 feet		

Legend

- Gage Location
- 2009 Cross Section Alignment
- Pipeline

Imagery Source: ConocoPhillips Alaska, 2004

Baker

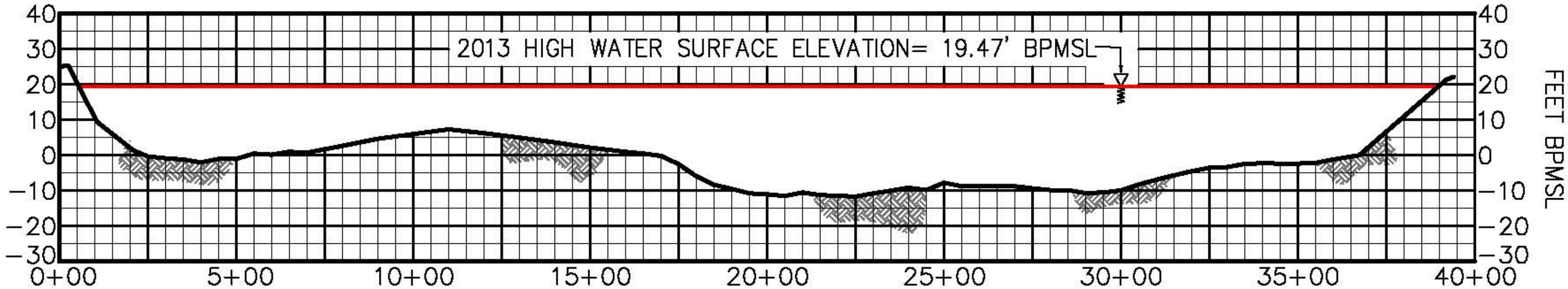
Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
Monument 9 / HDD
PLAN

FIGURE: 3.4

(SHEET 1 of 2)

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



1 COLVILLE EAST CHANNEL CROSS SECTION AT MONUMENT 9

250 0 250 500
HORIZONTAL SCALE IN FEET

25 0 25 50
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/17/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.4.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
COLVILLE EAST CHANNEL
MONUMENT 9 CROSS SECTION

FIGURE 3.4
(SHEET 2 OF 2)

3.2.3 MONUMENT 20

MON20 is positioned on the Nigliq Channel east bank at RM N12.2. This location is upstream (south) of all ADP and ASDP facilities and approximately 11 RM downstream from MON1C. MON20 gages have been monitored intermittently since 1998.

1) Spring Breakup Observations

The leading edge passed MON20 sometime between May 29 and May 30. Stage was first measureable on the MON20 gages on May 31. On June 4, an ice jam, located approximately 1 RM upstream of CD4, was observed in the Nigliq Channel near MON20. Extensive overbank flooding was observed in the vicinity of MON20 as floodwater was diverted around the ice jam (Photo 3.14).

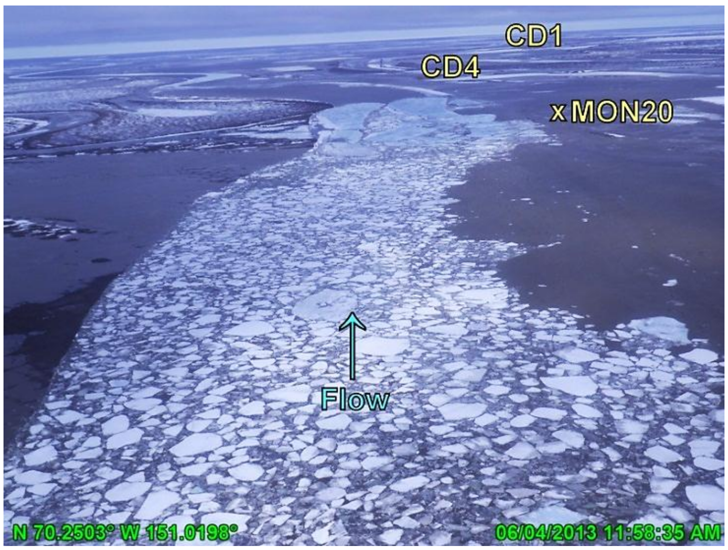


Photo 3.14: Ice jam and resulting backwater at near MON20, looking north; June 4, 2013

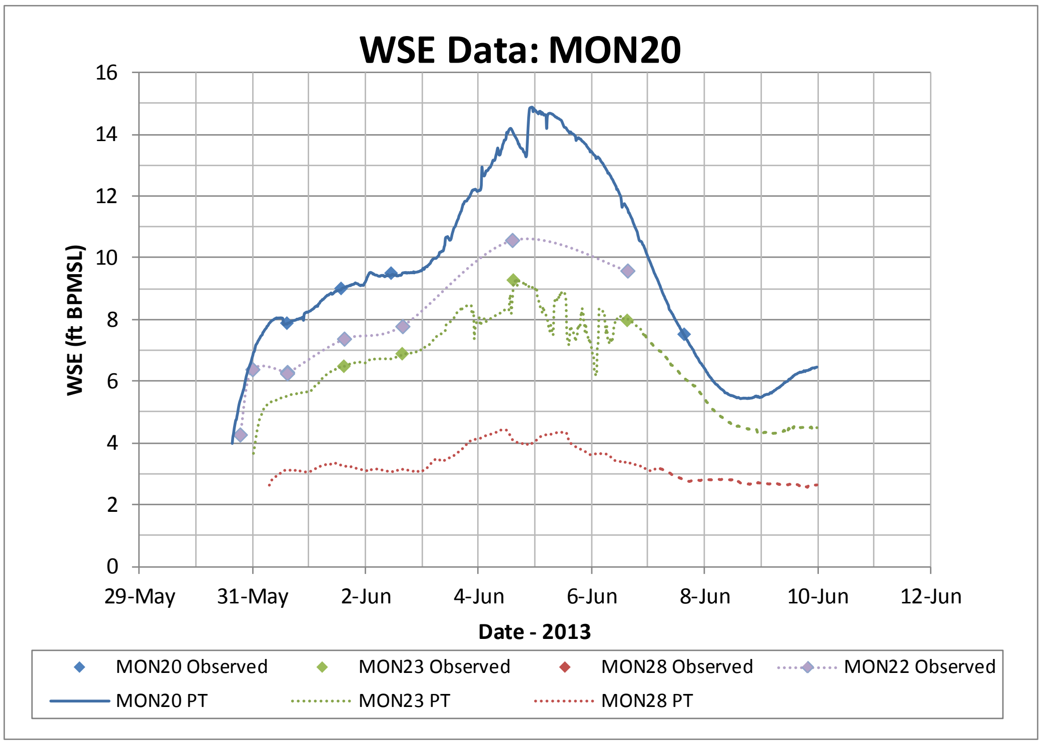
On the evening of June 4, recorded PT data at MON20 captured a sharp increase in water level as backwater continued to build up behind the ice jam. A peak WSE of 14.88 feet BPMSL was recorded around 10:45 PM on June 4 (Table 3.3 and Graph 3.5). By June 6, the ice jam had advanced approximately 2 RM downstream of MON20 and stage was rapidly decreasing. The Nigliq Channel at MON20 was free of ice by June 7.

Table 3.3: 2013 Stage Data for MON20

Date and Time	WSE (feet BPMSL)	Observations
	MON20	
5/30/13 7:20 PM	-	Leading edge in Nigliq Channel just north of CD2
5/31/13 2:45 PM	7.85	
6/1/13 1:45 PM	8.97	
6/2/13 11:30 AM	9.46	
6/4/13 10:45 PM	14.88	Peak Stage at MON20 - based on PT data. Ice jam in the Nigliq Channel, approximately 1 RM upstream of CD4 pad, caused overbank flow and backwater to build south of the CD4 pad
6/7/13 3:30 PM	7.48	Ice free conditions in the Nigliq Channel at MON20

Note:

1. Elevations based on PBM-P at 21.090 ft BPMSL, surveyed by LCMF in 2013



Graph 3.5: 2013 Stage Data for MON20 (including MON28/MON28 PT and MON22 Observed)

3.2.4 MONUMENT 22

MON22 is positioned on the Nigliq Channel west bank approximately midway between CD2 and CD4 at RM N8.8. MON22 gages have been monitored intermittently since 1998.

1) Spring Breakup Observations

Stage was first measured at MON22 as the leading edge passed on May 30. Overbank flow across the Nigliq Channel from MON22 was observed entering Nanuq Lake on May 31.

On June 4, an ice jam, located approximately 1 RM upstream of CD4, was observed in the Nigliq Channel. Floodwater was diverted around the upstream ice jam and extensive overbank flooding was observed around MON22 (Photo 3.15). No HWM was apparent on the MON22 gages. The observed peak WSE of 10.56 feet BPMSL was recorded on June 4 around 2:45 PM and is likely lower than the actual peak WSE (Table 3.4 and Graph 3.6). By June 6, stage had receded and grounded ice floes were observed on the bar near MON22 (Photo 3.16). Channel ice remained intact.

Photo 3.15: Extensive overbank flooding at MON22, looking north; June 4, 2013

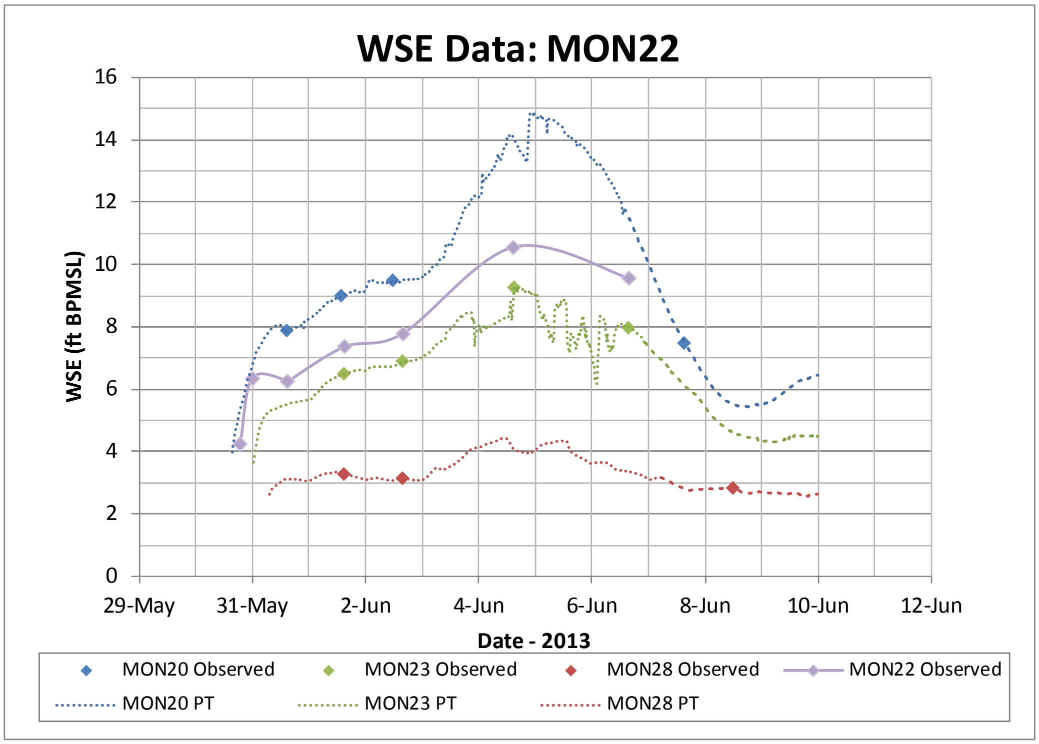
Photo 3.16: Intact channel ice in the Nigliq Channel with grounded ice floes on the bar near MON22; June 6, 2013

Table 3.4: 2013 Stage Data for MON22

Date and Time	WSE (feet BPMSL)	Observations
	MON22	
5/30/13 6:49 PM	4.23	
5/30/13 7:20 PM	-	Leading edge of Nigliq Channel just north of CD2
5/31/13 12:00 AM	6.36	Overbank flow entering Nanuq Lake
5/31/13 3:05 PM	6.27	
5/31/13 3:05 PM	6.25	
6/1/13 3:00 PM	7.36	
6/2/13 3:39 PM	7.78	
6/4/13 2:49 PM	10.56	Peak Stage at MON22 - based on observed WSE
6/6/13 3:25 PM	9.53	Channel ice intact

Note:

1. Elevations based on MONUMENT 22 at 10.030 ft BPMSL, surveyed by Baker in 2010
2. No HWM was captured at MON22



Graph 3.6: 2013 Stage Data for MON22 (including MON20 PT/Observed. MON23 PT/Observed, and MON28 PT/Observed)

3.2.5 MONUMENT 23

MON23 is positioned on the Nigliq Channel east bank at RM N6.9 downstream of CD2. MON23 gages have been monitored intermittently since 1998.

1) SPRING BREAKUP OBSERVATIONS

The leading edge in the Nigliq Channel passed MON23 on May 30. Stage was first measureable on the MON23 gages on June 1. On June 4, an ice jam, located approximately 1 RM upstream of CD4, was observed in the Nigliq Channel. Floodwater was diverted around the upstream ice jam and extensive overbank flooding was observed between MON23 and CD2 pad (Photo 3.17).

On June 4, recorded PT data at MON23 captured a peak WSE of 9.27 feet at 4:15 PM (Table 3.5 and Graph 3.7). On the afternoon of June 6, the channel ice in the Nigliq Channel near MON23 was still intact (Photo 3.18). On June 6, the ice jam advancing down the Nigliq Channel was near the Nigliagvik confluence. Graph 3.7 illustrates the fluctuating WSE at MON23, between the evening of June 3 and the morning of June 7, as water levels responded to the progression of the upstream Nigliq Channel ice jam. WSE began receding more steadily on June 7 after the ice jam had dispersed.

Photo 3.17: Extensive overbank flooding between MON23 and CD2 pad, looking southeast; June 4, 2013

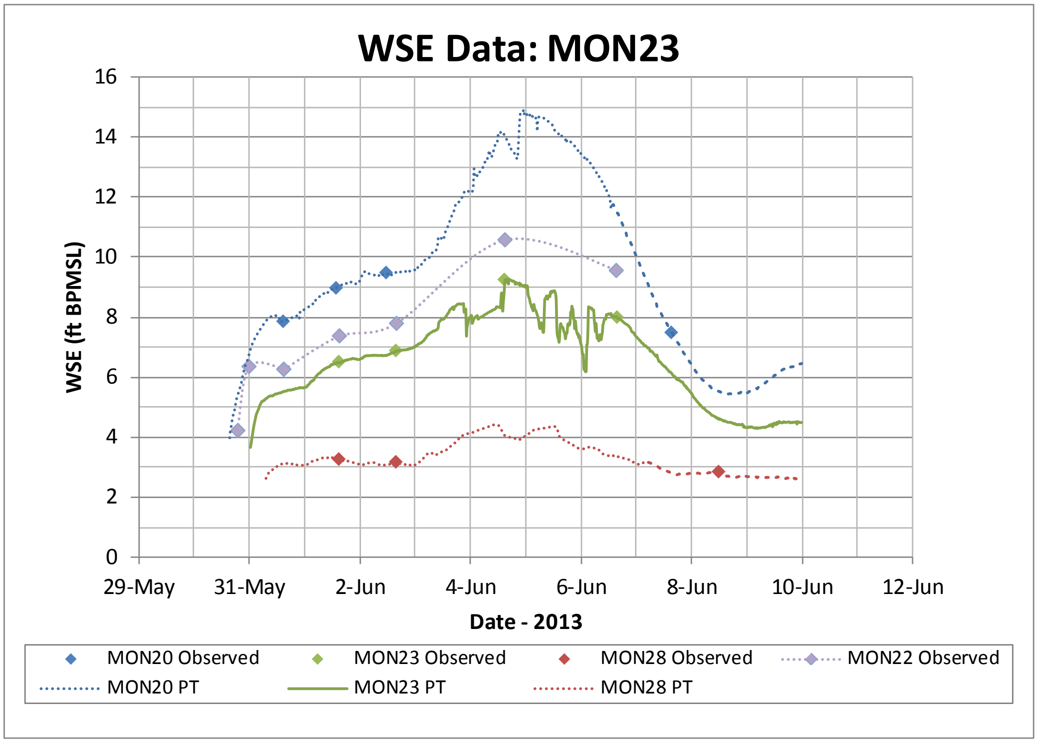
Photo 3.18: Intact channel ice in the Nigliq Channel at MON23, looking north; June 6, 2013

Table 3.5: 2013 Stage Data for MON23

Date and Time	WSE (feet BPMSL)	Observations
	MON23	
5/30/13 7:20 PM	-	Leading edge of Nigliq Channel just north of CD2
6/1/13 3:15 PM	6.48	
6/2/13 3:45 PM	6.87	
6/4/13 3:00 PM	9.24	Extensive overbank flooding near CD2
6/4/13 4:15 PM	9.27	Peak Stage at MON23 - based on PT data
6/6/13 3:45 PM	7.96	Channel ice remains intact

Note:

1. Elevations based on MONUMENT 23 at 9.546 ft BPMSL, surveyed by Baker in 2009



Graph 3.7: 2013 Stage Data for MON23 (including MON20 PT/Observed, MON28 PT/Observed, and MON22 Observed)

2) INDIRECT DISCHARGE

The slope-area method was used to calculate the indirect discharge at MON23. Discharge was calculated using the energy grade-line slope as approximated by the water surface slope from MON22 to MON23, WSE at MON23, and the 2005 LCMF topographic channel cross-section survey. A PT was not installed at MON22; therefore, WSEs were limited to observations.

The cross-section location and profile at MON23 are presented in Figure 3.5. The calculated indirect discharge on June 4 at MON23 was 88,000 cfs. The indirect discharge was determined using an observed WSE of 10.56 feet BPMSL at MON22 and a corresponding PT reading at MON23 of 8.98 feet BPMSL. A HWM at MON22 was not apparent and as a result the indirect discharge computed on June 4 is likely an underestimate of the actual peak discharge at MON23. As a comparison, the Nigliq Channel peak indirect discharge computed for the proposed CD5 Nigliq Channel was 110,000 cfs.

ConocoPhillips Alaska

Feet 0 500 1,000

Date:	11/01/2013	Project:	135141
Drawn:	BTG	File:	Figure 3.5
Checked:	SME	Scale:	1 in = 1000 feet

Legend

- Gage Location
- 2005 Cross Section Alignment
- Pipeline
- Existing Facility

Imagery Source: ConocoPhillips Alaska, 2004

Baker

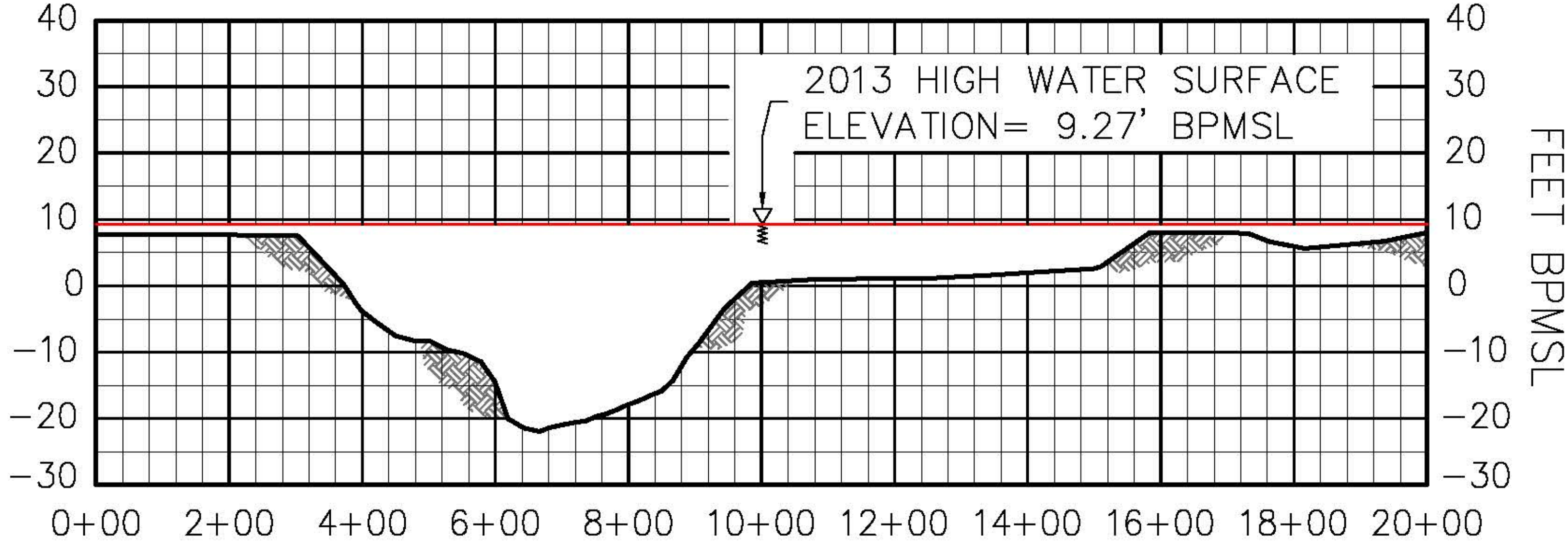
Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
MONUMENT 23
PLAN

FIGURE: 3.5

(SHEET 1 of 2)

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



1 NIGLIQ CHANNEL CROSS SECTION AT MONUMENT 23

200 0 200 400
HORIZONTAL SCALE IN FEET

20 0 20 40
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/17/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.5.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

Baker
Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
NIGLIQ CHANNEL
MONUMENT 23 CROSS SECTION

FIGURE 3.5
(SHEET 2 OF 2)

3.2.6 MONUMENT 28

MON28 is positioned on the Nigliq Channel east bank at RM N0.8. Nearest to Harrison Bay, MON28 is the northernmost gage location along the Nigliq Channel. MON28 is potentially affected by tidal events and ice jams. The ice jam effects at the outer delta near MON28 are likely less significant than near facilities as water level response is attenuated. MON28 has been intermittently monitored since 1999.

1) Spring Breakup Observations

The leading edge passed MON28 sometime between May 30 and May 31. Stage was first measurable on the MON28 gage on the morning of May 31. On June 2, extensive overflow onto sea ice was observed north of MON28 (Photo 3.19).

A peak stage of 4.43 feet BPMSL was recorded by the PT on June 4 around 11:00 AM (Table 3.6 and Graph 3.8). Minor fluctuations in stage, between June 3 and June 6 are evident in Graph 3.8 and are likely attributed to the progression of the upstream Nigliq Channel ice jam. On the afternoon of June 8, intact channel ice was still present in the Nigliq Channel near MON28 (Photo 3.20).

Photo 3.19: Extensive overflow onto bottom fast sea ice near MON28, looking northwest; June 2, 2013

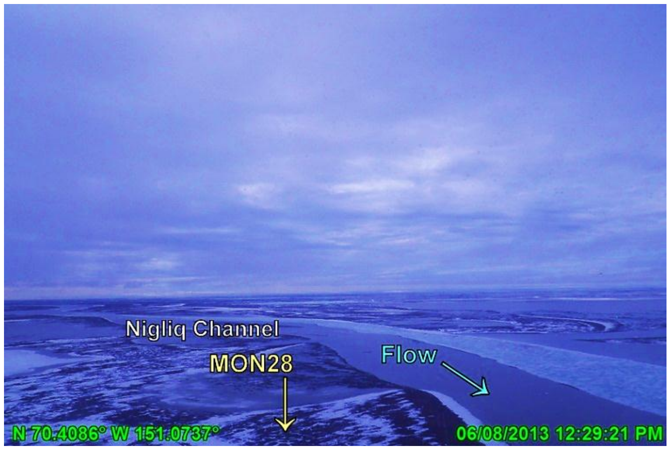


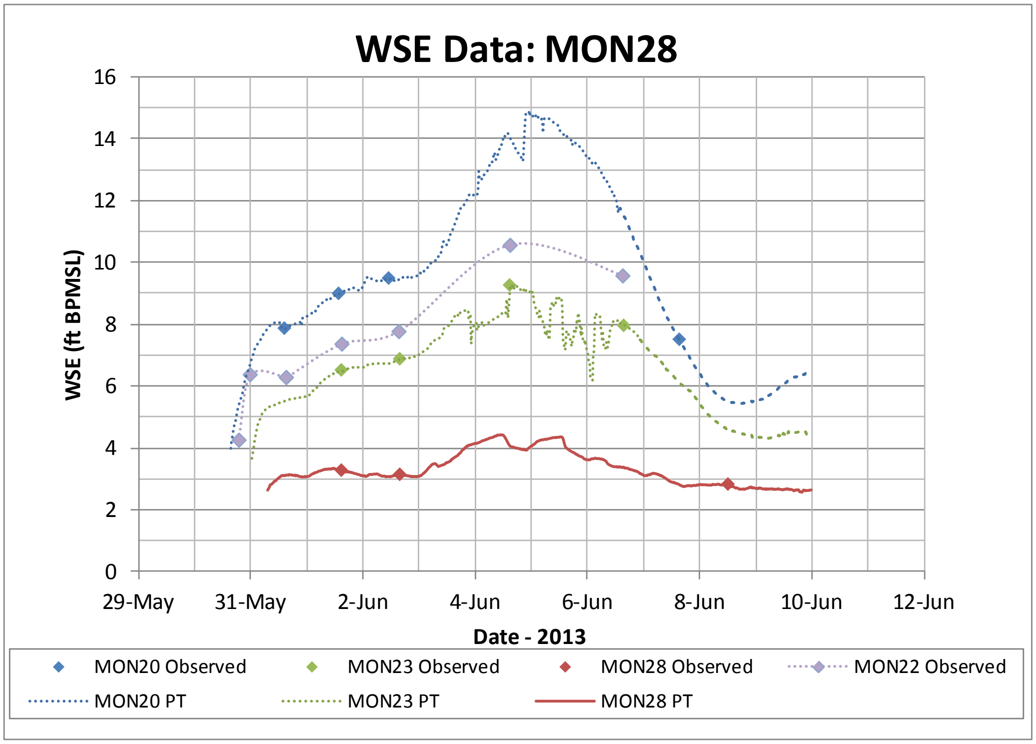
Photo 3.20: Intact channel ice in the Nigliq Channel south of MON28, looking south; June 8, 2013

Table 3.6: 2013 Stage Data for MON28

Date and Time	WSE (feet BPMSL) MON28	Observations
5/30/13 7:20 PM	-	Leading edge of Nigliq Channel just north of CD2
5/31/13 3:15 PM	3.12	
6/1/13 3:15 PM	3.25	
6/2/13 4:00 PM	3.14	Extensive overflow onto bottom fast sea ice
6/4/13 11:00 AM	4.43	Peak Stage at MON28 - based on PT data
6/8/13 12:15 PM	2.83	Intact channel ice in the Nigliq Channel

Note:

1. Elevations based on MONUMENT 28 at 3.650 ft BPMSL, surveyed by LCMF in 2002



Graph 3.8: 2013 Stage Data for MON28 (includes MON20 PT/Observed, MON23 PT/Observed, and MON22 Observed)

3.2.7 MONUMENT 35

MON35 is located at the Helmericks Homestead on Anachlik Island at RM E3.0. Located on the west bank, it is the farthest downstream gage site on the Colville East Channel and is near Harrison Bay. MON35 has been monitored intermittently since 1999. Stage data, observations, and photographs for this location are collected and provided by Jim Helmericks.

1) Spring Breakup Observations

Water levels reached MON 35 gage D in the early morning of May 31. On June 1 and 2, the channel ice remained intact. By June 3, low sections of Anachlik Island and the runway were under water (Photo 3.21 and Photo 3.22). Flood water entered the Helmericks family's drinking water lake on June 4 (Photo 3.23). On the morning of June 5, a peak WSE of 6.03 feet BPMSL was recorded around 8:30 AM (Table 3.7 and Graph 3.9).

Photo 3.21: Helmericks' flooded yard near the river edge; looking south; June 4, 2013

Photo 3.22: Water level up to foundation of lodge; looking west; June 5, 2013

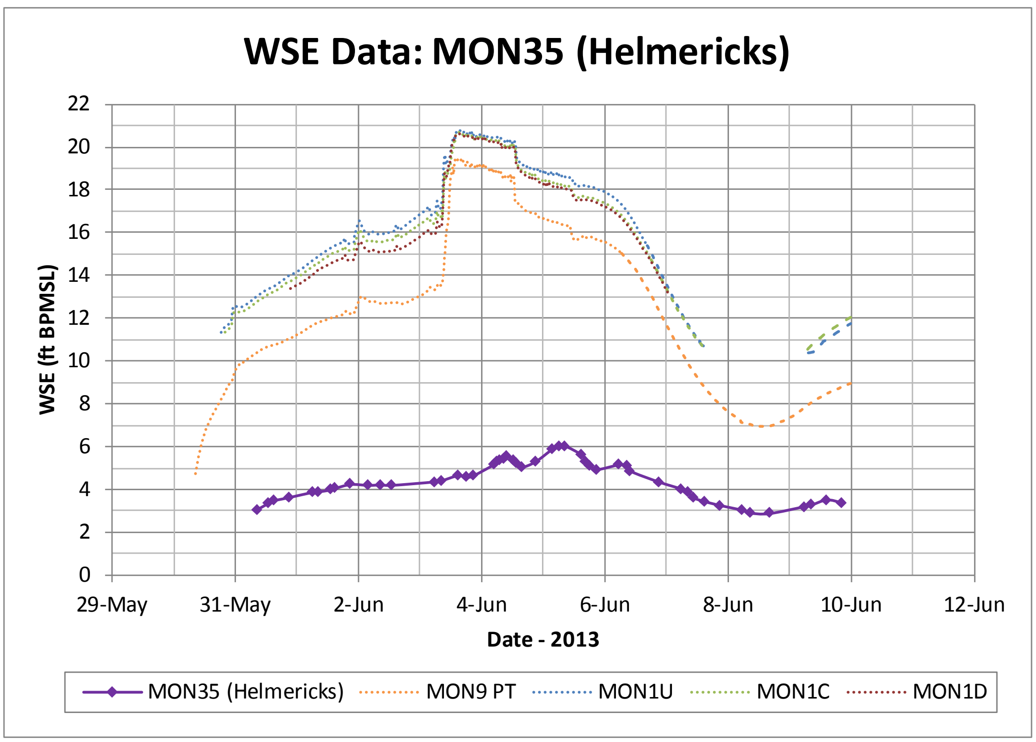
Photo 3.23: Tundra swans feeding at flooded Lake B8544, Helmericks family's drinking water source; June 6, 2013

Table 3.7: 2013 Stage Data for MON35

Date and Time	WSE (feet BPMSL) MON35 (Helmericks)	Observations
5/31/13 1:00 PM	3.35	Waterway opening between shore and ice cover (shore lead), no ice movement, ribbon ice is solid
6/1/13 6:00 AM	3.86	Shore lead, no ice movement
6/2/13 3:50 AM	4.19	Shore lead, no ice movement
6/3/13 3:00 PM	4.65	Low sections of Helmericks runway underwater
6/4/13 7:00 AM	5.38	Flooding into Helmericks water supply lake
6/4/13 9:00 PM	5.29	Some ice movement in the channel east of Helmericks.
6/5/13 3:30 AM	5.87	Water surrounds Helmericks house and infiltrates warehouses
6/5/13 8:30 AM	6.03	Peak Stage at MON35 - based on observed WSE
6/8/13 5:30 AM	3.03	No local ice movement
6/8/13 8:30 AM	2.90	Ice jam holding between Dune and Seal Island
6/9/13 8:30 AM	3.27	Channel ice begins to breakup and large floes move down the channel
6/10/13 8:30 AM	3.03	Ice jam still holding at the lower reaches of the Colville East Channel near the Helmericks Homestead
6/11/13 9:00 PM	2.53	Ice jam up river released. Large sections of broken ice moving.

Note:

1. Elevations based on MONUMENT 35 at 5.570 ft BPMSL, surveyed by Lounsbury in 1996



Graph 3.9: 2013 Stage Data for MON35 (including MON1 and MON9 PT)

According to Jim Helmericks, the water level reached the second highest stage in the past 20 years and the breakup flood stage had not surpassed 6 feet since 2000 (6.03 in 2013). After June 5, water levels began to drop. On June 9, the channel ice began to break up and large floes mixed with sticks and crushed ice began to flow through the channel (Photo 3.24). An ice jam holding in the lower reaches of the Colville East Channel near Helmericks Homestead released on the evening of June 11.

Photo 3.24: Ice movement in the channel; June 9, 2013

3.3 ALPINE AREA FACILITIES AND ROADS

Both permanent, direct-read staff gages and indirect-read staff gages are used to monitor water levels at Alpine facilities and lakes. Gages have been established at all pads adjacent to major water features to monitor the effects of breakup flood stage on facilities infrastructure. Additional gages have been established along the CD2 and CD4 access roads adjacent to drainage structures that have historically experienced the passage of breakup flood flow. These gages are paired, one on the upstream and one on the downstream side of the drainage structure, to determine stage differential.

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

To promote the passage of breakup flow, CPAI maintains the drainage structures to keep them free of ice and snow blockages that would otherwise accumulate during the winter months. Techniques include covering the culvert inlets and outlets during the winter and mechanically removing wind driven snow from the immediate upstream and downstream areas of all culverts and bridges in the spring prior to breakup flooding. Drainage structures are monitored for stage differential and functionality during spring breakup flooding. Spring breakup is typically the only event that produces sufficient quantities of water and increased stage which results in these structures passing flow.

Breakup progression at Alpine facilities is driven by conditions in the Sakoonang, Tamayayak, and Ulamnigiaq channels to the east, and the Nigliq Channel to the west. Floodwaters typically overtop the active channel banks of the Nigliq and Sakoonang channels and contribute to the annual recharge of many lakes and paleolake areas through overbank inundation or established drainages. Floodwater extents depend on WSE and ice and snow presence, which has a greater impact during lower stage conditions. Breakup at Alpine facilities generally begins with local melt, with floodwaters arriving one to two days after the leading edge reaches MON1.

3.3.1 GAGES AND DRAINAGE STRUCTURES

The 2013 water levels observed at facilities were the highest on record. The breakup floodwater began approaching facility gages from the Sakoonang Channel and the Nigliq Channel via Nanuq Lake and Tapped Lake on May 31. On June 1, floodwaters began to reach the CD2 road and the swale bridges as Nanuq Lake flooded into Lake M9524 (Photo 3.25). The Sakoonang Channel was flowing into Lake L9324 via the south paleolake (Photo 3.26).

Photo 3.25: Initial flow through the swale bridges, looking south; June 1, 2013

Photo 3.26: Sakoonang Channel flowing into Lake L9324, looking south; June 1, 2013

On June 2, stage was measurable on all gages around facilities as floodwaters continued to rise. On June 3, Sakoonang Channel floodwater was entering Lake L9323 via the south CD4 culvert battery and Lake M9525 via the north paleolake. Stage at facilities was rapidly increasing. The field crew notified CPAI management, Roads and Pads team lead, and the CD2 Drill Site Operator that water levels were approaching the 10-year flood mark at G3 on the south side of the swale bridges. On the morning of June 4, stage at facilities continued to increase as diverted floodwater from ice jams in the Colville East Channel and in the Nigliq Channel caused water levels to rise. WSE peaked at the CD2 road and pad gages on the afternoon of June 4 (Photo 3.27 and Photo 3.28). Peak stage along the CD2 road was 10.27 feet BPMSL at gage G3, 10.36 feet BPMSL at gage G6, and 10.61 feet BPMSL at gage G12. Peak stage at the CD2 pad was 9.77 feet BPMSL recorded at gage G8. Stage began receding around CD2 facilities on the evening of June 4 as water levels upstream and downstream of the CD2 road began equalizing. Stage continued to increase at the CD4 road and pad as backwater was diverted around the Nigliq Channel ice jam (Photo 3.29).

Photo 3.27: Floodwaters around CD2 road and pad near peak flood conditions, looking east; June 4, 2013

Photo 3.28: CD2 road during peak flood conditions, looking east; June 4, 2013

Photo 3.29: CD4 road and pad with accumulating backwater from the Nigliq Channel ice jam, looking east; June 4, 2013

On June 5, water levels peaked at the CD1 and CD4 pads. Peak stage at CD1 pad was 9.90 feet BPMSL, recorded at gage G1. Peak stage at CD4 pad was 14.20 feet BPMSL, recorded at gage G19. Gages at monitoring location G20, on Tapped Lake east of CD4 pad, were submerged and inaccessible during peak conditions. Peak stage along the southern end of the CD4 road was 14.15 feet BPMSL at gage G18. Peak stage at gage G15 and gage G16 is expected to have occurred on June 5; however HWMs were difficult to determine at either gage. Floodwaters remained high around facilities on June 6 as the Nigliq Channel ice jam slowly advanced downstream (Photo 3.30). On June 7 stage began quickly receding and by June 8, all gages around facilities were dry (Photo 3.31).

The CD3 pad and airstrip remained above flood level for the duration of the 2013 breakup flood event (Photo 3.32). Only local melt was observed at gage G11.

Stage-hydrographs for the Alpine Area Facilities road and pad gages are provided in Table 3.8 through Table 3.16 and Graph 3.10 through Graph 3.18, and are in numerical order.

Photo 3.30: Nigliq Channel floodwaters remained high around the CD2 pad, looking northeast; June 6, 2013

Photo 3.31: Recession of floodwater along the CD2 road, looking east; June 8, 2013

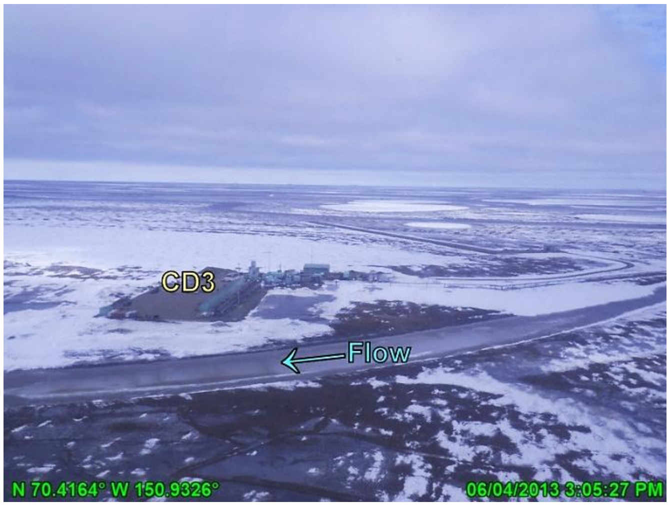


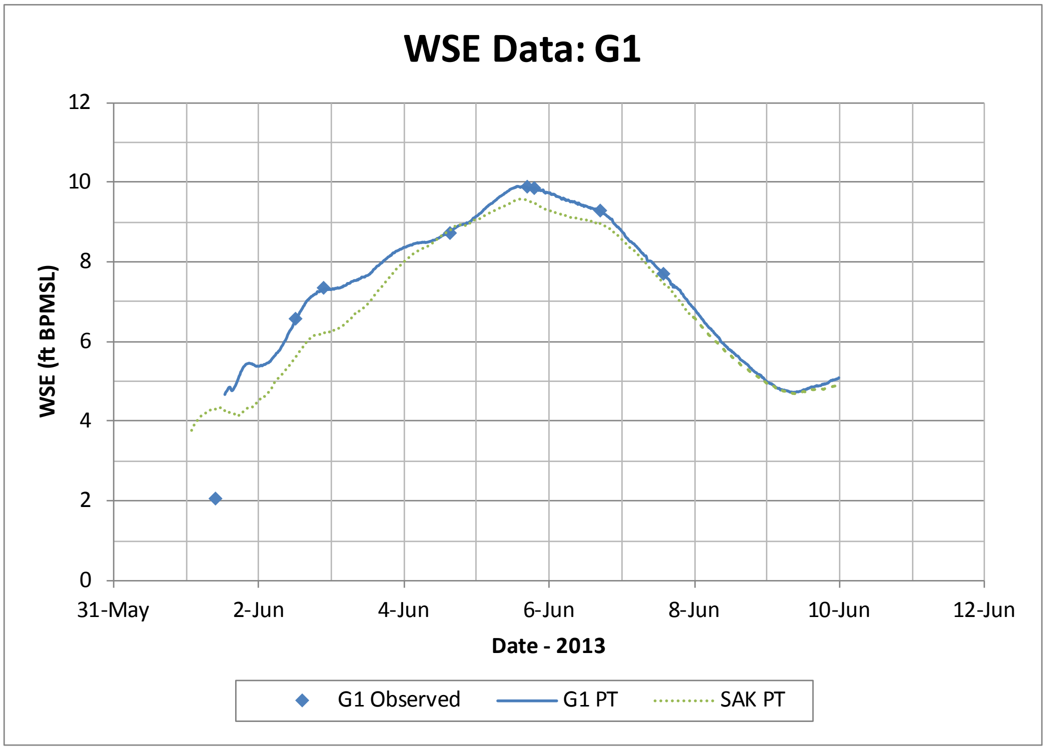
Photo 3.32: CD3 pad and airstrip near peak flood conditions, looking east; June 4, 2013

Table 3.8: 2013 Stage Data for G1

Date and Time	WSE (feet BPMSL)	Observations
	G1	
6/1/13 9:55 AM	2.04	
6/3/13 12:15 PM	6.54	
6/3/13 9:45 PM	7.33	
6/4/13 3:15 PM	8.72	
6/5/13 1:45 PM	9.90	Peak Stage at G1 - based on PT data
6/5/13 4:45 PM	9.86	
6/5/13 7:30 PM	9.85	
6/6/13 5:15 PM	9.26	
6/7/13 1:55 PM	7.67	

Notes:

1. Elevations based on MONUMENT 21 at 13.281 ft BPMSL, surveyed by LCMF in 2013
2. G1 is a permanent staff gage surveyed for elevation by LCMF in May 2013

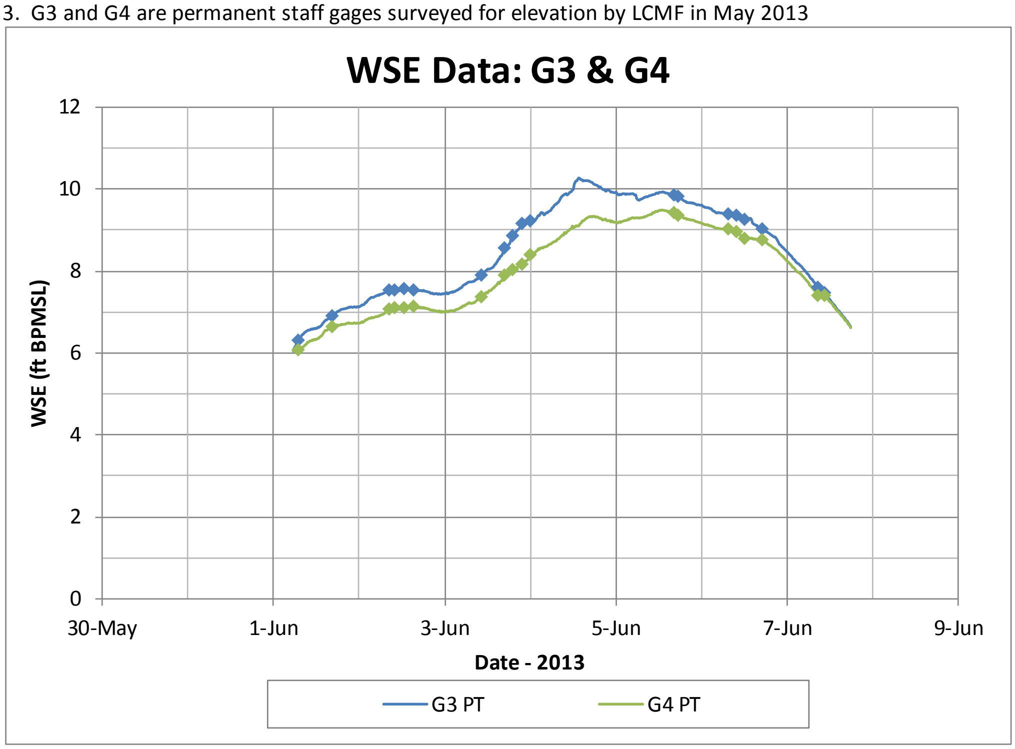


Graph 3.10: 2013 Stage Data for G1 (includes SAK PT)

Table 3.9: 2013 Stage Data for G3/G4

Date and Time	WSE (feet BPMSL)		Observations
	G3	G4	
6/1/13 7:00 AM	6.31	6.07	Both long and short swale bridges along CD2 road unobstructed and conveying flow. The culverts adjacent to the swale bridges are conveying flow.
6/1/13 4:30 PM	6.89	6.62	
6/2/13 8:30 AM	7.52	7.06	Some snow pack remains on the eastern side of the long swale bridge
6/2/13 3:30 PM	7.52	7.12	
6/3/13 10:15 AM	7.87	7.35	Field crew notified CPAI management, Roads and Pads team lead, and the CD2 Drill Site Operator that water levels were approaching 10-year flood mark at G3 on the south side of the swale bridges
6/3/13 9:45 PM	9.13	8.16	
6/4/13 12:15 AM	9.20	8.37	
6/4/13 1:30 PM	10.27	-	Peak Stage for G3 - based on PT data
6/5/13 12:45 PM	-	9.49	Peak Stage for G4 - based on PT data
6/6/13 12:15 PM	9.26	8.79	
6/7/13 10:30 AM	7.46	7.40	

Notes:
1. G3 elevations based on CD2-22S at 9.053 ft BPMSL, surveyed by LCMF in 2013
2. G4 elevations based on CD2-22N at 9.132 ft BPMSL, surveyed by LCMF in 2013
3. G3 and G4 are permanent staff gages surveyed for elevation by LCMF in May 2013



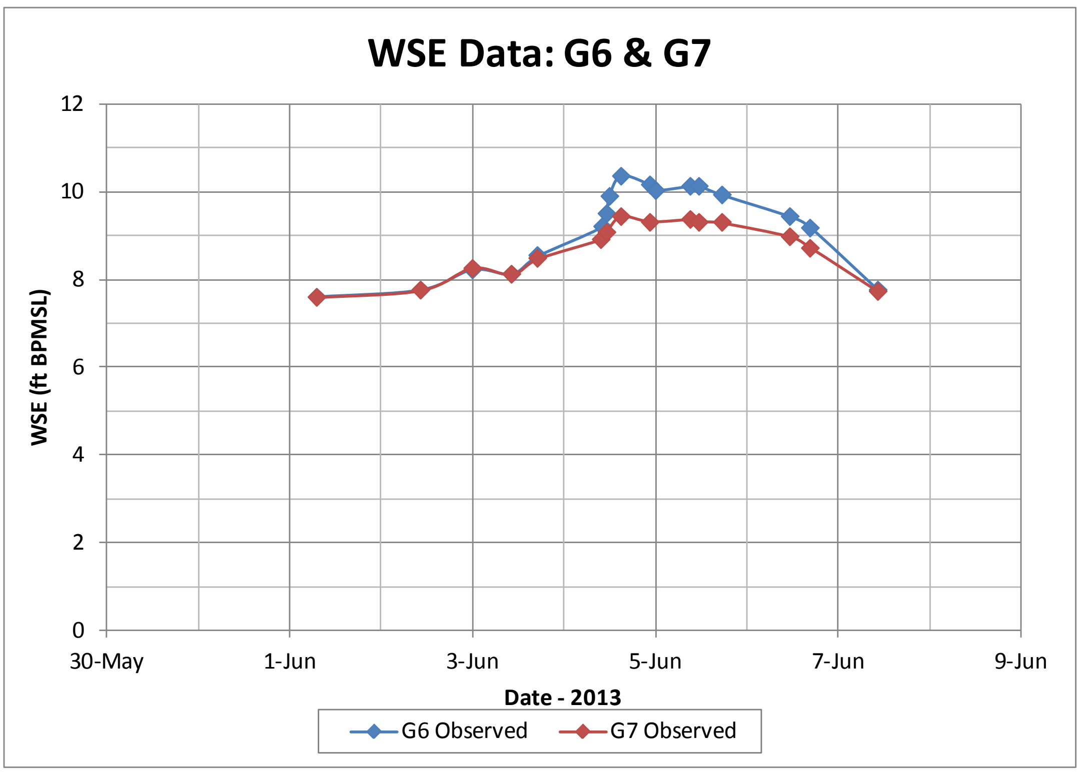
Graph 3.11: 2013 Stage Data for G3/G4

Table 3.10: 2013 Stage Data for G6/G7

Date and Time	WSE (feet BPMSL)		Observations
	G6	G7	
6/1/13 7:20 AM	7.60	7.59	
6/2/13 10:31 AM	7.76	7.75	
6/3/13 12:00 AM	8.22	8.26	
6/3/13 10:23 AM	8.12	8.11	
6/3/13 5:16 PM	8.53	8.47	
6/4/13 9:59 AM	9.19	8.92	
6/4/13 11:18 AM	9.50	9.09	
6/4/13 11:54 AM	9.88	-	
6/4/13 3:05 PM	10.36	9.44	Peak Stage for G6 and G7 - based on observed WSE
6/4/13 10:48 PM	10.14	9.32	
6/5/13 12:00 AM	10.02	-	
6/5/13 9:20 AM	10.12	9.37	
6/5/13 11:32 AM	10.12	9.32	
6/5/13 5:30 PM	9.92	9.29	
6/6/13 11:35 AM	9.42	8.97	
6/6/13 4:50 PM	9.17	8.72	
6/7/13 10:27 AM	7.76	7.73	

Notes:

1. Elevations based on MONUMENT 12 at 9.000 ft BPMSL, surveyed by UMIAQ in 2009
2. G6 and G7 are permanent staff gages surveyed for elevation by LCMF in May 2013



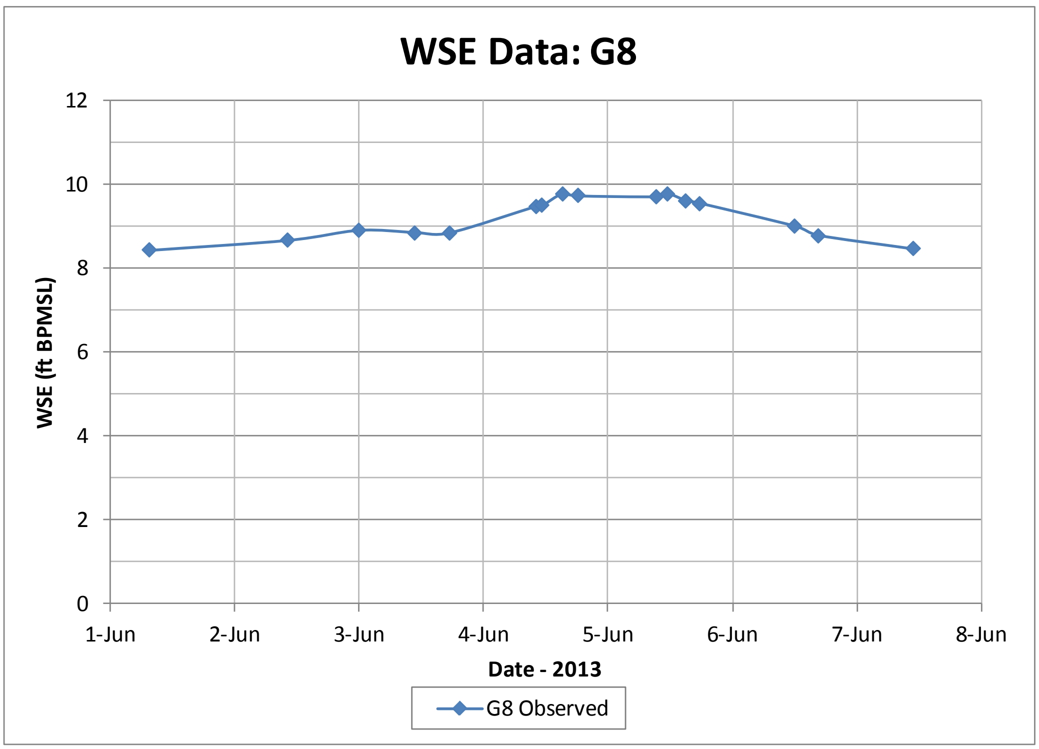
Graph 3.12: 2013 Stage Data for G6/G7

Table 3.11: 2013 Stage Data for G8

Date and Time	WSE (feet BPMSL)	Observations
	G8	
6/1/13 7:26 AM	8.42	
6/2/13 10:15 AM	8.66	
6/3/13 12:00 AM	8.90	
6/3/13 10:41 AM	8.85	
6/3/13 5:27 PM	8.84	
6/4/13 10:06 AM	9.47	
6/4/13 11:20 AM	9.49	
6/4/13 3:10 PM	9.77	Peak Stage at G8 - based on observed WSE
6/4/13 6:08 PM	9.72	
6/5/13 9:25 AM	9.70	
6/5/13 11:35 AM	9.77	
6/5/13 3:30 PM	9.61	
6/5/13 5:35 PM	9.55	
6/6/13 12:05 PM	9.00	
6/6/13 4:40 PM	8.78	
6/7/13 10:44 AM	8.46	

Note:

1. Elevations based on PBM-F at 17.855 ft BPMSL, surveyed by LCMF in 2013



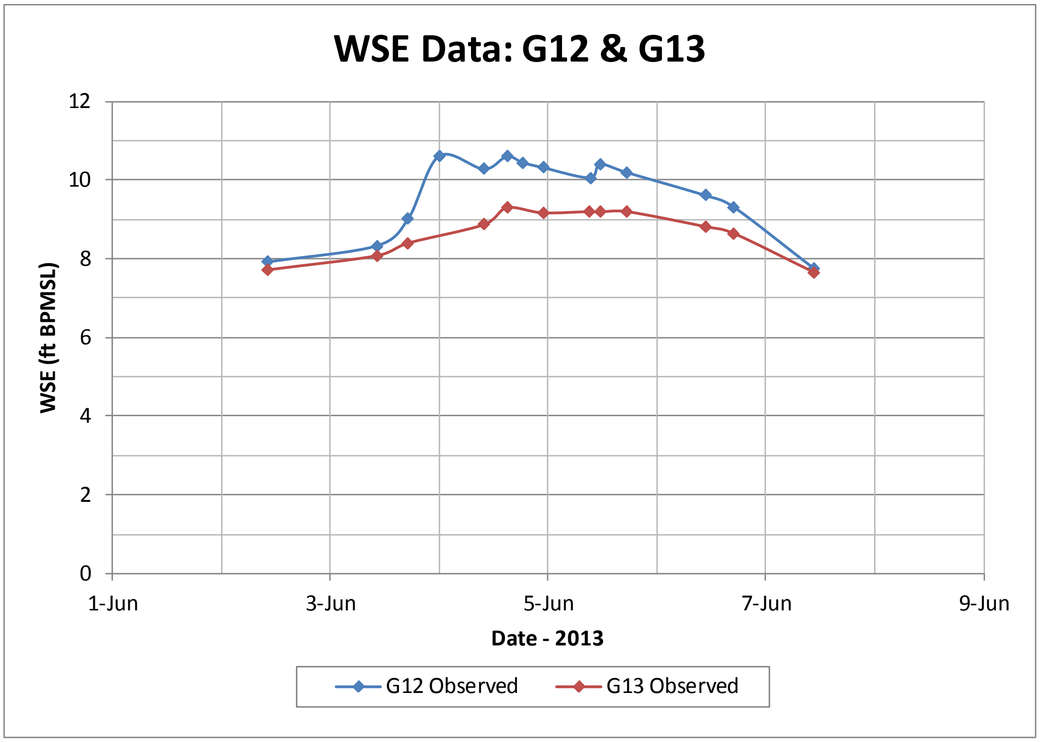
Graph 3.13: 2013 Stage Data for G8

Table 3.12: 2013 Stage Data for G12/G13

Date and Time	WSE (feet BPMSL)		Observations
	G12	G13	
6/1/13 12:00 PM	-	-	
6/2/13 10:11 AM	7.92	7.72	
6/3/13 10:15 AM	8.33	8.08	
6/3/13 5:11 PM	9.01	8.40	
6/4/13 12:00 AM	10.61	-	Peak Stage for G12 - based on observed WSE
6/4/13 9:54 AM	10.28	8.87	
6/4/13 2:55 PM	10.60	9.30	Peak Stage for G13 - based on observed WSE
6/4/13 6:31 PM	10.44	-	
6/4/13 10:51 PM	10.32	9.17	
6/5/13 9:15 AM	10.06	9.20	
6/5/13 11:26 AM	10.41	9.19	
6/5/13 5:27 PM	10.19	9.20	
6/6/13 10:40 AM	9.61	8.82	
6/6/13 4:52 PM	9.32	8.65	
6/7/13 10:25 AM	7.77	7.67	

Notes:

1. G12 elevations based on CD2-14S at 11.097 ft BPMSL, surveyed by LCMF in 2013
2. G13 elevations based on CD2-14N at 10.849 ft BPMSL, surveyed by LCMF in 2013



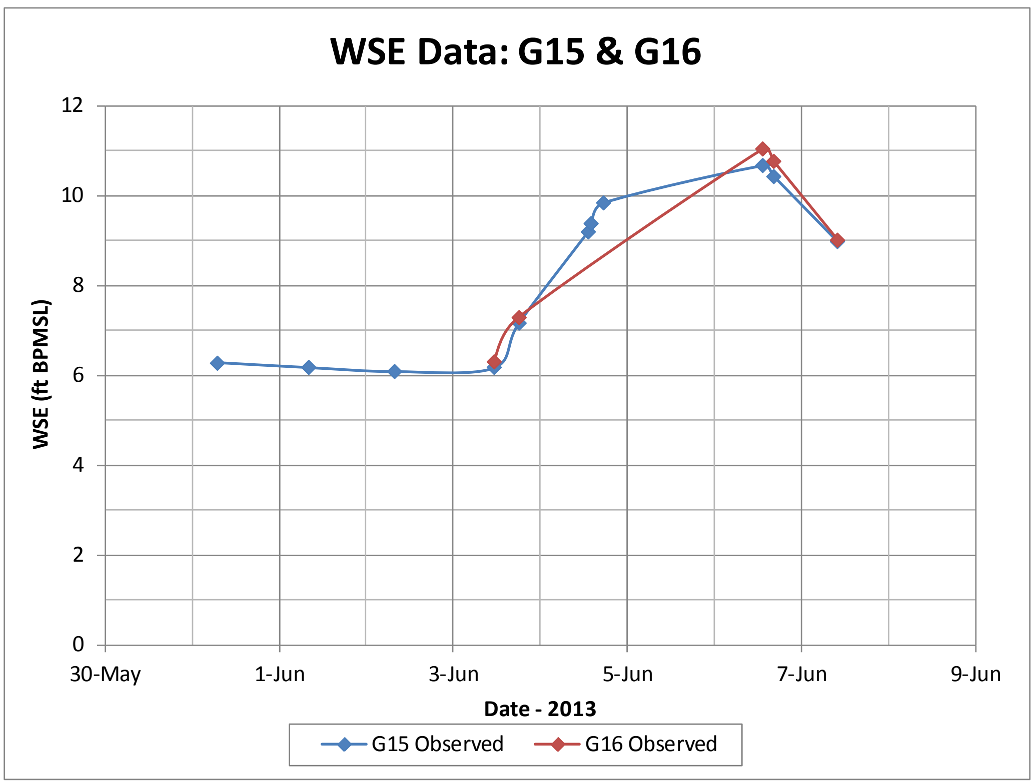
Graph 3.14: 2013 Stage Data for G12/G13

Table 3.13: 2013 Stage Data for G15/G16

Date and Time	WSE (feet BPMSL)		Observations
	G15	G16	
5/31/13 7:00 AM	6.28	-	
6/1/13 8:03 AM	6.17	-	
6/2/13 7:47 AM	6.08	-	
6/3/13 11:13 AM	6.16	6.29	
6/3/13 6:11 PM	7.17	7.29	
6/4/13 1:17 PM	9.20	-	
6/4/13 2:10 PM	9.38	-	
6/4/13 5:23 PM	9.83	-	
6/6/13 1:25 PM	10.66	11.04	Peak Stage for G15 and G16 - based on observed WSE
6/6/13 4:20 PM	10.43	10.77	
6/7/13 10:09 AM	8.96	9.00	

Notes:

1. G15 elevations based on CD4-20E at 7.828 ft BPMSL, surveyed by LCMF in 2013
2. G16 elevations based on CD4-20W at 6.762 ft BPMSL, surveyed by LCMF in 2013
3. HWMs not apparent at gage G15 or G16



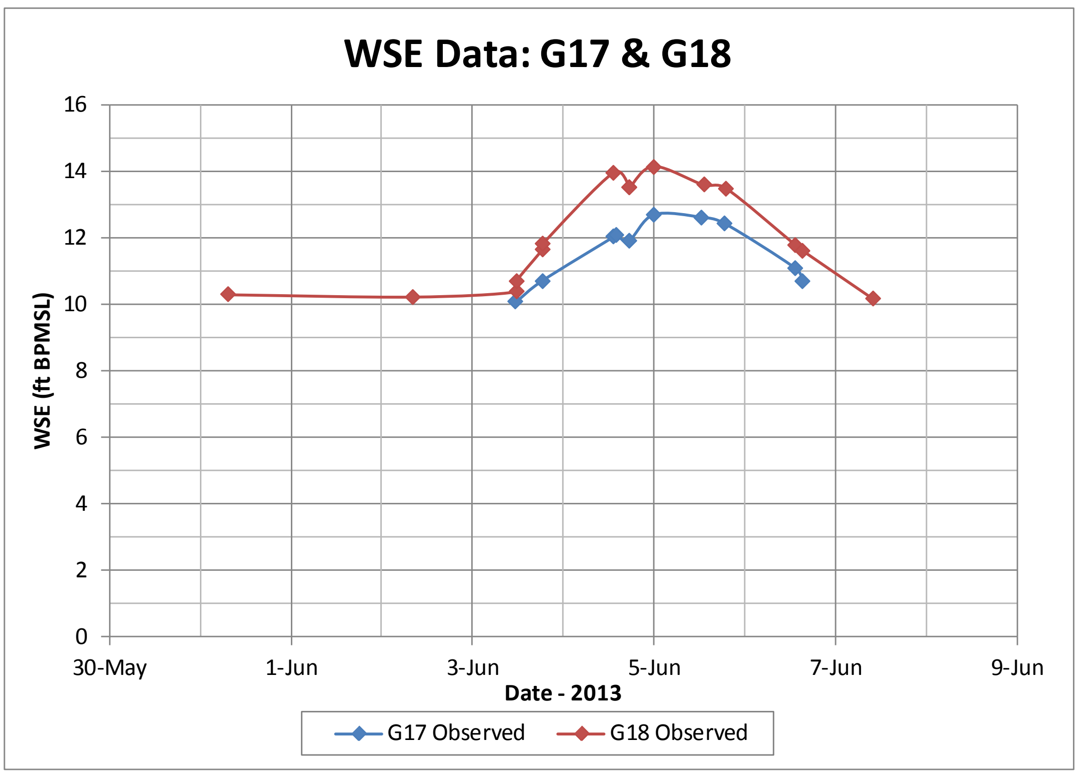
Graph 3.15: 2013 Stage Data for G15/G16

Table 3.14: 2013 Stage Data for G17/G18

Date and Time	WSE (feet BPMSL)		Observations
	G17	G18	
5/31/13 7:12 AM	-	10.29	
6/2/13 8:11 AM	-	10.22	
6/3/13 11:31 AM	10.07	10.37	
6/3/13 11:35 AM	-	10.69	
6/3/13 6:28 PM	10.71	11.64	
6/3/13 6:31 PM	-	11.81	
6/4/13 1:24 PM	12.03	13.97	
6/4/13 2:04 PM	12.09	-	
6/4/13 5:29 PM	11.92	13.53	
6/4/13 12:00 AM	-	14.02	
6/4/13 5:38 PM	-	13.52	
6/5/13 12:00 AM	12.70	14.15	Peak Stage at G17 and G18 - based on HWM
6/5/13 1:08 PM	12.62	13.59	
6/5/13 7:03 PM	12.43	13.49	
6/6/13 1:30 PM	11.08	11.77	
6/6/13 3:25 PM	10.70	11.60	
6/7/13 10:00 AM	-	10.16	

Notes:

1. G17 elevations based on CD4-29W at 12.566 ft BPMSL, surveyed by LCMF in 2013
2. G18 elevations based on CD4-28E at 12.886 ft BPMSL, surveyed by LCMF in 2013



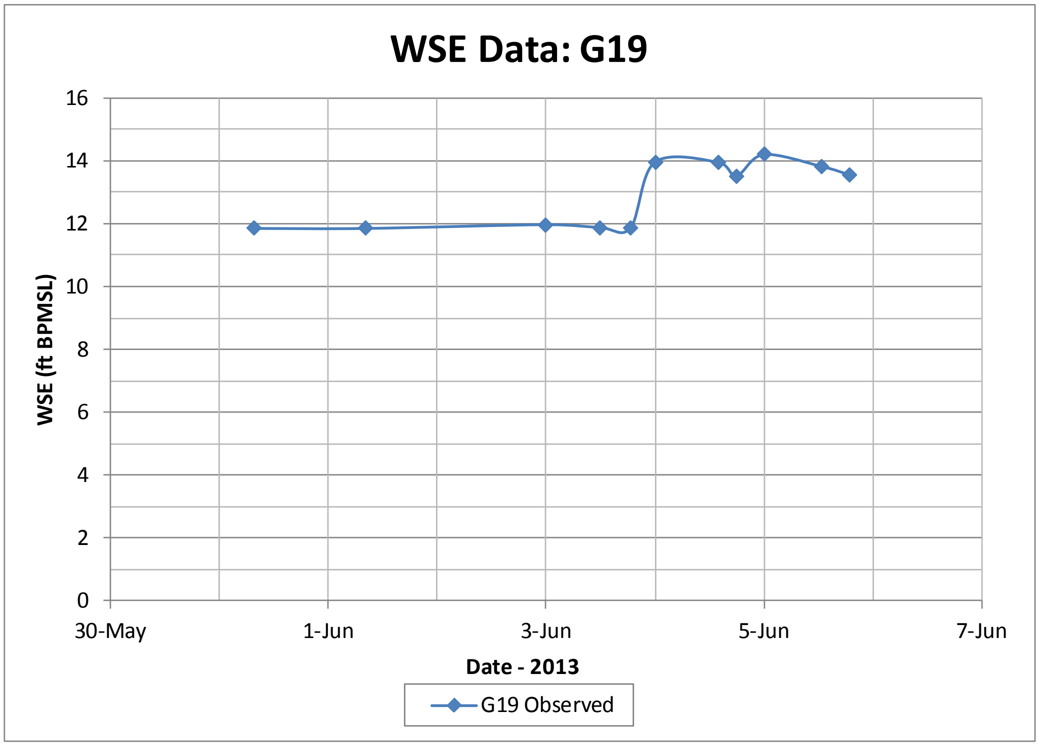
Graph 3.16: 2013 Stage Data for G17/G18

Table 3.15: 2013 Stage Data for G19

Date and Time	WSE (feet BPMSL)	Observations
	G19	
5/31/13 7:28 AM	11.85	Local melt
6/1/13 8:12 AM	11.85	
6/3/13 12:00 AM	11.97	
6/3/13 11:50 AM	11.88	
6/3/13 6:36 PM	11.87	
6/4/13 12:00 AM	13.96	
6/4/13 2:02 PM	13.95	
6/4/13 5:55 PM	13.51	
6/5/13 12:00 AM	14.20	Peak Stage at G19 - based on HWM
6/5/13 12:47 PM	13.82	
6/5/13 6:50 PM	13.56	

Note:

1. Elevations based on PBM-P at 21.109 ft BPMSL, surveyed by LCMF in 2013



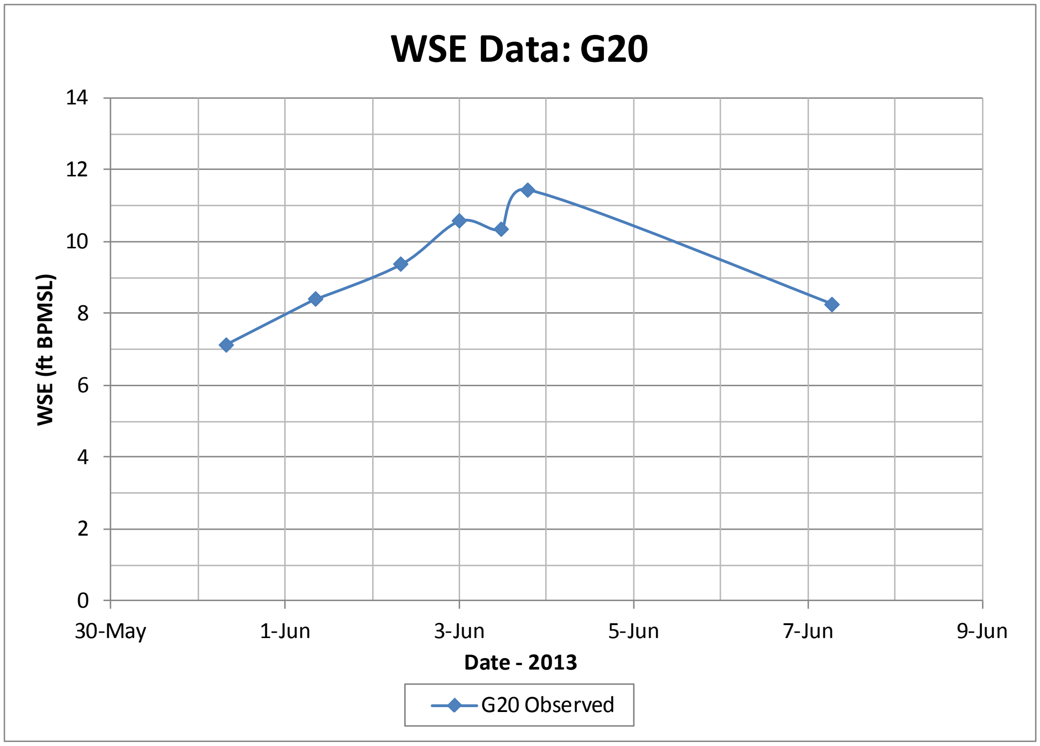
Graph 3.17: 2013 Stage Data for G19

Table 3.16: 2013 Stage Data for G20

Date and Time	WSE (feet BPMSL)	Observations
	G20	
5/31/13 7:40 AM	7.12	
6/1/13 8:15 AM	8.39	
6/2/13 8:02 AM	9.36	
6/3/13 12:00 AM	10.56	
6/3/13 11:42 AM	10.34	
6/3/13 6:47 PM	11.44	Peak Stage at G20 - based on observed WSE
6/7/13 6:41 AM	8.26	

Note:

1. Elevations based on PBM-P at 21.109 ft BPMSL, surveyed by LCMF in 2013
2. HWM not apparent at gage G20



Graph 3.18: 2013 Stage Data for G20

3.3.2 ALPINE CULVERT DISCHARGE

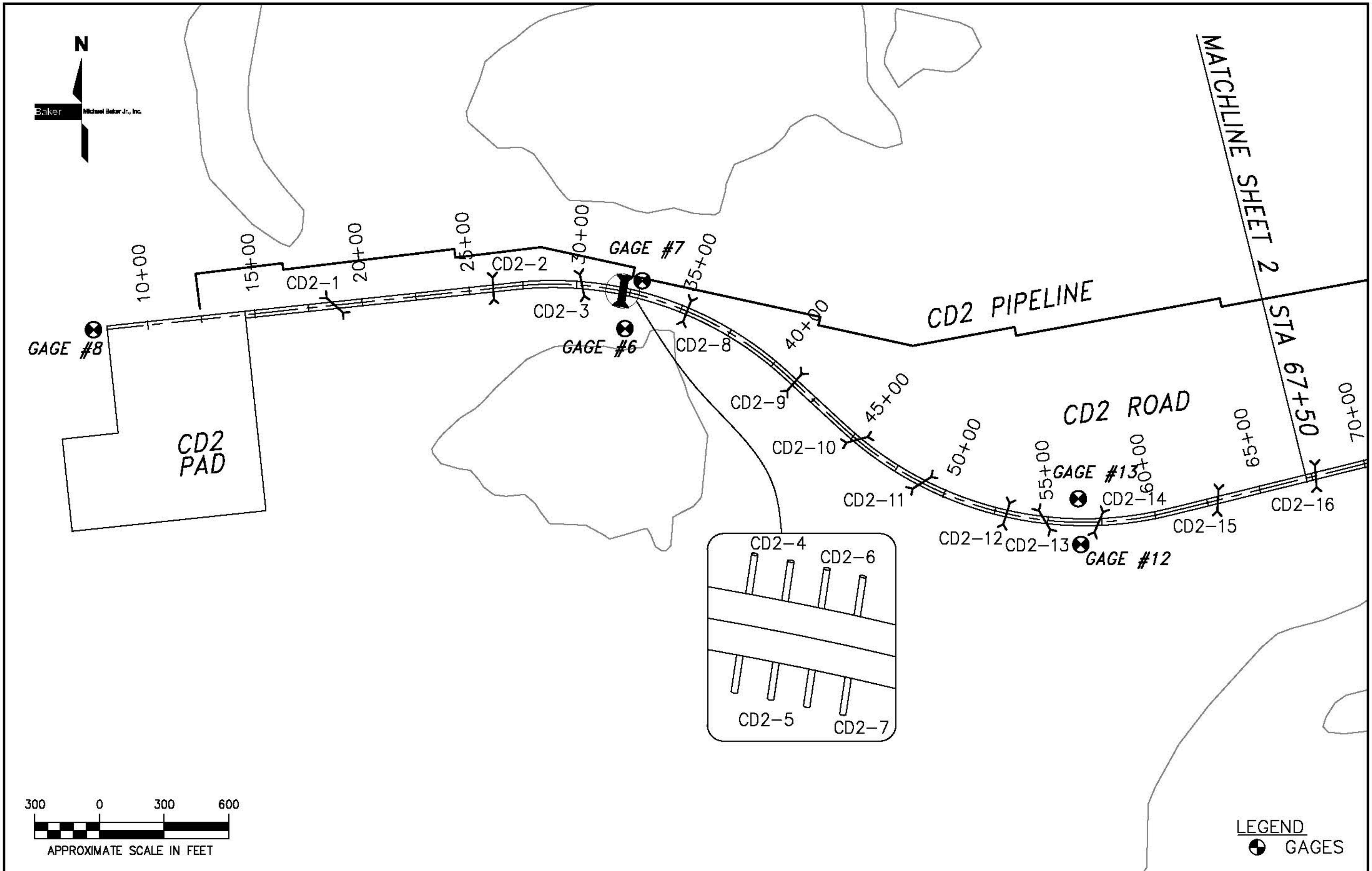
Peak stage, head differential, and peak flow were measured at the culverts along the CD2 and CD4 access roads. The peak velocities were calculated using indirect methods to determine the effectiveness of the drainage structures and to comply with monitoring requirements. Direct discharge during peak stage was also computed from velocity and depth measurements taken at accessible culverts.

Both observed WSE data and measured culvert dimensions are used to perform indirect culvert discharge calculations for a variety of conditions during the course of breakup. The CD2 and CD4 culvert invert elevations were surveyed by LCMF in May 2013. Culvert length and diameter were obtained using as-built surveys performed by LCMF in 2002 and 2005. Figure 3.6 illustrates the locations of the Alpine facilities drainage structures.

In September 2008, changes were made to 6 of the CMPs; CD2-9 through CD2-14. These culverts were deformed because of road prism loading. The CMPs were retrofitted by inserting circular smooth steel sleeves anchored at each end. Forty-eight-inch-diameter sleeves were installed in the five, 60-inch diameter CMPs, and a 60-inch-diameter sleeve was inserted into the 72-inch diameter CMP. The sleeves reduce some friction losses in the culvert, but there is smaller diameter available for conveyance of flow. Also, the smooth sleeves are centered in the CMP and do not extend the full length.

Flow through the CD2 road culverts first occurred on June 1. Culvert covers were removed prior to arrival of spring melt water. Each culvert battery was cleared of snow to better facilitate passage of floodwater. By June 2, most CD2 road culverts were passing water. Calculated peak discharge and velocity through the CD2 culverts occurred in the afternoon of June 4 coinciding with peak WSE at gages along the south side of the CD2 road. By June 7, water had stopped flowing through the CD2 culverts.

Flow through the CD4 road culverts first occurred on June 3. Culvert covers were removed prior to arrival of spring melt water. Each culvert battery was cleared of snow to better facilitate passage of floodwater. Calculated peak discharge and velocity through the CD4 culverts occurred between June 4 and June 6. Equalizing of fluctuating water levels around the CD4 road caused peak conditions at CD4 culverts to occur on different days. Floodwaters did not reach culverts CD4-11 through CD4-14 and CD4-33. Flow through the CD4 culverts was estimated to have stopped after June 7.



ConocoPhillips Alaska, Inc.

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

DATE:	10/21/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.6.DWG
CHECKED:	SME	SCALE:	AS SHOWN

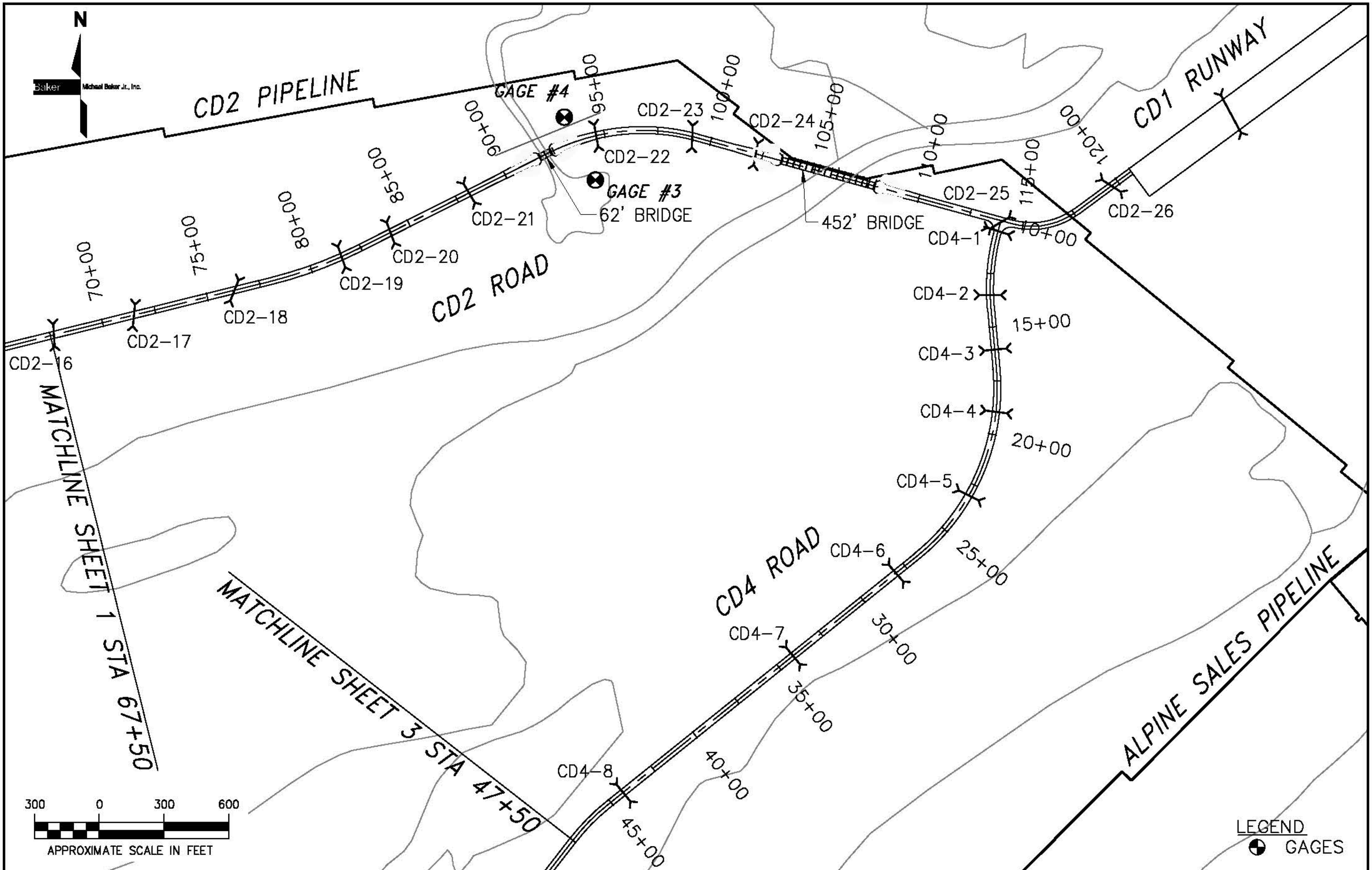
2013 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 3.6

(SHEET 1 OF 6)



ConocoPhillips
Alaska, Inc.

DATE:	10/21/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.6.DWG
CHECKED:	SME	SCALE:	AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

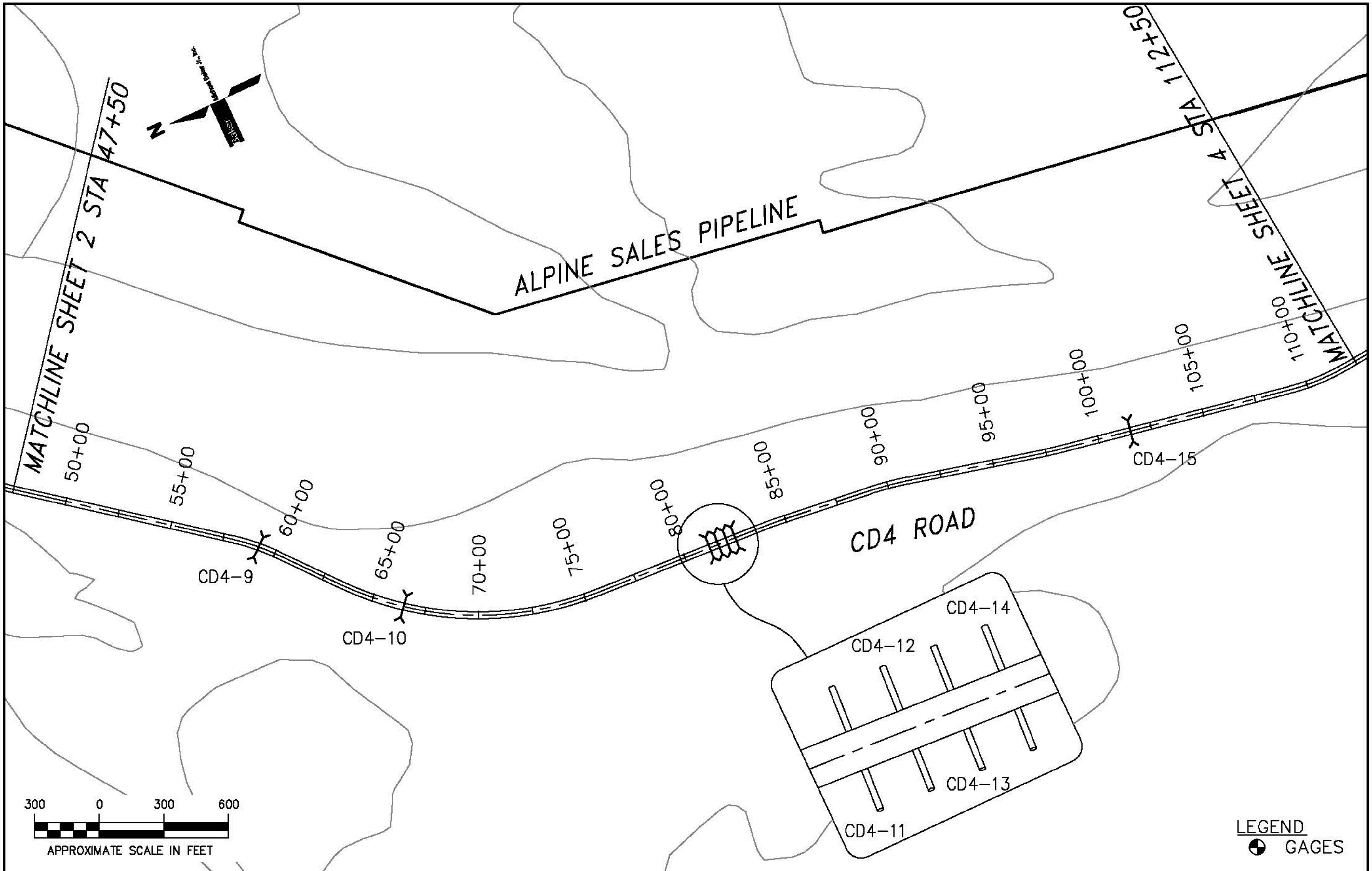
2013 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 3.6

(SHEET 2 OF 6)



ConocoPhillips
Alaska, Inc.

DATE:	10/21/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.6.DWG
CHECKED:	SME	SCALE:	AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

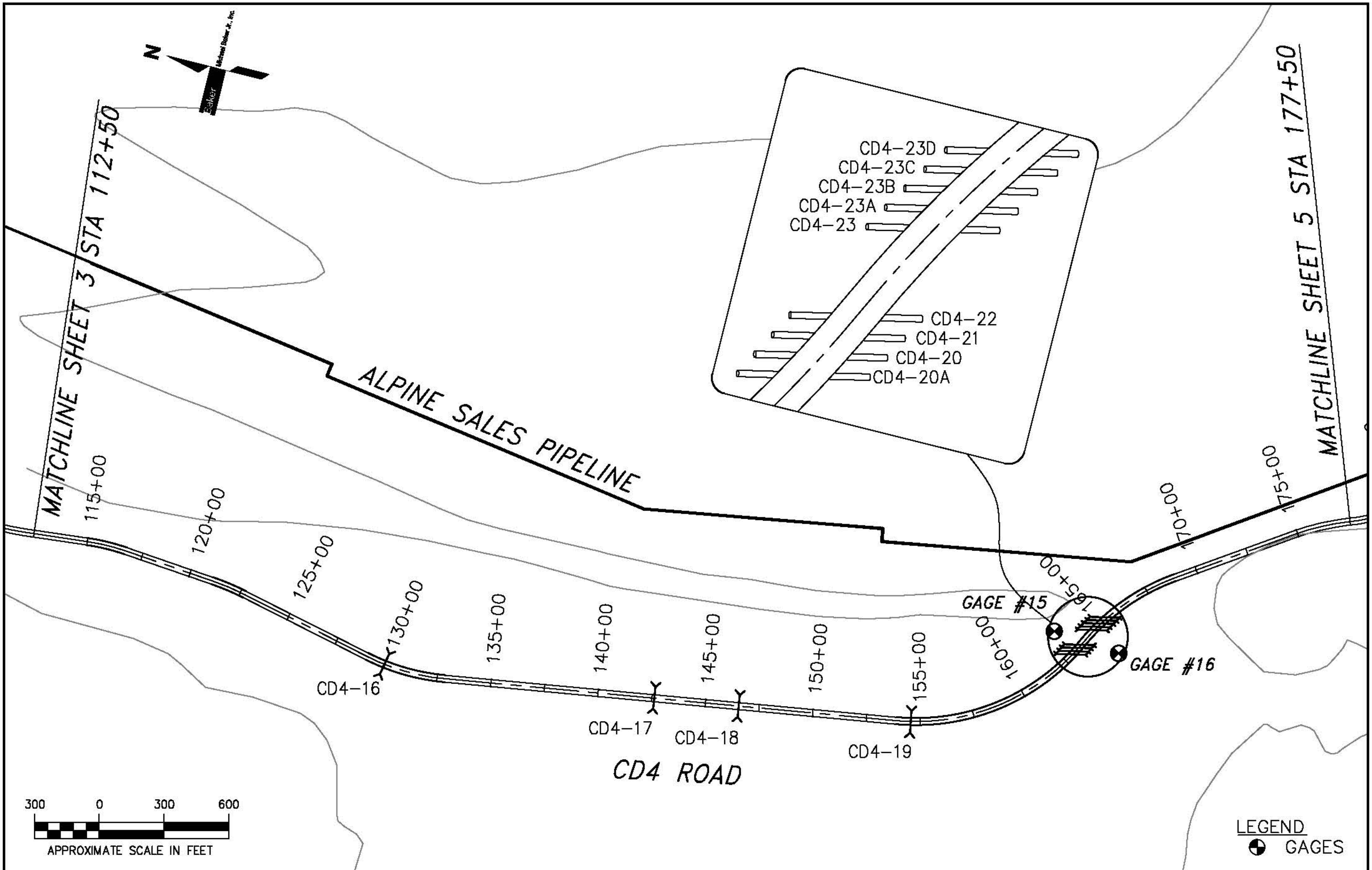
2013 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 3.6

(SHEET 3 OF 6)



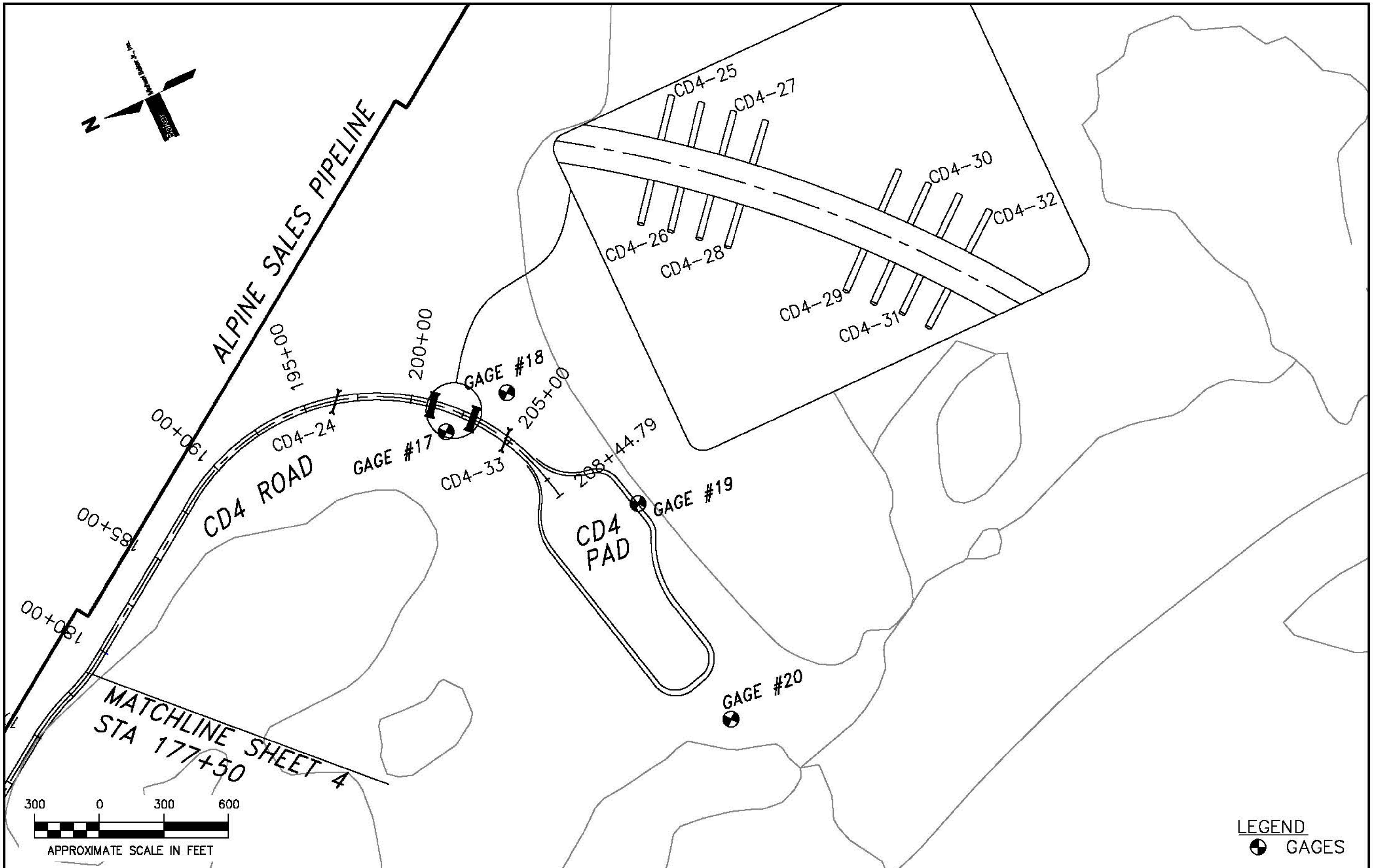
ConocoPhillips Alaska, Inc.

DATE: 10/21/2013	PROJECT: 135141
DRAWN: MNU	FILE: FIGURE 3.6.DWG
CHECKED: SME	SCALE: AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 3.6
(SHEET 4 OF 6)

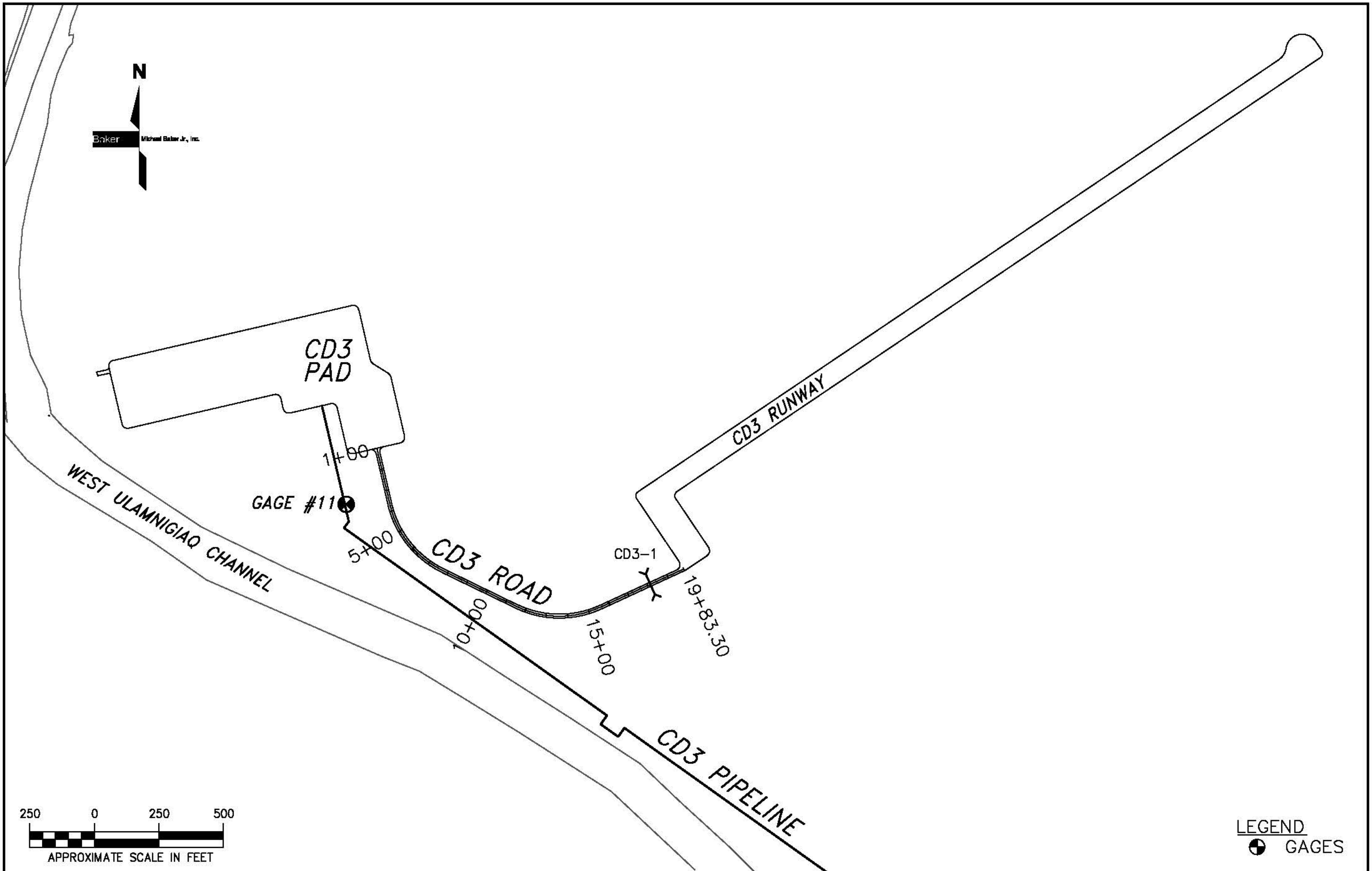


ConocoPhillips Alaska, Inc.

DATE: 10/21/2013	PROJECT: 135141		
DRAWN: MNU	FILE: FIGURE 3.6.DWG		
CHECKED: SME	SCALE: AS SHOWN		

Baker
Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 3.6
(SHEET 5 OF 6)



ConocoPhillips Alaska, Inc.

DATE:	10/21/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.6.DWG
CHECKED:	SME	SCALE:	AS SHOWN

Baker
Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAK-UP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 3.6

(SHEET 6 OF 6)

1) Direct Discharge and Velocity

On June 6, water depth and velocity measurements were obtained at all accessible road culverts passing flow to calibrate indirect culvert calculations. Velocity measurements were taken at the downstream side of the culvert. A Price AA meter and graduated USGS wading rod were used to measure a single point velocity, typically at six-tenths of the culvert's total water depth. This velocity was used as a representative average cross sectional velocity in the culvert.

Conditions observed during measurements at culverts close to the time of peak stage represent conditions observed at neighboring road gages. The measured velocities ranged from zero, where the culvert was free of blockages, and water levels were below the inverts, to 5.5 fps.

Based on direct depth and velocity measurements, the total discharge, flowing south to north, through CD2 culverts was 565 cfs, ranging from zero cfs to 52 cfs in individual culverts. The outlet of culverts CD2-4 through CD2-8, CD2-12, CD2-23, and CD2-24 were submerged and did not provide safe access to collect velocity measurements. The total direct discharge measured through CD4 culverts was 281 cfs, with flows through culverts CD4-7 through CD4-10, east to west, and flows through CD4-24 through CD4-32, west to east. The CD4-20A through CD4-23D culvert outlets were submerged and did not provide safe access to collect velocity measurements. Table 3.17 and Table 3.18 present the direct discharge and velocity summaries.

Table 3.17: CD2 Road Culvert Direct Velocity and Discharge

Culvert	Date & Time	Depth (ft)	Area (ft^2)	Measured Velocity (ft/s)	Direct Discharge (cfs)
CD2-1	6/6/13 11:45	2.6	8.6	5.0	43.4
CD2-2	6/6/13 11:40	2.6	8.6	4.8	41.5
CD2-3	6/6/13 11:35	3.3	11.1	4.7	52.1
CD2-4[1]	6/6/13 11:30	-	-	-	-
CD2-5[1]	6/6/13 11:25	-	-	-	-
CD2-6[1]	6/6/13 11:20	-	-	-	-
CD2-7[1]	6/6/13 11:15	-	-	-	-
CD2-8[1]	6/6/13 11:10	-	-	-	-
CD2-9	6/6/13 11:05	2.3	7.5	5.5	41.3
CD2-10	6/6/13 11:00	2.3	8.8	5.1	45.3
CD2-11	6/6/13 10:55	2.6	8.6	4.4	38.2
CD2-12[1]	6/6/13 10:50	-	-	-	-
CD2-13	6/6/13 10:45	2.8	11.3	4.2	47.6
CD2-14	6/6/13 10:40	3.0	12.3	4.1	51.0
CD2-15	6/6/13 10:35	2.4	7.9	5.0	39.1
CD2-16	6/6/13 10:30	0.5	0.9	4.1	3.7
CD2-17	6/6/13 10:25	0.7	1.5	3.9	5.8
CD2-18	6/6/13 10:20	1.7	5.1	3.9	20.0
CD2-19	6/6/13 10:15	1.0	2.5	4.1	10.1
CD2-20	6/6/13 10:10	3.0	10.1	4.2	42.6
CD2-21	6/6/13 10:05	3.8	12.3	3.1	38.1
CD2-22	6/6/13 10:00	3.8	12.3	3.7	45.5
CD2-23[1]	6/6/13 9:55	-	-	-	-
CD2-24[1]	6/6/13 9:50	-	-	-	-
CD2-25[2]	6/6/13 9:45	0	0	0	0
CD2-26[2]	6/6/13 9:40	0	0	0	0
Average Measured Velocity				3.9	
Total Measured Discharge				565	

Notes:

1. Outlet was submerged during time of measurements; conditions were not safe to collect data
2. Water level below the inverts

Table 3.18: CD4 Road Culvert Direct Velocity and Discharge

Culvert	Date & Time	Depth (ft)	Area (ft^2)	Measured Velocity (ft/s)	Direct Discharge (cfs)
CD4-1[2]	6/6/13 16:00	0	0	0	0
CD4-2[2]	6/6/13 15:55	0	0	0	0
CD4-3[2]	6/6/13 15:51	0	0	0	0
CD4-4[2]	6/6/13 15:47	0	0	0	0
CD4-5[2]	6/6/13 15:43	0	0	0	0
CD4-6[2]	6/6/13 15:39	0	0	0	0
CD4-7[3]	6/6/13 15:35	1.6	3.8	1.4	5
CD4-8[3]	6/6/13 15:31	2.7	6.7	2.1	14
CD4-9[3]	6/6/13 15:27	1.2	2.6	1.0	3
CD4-10[3]	6/6/13 15:23	2.1	6.7	1.4	9
CD4-11[2]	6/6/13 15:19	0	0	0	0
CD4-12[2]	6/6/13 15:15	0	0	0	0
CD4-13[2]	6/6/13 15:11	0	0	0	0
CD4-14[2]	6/6/13 15:07	0	0	0	0
CD4-15[2]	6/6/13 15:03	0	0	0	0
CD4-16[2]	6/6/13 14:59	0	0	0	0
CD4-17[2]	6/6/13 14:55	0	0	0	0
CD4-18[2]	6/6/13 14:51	0	0	0	0
CD4-19[2]	6/6/13 14:47	0	0	0	0
CD4-20A[1]	6/6/13 14:42	-	-	-	-
CD4-20[1]	6/6/13 14:38	-	-	-	-
CD4-21[1]	6/6/13 14:34	-	-	-	-
CD4-22[1]	6/6/13 14:30	-	-	-	-
CD4-23[1]	6/6/13 14:26	-	-	-	-
CD4-23A[1]	6/6/13 14:22	-	-	-	-
CD4-23B[1]	6/6/13 14:18	-	-	-	-
CD4-23C[1]	6/6/13 14:14	-	-	-	-
CD4-23D[1]	6/6/13 14:10	-	-	-	-
CD4-24	6/6/13 14:06	2.2	7.1	3.8	27
CD4-25	6/6/13 14:02	1.9	5.9	4.3	25
CD4-26	6/6/13 13:58	1.9	5.9	3.9	23
CD4-27	6/6/13 13:54	2.1	6.7	4.4	30
CD4-28	6/6/13 13:50	2.1	6.7	4.0	27
CD4-29	6/6/13 13:46	2.5	8.3	3.5	29
CD4-30	6/6/13 13:42	2.5	8.3	3.8	32
CD4-31	6/6/13 13:38	2.3	7.5	3.7	28
CD4-32	6/6/13 13:34	2.0	6.3	4.7	30
CD4-33[2]	6/6/13 13:30	0	0	0	0
			Average Measured Velocity	1.5	
			Total Measured Discharge	281	

Notes:

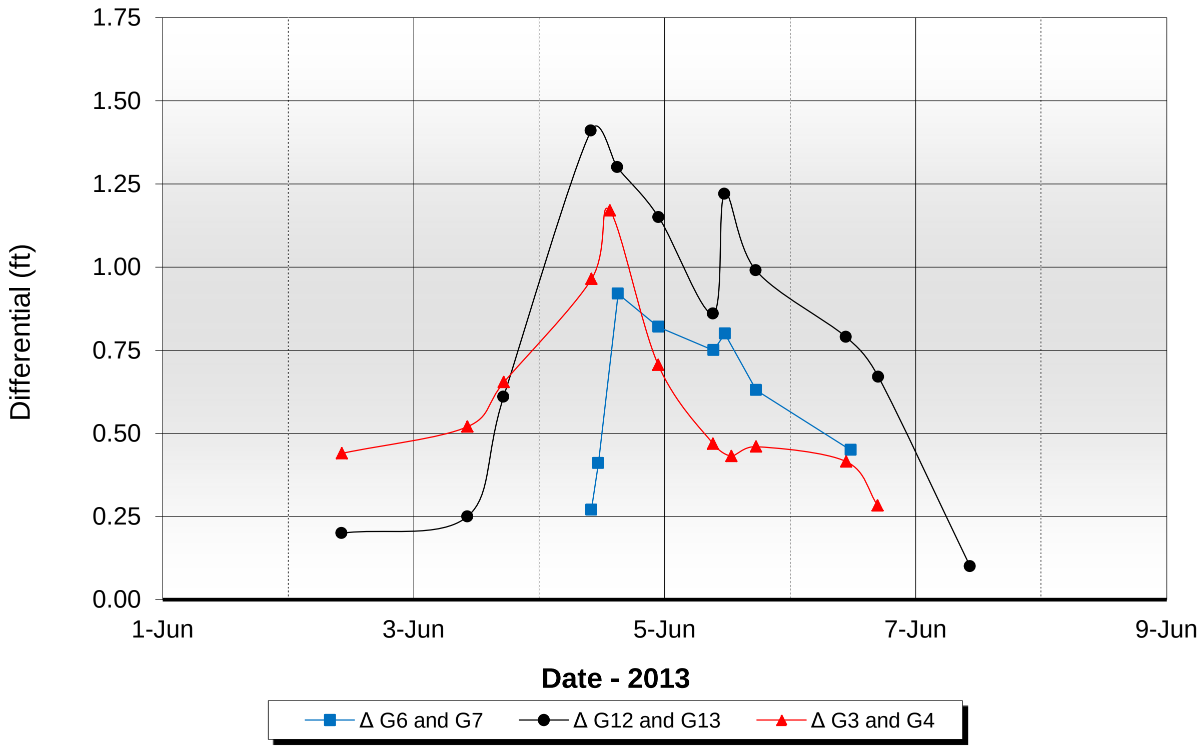
1. Outlet was submerged during time of measurements; conditions were not safe to collect data.
2. Water level below the inverts
3. Flow through culverts CD4-7 through CD4-10 moving from east to west

2) Indirect Discharge and Velocity

Indirect calculations were based on the closest set of paired gages for each culvert; gages G6/G7 were used for culverts CD2-1 through CD2-8, gages G12/G13 for CD2-9 through CD2-18, gages G3/G4 for CD2-19 through CD2-26, gages M9525/G3 for CD4-6 through CD4-17, gages G15/G16 for CD4-18 through CD4-23D, and gages G17/G18 for CD4-24 through CD4-33. Indirect discharge and velocity calculations for Lake M9525 and G3 gages are rough approximations because of their location and distance from culverts CD4-6 through CD4-17.

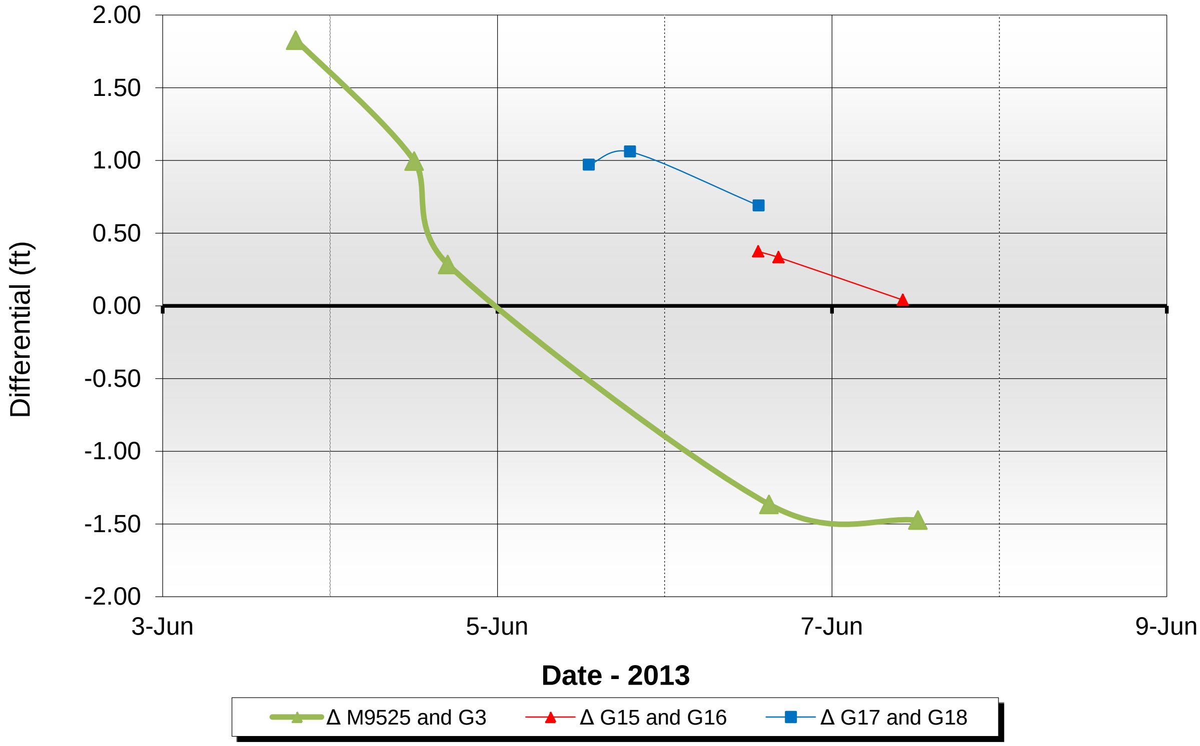
Water Surface Elevation Differential

Along the CD2 road, a maximum differential of 0.93 feet between G6/G7 occurred in the afternoon on June 4 coinciding with peak stage. A maximum differential of 1.41 feet between G12/G13 occurred in the morning on June 4. A maximum differential of 1.17 feet between G3/G4 occurred in the afternoon on June 4 also coinciding with peak stage. The differential WSE throughout breakup at all paired gage locations along the CD2 road is presented in Graph 3.19.



Graph 3.19: CD2 Road WSE Differential

Along the CD4 road, a maximum differential recorded with culverts passing flow from gage M9525 to gage G3 was 1.47 feet around noon on June 6. Maximum differential with culverts passing flow from gage G3 to gage M9525 was 1.83 feet in the evening of June 3. A maximum recorded differential of 0.37 feet between G15/G16 occurred in the afternoon on June 6. A maximum differential of 1.06 feet between G17/G18 occurred in the evening on June 5. The differential WSE throughout breakup at all paired gage locations along the CD4 road is presented in Graph 3.20.



Graph 3.20: CD4 Road WSE Differential

Indirect Velocity and Discharge Summaries

The peak discharge of 90 cfs through culvert CD2-12 occurred in the afternoon on June 4 with a corresponding velocity of 6.5 fps. Average velocity for CD2 culverts CD2-1 through CD2-8 at peak discharge in the afternoon on June 4 was 5.3 fps with a corresponding total discharge of 508 cfs passing from south to north. Average velocity for CD2 culverts CD2-9 through CD2-18 at peak discharge in the evening on June 4 was 6.3 fps, corresponding with a total discharge of 598 cfs passing from south to north. Average velocity for CD2 culverts CD2-19 through CD2-26 at peak discharge in the afternoon on June 4 was 5.5 fps with a corresponding total discharge of 397 cfs passing from south to north. Average velocity for all CD2 culverts at peak discharge on June 4 was 5.7 fps with a corresponding total discharge of 1,503 cfs through all CD2 culverts. Calculated indirect peak discharge and corresponding velocities for CD2 culvert that passed flood flow are presented in Table 3.19 and Table 3.20, respectively.

Table 3.19: CD2 Road Culverts 2013 Indirect Velocity Summary

CD2 Culverts near G3/G4		CD2 Culverts near G6/G7		CD2 Culverts near G12/G13	
Culvert	**Jun 04 1:30 PM**	**Culvert**	**Jun 04 3:05 PM**	**Culvert**	**Jun 04 2:55 PM**
CD2-19	5.9	CD2-1	5.5	CD2-9	6.7
CD2-20	6.0	CD2-2	5.5	CD2-10	6.4
CD2-21	5.9	CD2-3	5.2	CD2-11	6.3
CD2-22	5.9	CD2-4	5.2	CD2-12	6.5
CD2-23	5.8	CD2-5	5.2	CD2-13	5.7
CD2-24	5.8	CD2-6	5.2	CD2-14	5.9
CD2-25	4.3	CD2-7	5.2	CD2-15	6.9
CD2-26	4.4	CD2-8	5.4	CD2-16	5.6
				CD2-17	5.9
				CD2-18	6.8
Average Velocity (ft/s)	**5.5**		**5.3**		**6.3**

Table 3.20: CD2 Road Culverts 2013 Indirect Discharge Summary

CD2 Culverts near G3/G4		CD2 Culverts near G6/G7		CD2 Culverts near G12/G13	
Culvert	**Jun 04 1:30 PM**	**Culvert**	**Jun 04 3:05 PM**	**Culvert**	**Jun 04 2:55 PM**
CD2-19	24	CD2-1	60	CD2-9	57
CD2-20	63	CD2-2	60	CD2-10	72
CD2-21	73	CD2-3	65	CD2-11	66
CD2-22	73	CD2-4	65	CD2-12	90
CD2-23	73	CD2-5	65	CD2-13	80
CD2-24	73	CD2-6	65	CD2-14	85
CD2-25	8	CD2-7	65	CD2-15	64
CD2-26	9	CD2-8	63	CD2-16	21
				CD2-17	24
				CD2-18	41
Total Discharge (cfs)	**397**		**508**		**598**

The peak discharge of 73 cfs through culvert CD4-23B occurred in the afternoon of June 6. Average velocity for CD4 culverts CD4-6 through CD4-17 at peak discharge on June 6 was 4.1 fps, corresponding with a total discharge of 47 cfs passing from east to west. Average velocity for CD4 culverts CD4-18 through CD4-23D at peak discharge in the afternoon on June 6 was 3.3 fps, corresponding with a total discharge of 544 cfs passing from south to north. Average velocity for CD4 culverts CD4-24 through CD4-33 at peak discharge in the afternoon on June 4 was 8.1 fps, corresponding with a total discharge of 760 cfs passing from south to north. Calculated indirect peak discharge and corresponding velocities for CD4 culverts that passed flood flow are presented in Table 3.21 and Table 3.22, respectively.

Table 3.21: CD4 Road Culverts 2013 Indirect Velocity Summary

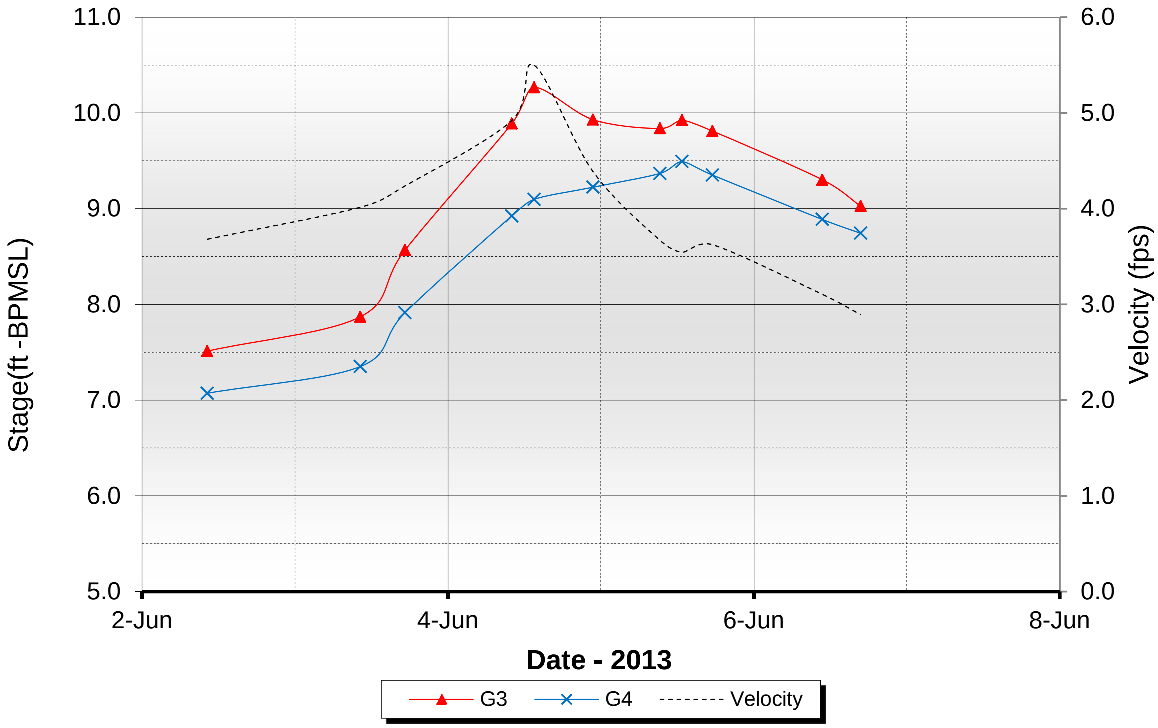
CD4 Culverts near M9525 & G3		CD4 Culverts near G15/G16		CD4 Culverts near G17/G18	
Culvert	Jun 06 3:00 PM	Culvert	Jun 06 1:25 PM	Culvert	Jun 04 1:24 PM
CD4-6	-	CD4-18	-	CD4-24	8.1
CD4-7	5.3	CD4-19	-	CD4-25	7.9
CD4-8	3.6	CD4-20A	3.3	CD4-26	8.3
CD4-9	1.9	CD4-20	3.3	CD4-27	8.4
CD4-10	5.5	CD4-21	3.3	CD4-28	8.2
CD4-11	-	CD4-22	3.3	CD4-29	7.9
CD4-12	-	CD4-23	3.3	CD4-30	7.9
CD4-13	-	CD4-23A	3.3	CD4-31	8.0
CD4-14	-	CD4-23B	3.7	CD4-32	8.5
CD4-15	-	CD4-23C	3.2	CD4-33	-
CD4-16	-	CD4-23D	3.2		
CD4-17	-				
Average Velocity (ft/s)	**4.1**		**3.3**		**8.1**
Note: Flow through culverts CD4-7 through CD4-10 moving from east to west					

Table 3.22: CD4 Road Culverts 2013 Indirect Discharge Summary

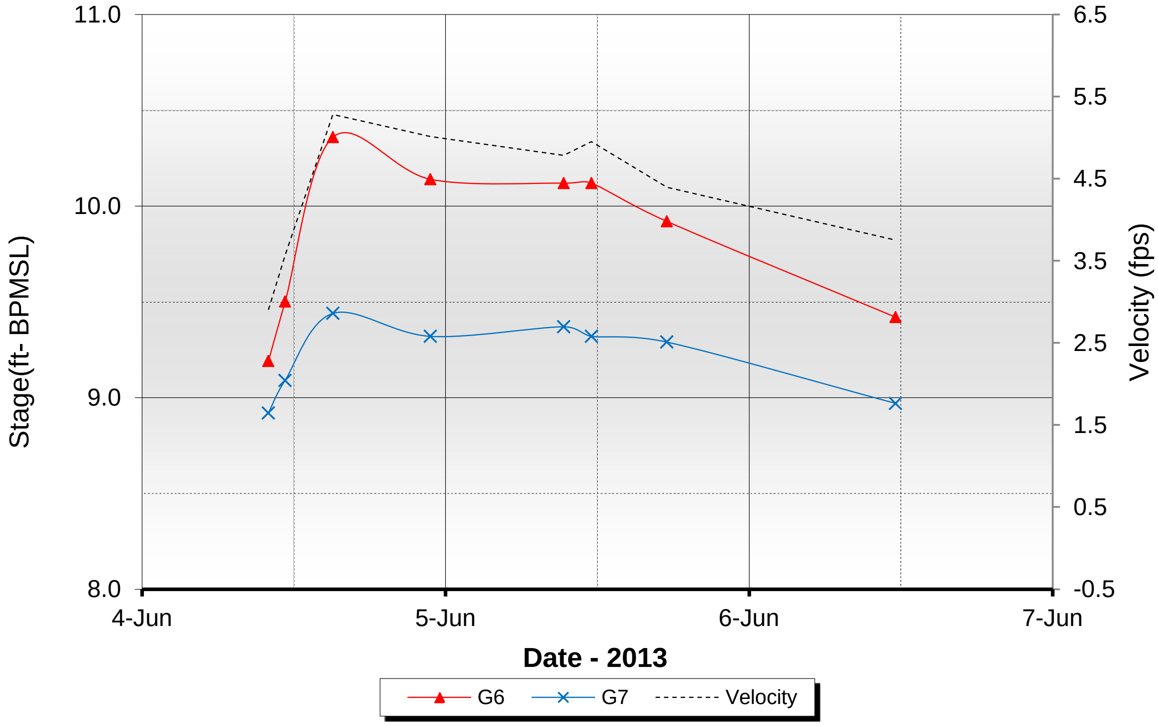
CD4 Culverts near M9525 & G3		CD4 Culverts near G15/G16		CD4 Culverts near G17/G18	
Culvert	Jun 06 3:00 PM	Culvert	Jun 06 1:25 PM	Culvert	Jun 04 1:24 PM
CD4-6	-	CD4-18	-	CD4-24	84
CD4-7	14	CD4-19	-	CD4-25	75
CD4-8	10	CD4-20A	65	CD4-26	81
CD4-9	4	CD4-20	65	CD4-27	84
CD4-10	20	CD4-21	65	CD4-28	83
CD4-11	-	CD4-22	65	CD4-29	90
CD4-12	-	CD4-23	65	CD4-30	90
CD4-13	-	CD4-23A	65	CD4-31	88
CD4-14	-	CD4-23B	73	CD4-32	83
CD4-15	-	CD4-23C	40	CD4-33	-
CD4-16	-	CD4-23D	41		
CD4-17	-				
Total Discharge (cfs)	**47**		**544**		**760**
Note: Flow through culverts CD4-7 through CD4-10 moving from east to west					

Indirect Velocity Compared to Observed Stage

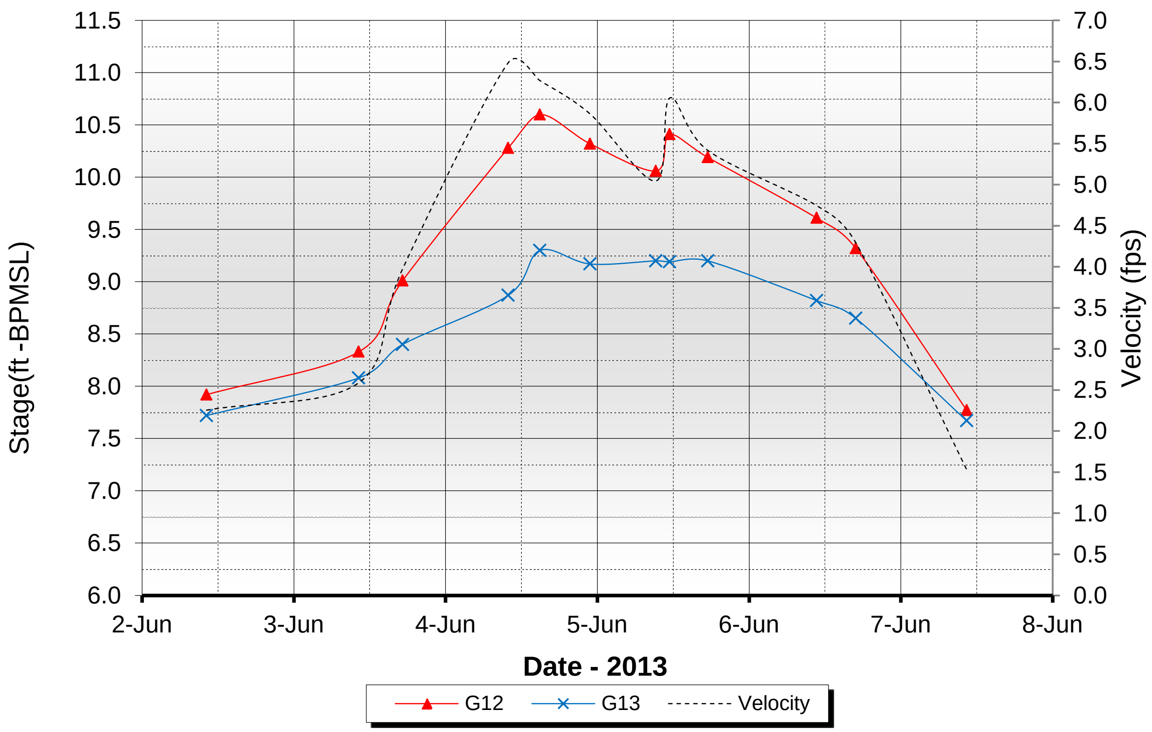
Calculated velocity for all culverts is related to WSE differentials between the culvert headwater and tailwater. A comparison of observed stage and indirect velocity for the CD2 and CD4 road culverts is presented in Graph 3.21 through Graph 3.26.



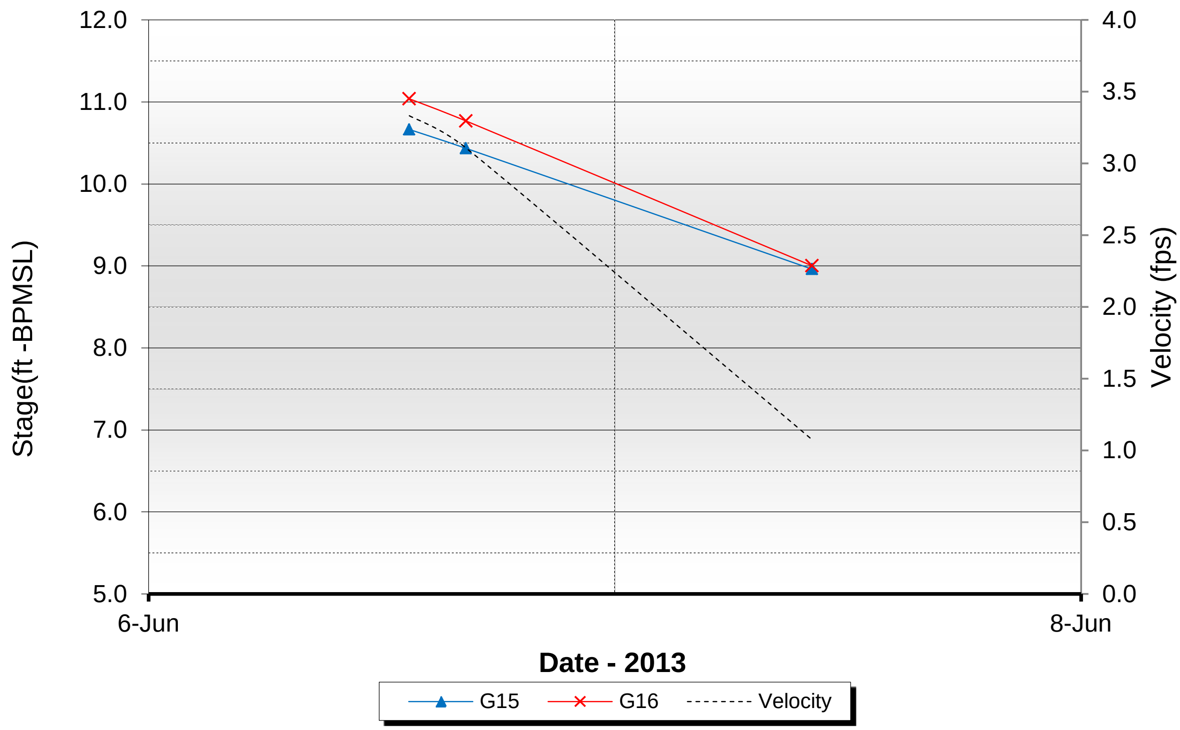
Graph 3.21: Indirect Velocity vs. Observed Stage, CD2 Road Culverts CD2-19 through CD2-26 near G3/G4



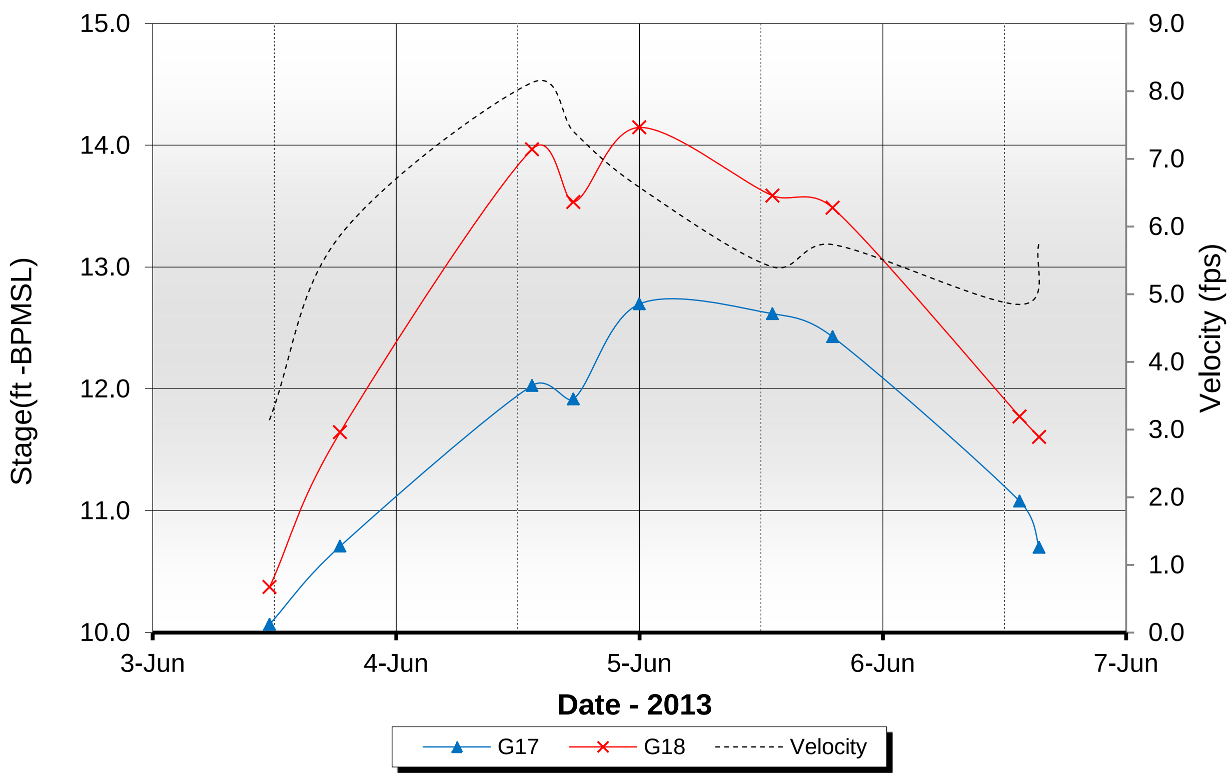
Graph 3.22: Indirect Velocity vs. Observed Stage, CD2 Road Culverts CD2-1 through CD2-8 near G6/G7



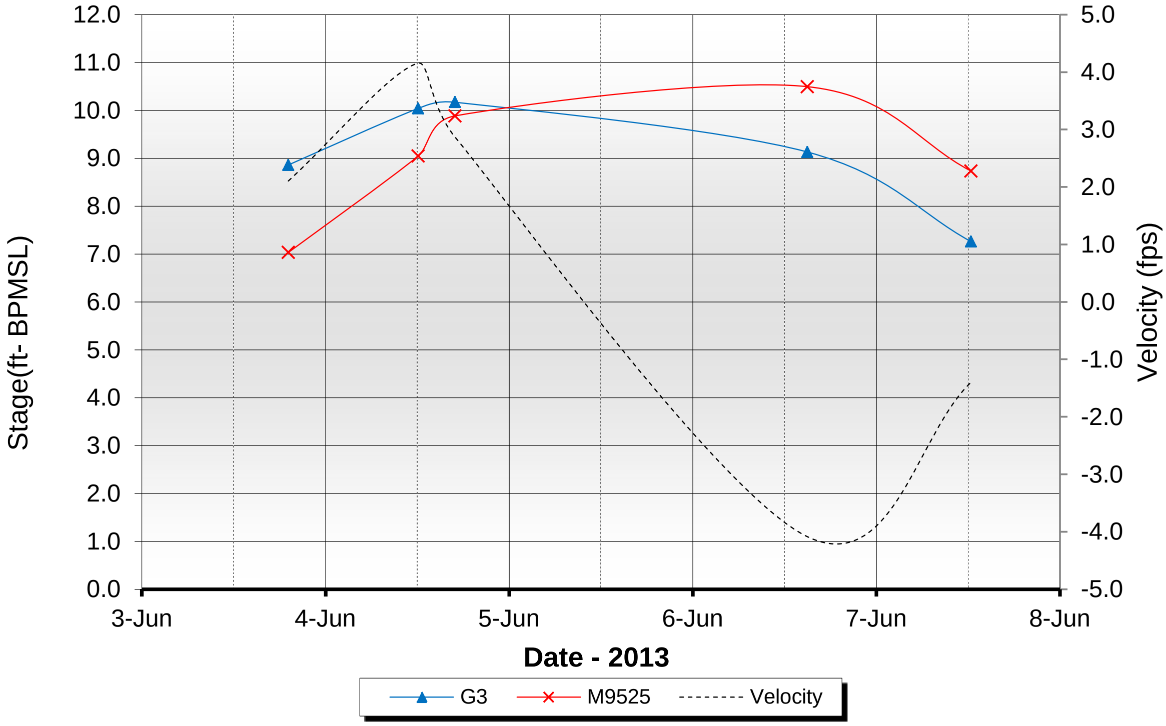
Graph 3.23: Indirect Velocity vs. Observed Stage, CD2 Road Culverts CD2-9 through CD2-18 near G12/G13



Graph 3.24: Indirect Velocity vs. Observed Stage, CD4 Road Culverts CD4-18 through CD4-23D near G15/G16



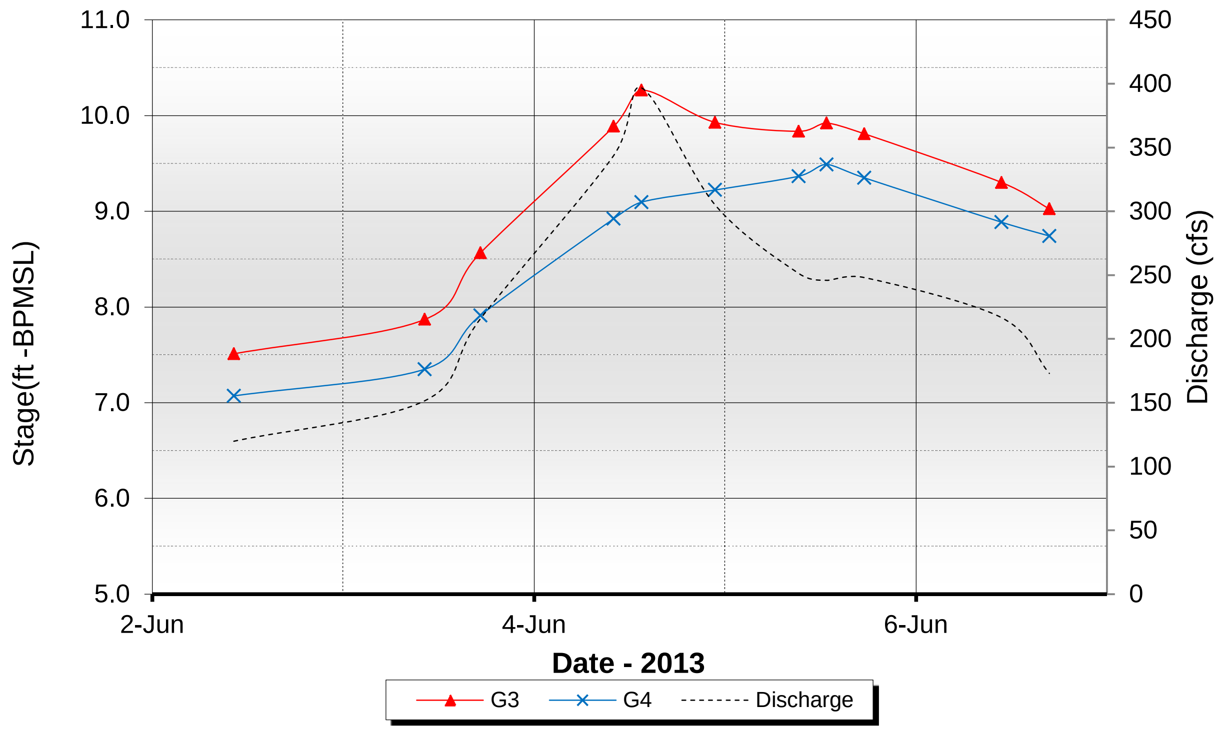
Graph 3.25: Indirect Velocity vs. Observed Stage, CD4 Road Culverts CD4-24 through CD4-33 near G17/G18



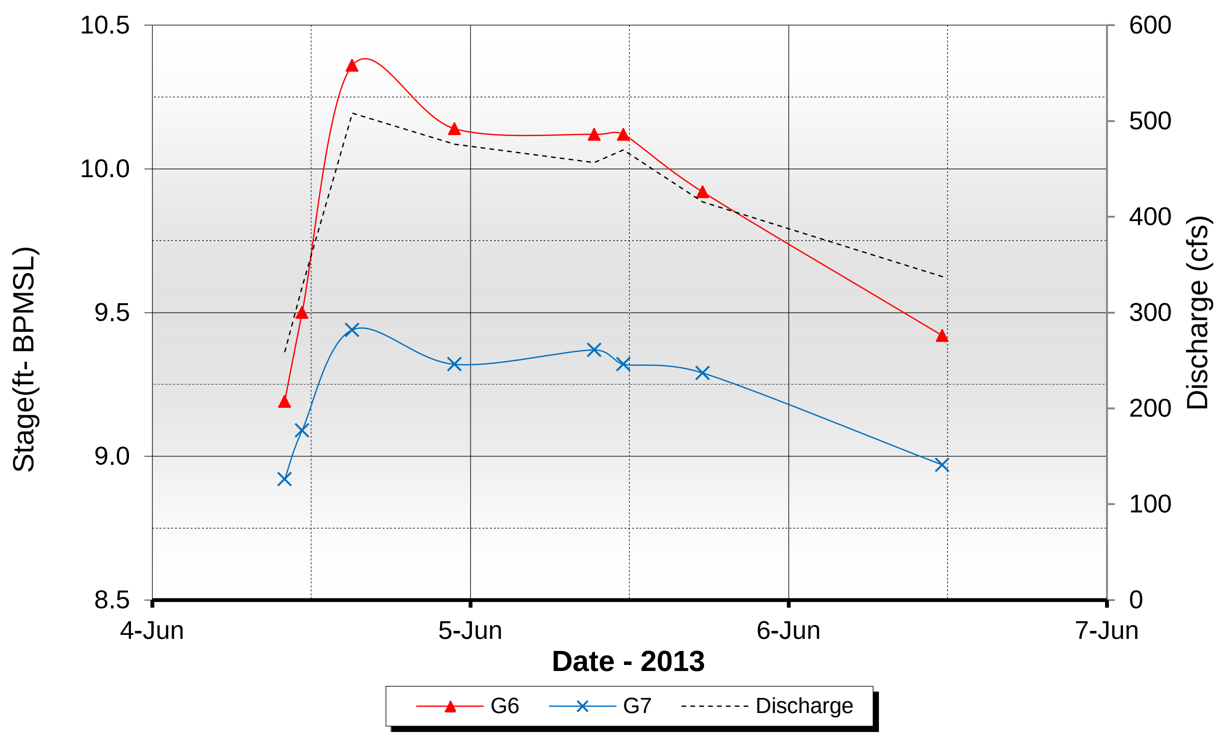
Graph 3.26: Indirect Velocity vs. Observed Stage, CD4 Road Culverts CD4-6 through CD4-17 near M9525/G3

Indirect Velocity Compared to Observed Discharge

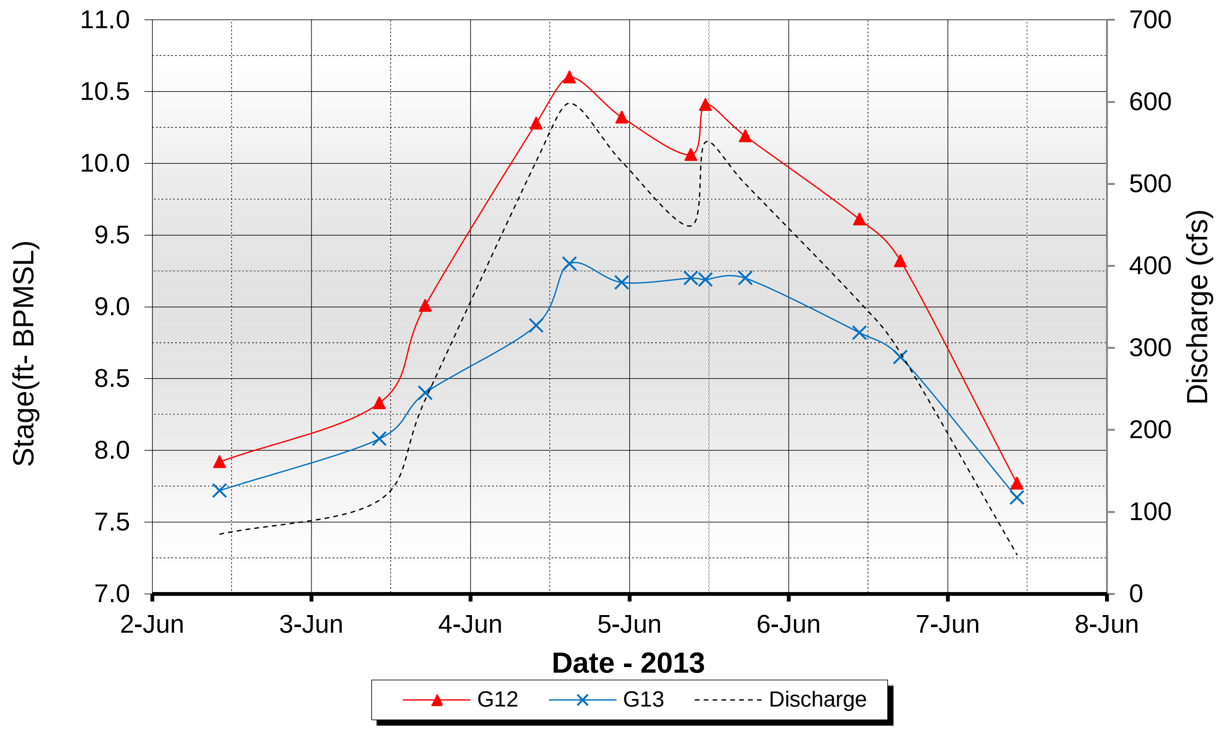
A comparison of observed stage and indirect discharge for the CD2 and CD4 road culverts is presented in Graph 3.27 through Graph 3.32.



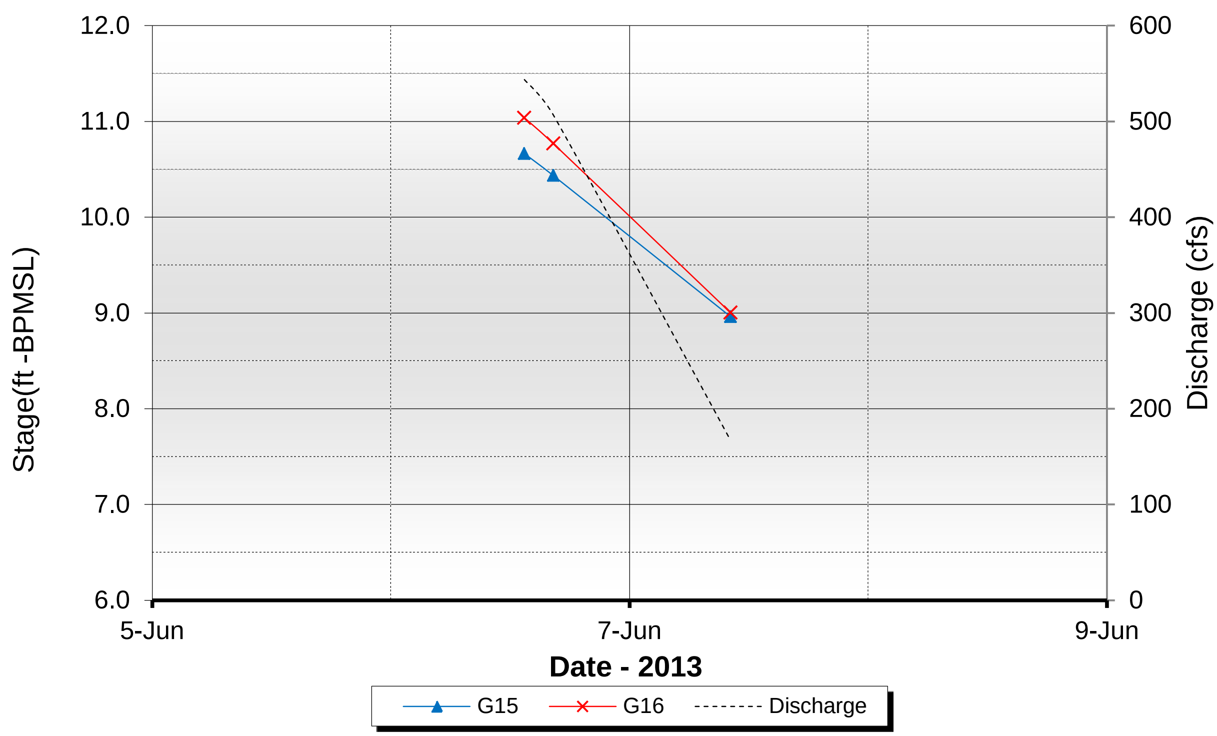
Graph 3.27: Indirect Discharge vs. Observed Stage, CD2 Road Culverts CD2-19 through CD2-26 near G3/G4



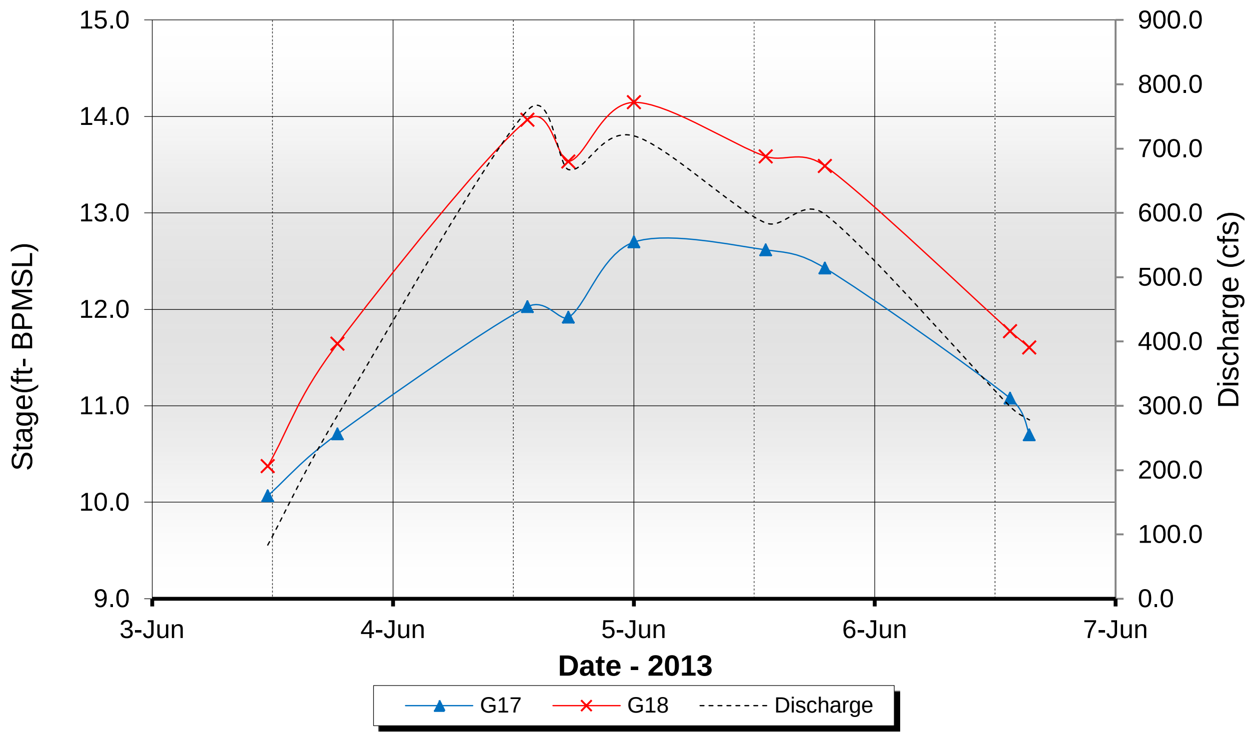
Graph 3.28: Indirect Discharge vs. Observed Stage, CD2 Road Culverts CD2-1 through CD2-8 near G6/G7



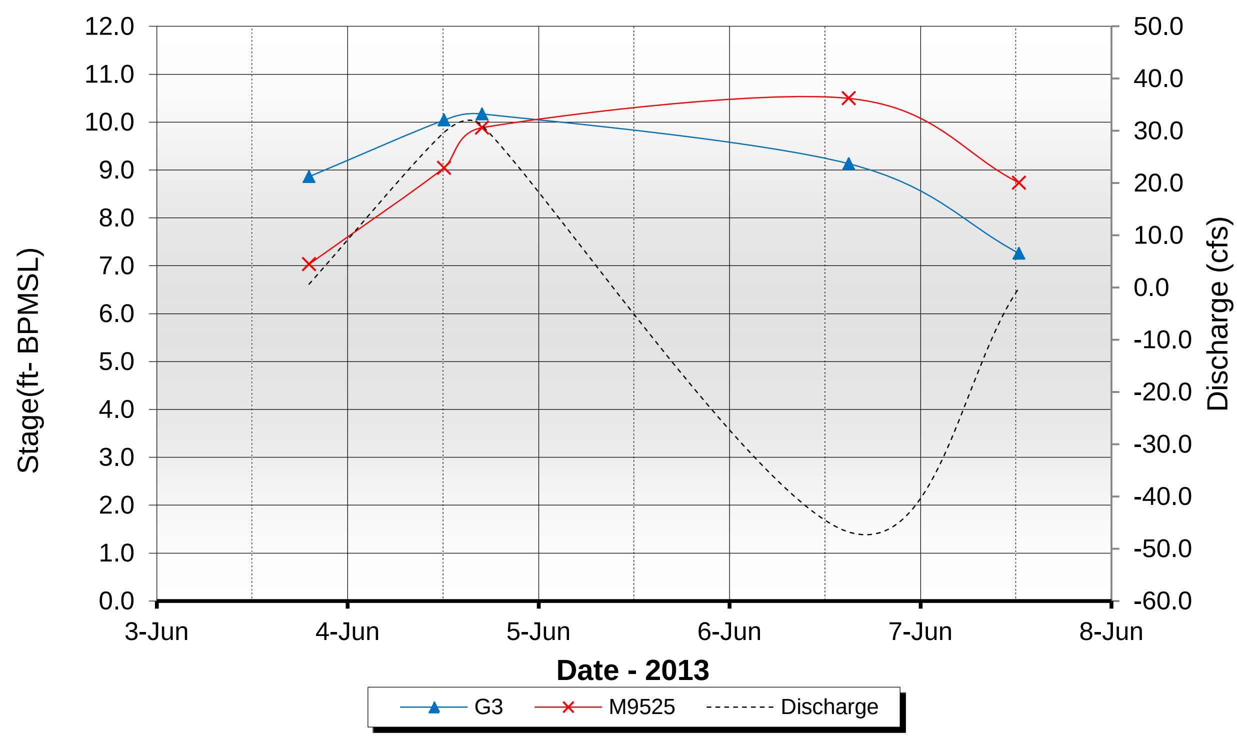
Graph 3.29: Indirect Discharge vs. Observed Stage, CD2 Road Culverts CD2-9 through CD2-18 near G12/G13



Graph 3.30: Indirect Discharge vs. Observed Stage, CD4 Road Culverts CD4-18 through CD4-23D near G15/G16



Graph 3.31: Indirect Discharge vs. Observed Stage, CD4 Road Culverts CD4-24 through CD4-33 near G17/G18



Graph 3.32: Indirect Discharge vs. Observed Stage, CD4 Road Culverts CD4-6 through CD4-17 near M9525/G3

3) Alpine Culverts Indirect and Direct Discharge Estimates Comparison

The indirect estimates were compared with the respective direct velocity measurements and associated discharge quantities to determine the relative accuracy of the indirect calculations. Discrepancies in these values are a result of culvert performance. Some snow and ice was present near culvert inlet and outlets at the time of field measurements on June 6. The indirect calculations assume ideal unobstructed conditions. The largest discrepancies in discharge occurred at culverts CD4-7 and CD4-10. The percent difference between measured and calculated mean discharge at CD4-7 was 149% and CD4-10 was -114%. The comparison between direct and indirect measurements for the road culverts are presented in Table 3.23 through Table 3.28. Large discrepancies between the total measured discharge and the total calculated discharge were caused by the lack of measured discharge at culverts which were covered by flood waters and inaccessible. Differences between measured and calculated velocities and discharge may also be attributed to the depth at which culvert velocities were measured. The velocity was measured at 0.6 flow depth in all culverts which is consistent with the mean velocity in typical open channel flow. For culverts flowing at near full conditions the vertical velocity distribution is likely shifted and the mean velocity is not located at 0.6 flow depth.

Table 3.23: Indirect/Direct Discharge Comparison, CD2 Road Culverts near G3/G4

Culvert	Direct			Indirect			Percent Difference	
	Time of Measurement June 6	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation June 6	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD2-19	10:15 AM	4.1	10.1	10:45 AM	3.7	8.8	-11%	13%
CD2-20	10:10 AM	4.2	42.6	10:45 AM	3.5	34.1	-17%	20%
CD2-21	10:05 AM	3.1	38.1	10:45 AM	3.5	42.4	13%	-11%
CD2-22	10:00 AM	3.7	45.5	10:45 AM	3.6	43.2	-3%	5%
CD2-23[1]	9:55 AM	-	-	10:45 AM	3.5	43.7	-	-
CD2-24[1]	9:50 AM	-	-	10:45 AM	3.5	43.6	-	-
CD2-25	9:45 AM	0	0	10:45 AM	1.3	0.1	-	-
CD2-26	9:40 AM	0	0	10:45 AM	2.3	0.8	-	-
Average Measured Velocity (ft/s)			2.52	**Average Calculated Velocity (ft/s)**		3.10	**Avg. V Difference**	-23%
Total Measured Discharge (cfs)			136.23	**Total Calculated Discharge (cfs)**		216.63	**Tot. Q Difference**	-59%
Notes	**1. Conditions near peak were not safe to perform a discharge measurement.**							

Table 3.24: Indirect/Direct Discharge Comparison, CD2 Road Culverts near G6/G7

Culvert	Direct			Indirect			Percent Difference	
	Time of Measurement June 6	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation June 6	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD2-1	11:45 AM	5.0	43.4	11:35 AM	4.0	37.4	-20%	14%
CD2-2	11:40 AM	4.8	41.5	11:35 AM	3.9	36.1	-19%	13%
CD2-3	11:35 AM	4.7	52.1	11:35 AM	3.7	42.4	-22%	19%
CD2-4[1]	11:30 AM	-	-	11:35 AM	3.6	45.5	-	-
CD2-5[1]	11:25 AM	-	-	11:35 AM	3.7	45.3	-	-
CD2-6[1]	11:20 AM	-	-	11:35 AM	3.6	45.4	-	-
CD2-7[1]	11:15 AM	-	-	11:35 AM	3.6	45.5	-	-
CD2-8[1]	11:10 AM	-	-	11:35 AM	3.9	40.2	-	-
Average Measured Velocity (ft/s)			4.84	**Average Calculated Velocity (ft/s)**		3.75	**Avg. V Difference**	23%
Total Measured Discharge (cfs)			137.09	**Total Calculated Discharge (cfs)**		337.70	**Tot. Q Difference**	-146%
Notes	**1. Conditions near peak were not safe to perform a discharge measurement.**							

Table 3.25: Indirect/Direct Discharge Comparison, CD2 Road Culverts near G12/G13

Culvert	Direct			Indirect			Percent Difference	
	Time of Measurement June 6	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation June 6	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD2-9	11:05 AM	5.5	41.3	10:40 AM	5.2	33.7	-6%	18%
CD2-10	11:00 AM	5.1	45.3	10:40 AM	4.9	42.7	-5%	6%
CD2-11	10:55 AM	4.4	38.2	10:40 AM	4.9	42.5	10%	-11%
CD2-12[1]	10:50 AM	-	-	10:40 AM	5.0	57.3	-	-
CD2-13	10:45 AM	4.2	47.6	10:40 AM	4.3	50.3	2%	-6%
CD2-14	10:40 AM	4.1	51.0	10:40 AM	4.4	53.7	7%	-5%
CD2-15	10:35 AM	5.0	39.1	10:40 AM	5.5	40.2	10%	-3%
CD2-16	10:30 AM	4.1	3.7	10:40 AM	4.0	6.2	-2%	-66%
CD2-17	10:25 AM	3.9	5.8	10:40 AM	4.3	8.2	10%	-42%
CD2-18	10:20 AM	3.9	20.0	10:40 AM	5.0	21.1	28%	-5%
Average Measured Velocity (ft/s)			4.49	Average Calculated Velocity (ft/s)		4.75	Avg. V Difference	-6%
Total Measured Discharge (cfs)			292.13	Total Calculated Discharge (cfs)		355.90	Tot. Q Difference	-22%
Notes	1. Conditions near peak were not safe to perform a discharge measurement.							

Table 3.26: Indirect/Direct Discharge Comparison, CD4 Road Culverts near G15/G16

Culvert	Direct			Indirect			Percent Difference	
	Time of Measurement June 6	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation June 6	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD4-18	2:34 PM	0	0	1:25 PM	0	0	-	-
CD4-19	2:31 PM	0	0	1:25 PM	0	0	-	-
CD4-20A[2]	2:28 PM	-	-	1:25 PM	3.3	64.9	-	-
CD4-20[2]	2:25 PM	-	-	1:25 PM	3.3	64.9	-	-
CD4-21[2]	2:21 PM	-	-	1:25 PM	3.3	64.8	-	-
CD4-22[2]	2:18 PM	-	-	1:25 PM	3.3	64.9	-	-
CD4-23[2]	2:15 PM	-	-	1:25 PM	3.3	65.1	-	-
CD4-23A[2]	2:12 PM	-	-	1:25 PM	3.3	65.1	-	-
CD4-23B[2]	2:08 PM	-	-	1:25 PM	3.7	73.1	-	-
CD4-23C[2]	2:05 PM	-	-	1:25 PM	3.2	40.5	-	-
CD4-23D[2]	2:02 PM	-	-	1:25 PM	3.2	40.6	-	-
Average Measured Velocity (ft/s)			0.0	Average Calculated Velocity (ft/s)		2.73	Avg. V Difference	-
Total Measured Discharge (cfs)			0.0	Total Calculated Discharge (cfs)		543.65	Tot. Q Difference	-

Table 3.27: Indirect/Direct Discharge Comparison, CD4 Road Culverts near G17/G18

Culvert	Direct			Indirect			Percent Difference	
	Time of Measurement June 6	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation June 6	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD4-24	1:59 PM	3.8	26.7	1:30 PM	4.8	32.9	27%	-23%
CD4-25	1:55 PM	4.3	25.4	1:30 PM	4.3	25.3	1%	0%
CD4-26	1:52 PM	3.9	23.2	1:30 PM	4.9	29.9	25%	-29%
CD4-27	1:49 PM	4.4	29.5	1:30 PM	5.1	32.8	15%	-11%
CD4-28	1:46 PM	4.0	26.9	1:30 PM	4.8	31.2	20%	-16%
CD4-29	1:42 PM	3.5	28.7	1:30 PM	4.8	38.3	37%	-33%
CD4-30	1:39 PM	3.8	31.8	1:30 PM	4.8	38.7	24%	-22%
CD4-31	1:36 PM	3.7	27.6	1:30 PM	4.7	36.1	28%	-31%
CD4-32	1:33 PM	4.7	29.5	1:30 PM	5.4	33.4	15%	-13%
CD4-33[2]	1:30 PM	-	-	1:30 PM	-	-	-	-
Average Measured Velocity (ft/s)			4.0	Average Calculated Velocity (ft/s)		4.85	Avg. V Difference	-21%
Total Measured Discharge (cfs)			249.2	Total Calculated Discharge (cfs)		298.56	Tot. Q Difference	-20%

Table 3.28: Indirect/Direct Discharge Comparison, CD4 Road Culverts near M9525/G3

Culvert	Direct			Indirect			Percent Difference	
	Time of Measurement June 6	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation June 6	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD4-6	3:13 PM	0	0	3:00 PM	0	0	-	-
CD4-7	3:10 PM	1.4	5.4	3:00 PM	5.3	13.5	274%	-149%
CD4-8	3:07 PM	2.1	13.8	3:00 PM	3.6	9.7	76%	29%
CD4-9	3:04 PM	1.0	2.7	3:00 PM	1.9	3.7	83%	-35%
CD4-10	3:00 PM	1.4	9.3	3:00 PM	5.5	19.8	299%	-114%
CD4-15	2:44 PM	0	0	3:00 PM	0	0	-	-
CD4-16	2:41 PM	0	0	3:00 PM	0	0	-	-
CD4-17	2:38 PM	0	0	3:00 PM	0	0	-	-
Average Measured Velocity (ft/s)			0.74	**Average Calculated Velocity (ft/s)**		2.04	**Avg. V Difference**	-177%
Total Measured Discharge (cfs)			31.21	**Total Calculated Discharge (cfs)**		46.82	**Tot. Q Difference**	-50%
Notes:	**1. Culverts not listed were blocked with snow and ice, covered or had not observed flow**							
	2. Flow through culverts CD4-7 through CD4-10 moving from east to west							

3.3.3 CD2 SWALE BRIDGES

1) DIRECT DISCHARGE

Discharge measurements at the 452-foot (long) and the 62-foot (short) swale bridges were performed near peak stage. Peak WSE at the CD2 road gages G3 and G4 occurred in the afternoon on June 4. Discharge measurements were performed in the afternoon on June 5 (Photo 3.33). Stage was falling during the discharge measurements. The direct discharge notes are available in Appendix D.

The resulting discharge and velocity values observed on June 5 at the long swale bridge were 7,286 cfs with an average velocity of 2.5 fps. The measurement was rated good based because no snow or ice obstructions were observed in the bridge profile between the abutments. Snow berms were present upstream of the long swale bridge which produced eddies causing a minor flow reversal along the left (west) abutment (Photo 3.34). Grounded ice was found downstream of the bridge and had no impact on the passage of flood water.

The observed discharge and velocity at the short swale bridge was 1,608 cfs and 3.6 fps. Minimal snow blockage along the left (west abutment) extending approximately 20 feet into the flow was observed at the time of measurement (Photo 3.35). The snow blockage did not appear to impede flow through the bridge opening; therefore, the measurement was rated good. Grounded ice was found downstream of the bridge and did not impact the passage of flood water (Photo 3.36).

Photo 3.33: Beginning direct discharge measurements at the long swale bridge with snow berm upstream of left bank, looking southwest; June 5 2013

Photo 3.34: Conditions through the long swale bridge during direct discharge measurements, looking east; June 5, 2013

Photo 3.35: Conditions upstream of the short swale bridge while preparing for the direct discharge measurements, looking east; June 5, 2013

Photo 3.36: Grounded ice downstream of short swale bridge, looking north; June 5, 2013

2) INDIRECT DISCHARGE

The 2013 peak discharge through the swale bridges is likely to have occurred around the same time as peak stage and the corresponding peak high-water surface differential, as determined by comparison of G3 (headwater) and G4 (tailwater) WSE readings. The peak stage at G3, 10.27 feet BPMSL, occurred in the afternoon on June 4 as shown in Table 3.9 above. The headwater-tailwater differential at that time was 1.17 feet, the highest G3/G4 differential calculated during monitoring. The calculated peak discharge on June 4 was 7,723 cfs through the long swale bridge and 1,706 cfs through the short swale bridge. The peak discharge estimates are approximately 6% greater than the direct discharge measured on June 5.

3.3.4 EROSION

The 2013 peak stage near facilities was the highest on record and as a result large extents of the Alpine roads and pads were in contact with floodwater, though no facilities were overtopped. Breakup effects were localized to certain areas of the road structures. Floodwater did not overtop any of the access roads or the gravel pad embankments at the CD1, CD2, CD3, or CD4 pads. The Alpine gravel pads and access roads were inspected for erosion before, during, and after breakup.

On June 1, floodwater was first observed coming into contact with the CD2 road prism in the vicinity of the swale bridges (G3 and G4), and reached the CD4 road prism near gages 17 and 18 on June 3. Peak WSE occurred at facilities on June 4 and June 5.

Moderate sized ice floes were observed occasionally passing through the swale bridges. Some of these floes grounded immediately downstream of the large swale bridge. An excavator was on site during peak conditions and helped facilitate the passage of ice floes through the large swale bridge. Ice floes were not observed contacting the road prisms or pads; therefore erosion attributed to ice impacts was not considered a risk.

Snow was cleared from the CD2 and CD4 culvert batteries prior to the arrival of floodwater. Excavated snow from the upstream side of culvert battery CD2-4 through CD2-7 was placed directly in front of the culverts. During breakup, flow was diverted around the snow piles and accelerated as it flowed parallel to the road embankment before entering the culvert inlets. The focused flow along the road embankment caused local erosion to the road embankment east of the culvert battery. This was quickly identified and mitigated through erosion prevention measures. Photo 3.37 through Photo 3.41 shows the initial erosion and protection of the road at the CD2 culverts. By June 8, floodwater had receded from the gravel structures.

Following peak stage, visual inspections of the CD2 and CD4 gravel road prisms were conducted. Photographic documentation of the condition of the gravel facilities was recorded on June 10. High-water marks due to erosion were identified by debris stranded on the road prism side slopes or where silts and fine-grained sands had been winnowed or washed away. Photo 3.39 shows an example of winnowing on the downstream side of the CD2 road near culvert CD2-23. Minimal erosion was observed along the CD4 road, and was localized near the culvert batteries. Photo 3.40 shows representative conditions near the north and south CD4 batteries. As floodwater receded, tension cracks, seen in Photo 3.41, formed at the top of the slope between the swale bridges.

Photo 3.37: Localized erosion at the CD2 culvert battery, looking east; June 4, 2013

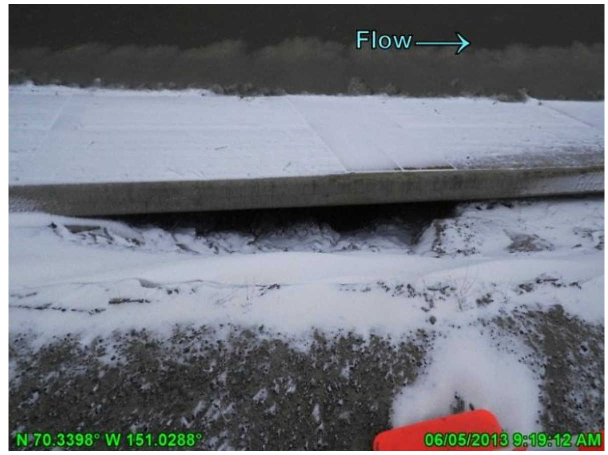


Photo 3.38: Erosion prevention implemented (rig mat) near peak WSE at CD2 culvert battery, June 5, 2013

Photo 3.39: Winnowing of fine grained material on the south side of the CD2 road; June 10, 2013

Photo 3.40: Representative conditions for CD4 culvert batteries, looking southeast; June 10, 2013

Photo 3.41: Tension cracks after flood water receded from the road prism near culvert CD2-23; June 10, 2013

3.4 ALPINE DRINKING WATER LAKES

Lakes L9312 and L9313 are the primary water sources for Alpine facilities, annually supplying the necessary daily quantities for camp and industrial operations. Influent and effluent is processed by the onsite Alpine water and wastewater treatment plant, and documentation of recharge is required by State water use permits. Recharge of these lakes is monitored using direct-read gages: G9 at Lake L9312 and G10 at Lake L9313. Bankfull lake recharge is achieved when the stage hydrograph exhibits a rise and then fall indicating either overland flow or local melt from within the drainage basin increased the lake WSE above bankfull conditions.

3.4.1 LAKES L9312 AND L9313 RECHARGE

Lakes L9312 and L9313 were monitored before, during, and after breakup to assess recharge and to evaluate recharge mechanisms. Primary recharge mechanisms are overland flood flow and local melt. Evaluation of recharge was made using photographic documentation, WSE surveys, and analysis of hydrographs generated by stage monitoring at gages G9 and G10.

Local melt of snow and ice within the lake drainage basins annually contributes to recharge. Lake L9312 is surrounded by higher tundra than L9313 and receives overland flood flow less frequently. Lake L9313 typically receives additional annual recharge during spring breakup from overland flood flow.

Lakes were determined to be fully recharged if bankfull conditions were met and either overland flood flow was observed overbanking into the lake drainage basin or there was evidence of a stage rise and fall on the hydrograph.

1) SPRING BREAKUP OBSERVATIONS

Recharge monitoring of lakes L9312 (G9) and L9313 (G10) began on May 6 when WSE was surveyed prior to breakup as part of the Alpine Lakes Water Quality project. Observations were recorded during breakup monitoring between June 1 and June 7. Final data collection took place on June 29 once the lakes had melted.

By May 31, all major channels in the CRD were conveying flow including the Sakoonang Channel. Overland flow began to recharge Lake L9313 from the Sakoonang Channel via the north paleolake and Lake M9525 sometime between June 2 and June 3. Overflow from Lake M9525 is typically the primary recharge mechanism for Lake L9313. Peak WSE at Lake L9313 (G10) was 10.44 feet BPMSL based on observations collected by field crews on June 5. Historical records indicate bankfull elevation is approximately 6.5 feet BPMSL (Baker 2006a, 2007b). Lake L9313 received overland flow until the evening of June 6. Water from the Sakoonang Channel began to reach Lake L9312 in the afternoon of June 4 and likely peaked on June 5 according to observations on the Sakoonang Channel at gage G1. Photo 3.42 and Photo 3.43 show lakes L9312 and L9313 receiving recharge. Stage-hydrographs for L9312 and L9313 are provided in Table 3.29/Graph 3.33 and Table 3.30/Graph 3.34, respectively.

Photo 3.42: Initial recharge from Lake M9525 approaching Lake L9313, looking southwest; May 31, 2013

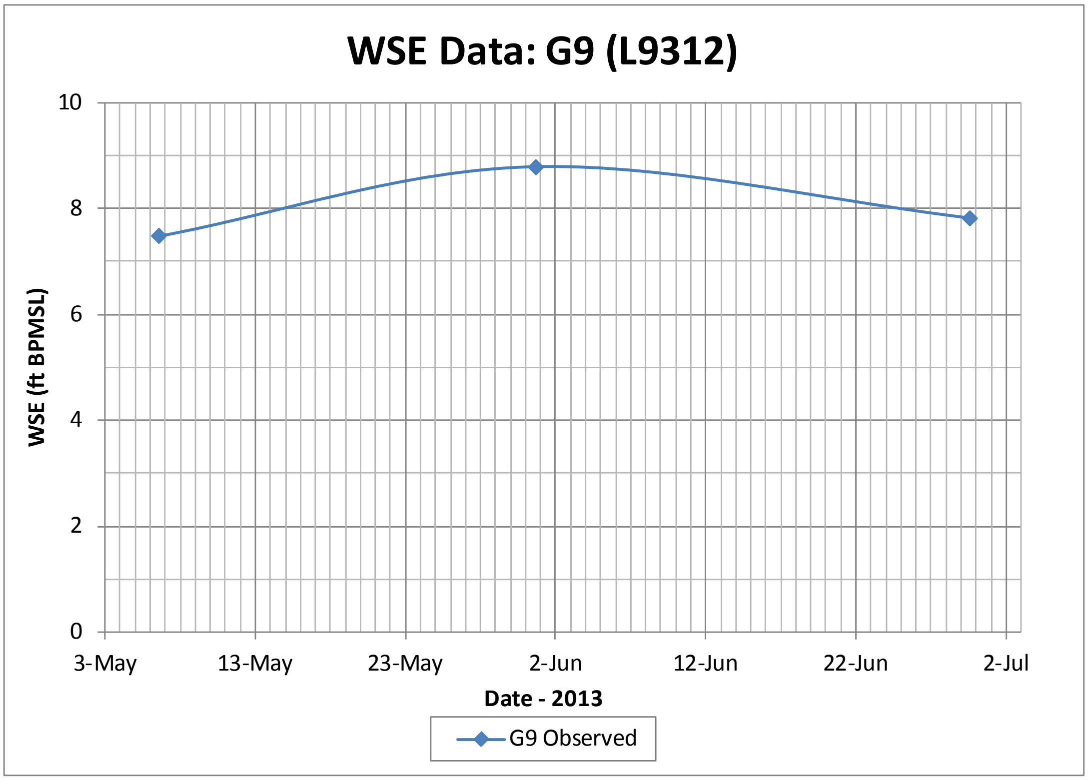
Photo 3.43: Lakes L9312 and L9313 receiving recharge from the Sakoonang Channel and Lake M9525 respectively, looking west; June 4, 2013

Table 3.29: 2013 Stage Data for G9 (Lake L9312)

Date and Time	WSE (feet BPMSL)	Observations
	G9	
5/6/13 3:00 PM	7.48	
5/31/13 3:55 PM	8.79	
6/29/13 2:52 PM	7.82	

Notes:

1. Elevations based on TBM CP02-01-39O at 11.450 ft BPMSL, surveyed by LCMF in 2007
2. G9 is a permanent staff gage surveyed for elevation by LCMF in May 2013.
3. Peak stage can not be accurately estimated due to limited data.



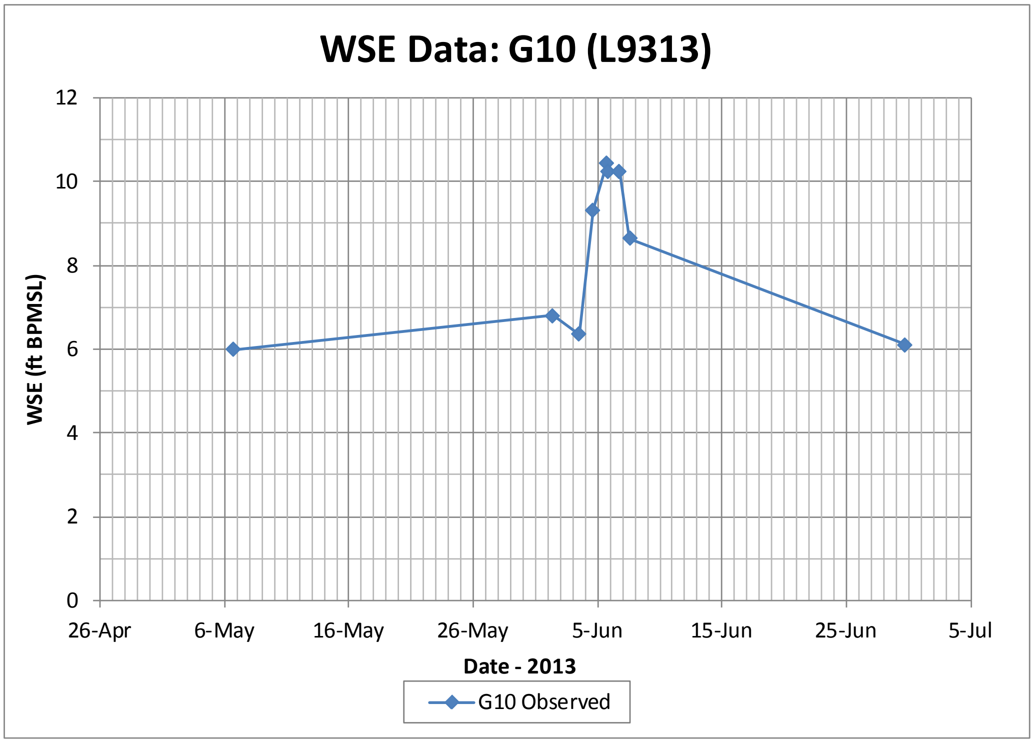
Graph 3.33: 2013 Stage Data for G9 (Lake L9312)

Table 3.30: 2013 Stage Data for G10 (Lake L9313)

Date and Time	WSE (feet BPMSL)	Observations
	G10	
5/6/13 4:30 PM	5.99	
6/1/13 9:35 AM	6.80	
6/3/13 12:10 PM	6.35	
6/4/13 3:10 PM	9.31	
6/5/13 4:55 PM	10.44	Peak Stage at G10 - based on observed WSE
6/5/13 7:28 PM	10.24	
6/6/13 5:05 PM	10.25	
6/7/13 1:41 PM	8.63	
6/29/13 5:20 PM	6.10	

Notes:

1. Elevations based on TBM CP-99-32-60 at 15.879 ft BPMSL, surveyed by UMIAQ in 2012
2. G10 is a permanent staff gage surveyed for elevation by LCMF in May 2013.



Graph 3.34: 2013 Stage Data for G10 (Lake L9313)

3.5 ICE BRIDGES

Ice roads are constructed annually to link the CD3 pad with the rest of Alpine facilities, and Alpine facilities and the Village of Nuiqsut with the permanent gravel road system to the east. These temporary routes are used for supply delivery and transportation of equipment to and from isolated areas. An ice road was constructed during the winter 2012-2013 between Alpine and 2L Pad, the nearest extent of the Kuparuk road system. This route crosses several drainages and channels. Ice road stream crossings are mechanically slotted by CPAI at the conclusion of the season to facilitate melt and the natural progression of breakup flooding.

Ice road crossings were monitored at the Colville East Channel, less than one-half-mile upstream from the HDD crossing and at the Kachemach River. Monitoring included visual observation of degradation and photo documentation of each crossing. Additional ice road crossings of smaller drainages were observed during breakup for any significant impacts to flow or channel morphology.

1) Spring Breakup Observations

Ice bridge melt progressed smoothly throughout the breakup period at all river crossings; no significant erosion or scour was observed as a result of ice bridge interaction with breakup flooding.

The leading edge passed the Colville ice bridge sometime between May 29 and May 30 (Photo 3.44). By the time peak WSE occurred, the ramp on the west side of the Colville ice bridge was all that remained intact (Photo 3.45).

Photo 3.44: The leading edge passed the Colville ice bridge, looking east; May 30, 2013

Photo 3.45: Colville ice bridge near peak WSE, looking east; June 4, 2013

Breakup progression at the Kachemach River ice bridge was slower than at the Colville ice bridge. On June 2, local melt was present at the Kachemach River ice bridge. Photo 3.46 shows the Kachemach River ice bridge during breakup passing flow on June 6.

Flooding and melt during breakup at all other ice road crossings in the CRD progressed unimpeded; Photo 3.47 and Photo 3.48 show bridges passing flow on the Tamayayak Channel and at Toolbox Creek. The exploration ice road crossing on the Nigliq Channel and the Nigliagvik are shown in Photo 3.49 and Photo 3.50.

Photo 3.46: Low velocity flow passing Kachemach River ice bridge, looking north; June 6, 2013

Photo 3.47: Tamayayak Channel ice bridge crossing, looking east; June 6, 2013

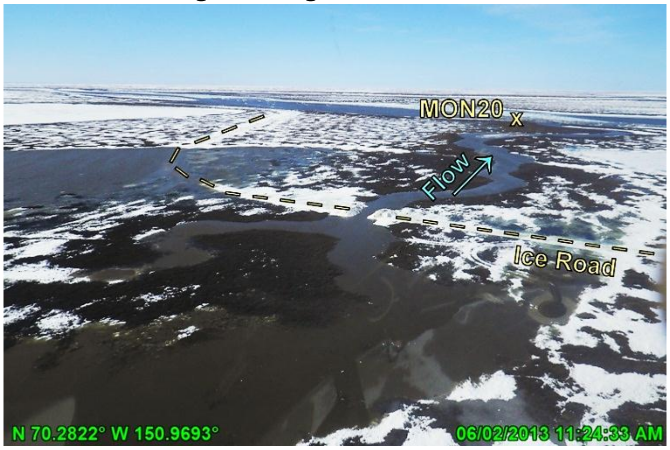


Photo 3.48: Low velocity flow passing Toolbox Creek ice bridge crossing, looking west; June 2, 2013

Photo 3.49: Nigliq Channel exploration ice bridge crossing passing flow, looking east; June 1, 2013

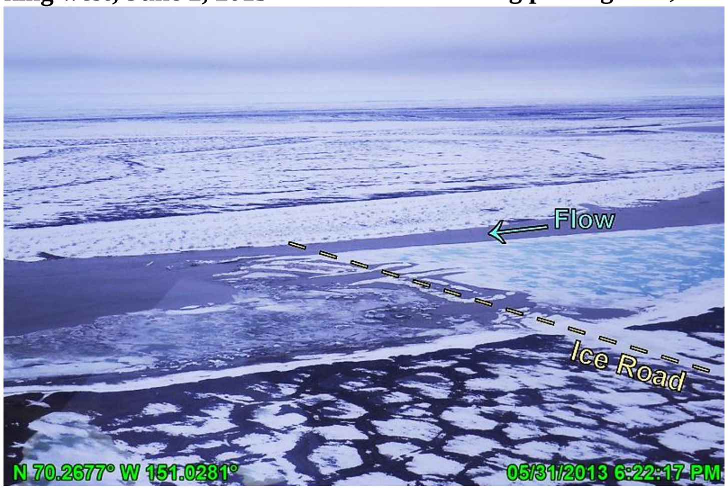


Photo 3.50: Nigliagvik exploration ice bridge crossing, looking southeast; May 31, 2013

3.6 CD3 PIPELINE CROSSINGS

The CD3 pipeline crosses three channels between CD1 and CD3; Crossing 2 at the Sakoonang Channel, Crossing 4 at the Tamayayak Channel, and Crossing 5 at the Ulamnigiaq Channel. Sakoonang (SAK) gages are located on the southwest bank, Tamayayak (TAM) gages are on the south bank, and Ulamnigiaq (ULAM) gages are on the northeast bank. The gages are located downstream of the pipeline crossings. Observations of breakup processes, effects of flooding on infrastructure, and stage data has been collected at these locations intermittently since 2000.

1) Spring Breakup Observations

On May 31, flow in the Tamayayak Channel was connected to Harrison Bay, and the Ulamnigiaq Channel was conveying flow along its reach. The Sakoonang Channel was receiving floodwater from the Tamayayak Channel confluence to the north and from the Colville East Channel to the south. By the afternoon of June 2, WSE was steadily increasing at all three pipeline crossings.

On June 4, an ice jam in the Colville East Channel at the Tamayayak Channel bifurcation was diverting floodwater down the Tamayayak and Sakoonang channels. According to PT data, peak stage at the TAM and ULAM occurred at 8:00 AM on June 4 with recorded WSEs of 9.49 feet BPMSL and 8.71 feet BPMSL, respectively (Table 3.31 and Graph 3.35). Extensive overbank flooding was observed at all three pipeline crossings (Photo 3.51 through Photo 3.53).

Floodwater directed through the CD2 swale bridges joined in the Sakoonang Channel downstream of the SAK pipeline crossing, contributing to the rising WSE on June 4. On June 6, an ice jam was observed on the Tamayayak Channel at the Ulamnigiaq Channel bifurcation causing a slight drop in WSE at the TAM and ULAM crossings (Photo 3.54).

Photo 3.51: Overbank flooding at the Sakoonang Channel pipeline crossing, looking south; June 4, 2013

Photo 3.52: Overbank flooding at the Tamayayak Channel pipeline crossing, looking north; June 4, 2013

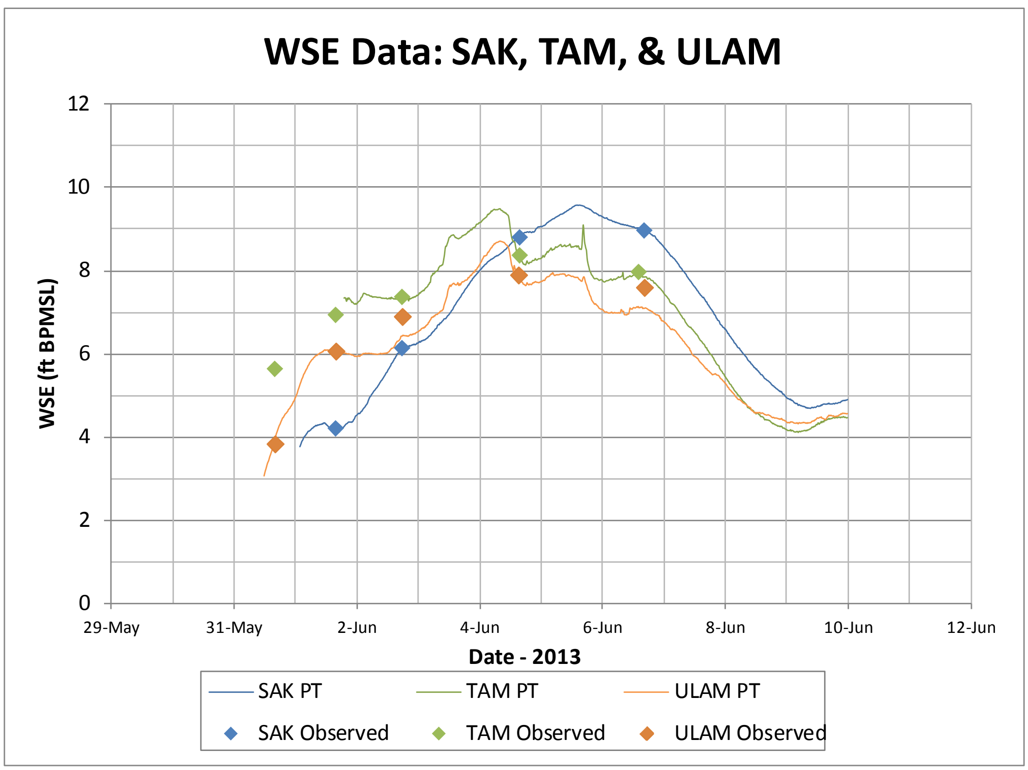
Photo 3.53: Overbank flooding at the Ulamnigiaq Channel pipeline crossing, Looking northwest; June 4, 2013

Photo 3.54: Ice jam on the Tamayayak Channel at the Ulamnigiaq Channel bifurcation, looking southeast; June 6, 2013

Table 3.31: 2013 Stage Data for SAK, TAM, and ULAM

Date and Time	WSE (feet BPMSL)			Observations
	SAK	TAM	ULAM	
5/31/13 3:30 PM	-	-	3.84	The Tamayayak and Ulamnigiaq channels are conveying flows along their reach, the Sakoonang Channel is receiving floodwater from the north and the south.
5/31/13 3:45 PM	-	5.62	-	All channels remain largely clear of ice floes, channel ice remains competent in all reaches.
6/1/13 3:30 PM	-	6.91	6.07	
6/1/13 3:45 PM	4.19	-	-	
6/2/13 5:15 PM	-	-	6.89	
6/2/13 5:30 PM	6.12	7.34	-	
6/4/13 8:00 AM	-	9.49	8.71	Peak Stage at TAM and ULAM - based on PT data
6/4/13 3:15 PM	8.79	8.36	7.88	Ice jam observed on the Colville East Channel at the Tamayayak Channel bifurcation
6/5/13 2:15 PM	9.58	-	-	Peak Stage at SAK - based on PT data
6/6/13 2:00 PM	-	7.94	-	
6/6/13 4:00 PM	8.96	-	7.58	

Notes:
1. SAK elevations based on CP-08-11-12 at 7.365 ft BPMSL, surveyed by Baker in 2012
2. TAM elevations based on CP-08-11-23 at 8.524 ft BPMSL, surveyed by LCMF in 2008
3. ULAM elevations based on CP-08-11-35 at 9.146 ft BPMSL, surveyed by LCMF 2008



Graph 3.35: 2013 Stage Data for SAK, TAM, and ULAM

3.7 PROPOSED CD5 ROAD CROSSINGS

In 2009, 2010, and 2011, three gage sites were used to monitor breakup conditions along the proposed CD5 pipeline/access road (CD5) route: G21 at the Nigliq Channel crossing, G22 at the Lake L9341 crossing, and G23. Changes were made in 2012 in support of continuing project design. Upstream and downstream gage sets were established to collect additional stage and discharge data for each crossing. Existing gages G21, G22, and G23 were upgraded to paired sets and given new identifiers: G26/G27, G32/G33, and G38/G39, respectively. Five new locations were monitored. One pair of gages was installed at the Lake L9323 crossing (G24/G25); one pair upstream and downstream of the Nigliq crossing (G28 and G29 respectively); and three pairs at shallow drainages along the route (G30/G31, G34/G35, and G36/G37). Monitoring sites remained the same for the 2013 breakup event. Monitoring was confined to the east of the National Petroleum Reserve – Alaska boundary.

1) Spring Breakup Observations

On May 30, the leading edge was observed downstream of the proposed Nigliq Channel crossing. Stage was first measurable on the proposed Nigliq Channel crossing gages on May 31 as water levels continued to rise in the Nigliq Channel.

On June 1, stage was first measurable on the proposed Lake L9341 and Nigliagvik crossings. Leading edge traveling upstream and downstream in the Nigliagvik was converging at the proposed crossing (Photo 3.55). Nigliq Channel backwater was entering Lake L9341 from the north (Photo 3.56).

Photo 3.55: Leading edge traveling upstream at the proposed Nigliagvik crossing, looking southwest; June 1, 2013

Photo 3.56: Nigliq Channel backwater entering Lake L9341 from the north, looking east; June 1, 2013

On June 2, water levels continued to increase in the Nigliq Channel. Channel ice remained intact at the proposed Nigliq Channel crossing and stage was approaching bankfull conditions (Photo 3.57). The small lake to the southeast of the proposed Nigliq Channel crossing was connected to the Nigliq Channel. Stage increased at the proposed Lake L9341 and Nigliagvik crossings; however, flow was stagnant at both locations.

Stage was first measureable on the gages at the proposed Lake L9323 crossing on June 3 as the Sakoonang Channel floodwater entered Lake L9323 via the south CD4 culvert battery. On June 4, an ice jam, located approximately 1 RM upstream of CD4, was observed in the Nigliq Channel. As floodwater was diverted around the upstream ice jam extensive overbank flooding was observed along the proposed CD5 road alignment and at all proposed crossings. Nigliq Channel floodwater inundated Lake L9323 and stage was measurable on gages G30/G31, situated on higher ground between the proposed Nigliq Channel and Lake L9341 crossings (Photo 3.58). Channel ice remained intact on the Nigliq Channel although some transverse cracks were forming (Photo 3.59).

On June 4, extensive flooding was observed on the high ground between the proposed Lake L9341 and Nigliagvik crossings (Photo 3.60). Gages G34/G35 and G36/G37 situated along the proposed CD5 road between the proposed Lake L9341 and Nigliagvik crossings had measurable stage. WSE gradients were observed at the proposed Lake L9341 and Nigliagvik crossings indicating south to north flow.

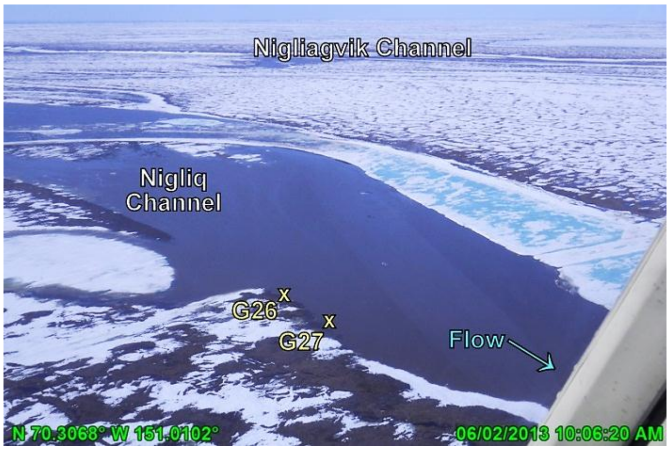


Photo 3.57: Bankfull conditions and intact channel ice at the proposed Nigliq Channel crossing, looking southwest; June 2, 2013

Photo 3.58: Overbank flooding at the proposed Lake L9323 and Nigliq Channel crossing, looking north; June 4, 2013

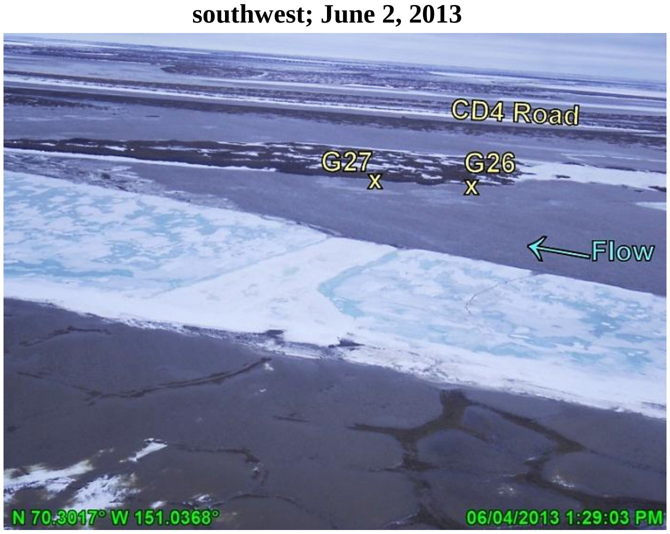


Photo 3.59: Intact channel ice with transverse cracks forming at the Nigliq Channel crossing, looking east; June 4, 2013

Photo 3.60: Extensive flooding along the proposed CD5 road alignment between the proposed Lake L9341 and Nigliagvik crossings, looking west; June 4, 2013

On the afternoon of June 4, a peak stage of 11.06 feet BPMSL was recorded downstream of the proposed Nigliq Channel crossing at gage G29. Peak stage upstream of the proposed Nigliq Channel crossing at G28 was 12.45 feet BPMSL occurring on the morning of June 5. On June 4, gages G26 and G27 at the proposed Nigliq Channel crossing were not accessible and were eventually destroyed by ice floes. Peak WSE at the proposed Nigliq Channel crossing (G26 and G27) was estimated to be 12.45 feet BPMSL based on the peak WSE at the proposed Lake L9323 crossing which is at the same lateral downstream location. Peak stage of 11.07 feet BPMSL was recorded on June 4 at Lake L9341 (G32) as inflow from the Nigliq Channel into the lake crested. A peak stage of 11.41 feet BPMSL was recorded at the proposed Nigliagvik crossing (G38) on June 4.

On June 5, a peak stage of 12.42 feet BPMSL was recorded at the proposed Lake L9323 (G25) crossing.

By June 6, the Nigliq Channel ice jam had advanced to the proposed Nigliq Channel crossing (Photo 3.61). Although stage had decreased at all proposed CD5 crossings, a large amount of backwater was retained by the ice jam causing overbank flooding at the proposed Nigliq Channel and Lake L9323 crossings. On the afternoon of June 6, the field crew observed the sudden release of the ice jam at the proposed Nigliq Channel crossing. Water levels were observed increasing as a surge of backwater and ice floes passed through the proposed crossing (Photo 3.62). A small ice jam was observed at the proposed Nigliagvik crossing on June 6, but did not appear to retain backwater.

Floodwaters had significantly receded at all the proposed CD5 crossings by June 8. Lakes L9323 and L9341 were no longer receiving floodwater from the Nigliq Channel, and the proposed Nigliq Channel crossing was clear of channel ice.

Photo 3.61: Ice jam at the proposed Nigliq Channel crossing, looking west; June 6, 2013

Photo 3.62: Ice jam release at the proposed Nigliq Channel crossing, looking east; June 6, 2013

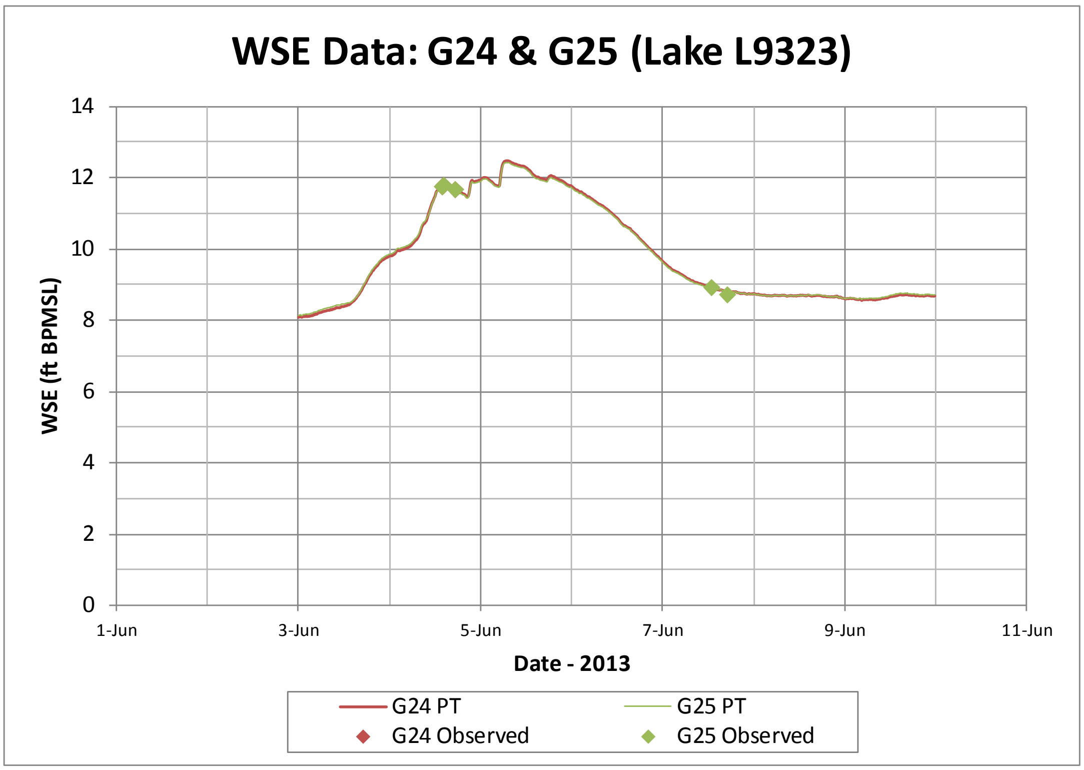
Stage-hydrographs for the proposed CD5 road crossings are provided in Table 3.32 through Table 3.38 and Graph 3.36 through Graph 3.42 and are in numerical order.

Table 3.32: 2013 Stage Data for G24 and G25 (Lake L9323)

Date and Time	WSE (feet BPMSL)		Observations
	G24	G25	
6/3/13 12:00 PM	-	-	Water from Lake L9324 beginning to flow into Lake L9323 from south CD4 culvert battery
6/4/13 1:45 PM	11.74	11.72	
6/4/13 2:15 PM	11.76	11.76	
6/4/13 5:15 PM	11.66	11.63	
6/5/13 6:45 AM	12.40	12.42	Peak Stage at G24 and G25 - based on PT data and HWM
6/7/13 12:45 PM	8.91	8.91	
6/7/13 4:45 PM	-	8.69	

Note:

1. G24 and G25 elevations based on CP-08-11-52A at 9.935 ft BPMSL, surveyed by LCMF in 2012



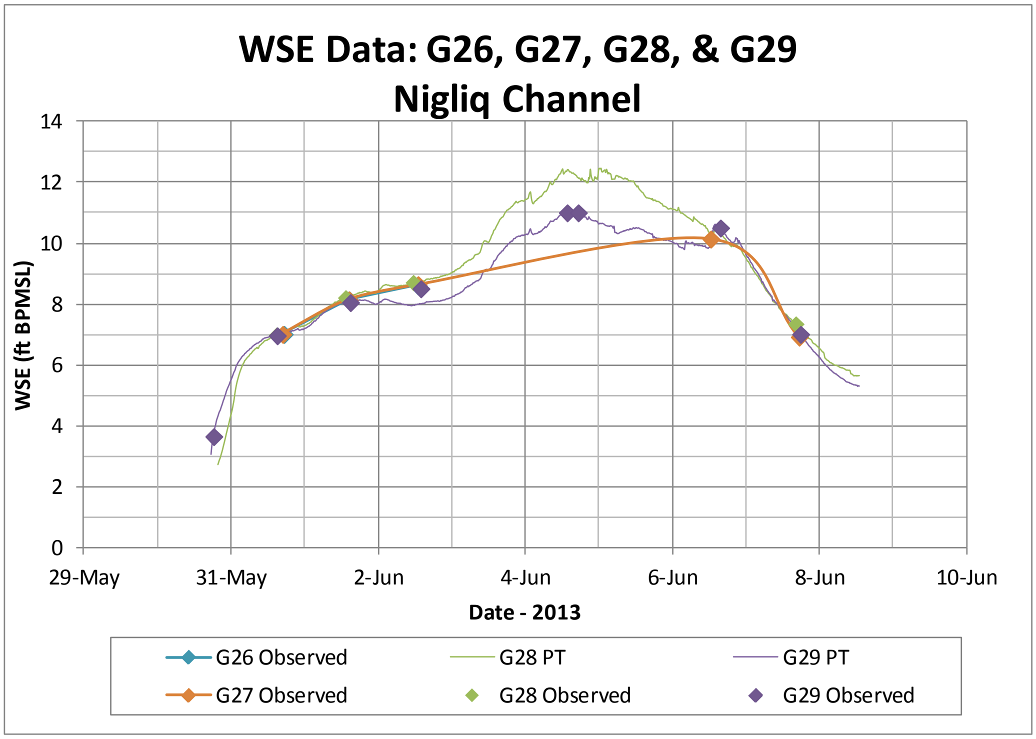
Graph 3.36: 2013 Stage Data for G24 and G25 (Lake L9323)

Table 3.33: 2013 Stage Data for G26, G27, G28, and G29 (Nigliq Channel)

Date and Time	WSE (feet BPMSL)				Observations
	G26	G27	G28	G29	
5/31/13 2:45 PM	-	-	6.96	6.98	
5/31/13 4:50 PM	7.04	7.04	-	-	
6/1/13 1:45 PM	-	-	8.20	-	
6/1/13 2:05 PM	8.15	8.15	-	-	
6/1/13 4:45 PM	-	-	-	8.09	
6/2/13 11:30 AM	-	-	8.69	-	Ice remains intact in the Nigliq Channel
6/2/13 12:50 PM	8.64	8.64	-	-	
6/2/13 1:45 PM	-	-	-	8.51	
6/4/13 3:00 PM	-	-	-	11.06	Peak Stage at G29 - based on PT data
6/4/13 3:30 PM	-	-	-	11.03	
6/4/13 5:15 PM	-	-	-	11.00	
6/5/13 12:45 AM	-	-	12.45	-	Peak Stage at G28 - based on PT data
6/6/13 12:31 PM	-	10.14	-	-	
6/6/13 3:15 PM	-	-	-	10.54	
6/7/13 4:15 PM	-	-	7.35	-	
6/7/13 5:00 PM	-	6.95	-	-	
6/7/13 5:30 PM	-	-	-	7.04	

Notes:

1. G26 and G27 elevations based on CP-08-11-53A at 8.075ft BPMSL, surveyed by LCMF in 2012
2. G28 elevations based on TBM 2010 at 11.380 ft BPMSL, surveyed by Baker in 2011
3. G29 elevations based on CP-08-11-60B at 9.859 ft BPMSL, surveyed by LCMF in 2012
4. G26 gages destroyed by ice before peak stage, therefore graph does not accurately depict peak stage
5. A HWM was not apparent at G27



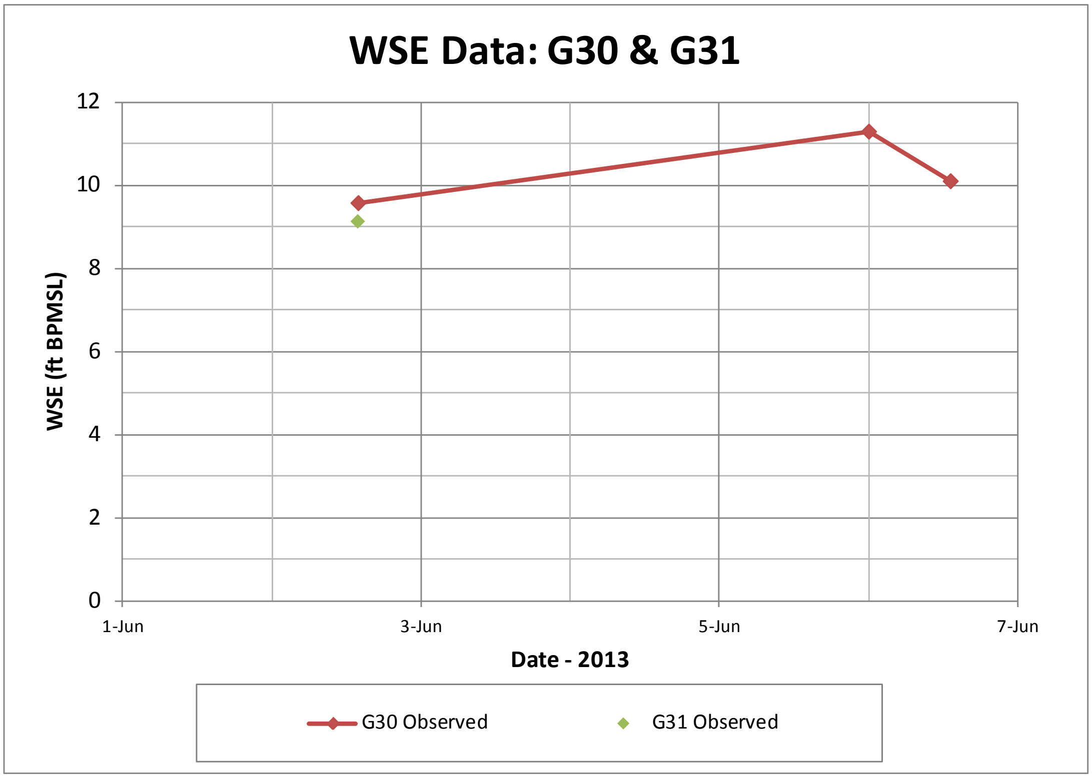
Graph 3.37: 2013 Stage Data for G26, G27, G28, and G29 (Nigliq Channel)

Table 3.34: 2013 Stage Data for G30 and G31

Date and Time	WSE (feet BPMSL)		Observations
	G30	G31	
6/1/13 2:15 PM	-	-	Local melt only
6/2/13 1:59 PM	9.58	9.12	
6/6/13 12:00 AM	11.29	-	HWM
6/6/13 1:20 PM	10.08	-	G31 could not be accessed

Note:

1. G30 and G31 elevations based on CP-08-11-60B at 9.859 ft BPMSL, surveyed by LCMF in 2012
2. Peak stage can not be accurately estimated due to limited data



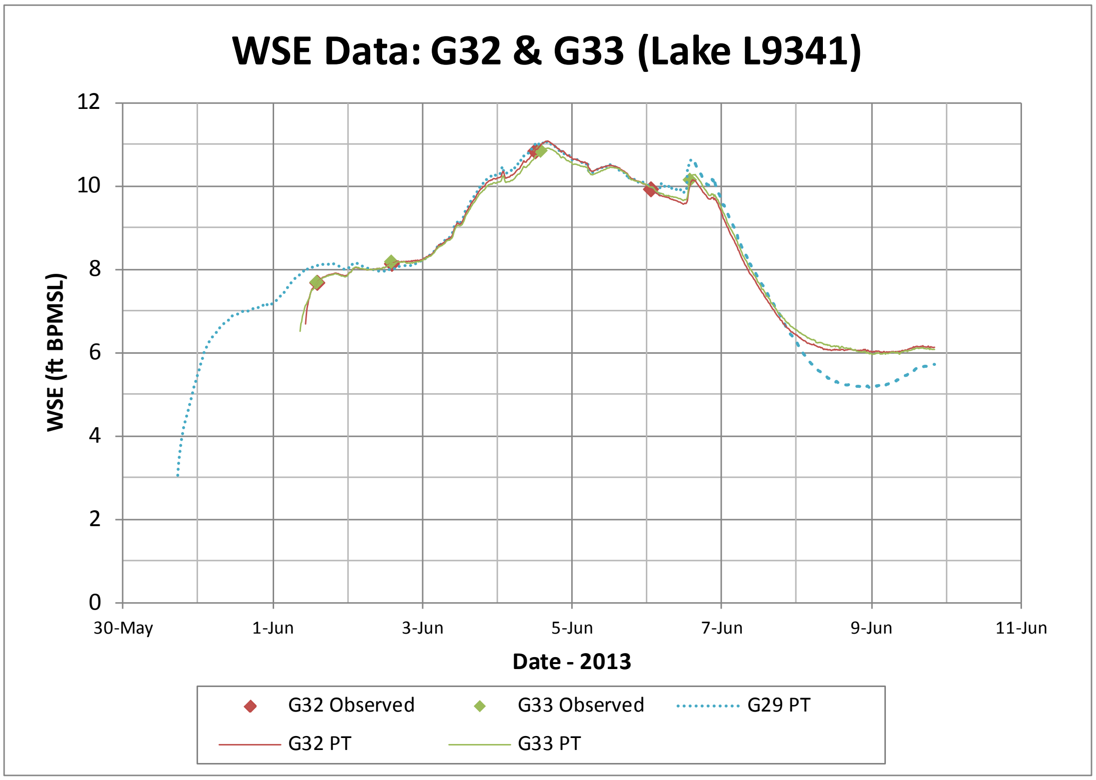
Graph 3.38: 2013 Stage Data for G30 and G31

Table 3.35: 2013 Stage Data for G32 and G33 (Lake L9341)

Date and Time	WSE (feet BPMSL)		Observations
	G32	G33	
6/1/13 2:15 PM	7.68	7.68	
6/2/13 2:15 PM	8.14	8.15	
6/4/13 12:00 PM	10.82	10.82	
6/4/13 4:15 PM	11.07	10.91	Peak Stage at G32 and G33 - based on PT data
6/6/13 1:30 PM	9.91	-	
6/6/13 1:45 PM	-	10.12	

Note:

1. G32 and G33 elevations based on CP-08-11-60C at 10.541 ft BPMSL, surveyed by LCMF in 2012



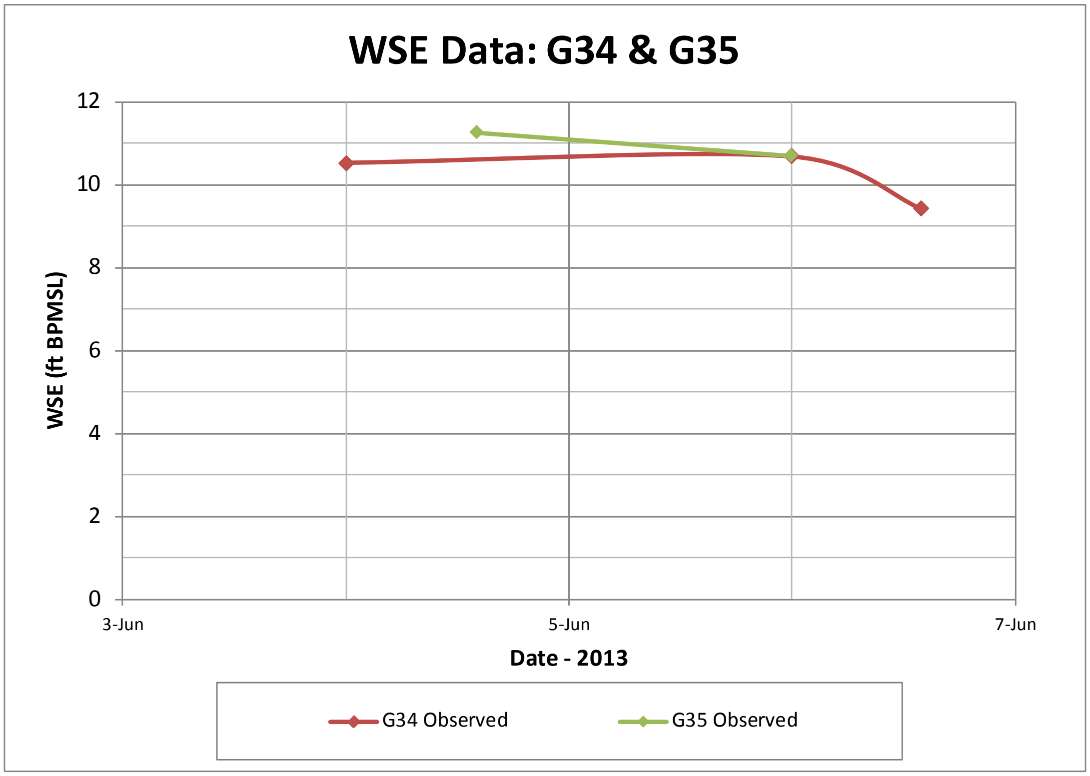
Graph 3.39: 2013 Stage Data for G32 and G33 (including G29 PT [Lake L9341])

Table 3.36: 2013 Stage Data for G34 and G35

Date and Time	WSE (feet BPMSL)		Observations
	G34	G35	
6/2/13 2:20 PM	-	-	All gages observed dry
6/4/13 12:00 AM	10.52	-	
6/4/13 2:10 PM	-	11.25	
6/6/13 12:00 AM	10.67	10.69	
6/6/13 1:53 PM	9.41	-	

Note:

1. G34 and G35 elevations based on CP-08-11-64C at 9.782 ft BPMSL, surveyed by LCMF in 2012
2. Peak stage can not be accurately estimated due to limited data



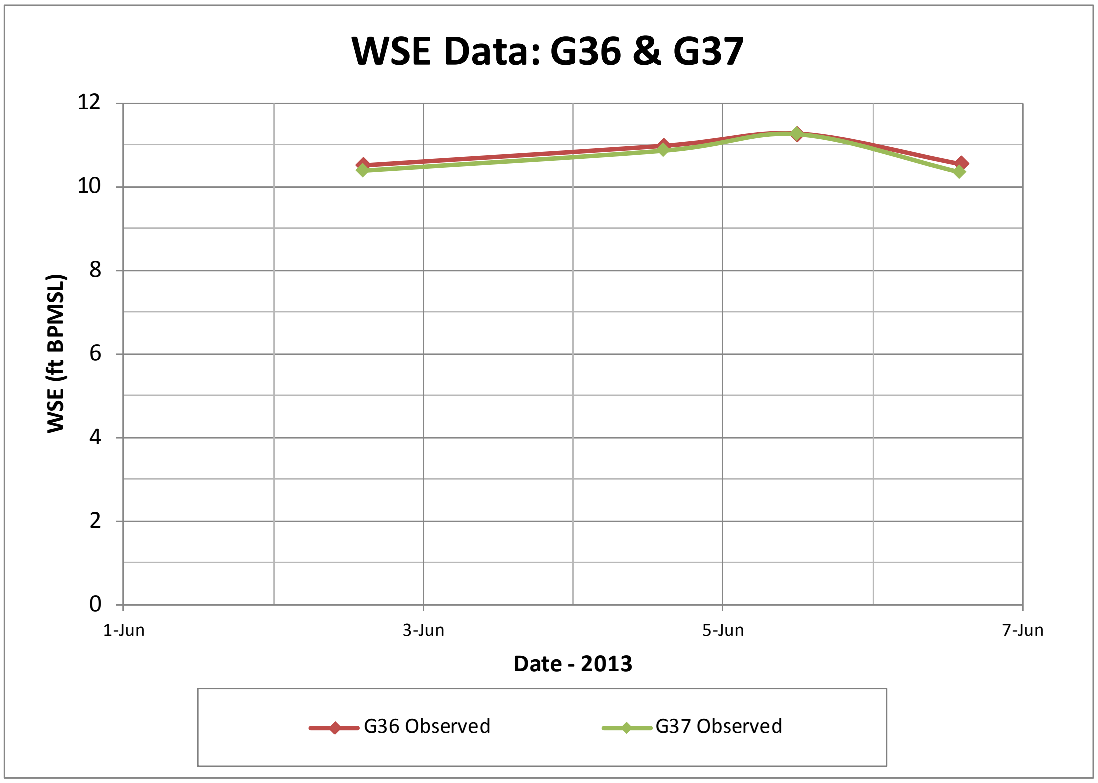
Graph 3.40: 2013 Stage Data for G34 and G35

Table 3.37: 2013 Stage Data for G36 and G37

Date and Time	WSE (feet BPMSL)		Observations
	G36	G37	
6/1/13 2:30 PM	-	-	All gages observed dry
6/2/13 2:20 PM	10.50	10.38	Local melt
6/4/13 2:35 PM	10.97	10.86	
6/5/13 12:00 PM	11.26	11.25	Peak Stage - based on HWM
6/6/13 2:08 PM	10.53	10.34	

Note:

1. G36 and G37 elevations based on CP-08-11-65C at 10.567 ft BPMSL, surveyed by LCMF in 2012



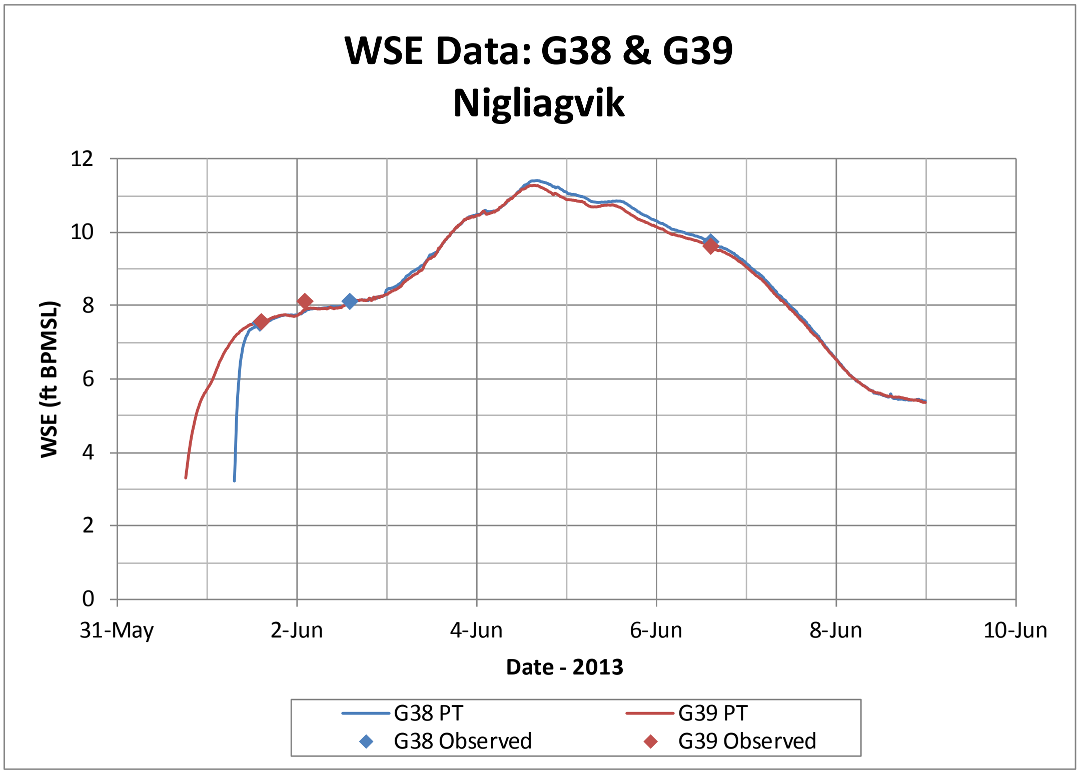
Graph 3.41: 2013 Stage Data for G36 and G37

Table 3.38: 2013 Stage Data for G38 and G39 (Nigliagvik)

Date and Time	WSE (feet BPMSL)		Observations
	G38	G39	
6/1/13 2:30 PM	7.51	-	
6/1/13 2:45 PM	-	7.56	
6/2/13 2:30 PM	8.11	8.10	
6/4/13 1:30 PM	-	11.28	Peak Stage at G39 - based on PT data
6/4/13 4:00 PM	11.41	-	Peak Stage at G38 - based on PT data
6/6/13 2:30 PM	-	9.60	
6/6/13 2:45 PM	9.71	-	

Note:

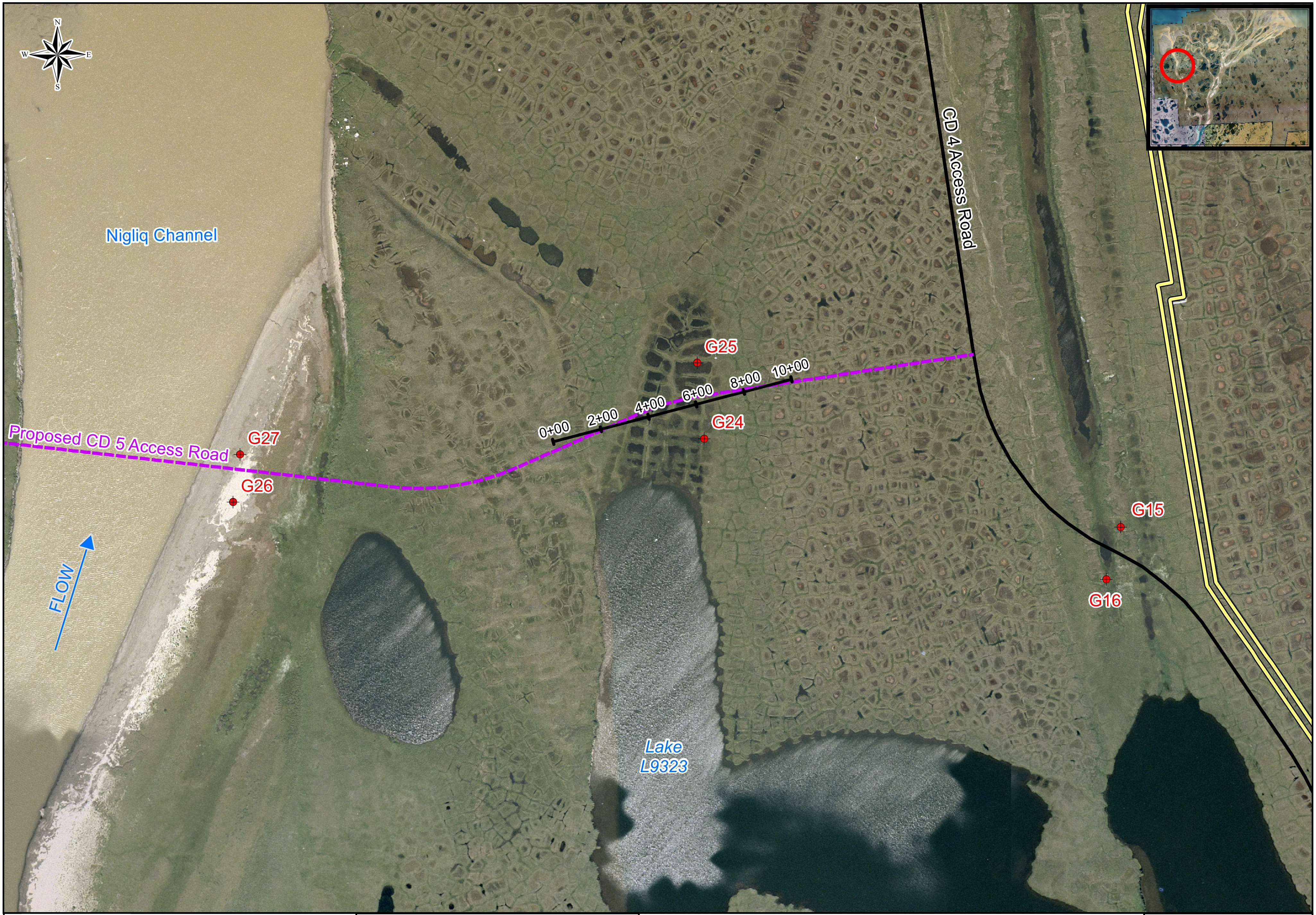
1. G38 and G39 elevations based on CP-08-11-66C at 10.674 ft BPMSL, surveyed by LCMF in 2012



Graph 3.42: 2013 Stage Data for G38 and G39 (Nigliagvik)

2) Indirect Discharge

The slope-area method was used to calculate the indirect discharge at the proposed Nigliq Channel, Lake L9341, and Nigliagvik crossings. Discharge was calculated using the energy grade-line slope as approximated by the water surface slope between gages positioned upstream and downstream of the proposed alignment at each crossing, and the LCMF topographic channel cross-section surveys. When intact ice was present at the crossings, indirect discharge computations were adjusted to account for the ice influences on discharge. Channel cross-section surveys were performed in 2008 for Lake L9341, and the Nigliagvik, and in 2003 at the Nigliq Channel. The cross-section location and profile at each of the proposed crossings are presented in Figure 3.7 through Figure 3.10. No flow was observed at the proposed Lake L9323 crossing; therefore, no indirect discharge was computed. The cross section profile of the proposed Lake L9323 crossing is provided in Figure 3.7 for reference.



ConocoPhillips Alaska

Feet
0 250 500

Date:	11/01/2013	Project:	135141
Drawn:	BTG	File:	Figure 3.7
Checked:	SME	Scale:	1 in = 500 feet

Legend

- Gage Location
- Existing Road
- 2012 Cross Section Alignment
- Proposed Road
- Pipeline

Imagery Source: ConocoPhillips Alaska, 2004

Baker

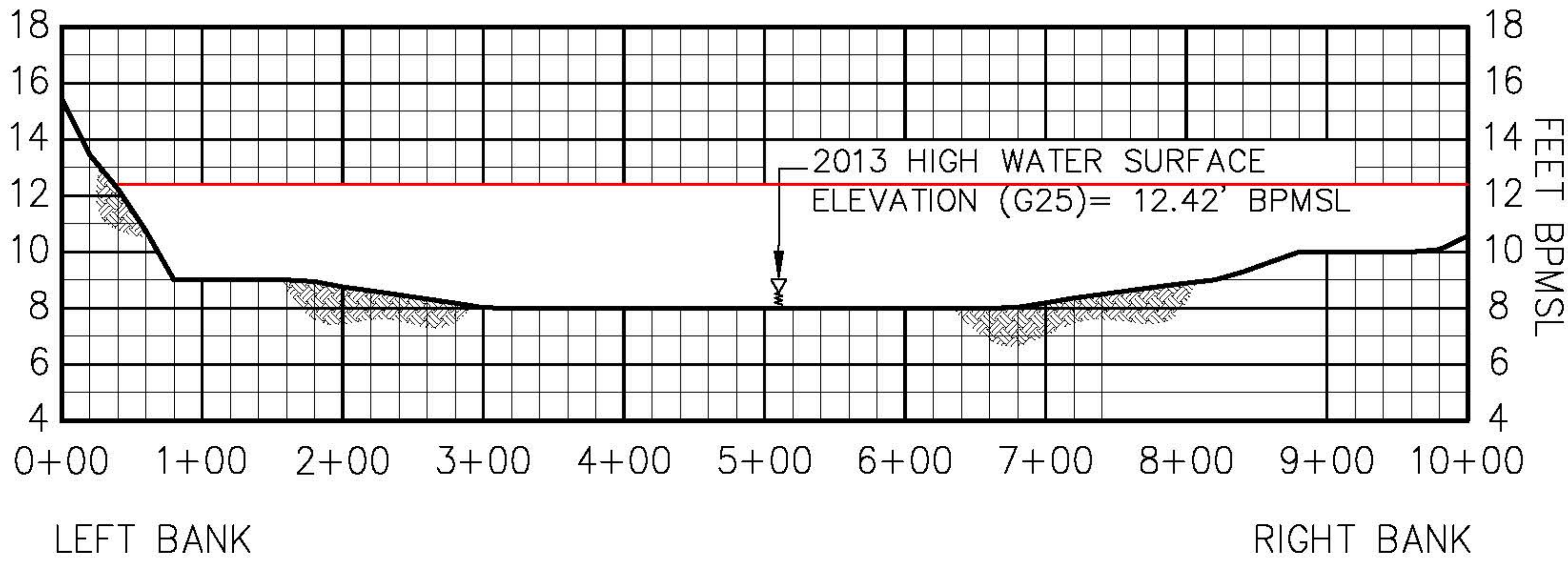
Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
CD5 Alignment
Lake L9323 Plan

FIGURE: 3.7

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, CP08-11-52A.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED SEPTEMBER 2012 BY UMIAQ (KUUKPIK/LCMF INC.)



1 PROPOSED CD5 CROSSING – LAKE L9323 CENTERLINE CROSS SECTION

100 0 100 200
HORIZONTAL SCALE IN FEET

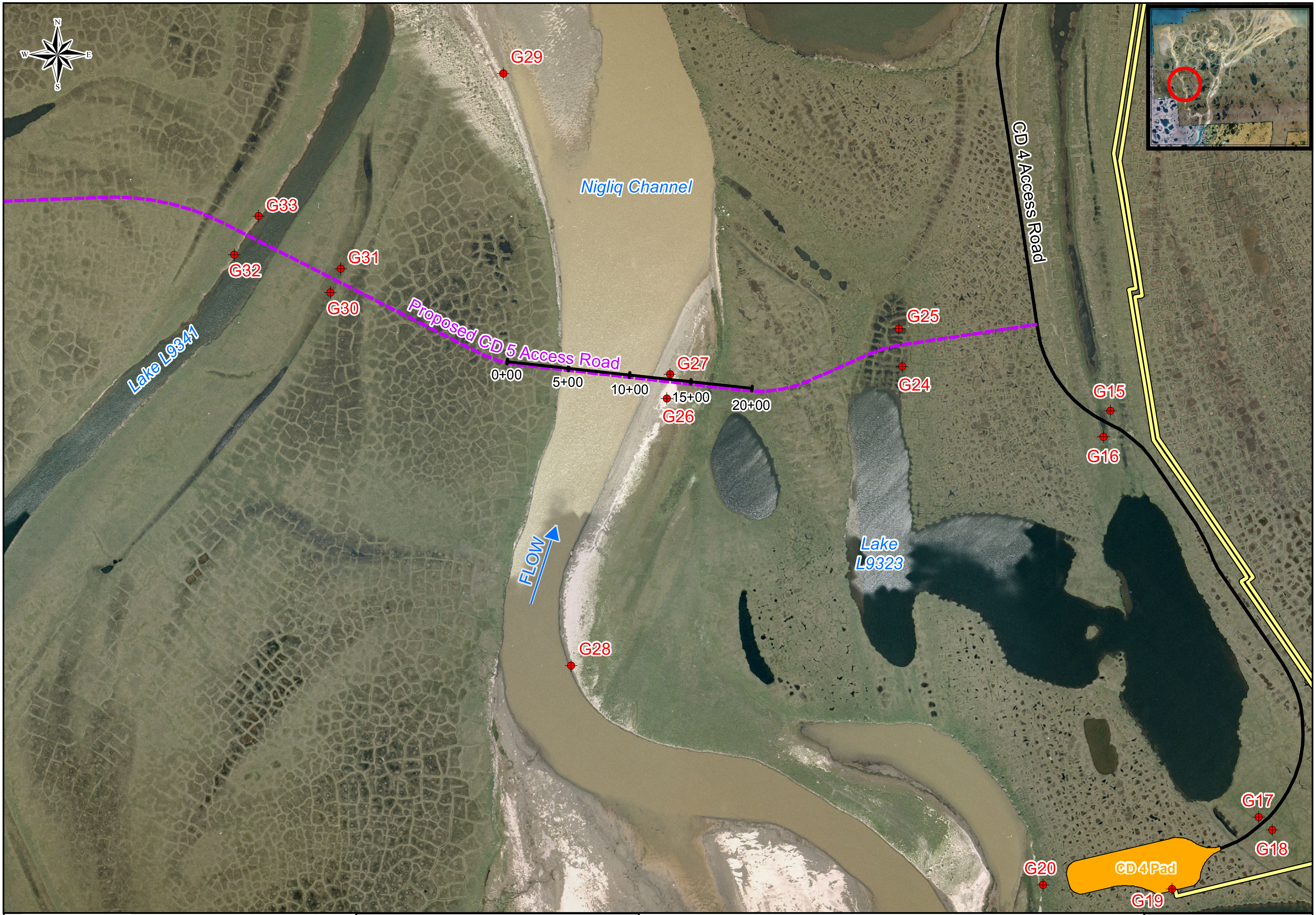
5 0 5 10
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/21/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.7.DWG
CHECKED:	SME	SCALE:	AS SHOWN

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
PROPOSED CD5 CROSSING
LAKE L9323 CENTERLINE
FIGURE 3.7
(SHEET 2 OF 2)



ConocoPhillips Alaska

Feet 0 500 1,000

Date: 11/01/2013	Project: 135141
Drawn: BTG	File: Figure 3.8
Checked: SME	Scale: 1 in = 1000 feet

Legend

- Gage Location
- 2005 Cross Section Alignment
- Pipeline
- Existing Road
- Proposed Road
- Existing Facility

Imagery Source: ConocoPhillips Alaska, 2004

Baker

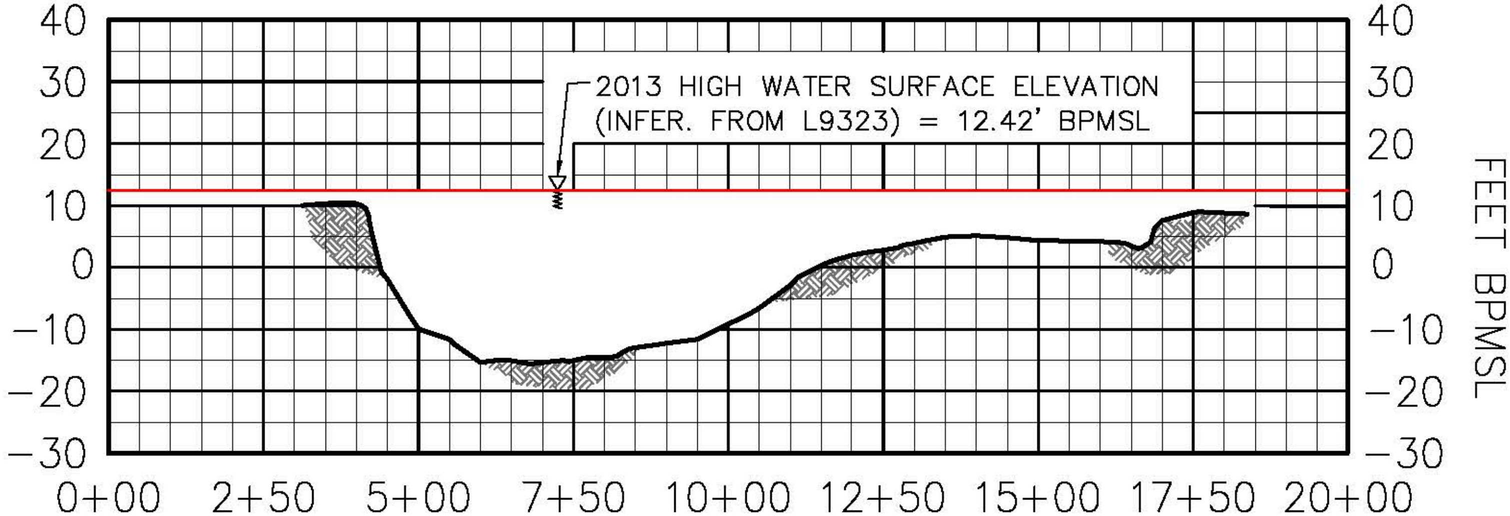
Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
CD5 Alignment
Nigliq Channel Plan

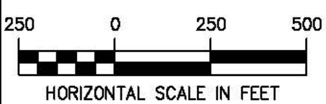
FIGURE: 3.8

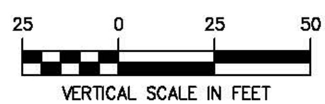
(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, BAKER TBM 2010.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2003 BY UMIAQ (KUUKPIK/LCMF INC.)



(1) PROPOSED CD5 CROSSING – NIGLIQ CHANNEL CENTERLINE CROSS SECTION



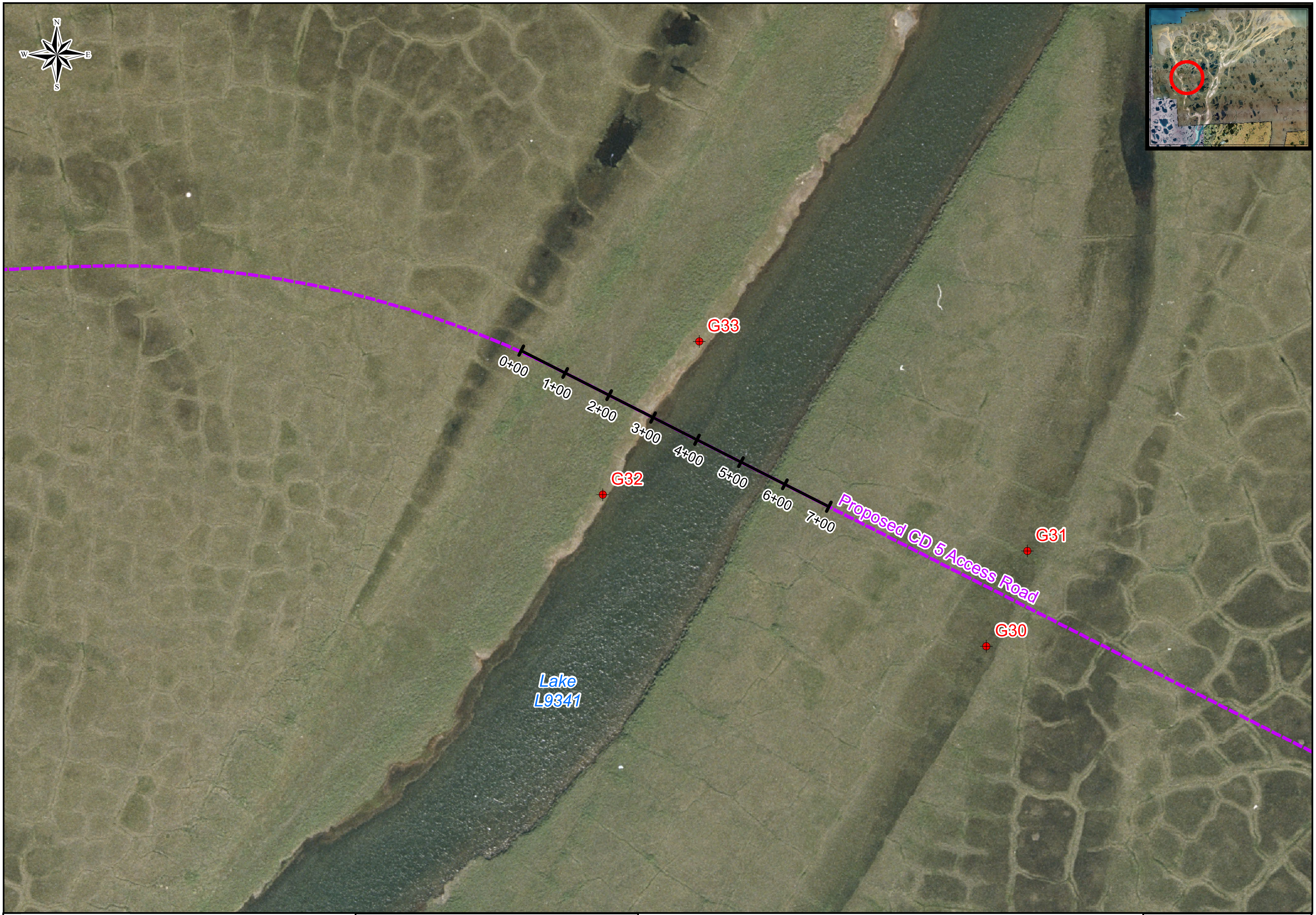


ConocoPhillips Alaska, Inc.

DATE:	10/31/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.8.DWG
CHECKED:	SME	SCALE:	AS SHOWN

Baker
Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
PROPOSED CD5 CROSSING
NIGLIQ CHANNEL CENTERLINE
FIGURE 3.8
(SHEET 2 OF 2)



ConocoPhillips Alaska

Feet
0 125 250

Date:	11/01/2013	Project:	135141
Drawn:	BTG	File:	Figure 3.9
Checked:	SME	Scale:	1 in = 250 feet

Legend

- Gage Location
- 2012 Cross Section Alignment
- Proposed Road

Imagery Source: ConocoPhillips Alaska, 2004

Baker

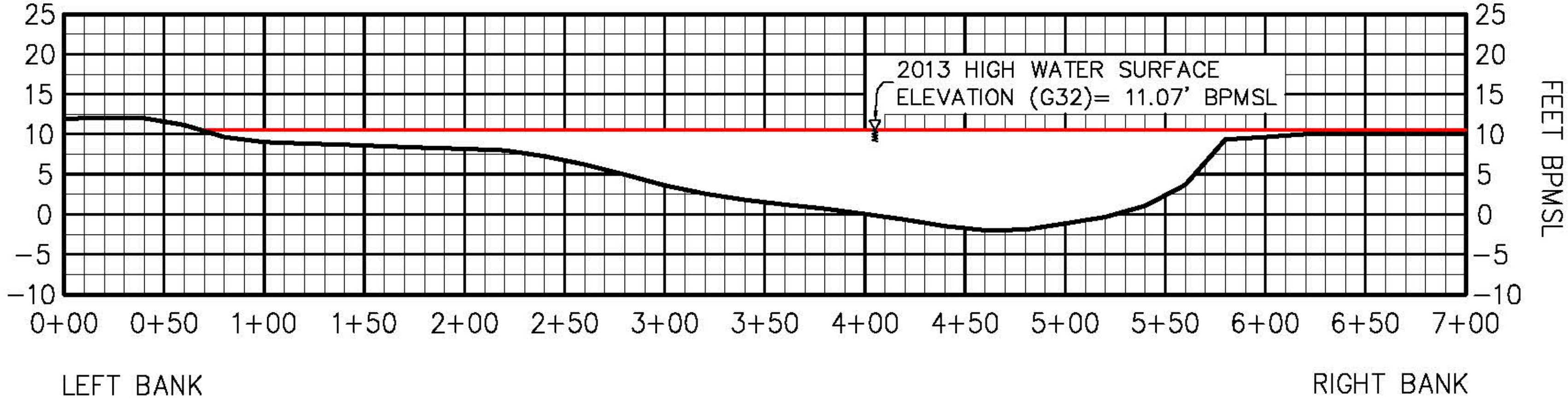
Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
CD5 Alignment
Lake L9341 Plan

FIGURE: 3.9

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, CP08-11-60C.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2008 BY UMIAQ (KUUKPIK/LCMF INC.)



1 PROPOSED CD5 CROSSING – LAKE L9341 CENTERLINE CROSS SECTION

50 0 50 100
HORIZONTAL SCALE IN FEET

12.5 0 12.5 25
VERTICAL SCALE IN FEET

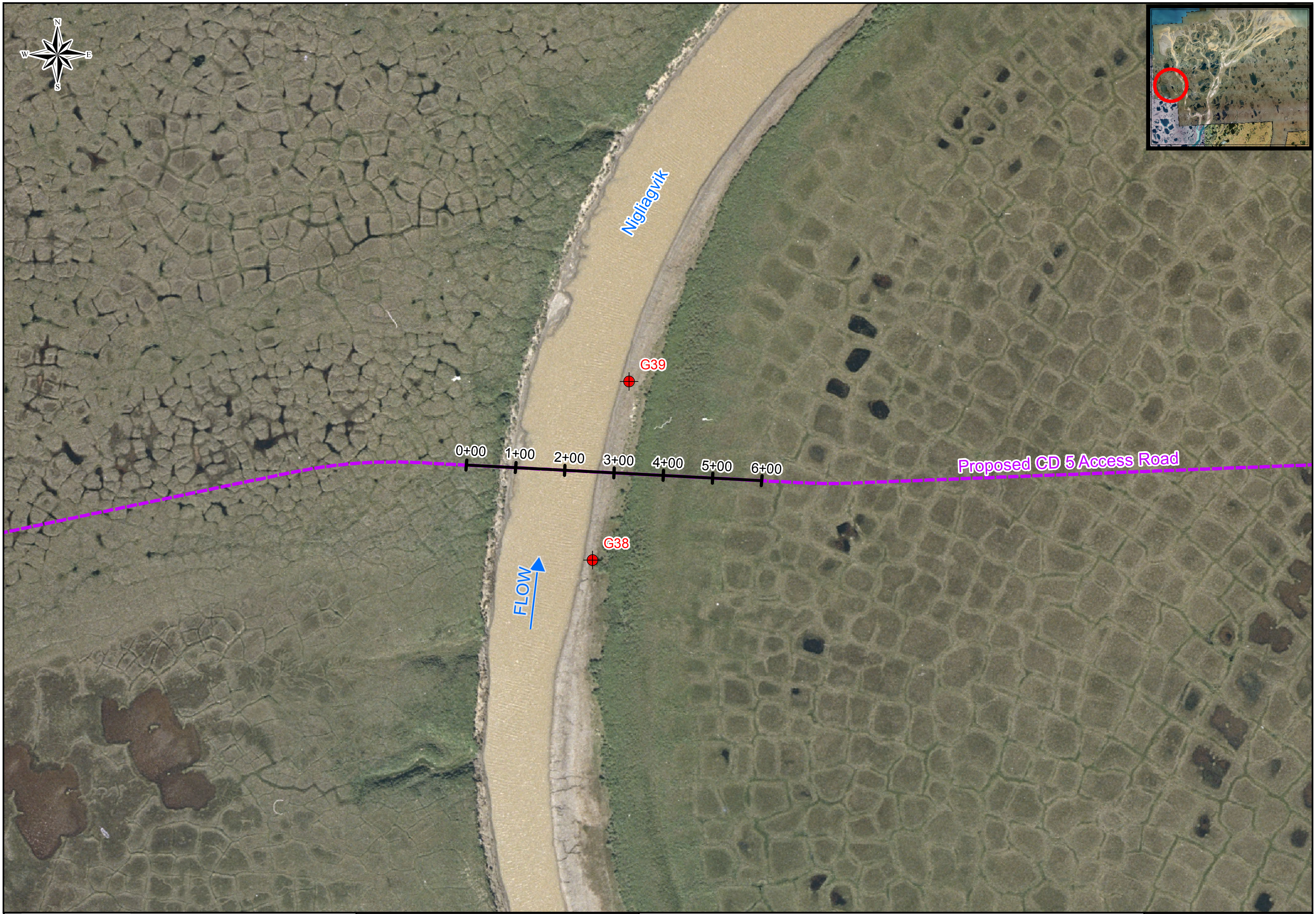
ConocoPhillips Alaska, Inc.

DATE:	10/21/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.9.DWG
CHECKED:	SME	SCALE:	AS SHOWN

Baker
Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
PROPOSED CD5 CROSSING
LAKE L9341 CENTERLINE

FIGURE 3.9
(SHEET 2 OF 2)



ConocoPhillips Alaska

Feet
0 125 250

Date:	11/01/2013	Project:	135141
Drawn:	BTG	File:	Figure 3.10
Checked:	SME	Scale:	1 in = 250 feet

Legend

- Gage Location
- 2012 Cross Section Alignment
- Proposed Road

Imagery Source: ConocoPhillips Alaska, 2004

Baker

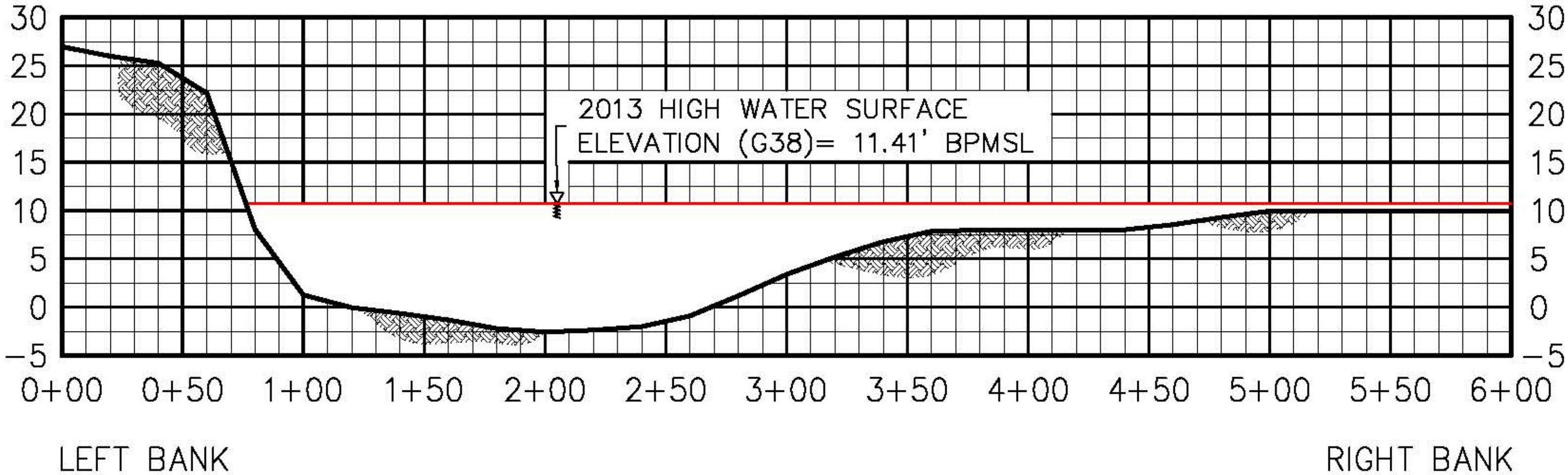
Michael Baker Jr., Inc.
1400 West Benson Blvd., Suite 200
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
CD5 Alignment
Nigliagvik Plan

FIGURE: 3.10

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, CP08-11-66C.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2008 BY UMIAQ (KUUKPIK/LCMF INC.)



1 PROPOSED CD5 CROSSING – NIGLIAGVIK CENTERLINE CROSS SECTION

50 0 50 100
HORIZONTAL SCALE IN FEET

12.5 0 12.5 25
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/21/2013	PROJECT:	135141
DRAWN:	MNU	FILE:	FIGURE 3.10.DWG
CHECKED:	SME	SCALE:	AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2013 SPRING BREAKUP
PROPOSED CD5 CROSSING
NIGLIAGVIK CENTERLINE

FIGURE 3.10
(SHEET 2 OF 2)

Nigliq Channel

Peak discharge at the Nigliq Channel crossing likely occurred on June 5. The helicopter was grounded and conditions were not observed at the Nigliq Channel crossing on June 5; therefore, the amount of channel ice and ice floes during peak indirect discharge is unknown. On June 4, channel ice remained intact along the west bank, and by June 6, the Nigliq Channel ice jam had advanced to the proposed crossing location. Based on the June 4 and June 6 conditions, large amounts of ice were likely present at the proposed crossing during peak discharge. The peak indirect discharge of 110,000 cfs at the proposed Nigliq Channel crossing was computed with channel ice incorporated. The corresponding WSEs for Gages G28 and G29 during peak discharge were 12.42 feet BPMSL and 10.57 feet BPMSL, respectively. The peak discharge at the proposed Nigliq Channel crossing likely resulted from a sudden release of the advancing upstream ice jam.

Lake L9341

On June 4, south to north flow through the proposed Lake L9341 crossing peaked at 5,000 cfs, with corresponding WSEs of 11.00 feet BPMSL and 10.82 feet BPMSL for gages G32 and G33, respectively. A large amount of snow and intact lake ice remained in Lake L9341 at the time of the peak indirect discharge on June 4. The indirect discharge was computed with the channel ice incorporated in the computations. On June 6, backwater from the Nigliq Channel ice jam caused flow to reverse direction.

Nigliagvik

The peak indirect discharge at the proposed Nigliagvik crossing was 7,800 cfs on the afternoon of June 4. The corresponding WSEs for Gages G38 and G39 were 11.24 feet BPMSL and 11.03 feet BPMSL, respectively. Significant snow and ice were present in the Nigliagvik at the time of the peak indirect discharge. The peak indirect discharge was computed with channel ice incorporated. The peak discharge at the proposed Nigliagvik crossing was likely the result of diverted backwater down the Nigliagvik from the Nigliq Channel ice jam downstream of the Nigliagvik bifurcation.

3.8 DOWNSTREAM NIGLIQ CHANNEL

Two additional sites in the downstream vicinity of the west Nigliq Channel overbank area were monitored in 2013. These areas are identified as FWR1 and FWR2 and are located in the northwest section of the CRD.

1) SPRING BREAKUP OBSERVATIONS

On June 2, much of the area around FWR1 and FWR2 was still frozen with snow cover and ponded water on top of bottom-fast ice in lakes and low centered polygons (Photo 3.63). Nigliq Channel overflow onto the sea ice in Harrison Bay was observed encroaching on the FWR1 and FWR1 area from the northwest.

By June 4, widespread inundation was observed in the FWR1 and FWR2 area. Flooding was observed from the Nigliq Channel to the south and from Harrison Bay overflow to the northwest (Photo 3.64).

On June 8, WSE readings were collected from the air as the helicopter hovered above the gages. Extensive ponded water around FWR1 and FWR2 prevented the helicopter from landing (Photo 3.65). On June 30, a driftwood line near FWR1 was surveyed to help evaluate the peak stage (Photo 3.66). Table 3.39 and Graph 3.43 present observations and WSE recorded for FWR1 and FWR2. The 2D surface-water model was used to help qualify the accuracy of the driftwood line. Model comparison with the peak stage at MON23, located 2 RM upstream of FWR1 and FWR2, was used to justify this approach. The 2D surface-water model assumes open water, steady-state conditions, and does not account for the snow, channel ice, or ice jams. Snow and ice have less of an effect on flood stage in the outer delta near MON23, FWR1, and FWR2. Peak stage at MON23 on June 4 was 9.27 feet BPMSL which is 0.92 feet below the 50-yr modeled elevation. The measured driftwood line near FRW1 was 6.20 feet BPMSL which is 0.88 feet below the 50-yr modeled flood elevation. The consistent difference between the 50-yr modeled WSE, the 2013 peak WSE at MON23, and the driftwood line suggests the driftwood line is a reasonable approximation of peak WSE near FWR1 and FWR2.

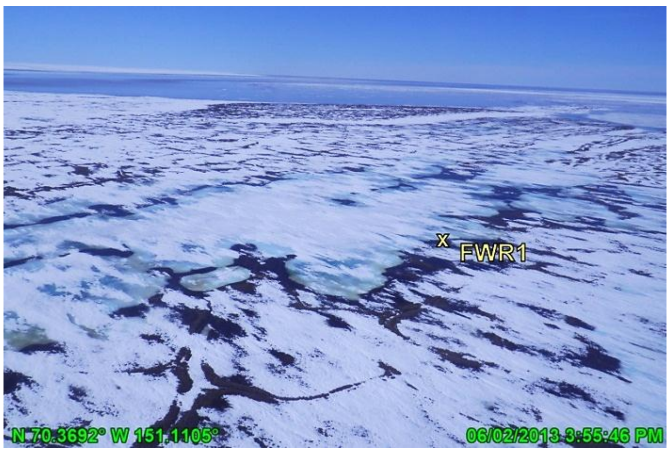


Photo 3.63: Snow cover and ponded water near FWR1; overflow in Harrison Bay, looking northwest; June 2, 2013

Photo 3.64: Widespread inundation near FWR1 and FWR2, looking northwest; June 4, 2013

Photo 3.65: Ponded water between FWR1 and FWR2, looking west; June 8, 2013

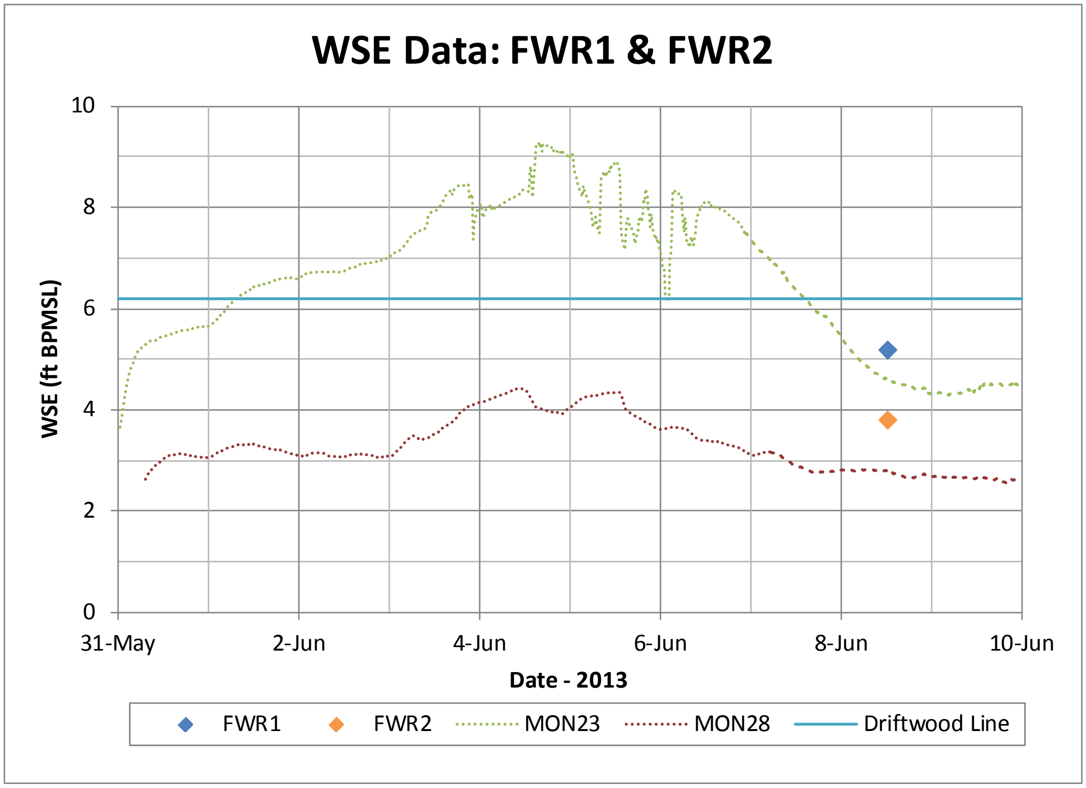
Photo 3.66: Surveyed driftwood line near FWR1, looking north; June 30; 2013

Table 3.39: 2013 Stage Data for FWR1 and FWR2

Date and Time	WSE (feet BPMSL)		Observations
	FWR1	FWR2	
6/8/13 12:30 PM	5.18	3.81	Extensive ponded water in area
6/30/13 12:00 PM	6.20		Surveyed driftwood line

Notes:

1. FWR1 and FWR2 elevations based on SHEWMAN at 7.085 ft BPMSL, surveyed by Baker in 2009
2. Widespread inundation limited access to gages during peak stage, WSE readings are from the air
3. The driftwood line was surveyed to assess the extent of flood water in the 2013 breakup flood event



Graph 3.43: 2013 Stage Data for FWR1 and FWR2 (including MON23 PT and MON28 PT)

4. 2013 RESULTS AND HISTORICAL DATA

4.1 BREAKUP TIMING IN THE COLVILLE RIVER DELTA

Since breakup studies began in 1962, Colville River breakup monitoring has been intermittently conducted at various locations in the delta. Monitoring of MON1 provides the most consistent historical record of annual peak stage and discharge observations available.

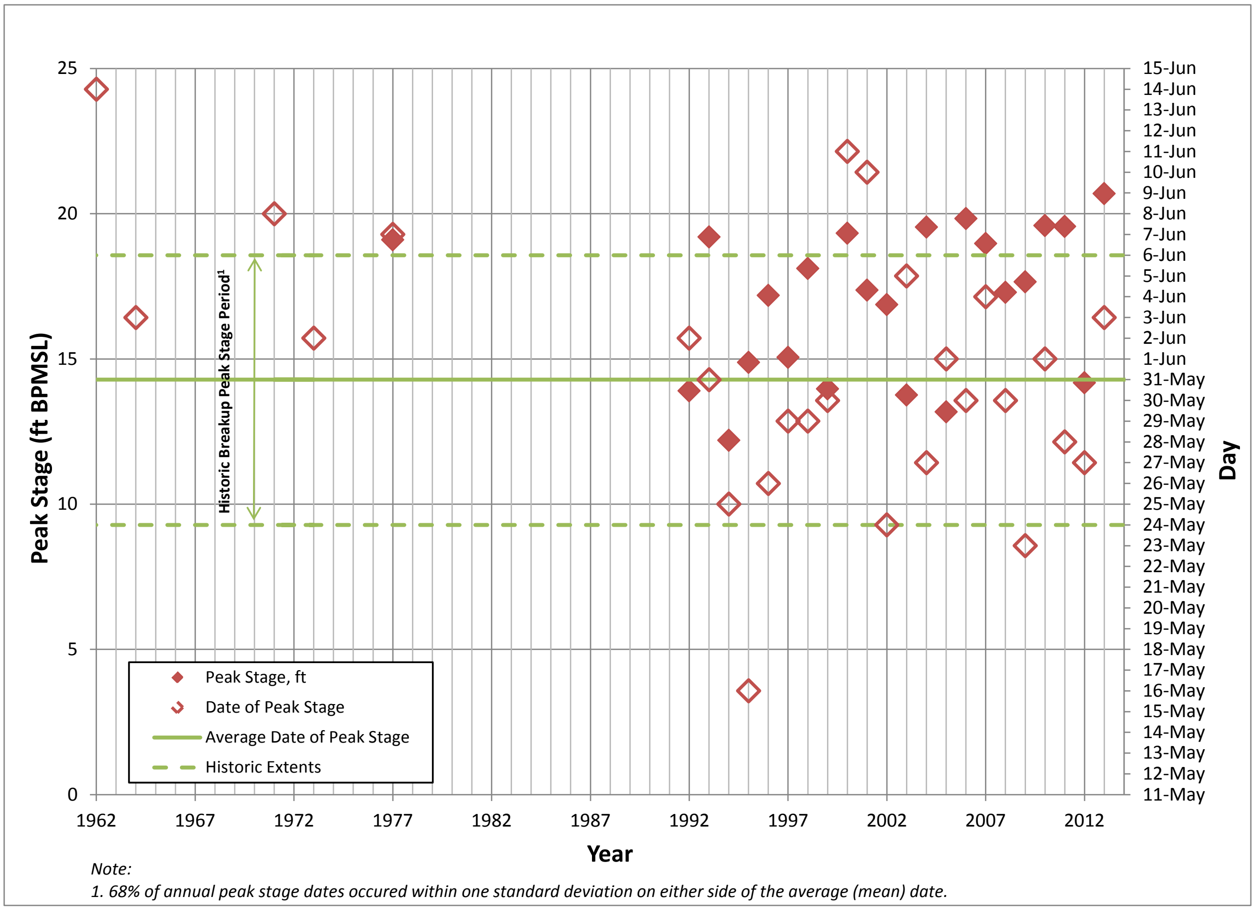
Table 4.1 shows the annual peak discharge and peak stage and the respective dates at gage MON1C. MON1C is the control for the three gage set.

The 2013 peak discharge value at MON1 was 497,000 cfs. The maximum historical peak discharge was 590,000 cfs in 2011 (Baker 2012a), and the average historical peak is 292,000 cfs. Peak discharge occurred on June 3, 2013. The average date of peak discharge is May 31, based on 19 recorded peak discharge dates.

The 2013 peak stage at MON1 was 20.69 feet BPMSL. This is the maximum historical peak stage. The second highest historical peak stage was 19.83 feet BPMSL in 2006 (Baker 2007a). The average historical peak is 17.00 feet BPMSL. In 2013, peak stage at MON1C occurred on June 3. The average date of peak stage is May 31 based on the 27 recorded peak stage dates. Graph 4.1 presents the date and WSE of peak stage at MON1C for years with available data.

Table 4.1: Colville Historical Peak Discharge, Stage & Date at MON1C Gage

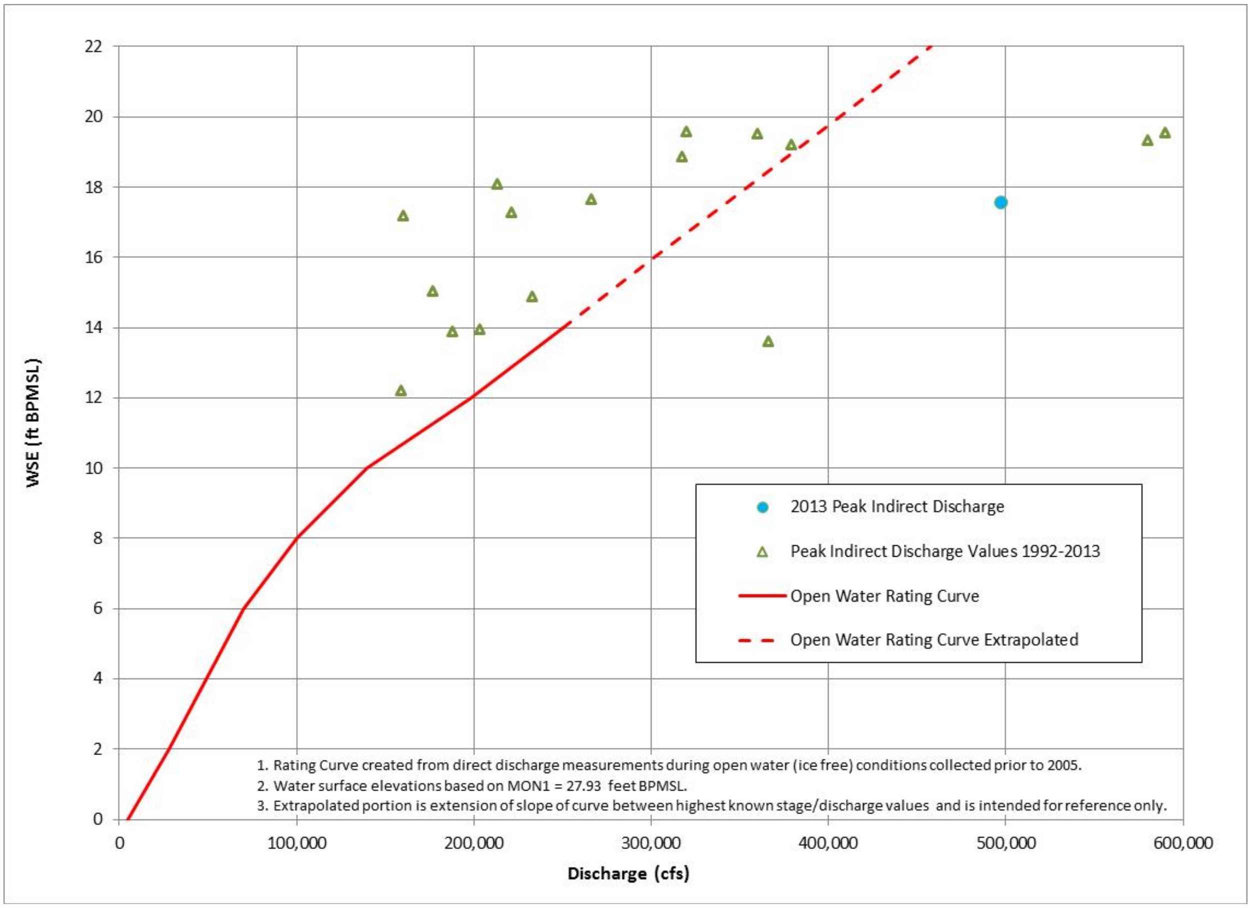
Year	Discharge		Stage (WSE)		Reference
	Peak Discharge (cfs)	Date	Peak Stage (ft BPMSL)	Date	
2013	**497,000**	**3-Jun**	**20.69**	**3-Jun**	**This report**
2012	366,000	1-Jun	14.18	27-May	Baker 2012b
2011	590,000	28-May	19.56	28-May	Baker 2012a
2010	320,000	31-May	19.59	1-Jun	Baker 2010
2009	266,000	23-May	17.65	23-May	Baker 2009b
2008	221,000	28-May	17.29	30-May	Baker 2008
2007	270,000	3-Jun	18.97	4-Jun	Baker 2007b
2006	281,000	30-May	19.83	30-May	Baker 2007a
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 2006a
2002	249,000	27-May	16.87	24-May	Baker 2006a
2001	255,000	11-Jun	17.37	10-Jun	Baker 2006a
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 1998b
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



Graph 4.1: MON1 Annual Peak Stage and Dates

Statistical analysis of the dates available for the 27-year historical peak stage record shows 68% of peak WSE for the CRD at MON1 have occurred during the 13-day period from May 24 to June 6. This represents one standard deviation of 6.3 days on either side of the average (mean) peak stage date of May 31 based on a normal distribution, as illustrated in Graph 4.1. The 2013 peak stage at MON1 on June 3 falls within this 13-day timeframe.

The MON1 stage-discharge rating curve, provided in Graph 4.2, represents a comparison between known stage and peak indirect discharge measurements collected between 1992 and 2013. It was calculated using ice-free conditions. The rating curve generally represents the relationship between stage and discharge at lower stage values when ice-free direct discharge measurements are possible. The stage-discharge rating curve may be used as a basis of comparison for accuracy of indirect discharge calculated values. The limitations of this curve are the ice effects on stage and discharge common during peak-flow periods. Open-water conditions rarely occur at or near recorded historical peak stage levels during breakup. The 2013 peak discharge of 497,000 cfs at 17.58 feet BPMSL falls to the right of the rating curve which is typical of values that tend to result from an upstream ice jam release. Conversely, values that fall to the left of the rating curve tend to be the result of downstream ice jam backwater effects. In Appendix C, an additional rating curve is shown to compare both ice-affected and non-ice-affected direct discharge measurements to historical indirect discharge values.



Graph 4.2: MON1 Stage-Discharge Rating Curve with 2013 and Historical Peak Discharge Values

Colville River Delta Peak Discharge Flow Distribution

Figure 4.1 represents the distribution of discharge through the CRD. This figure compares peak discharge at MON1 with the peak discharges through MON9 in the Colville East Channel, MON23 in the Nigliq Channel, the long and short swale bridges, and the CD2 culverts. Each section of the pie graph is represented by that location's peak discharge. Peak discharge did not occur at the same time and date for each location. As shown in the figure, approximately 15.9% of discharge is unaccounted. Peak discharge at MON9 was not captured prior to June 4 because the PT malfunctioned. Therefore, the Colville East Channel flow distribution is likely underestimated. In addition, the peak discharge in the Nigliq Channel at MON23 is likely underestimated.

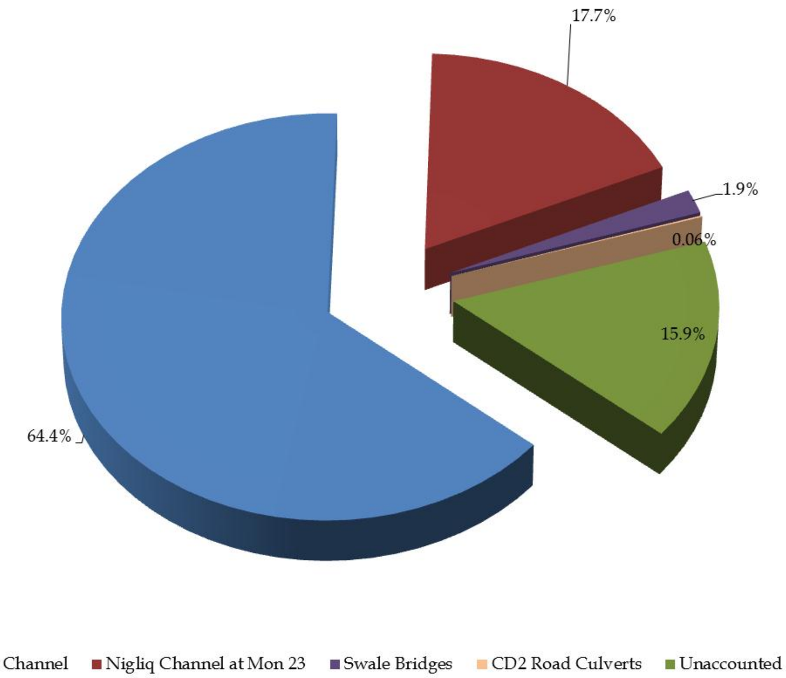


Figure 4.1: 2013 CRD Estimated Peak Flow Distribution Chart

4.2 ALPINE SWALE BRIDGES

A summary of the 2013 direct discharge measurements at the Alpine swale bridges is presented with historical data in Table 4.2. Table 4.3 summarizes the calculated peak annual discharge data at the Alpine swale bridges between 2000 and 2013. Complete notes for all direct discharge measurements for both swale bridges are included in Appendix D.

Table 4.2: Direct Discharge Historical Summary: Alpine Swale Bridges (2000 – 2013)

Site	Date	WSE[1] (ft)	Width (ft)	Area (ft^2)	Mean Velocity (ft/s)[2]	Discharge (cfs)	Measurement Rating[3]	Number of Sections	Measurement Type	Reference
62-foot Bridge	**06/05/13**	**9.75**	**54**	**446**	**3.60**	**1608**	**G**	**36**	**Cable**	**This report**
	06/03/12	7.04	52	306	1.26	386	F	19	Cable	Baker 2012b
	05/28/11	8.15	52	336	2.51	840	F	27	Cable	Baker 2012a
	06/03/10	7.58	55	316	1.79	570	F	28	Cable	Baker 2010
	–[4]	–	–	–	–	–	–	–	–	Baker 2009b
	05/29/08	6.35	55	211	0.58	120	P	14	Cable	Baker 2008
	06/05/07	7.83	55	292	1.18	350	F	20	Cable	Baker 2007b
	05/31/06	8.49	55	615	1.59	980	F	20	Cable	Baker 2007a
	–[4]	–	–	–	–	–	–	–	–	Baker 2005b
	05/29/04	8.34	55	451	1.60	720	F	17	Cable	Baker 2005a
	–[4]	–	–	–	–	–	–	–	–	Baker 2003
	05/25/02	6.74	56.0	283	1.52	430	G	17	Cable	Baker 2002b
	06/11/01	7.64	56	336	1.79	600	G	15	Cable	Baker2001
	06/10/00	7.87	47	175	3.30	580	F	13	Cable	Baker2000
452-foot Bridge	**06/05/13**	**9.87**	**448**	**2947**	**2.47**	**7286**	**G**	**36**	**Cable**	**This report**
	06/03/12	7.10	445	1686	1.53	2582		26	Cable	Baker 2012b
	05/29/11	8.16	447	2027	2.22	4500	F	26	Cable	Baker 2012a
	06/01/10	7.97	441	1699	2.66	4500	G	25	Cable	Baker 2010
	05/26/09	5.89	445	1592	0.82	730	F	27	Wading	Baker 2009b
	05/29/08	6.35	445	949	2.03	1930	F	21	Wading	Baker 2008
	06/05/07	7.76	447	1670	0.74	1240	F	20	Cable	Baker 2007b
	05/31/06	8.42	409	1730	1.89	3260	F	29	Cable	Baker 2007a
	06/02/05	6.13	445	841	1.37	1100	G	20	Wading	Baker 2005b
	05/29/04	8.34	446	1700	1.40	2400	F	18	Cable	Baker 2005a
	06/08/03	5.48	444	478	0.88	420	G	16	Wading	Baker 2003
	05/25/02	6.74	445	930	3.47	3200	G	17	Cable	Baker 2002b
	06/11/01	7.64	460	1538	2.4	3700	G	16	Cable	Baker 2001
	06/09/00	7.34	437	1220	3.27	4000	F	15	Cable	Baker 2000

Notes:
1. Source of WSE is G3
2. Mean velocities adjusted with angle of flow coefficient
3. Measurement Rating -
   - E - Excellent: Within 2% of true value
   - G - Good: Within 5% of true value
   - F - Fair: Within 7-10% of true value
   - P - Poor: Velocity < 0.70 ft/s; Shallow depth for measurement; less than 15% of true value
4. Bridge obstructed with snow or ice, no measurement made

Table 4.3: Calculated Peak Discharge Historical Summary: Alpine Swale Bridges (2000 - 2013)

Date & Time[1]	Peak WSE (ft)[2]	452-Foot Bridge		62-Foot Bridge		References
		Discharge (cfs)[3]	Mean Velocity (ft/s)	Discharge (cfs)[3]	Mean Velocity (ft/s)	
6/4/13 1:00 PM	**10.27**	**7723**	**2.47**	**1706**	**3.60**	**This report**
6/3/12 12:00 AM	7.6	2940	1.53	425	1.26	Baker 2012b
5/29/11 10:00 PM	8.89	5200	2.22	940	2.51	Baker 2012a
6/2/10 8:15 AM	8.64	5300	2.66	670	1.79	Baker 2010
5/25/09 1:00 PM	7.63	1400	0.82	–[4]	–[4]	Baker 2009b
5/30/08 12:00 PM	6.49	2100	0.49	100	0.58	Baker 2008
6/5/07 4:00 AM	8.60	1500	1.35	400	1.18	Baker 2007b
5/31/06 3:00 AM	9.72	4400	1.77	1100	1.59	Baker 2007a
5/31/05 8:00 AM	6.48	1400	1.37	–[4]	–[4]	Baker 2005b
5/27/04 1:30 PM	9.97	3400	1.38	900	1.59	Baker 2005a
06/07/2003[5]	6.31	700	0.88	–[4]	–[4]	Baker 2003
05/26/2002[5]	7.59	4000	3.47	500	1.52	Baker 2002b
06/11/2001[5]	7.95	3900	2.40	600	1.79	Baker 2001
06/12/2000[5]	9.48	7100	3.60	1000	4.30	Baker 2000

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

4.3 ALPINE DRINKING WATER LAKES

A historical summary of Alpine drinking water lakes recharge from overland breakup flooding is shown in Table 4.4.

Table 4.4: Alpine Drinking Water Lakes Historical Summary of Recharge during Spring Breakup Resulting from Overland Flood Flow, 1998 to 2013

Year	Lake L9312	Lake L9313	Reference
2013	**Yes**	**Yes**	**This Report**
2012	No	Yes	Baker 2012b
2011	Yes	Yes	Baker 2012a
2010	No	Yes	Baker 2011
2009	No	Yes	Baker 2011
2008	No	Yes	Baker 2011
2007	Yes	Yes	Baker 2011
2006	Yes	Yes	Baker 2011
2005	No	No	Baker 2011
2004	Yes	Yes	Baker 2005a
2003	No	Yes	Baker 2003
2002	Yes	Yes	Baker 2002b
2001	No	Yes	Baker 2001
2000	Yes	Yes	Baker 2000
1999	No	No	Baker 1999
1998	Yes	Yes	Baker 1998b

Note:
1. This data does not include recharge as a result of local melt.

4.4 PROPOSED CD5 ROAD CROSSINGS

A historical summary of the peak WSE and peak discharge during breakup flood events for the proposed CD5 crossings at Nigliq Channel, Lake L9341, and Nigliagvik is shown in Table 4.5.

Table 4.5: Proposed CD5 Crossing Historical Summary of Peak WSE and Discharge, 2009 to 2013

Year	Nigliq Channel Crossing		Lake L9341 Crossing		Nigliagvik Crossing	
	Peak Indirect Discharge (cfs)	Peak WSE (ft BPMSL)	Peak Indirect Discharge (cfs)	Peak WSE (ft BPMSL)	Peak Indirect Discharge (cfs)	Peak WSE (ft BPMSL)
2009	57,000 [3]	7.91	- [1]	7.98	- [1]	7.71
2010	134,000 [3]	9.65	- [1]	5.85	- [1]	8.69
2011	141,000 [3]	9.89	- [1]	9.50	- [1]	8.78
2012	94,000 [3]	8.82	6,000 [3]	8.58	11,000 [3]	8.51
2013	110,000 [4]	12.42 [2]	5,000 [4]	11.07	7,800 [4]	11.41

Notes:
1. Data not available
2. Inferred from G25 at proposed Lake L9323 Crossing
3. Indirect discharge computed as open water conditions, even though channel ice was present at time of peak discharge
4. Indirect discharge computed with consideration of intact channel ice present at time of peak discharge

4.5 FLOOD AND STAGE FREQUENCY ANALYSIS

A flood frequency analysis was performed in 2002 to estimate the recurrence interval and magnitude of peak flood discharge on the Colville River (Baker and Hydroconsult 2002). The analysis was revisited in 2006 (Baker 2007a), 2009 (Baker 2009a) and again in 2012 (Baker 2012a). The results of the 2002 and 2012 analyses are presented in Table 4.6. The 2002 results are the basis for current design criteria.

Table 4.6: Colville River Flood Frequency Analysis Results

2012 Results		2002 Results (Basis for Current Design Criteria)	
Return Period	Flood Peak Discharge (cfs)	Return Period	Flood Peak Discharge (cfs)
2-year	249,000	2-year	240,000
5-year	379,000	5-year	370,000
10-year	476,000	10-year	470,000
25-year	612,000	25-year	610,000
50-year	722,000	50-year	730,000
100-year	840,000	100-year	860,000
200-year	967,000	200-year	1,000,000

The 2013 peak discharge of 497,000 cfs has an estimated recurrence interval of 12 years, based on the flood frequency analysis results for current design criteria. The 2013 peak discharge was the result of an ice jam release that sent a surge of ice floes and backwater through the MON1 reach and was not a sustained event. The associated recurrence interval should be considered with respect to conditions at the time of peak discharge.

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

The Colville River 2D surface-water model was first developed in 1997 to estimate WSE and velocities at the proposed ADP facilities locations (Baker 1998a). 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 2002a). In 2006, the model was modified to include as-built alignment conditions along the CD4 access road and pad and the 2004-2005 survey data of the Nigliq Channel near MON23 (Baker 2006b). The model was completely reconstructed in 2009 (Baker 2009a). In 2012 additional topographic survey data at the proposed CD5 crossings was incorporated into the model (Baker 2012b).

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

In general, the 2D model under-predicts stage for lower-return periods of approximately 10 years and less. This is to be expected, as the 2D model does not account for ice- and snow-related events, which have a large effect on lower-magnitude flood events and less of an effect on higher-magnitude flood events. With an extended period of record, a stage frequency analysis can be a better estimate of low flood stage within the delta affected by recurrent ice jamming. The current 2D surface-water model predictions and the 2013 observations are presented in Table 4.7.

Overall, flood stage recurrence averaged approximately 32 years throughout the CRD, based on the 2D model results. Outlying results are generally attributable to effects related to localized ice jam events as discussed below.

Discrepancy in recurrence intervals between MON1, MON9, and MON35 is the result of timing and locations of ice jam formation and release in the Colville East Channel, and is not considered to be representative of actual volumes and related stage of breakup flow. Stage and discharge resulting from ice jam formation and release are not typically sustained, as they would otherwise be if sufficient breakup melt was present to induce lower-frequency flood recurrence intervals. A major ice jam formed upstream of MON1 during the 2013 breakup season. When it released, it re-formed in the Nigliq and Colville East channels and sporadically advanced out of the CRD as lingering intact channel ice obstructed ice floes. High stage recurrence intervals in the Nigliq Channel and around facilities reflect the accumulation of backwater from the ice jams and lingering intact channel ice. Stage recurrence at MON28 was also high. MON28 is located on the Nigliq Channel at the edge of Harrison Bay and is the farthest from facilities. It is potentially affected by tidal events as well as ice jams. The ice jam effects at the delta fringe near MON28 are likely less significant than near facilities. In addition, MON28 is near the downstream boundary of the 2D model and predicted conditions are more susceptible to error.

The ice jam that reformed in the Colville East Channel downstream of the Tamayayak Channel bifurcation diverted backwater into the Tamayayak Channel. The diverted backwater and the intact channel ice remaining in the Tamayayak and Ulamnigiaq channels likely affected the peak stage at the TAM and ULAM pipeline crossings.

Table 4.7: Colville River Delta 2012 2D Model Predicted and 2013 Observed Peak WSE

Monitoring Sites	2D Model Predicted Water Surface Elevation [based on open water conditions] (feet BPMSL)				2013 Observed Peak WSE (feet BPMSL)	Approximate Recurrence Interval of Observed Peak WSE (years)
	2-year	10-year	50-year	200-year		
Monuments - Colville East Channel						
Monument 1 (Centerline)	13.9	19.2	23.0	25.9	20.7	19
Monument 9 (HDD)	11.5	16.1	19.0	21.1	19.5	68
Monument 35 (Helmericks)	4.3	5.4	6.1	6.5	6.0	46
Monuments - Nigliq Channel						
Monument 20	7.8	11.4	14.6	16.8	14.9	59
Monument 22	6.3	9.3	12.1	14.2	10.6	20
Monument 23	5.1	7.4	10.2	12.0	9.3	29
Monument 28	3.1	3.4	3.9	4.3	4.4	>200
CD1 Pad						
Gage 1	7.3	9.7	12.5	14.6	9.9	11
Gage 9	8.3	10.8	13.4	15.7	-	-
Gage 10	8.3	10.8	13.4	15.7	10.4	8
CD2 Pad						
Gage 8	\	8.7	10.6	12.3	9.8	25
CD2 Road						
Gage 3	6.4	9.4	12.0	14.0	10.3	17
Gage 4	6.2	8.5	10.1	11.7	9.5	27
Gage 6	\	9.5	12.2	14.2	10.4	17
Gage 7	\	8.4	10.0	11.6	9.4	29
Gage 12	\	9.5	12.1	14.2	10.6	20
Gage 13	\	8.4	10.0	11.6	9.3	25
CD3 Pad						
Gage 11	5.2	6.4	6.9	8.0	-	-
CD4 Pad						
Gage 19	\	11.9	14.6	16.6	14.2	39
Gage 20	\	11.1	14.2	16.3	-	-
CD4 Road						
Gage 15	8.4	10.8	13.5	15.8	-	-
Gage 16	8.4	11.1	14.2	16.1	-	-
Gage 17	\	11.1	14.2	16.2	12.7	23
Gage 18	\	11.9	14.7	16.7	14.2	37
CD3 Pipeline Crossings						
Sakoonang (Crossing #2) Gage	6.4	8.9	11.2	12.9	9.6	16
Tamayagiaq (Crossing #4) Gage	6.7	8.5	9.0	9.8	9.5	117
Ulamnigiaq (Crossing #5) Gage	5.5	7.1	7.8	8.7	8.7	>200
Proposed CD5 Road Crossings						
Gage 24 (L9323)	\	11.1	14.0	15.8	12.4	21
Gage 26 (Nigliq Channel)	6.7	9.8	12.5	14.6	-	-
Gage 30	\	\	12.8	14.8	11.3	<50
Gage 32 (L9341)	\	\	12.8	14.8	11.1	<50
Gage 34	\	\	12.7	14.8	10.7	<50
Gage 36	\	\	12.7	14.8	11.3	<50
Gage 38 (Nigliagvik)	6.9	10.0	12.7	14.9	11.4	23

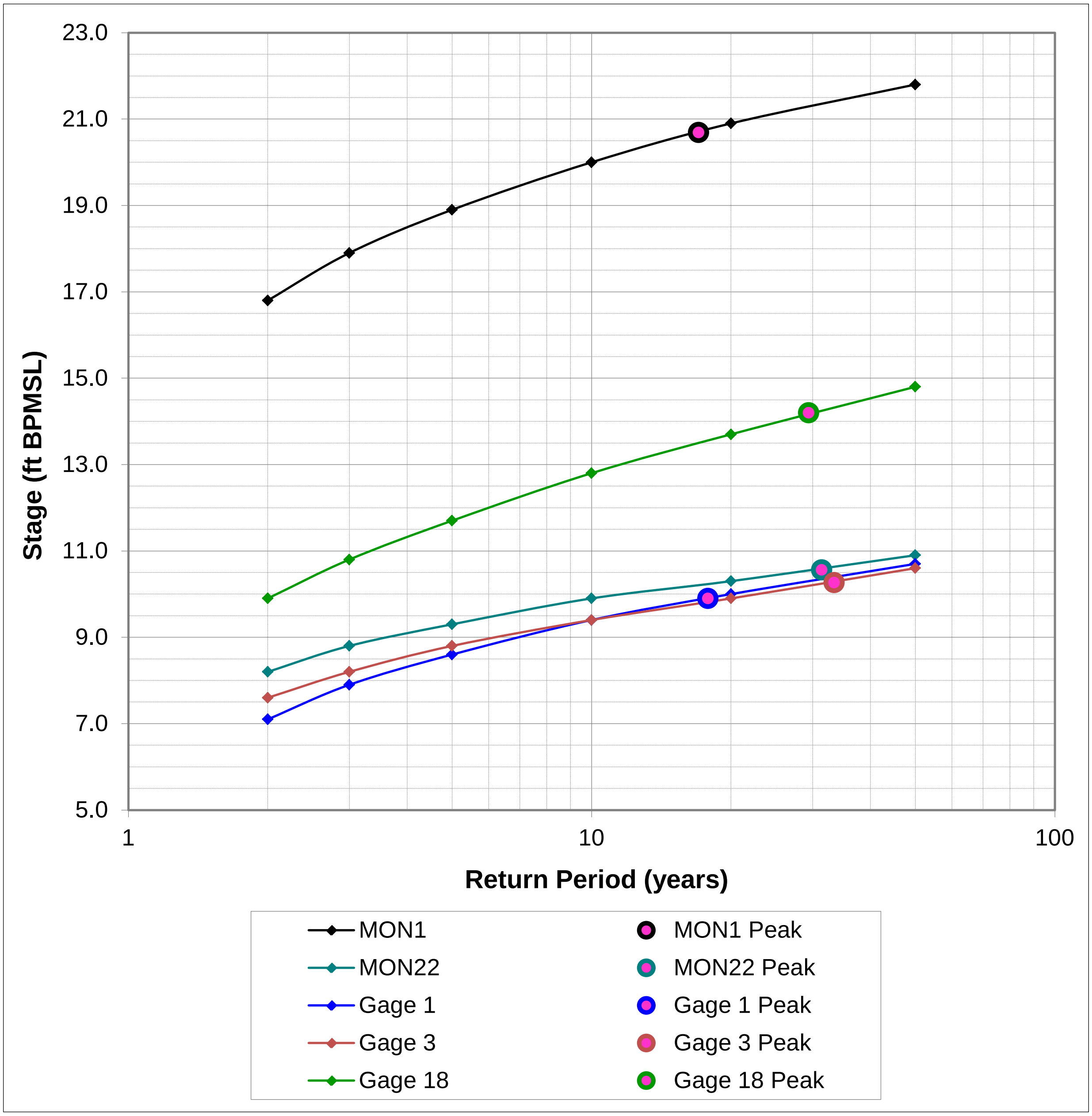
Notes:
1. Sites having dry ground in 2D model are denoted with a backward slash "\".
2. Sites not observed or having a reliable Peak WSE in 2013 are denoted with a dash "-".

4.5.2 COLVILLE RIVER DELTA STAGE FREQUENCY

A stage frequency analysis was performed for a limited group of sites in 2006 (Baker 2007a), 2009 (Baker 2009a) and in 2012 (Baker 2012b). The location and distribution of sites that have been monitored since 1992 has varied based on the objectives of each year's field program. MON1, MON22, G1, G3, and G18 were selected because each has a relatively long-term record of data. The data reflects ice-affected flooding conditions; thus, the stage analysis incorporates these conditions. Resulting values from the 2012 analysis are compared to the 2013 observed peak WSE and are presented in Table 4.8 and Graph 4.3.

Table 4.8: Colville River Delta 2012 Stage Frequency Analysis Results and 2013 Observed Peak WSE

Monitoring Sites	Stage Frequency - Log-Pearson Type III (feet BPMSL)						2013 Observed Peak WSE (feet BPMSL)	Approximate Recurrence Interval of Observed Peak WSE (years)
	2-year	3-year	5-year	10-year	20-year	50-year		
Monument 1	16.8	17.9	18.9	20.0	20.9	21.8	20.7	17
Monument 22	8.2	8.8	9.3	9.9	10.3	10.9	10.6	31
Gage 1	7.1	7.9	8.6	9.4	10.0	10.7	9.9	18
Gage 3	7.6	8.2	8.8	9.4	9.9	10.6	10.3	33
CD4 Pad (Gage 18)	9.9	10.8	11.7	12.8	13.7	14.8	14.2	29



Graph 4.3: Colville River Delta 2009 Stage Frequency Analysis Results and 2013 Observed Peak Water Surface Elevation for Selected Locations

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

5. REFERENCES

Alaska Biological Research (ABR). 1996. Geomorphology and Hydrology of the Colville River Delta, Alaska, 1995. Prepared for ARCO Alaska, Inc.

Benson, M. A. and Tate Dalrymple. 1967. General Field and Office Procedures for Indirect Discharge Measurements. In *Techniques of Water-Resources Investigations of the United States Geological Survey*. Book 3, Chapter A1. United States Government Printing Office, Washington, DC. USGS. 1967.

Helmericks, Jim. E-mail message to Karen Brown, October 2, 2013.

Michael Baker Jr., Inc. (Baker). 1998a. Colville River Delta Two-Dimensional Surface Water Model Project Update. September 1998. Prepared for ARCO Alaska, Inc.

-------- 1998b. 1998 Spring Breakup and Hydrologic Assessment, Colville River Delta, North Slope, Alaska. October 1998. Prepared for ARCO Alaska, Inc.

-------- 1999. 1999 Spring Breakup and Hydrologic Assessment, Colville River Delta, North Slope, Alaska. November 1999. Prepared for ARCO Alaska, Inc.

-------- 2000. Alpine Facilities Spring 2000 Breakup Monitoring Alpine Development Project. November 2000. Prepared for Phillips Alaska, Inc.

-------- 2001. Alpine Facilities 2001 Spring Breakup and Hydrologic Assessment. August 2001. Prepared for Phillips Alaska, Inc.

-------- 2002a. Colville River Delta Two-Dimensional Surface Water Model, CD-Satellite Project Update. May 2002. Prepared for ConocoPhillips Alaska, Inc.

-------- 2002b. Alpine Facilities 2002 Spring Breakup and Hydrologic Assessment. October 2002. Prepared for ConocoPhillips Alaska, Inc.

-------- 2003. Alpine Facilities 2003 Spring Breakup and Hydrologic Assessment. September 2003. Prepared for ConocoPhillips Alaska, Inc.

-------- 2005a. Alpine Facilities 2004 Spring Breakup and Hydrologic Assessment. March 2005. Prepared for ConocoPhillips Alaska, Inc.

-------- 2005b. 2005 Colville River Delta and Fish Creek Basin Spring Breakup and Hydrologic Assessment. December 2005. Prepared for ConocoPhillips Alaska, Inc.

-------- 2006a. 1992-2005 Annual Peak Discharge Colville River Monument 1 Estimate, Calculation, and Method Review. Prepared for ConocoPhillips Alaska, Inc.

-------- 2006b. Colville River Delta Two-Dimensional Surface Water Model CD5 Update. February 2006. Prepared for ConocoPhillips Alaska, Inc.

-------- 2007a. 2006 Colville River Delta and Fish Creek Basin Spring Breakup and Hydrological Assessment. January 2007. Prepared for ConocoPhillips Alaska, Inc.

-------- 2007b. 2007 Colville River Delta Spring Breakup and Hydrologic Assessment. November 2007. Prepared for ConocoPhillips Alaska, Inc.

-------- 2008. 2008 Colville River Delta Spring Breakup and Hydrologic Assessment. December 2008. Prepared for ConocoPhillips Alaska, Inc.

-------- 2009a. Colville River Delta, Two-Dimensional Surface Water Model Update. CD5 Alpine Satellite Development Project. September 2009. Prepared for ConocoPhillips Alaska, Inc.

-------- 2009b. Colville River Delta Spring Breakup 2009 Hydrologic Assessment. December 2009. Prepared for ConocoPhillips Alaska, Inc.

-------- 2009c. Alpine Pipeline River Crossings 2009 Monitoring Report. September 2009. Prepared for ConocoPhillips Alaska, Inc.

-------- 2010. 2010 Colville River Delta Spring Breakup 2010 Hydrologic Assessment. November 2010. Prepared for ConocoPhillips Alaska, Inc.

-------- 2011. 2011-2012 Alpine Lakes Drinking Water Quality. Project Note: Historical Review of Lake L9312 & L9313 Monitoring, Winter 2005 to Spring 2011. December 2011. Prepared for ConocoPhillips Alaska, Inc.

-------- 2012a. Colville River Delta Spring Breakup 2011 Hydrologic Assessment. January 2012. Prepared for ConocoPhillips Alaska, Inc.

-------- 2012b. 2012 Colville River Delta Spring Breakup Monitoring and Hydrologic Assessment. December 2012. Prepared for ConocoPhillips Alaska, Inc.

Michael Baker, Jr., Inc. (Baker) and Hydroconsult EN3 Services, Ltd. 2002. Colville River Flood Frequency Analysis, Update. September 2002. Prepared for ConocoPhillips Alaska, Inc.

Office of Surface Water (OSW). 1999. Technical Memorandum No. 99.06. Website access 2009. (http://water.usgs.gov/admin/memo/SW/sw99.06.html). United States Geological Survey (USGS).

PND Engineers, Inc. (PND). 2012. AutoCAD File: road alignment with bridges and CD5 Pad.dwg. April 5, 2012.

Shannon & Wilson, Inc. 1996. 1996 Colville River Delta Spring Breakup and Hydrologic Assessment, North Slope, Alaska. November 1996. Prepared for Michael Baker Jr., Inc.

UMIAQ. 2002. As-built survey. CD2 and CD4 culverts. Prepared for ConocoPhillips Alaska, Inc. (Submitted as Kuukpik/LCMF LLC, Inc. [LCMF]).

-------- 2004. Cross-section survey, Colville River at Monument 01. Prepared for Michael Baker Jr., Inc. (Submitted as Kuukpik/LCMF LLC, Inc. [LCMF]).

-------- 2005. Cross-section survey, Colville River at Monument 23. Prepared for Michael Baker Jr., Inc. (Submitted as Kuukpik/LCMF LLC, Inc. [LCMF]).

-------- 2008. Cross-section survey, proposed 2008 CD-5 Road Nechelik [Nigliq] Channel Crossing. Prepared for Conoco Phillips Alaska, Inc. (Submitted as Kuukpik/LCMF LLC, Inc. [LCMF]).

-------- 2012. As-built survey, CD2 and CD4 culvert invert elevations. Prepared for ConocoPhillips Alaska, Inc. May 2012.

-------- 2013. As-built survey, CD2 and CD4 culvert invert elevations. Prepared for ConocoPhillips Alaska, Inc. May 2013.

United States Geological Survey (USGS). 1982. Measurement and Computation of Streamflow, Vols. 1 and 2. S.E. Rantz and others. Water Supply Paper 2175.

-------- 2005. Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers. Lipscomb, Steven W., Scientific Investigations Report 2005-5183.

-------- 2006a. User’s Manual for Program PeakFQ, Annual Flood-Frequency Analysis Using Bulletin 17B Guidelines. Flynn, K.M., Kirby, W.H., and Hummel, P.R. Techniques and Methods 4-B4.

-------- 2006b. Application of the Loop Method for Correcting Acoustic Doppler Current Profiler Discharge Measurements Biased by Sediment Transport. Scientific Investigations Report 2006-5079.

-------- 2009. Mueller, D.S., and Wagner, C.R., 2009, Measuring discharge with acoustic Doppler current profilers from a moving boat: U.S. Geological Survey Techniques and Methods 3A-22, 72 p. (http://pubs.water.usgs.gov/tm3a22).

-------- 2013a. Website access summer 2013. (http://waterdata.usgs.gov/ak/nwis/uv?site_no=15875000).

-------- 2013b. Website access summer 2013 for Nuiqsut and Umiat. (http://livecam.buckeyecam.com).

Weather Underground. Website access summer 2013. (http://www.wunderground.com).

APPENDIX A 2013 VERTICAL CONTROL AND GAGE LOCATIONS

2013 Vertical Control					
Control	**Elevation (BPMSL - Feet)**	**Latitude (NAD 83)[1]**	**Longitude (NAD 83)**	**Control Type**	**Reference**
Baker TBM 2010	11.380	N 70.29631°	W 151.02686°	Angle Iron	Baker 2011
CD2-13S	11.097	N 70.33691°	W 151.01119°	Culvert top	UMIAQ 2013
CD2-14N	10.849	N 70.33712°	W 151.01101°	Culvert top	UMIAQ 2013
CD4-20E	7.828	N 70.30216°	W 150.99347°	Culvert top	UMIAQ 2013
CD4-20W	6.762	N 70.30188°	W 150.99334°	Culvert top	UMIAQ 2013
CD4-28E	12.866	N 70.29339°	W 150.98215°	Culvert top	UMIAQ 2013
CD4-29W	12.566	N 70.29312°	W 150.98287°	Culvert top	UMIAQ 2013
CP-08-11-12	7.365	N 70.36395°	W 150.92047°	Alcap	Baker 2012
CP08-11-23	8.524	N 70.39158°	W 150.90787°	Alcap	UMIAQ 2008
CP08-11-35	9.146	N 70.40661°	W 150.88220°	Alcap	UMIAQ 2008
CP08-11-52A	9.935	N 70.30339°	W 151.00572°	Alcap	UMIAQ 2012
CP08-11-53A	8.075	N 70.30222°	W 151.01896°	Alcap	UMIAQ 2012
CP-08-11-60B	9.859	N 70.30459°	W 151.04531°	Alcap	UMIAQ 2012
CP 08-11-60C	10.541	N 70.30504°	W 151.04836°	Alcap	UMIAQ 2012
CP-08-11-64C	9.474	N 70.30594°	W 151.06811°	Alcap	UMIAQ 2012
CP-08-11-65C	10.410	N 70.30525°	W 151.09266°	Alcap	UMIAQ 2012
CP08-11-66C	10.674	N 70.30505°	W 151.11638°	Alcap	UMIAQ 2012
MONUMENT 1	27.930	N 70.16588°	W 150.93995°	Alcap	UMIAQ 2006
MONUMENT 9	25.060	N 70.24458°	W 150.85831°	Alcap	UMIAQ 2008
MONUMENT 22	10.030	N 70.31809°	W 151.05605°	Alcap	Baker 2010
MONUMENT 23	9.546	N 70.34445°	W 151.06131°	Alcap	Baker 2009
MONUMENT 28	3.650	N 70.42557°	W 151.06698°	Alcap	UMIAQ GPS 2002
MONUMENT 35	5.570	N 70.43250°	W 150.38344°	Alcap	Lounsbury 1996
PBM-F	17.855	N 70.33933°	W 151.04675°	PBM in Casing	UMIAQ 2013
PBM-P	21.109	N 70.29140°	W 150.98890°	PBM in Casing	UMIAQ 2013
Pile 08	16.735	-	-	HSM - cap SW bolt	UMIAQ 2010
SHEWMAN	7.085	N 70.37228°	W 151.11483°	Alcap	BAKER 2009
1. North American Datum of 1989 (NAD 83)					

2013 Gage Locations				
Gage Site	**Gage**	**Latitude (NAD 83)**	**Longitude (NAD 83)**	**Basis of Elevation**
Monuments - Colville East Channel				
Monument 1 Upstream	MON1U-A[1]	N 70.15855°	W 150.94499°	MONUMENT 1
	MON1U-B	N 70.15853°	W 150.94562°	
	MON1U-C	N 70.15849°	W 150.94616°	
	MON1U-D	N 70.15846°	W 150.94637°	
	MON1U-E	N 70.15849°	W 150.94641°	
	MON1U-F	N 70.15849°	W 150.94653°	
Monument 1 Centerline	MON1C-A[1]	N 70.16575°	W 150.93838°	MONUMENT 1
	MON1C-B	N 70.16580°	W 150.93886°	
	MON1C-C	N 70.16582°	W 150.93923°	
	MON1C-D	N 70.16582°	W 150.93932°	
	MON1C-E	N 70.16583°	W 150.93946°	
	MON1C-F	N 70.16586°	W 150.93967°	
Monument 1 Downstream	MON1D-A[1]	N 70.17383°	W 150.93591°	MONUMENT 1
	MON1D-B	N 70.17378°	W 150.93656°	
	MON1D-C	N 70.17376°	W 150.93715°	
	MON1D-D	N 70.17375°	W 150.93737°	
	MON1D-Z[2]	N 70.17371°	W 150.93758°	
Monument 9	MON9-A[1]	N 70.24465°	W 150.85729°	MONUMENT 9
	MON9-B	N 70.24465°	W 150.85749°	
	MON9-C	N 70.24465°	W 150.85778°	
	MON9-D	N 70.24462°	W 150.85796°	
	MON9-E	N 70.24462°	W 150.85798°	
	MON9-F	N 70.24462°	W 150.85801°	
	MON9-G	N 70.24463°	W 150.85808°	
	MON9-BARO[3]	N 70.24424°	W 150.86045°	
	MON9D-PT[1]	N 70.25857°	W 150.85938°	
Monument 35 (Helmericks)	MON35-A	N 70.42603°	W 150.40575°	MONUMENT 35
	MON35-B	N 70.42604°	W 150.40575°	
	MON35-C	N 70.42606°	W 150.40581°	
	MON35-D	N 70.42607°	W 150.40578°	
	MON35-E	N 70.42608°	W 150.40581°	

Notes:
1. Pressure transducer
2. Angle iron without gage
3. BaroTROLL or Barologger barometer

2013 Gage Locations				
Gage Site	**Gage**	**Latitude (NAD 83)**	**Longitude (NAD 83)**	**Basis of Elevation**
Monuments - Nigliq Channel				
Monument 20	MON20-A[1]	N 70.27857°	W 150.99862°	PBMP
	MON20-B	N 70.27856°	W 150.99852°	
	MON20-C	N 70.27856°	W 150.99830°	
Monument 22	MON22-A	N 70.31862°	W 151.05456°	MONUMENT 22
	MON22-B	N 70.31850°	W 151.05487°	
	MON22-C	N 70.31846°	W 151.05504°	
	MON22-D	N 70.31830°	W 151.05548°	
Monument 23	MON23-A[1]	N 70.34360°	W 151.06587°	MONUMENT 23
	MON23-B	N 70.34362°	W 151.06570°	
	MON23-C	N 70.34363°	W 151.06522°	
	MON23-D	N 70.34360°	W 151.06491°	
Monument 28	MON28-A[1]	N 70.42580°	W 151.06970°	MONUMENT 28
	MON28-B	N 70.42573°	W 151.06923°	
	MON28-C	N 70.42556°	W 151.06716°	
Alpine Facilities and Roads				
CD 1	**G1**[1]	N 70.34278°	W 150.92083°	*
Lake L9312	**G9**	N 70.33361°	W 150.95194°	*
Lake L9313	**G10**	N 70.34250°	W 150.93278°	*
CD 2	**G3**[1]	N 70.34000°	W 150.98306°	*
	G4[1]	N 70.34028°	W 150.98333°	*
	G6	N 70.33972°	W 151.02917°	*
	G7	N 70.34000°	W 151.02889°	*
	G8	N 70.33933°	W 151.04905°	PBM-F
	G12	N 70.33672°	W 151.01172°	CD2-14S
	G13	N 70.33732°	W 151.01184°	CD2-14N
CD3	**G11**	N 70.41750°	W 150.91053°	Pile 08 cap SW bolt
CD4	G15-A	N 70.30225°	W 150.99289°	CD4-20E
	G15-B	N 70.30244°	W 150.99389°	
	G16-A	N 70.30167°	W 150.99333°	CD4-20W
	G16-B	N 70.30175°	W 150.99431°	
	G17	N 70.29330°	W 150.98272°	CD4-29W
	G18-A	N 70.29302°	W 150.98182°	CD4-28E
	G18-B	N 70.29245°	W 150.98276°	
	G18-Z	N 70.29253°	W 150.98373°	
	G19	N 70.29167°	W 150.98833°	PBM-P
	G20-A	N 70.29172°	W 150.99681°	PBM-P
	G20-B	N 70.29171°	W 150.99681°	

Notes:
1. Pressure transducer
2. Angle iron without gage
GX - direct-read permanent staff gage
* Direct-read gage is surveyed and adjusted for elevation annually by LCMF.

2013 Gage Locations				
Gage Site	**Gage**	**Latitude (NAD 83)**	**Longitude (NAD 83)**	**Basis of Elevation**
Pipeline River Crossings				
Sakoonang Pipe Bridge	SAK-A[1]	N 70.36457°	W 150.92165°	Pile 568 cap SW bolt
	SAK-B	N 70.36450°	W 150.92195°	and
	SAK-C	N 70.36448°	W 150.92201°	CP-08-11-12
Tamayagiaq Pipe Bridge	TAM-A[1]	N 70.39166°	W 150.91149°	CP-08-11-23
	TAM-B	N 70.39151°	W 150.91129°	
	TAM-C	N 70.39142°	W 150.91126°	
	TAM-Z[2]	N 70.39120°	W 150.91086°	
Ulamnigiaq Pipe Bridge	ULAM-A[1]	N 70.40682°	W 150.88347°	CP-08-11-35
	ULAM-B	N 70.40690°	W 150.88330°	
	ULAM-C	N 70.40697°	W 150.88322°	
	ULAM-Z[2]	N 70.40701°	W 150.88308°	
Proposed CD5 Crossings				
Lake L9323	G24-A[1]	N 70.30316°	W 151.00666°	CP-08-11-52A
	G24-B	N 70.30337°	W 151.00407°	
	G25-A[1]	N 70.30400°	W 151.00692°	
	G25-B	N 70.30421°	W 151.00442°	
Nigliq Channel	G26-A	N 70.30237°	W 151.02211°	CP08-11-53A
	G26-A1	N 70.30228°	W 151.02056°	
	G26-B	N 70.30222°	W 151.01918°	
	G26-C	N 70.30219°	W 151.01901°	
	G27-A	N 70.30290°	W 151.02190°	
	G27-B	N 70.30291°	W 151.02173°	
	G27-B1	N 70.30285°	W 151.01893°	
	G27-C	N 70.30287°	W 151.01977°	
	G27-D	N 70.30288°	W 151.01882°	
	G28-A[1]	N 70.29641°	W 151.02809°	Baker TBM 2010
	G28-B	N 70.29641°	W 151.02798°	
	G28-C	N 70.29643°	W 151.02792°	
	G28-D	N 70.29646°	W 151.02755°	
	G29-A[1]	N 70.30951°	W 151.03322°	CP-08-11-60B
	G29-B	N 70.30948°	W 151.03344°	
	G29-C	N 70.30945°	W 151.03367°	
	G29-D	N 70.30937°	W 151.03433°	
	G29-E	N 70.30925°	W 151.03500°	
Lake L9341	G32-A[1]	N 70.30539°	W 151.05069°	CP 08-11-60C
	G32-B	N 70.30551°	W 151.05127°	
	G33-A[1]	N 70.30625°	W 151.04914°	
	G33-B	N 70.30637°	W 151.04965°	

Notes:
1. Pressure transducer
2. Angle iron without gage

2013 Gage Locations				
Gage Site	**Gage**	**Latitude (NAD 83)**	**Longitude (NAD 83)**	**Basis of Elevation**
Proposed CD5 Crossings (cont)				
CD5 Small Drainages	G30	N 70.30459°	W 151.04434°	CP-08-11-60B
	G31	N 70.30512°	W 151.04369°	
	G34	N 70.30597°	W 151.07097°	CP-08-11-64C
	G35	N 70.30674°	W 151.07109°	
	G36	N 70.30552°	W 151.09677°	CP-08-11-65C
	G37	N 70.30621°	W 151.09687°	
Nigliagvik	G38-A[1]	N 70.30508°	W 151.11857°	CP08-11-66C
	G38-B	N 70.30507°	W 151.11847°	
	G38-C	N 70.30506°	W 151.11822°	
	G39-A[1]	N 70.30608°	W 151.11802°	
	G39-B	N 70.30607°	W 151.11790°	
	G39-C	N 70.30606°	W 151.11765°	
Additional Monitoring Sites				
Downstream Nigliq Channel	FWR1-A	N 70.37049°	W 151.11409°	SHEWMAN
	FWR2-A	N 70.36666°	W 151.12189°	

Notes:
1. Pressure transducer
2. Angle iron without gage

APPENDIX B 2013 MON1 ADCP DIRECT DISCHARGE DATA

Station Number:

Station Name: Colville River Mon1

Meas. No: 0

Date: 06/08/2013

Party: GCY,SMC, WAB,AJG

Boat/Motor: Inflatable

Gage Height: 0.00 ft

Width: 2,430 ft

Area: 35,500 ft²

G.H.Change: 0.000 ft

Processed by:

Mean Velocity: 3.22 ft/s

Discharge: 114,000 ft³/s

Area Method: Avg. Course

Nav. Method: Bottom Track

MagVar Method: None (19.9°)

Depth Sounder: Not Used

ADCP Depth: 1.590 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 ft²

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.: 7.00 ft/s

Use Weighted Mean Depth: YES

Max. Vel.: 6.50 ft/s

Max. Depth: 29.6 ft

Mean Depth: 14.7 ft

% Meas.: 62.89

Water Temp.: None

ADCP Temp.: 40.8 °F

ADCP:

Type/Freq.: Workhorse/600 kHz

Serial #: 12664

Firmware: 51.40

Bin Size: 50 cm

Blank: 25 cm

BT Mode: 5

BT Pings: 1

WT Mode: 1

WT Pings: 1

WV : 175

Performed Diag. Test: NO

Performed Moving Bed Test: NO

Performed Compass Test: YES

Meas. Location:

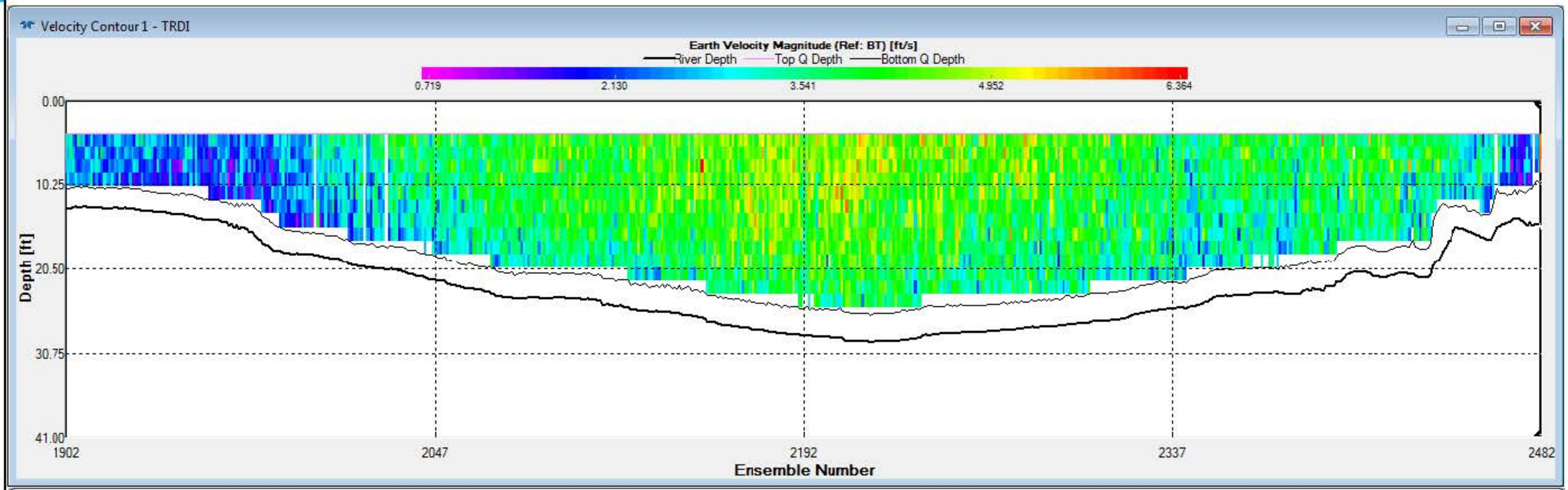
Project Name: 2013 cpi mon1 q_adj.mmt

Software: 2.07

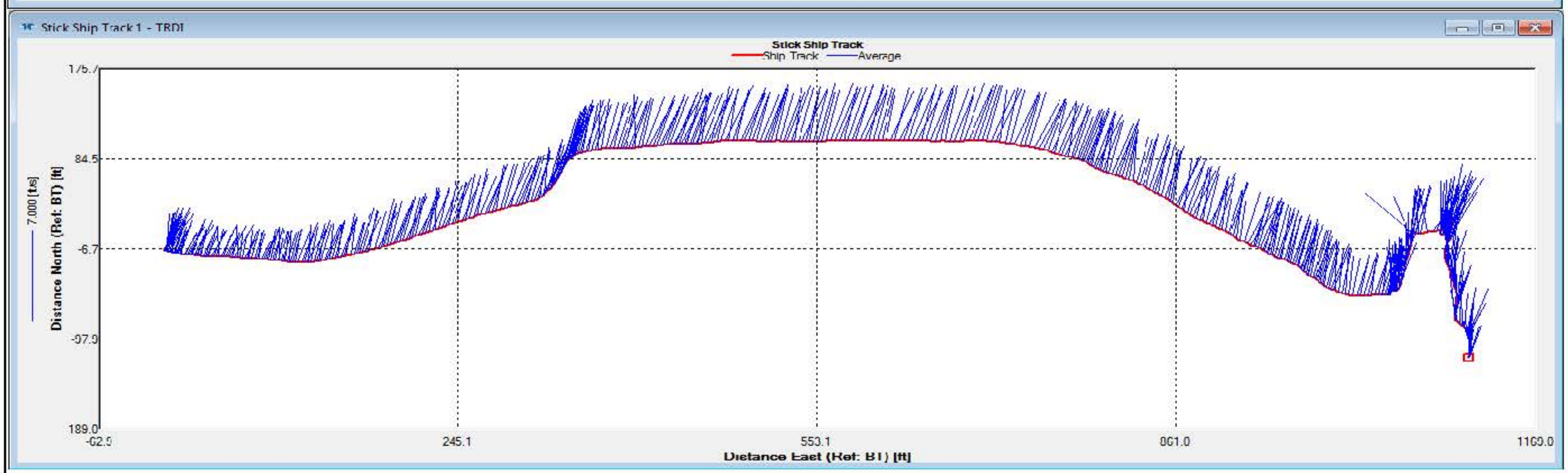
Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad		
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins	
002	L	1250	30	581	17549	70415	11540	14671	332	114506	2397	35858	22:47	22:56	2.80	3.19	1	0	#
003	R	1190	30	493	18970	72492	12491	9525	909	114387	2430	36079	23:00	23:07	3.15	3.17	0	0	#
004	L	1180	30	541	18848	72433	12469	9278	1003	114032	2435	35281	23:07	23:15	2.86	3.23	0	0	#
005	R	1200	30	438	19006	72356	12735	9575	833	114505	2442	34972	23:16	23:23	3.40	3.27	1	0	
Mean		1205	30	513	18593	71924	12309	10762	769	114358	2426	35547	**Total**	00:35	3.06	3.22	1	0	
SDev		31	0	62	699	1008	527	2609	300	224	20.0	510.0			0.28	0.05			
SD/M		0.03	0.00	0.12	0.04	0.01	0.04	0.24	0.39	0.00	0.01	0.01			0.09	0.01			

Remarks:

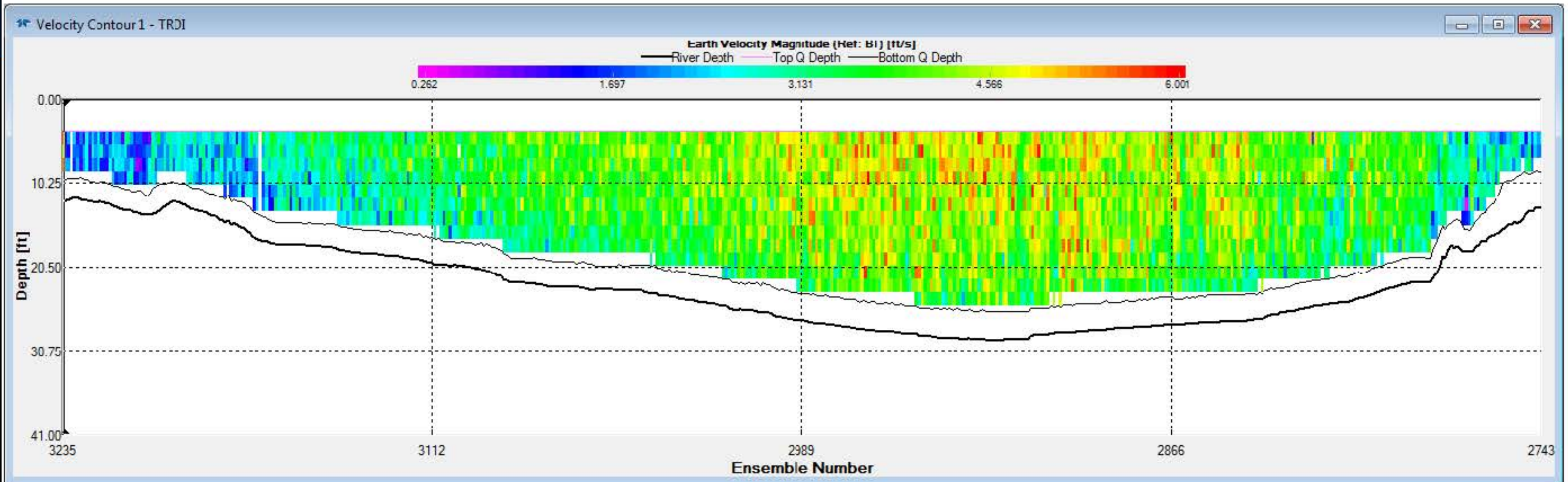
- transect has been subsectioned

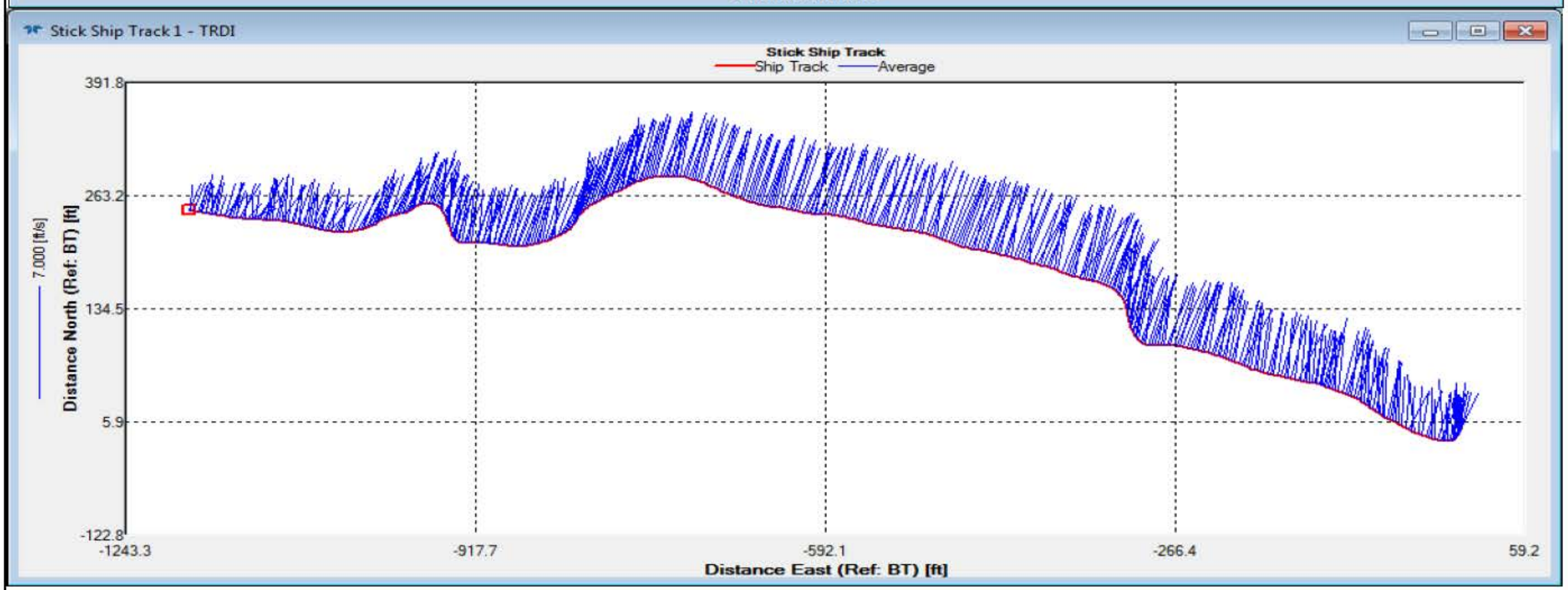


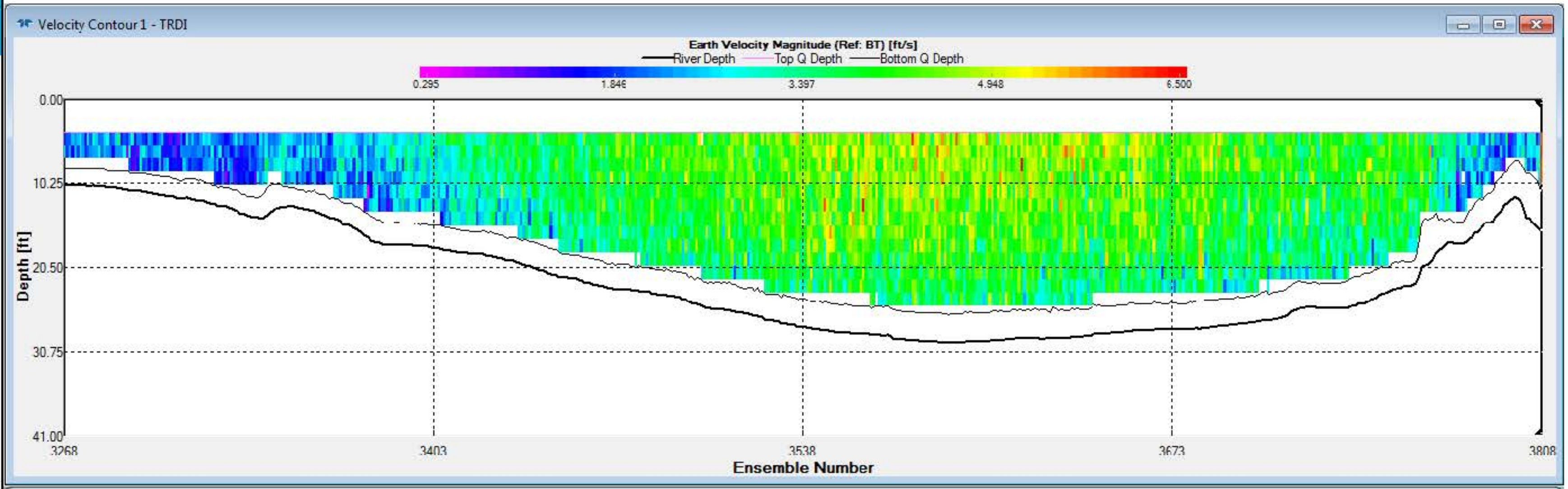
Velocity Contour 1 - TRDI
Earth Velocity Magnitude (Ref: BT) [ft/s]
River Depth
Top Q Depth
Bottom Q Depth
0.719
2.130
3.541
4.952
6.364
Depth [ft]
0.00
10.25
20.50
30.75
41.00
1902
2047
2192
2337
2482
Ensemble Number

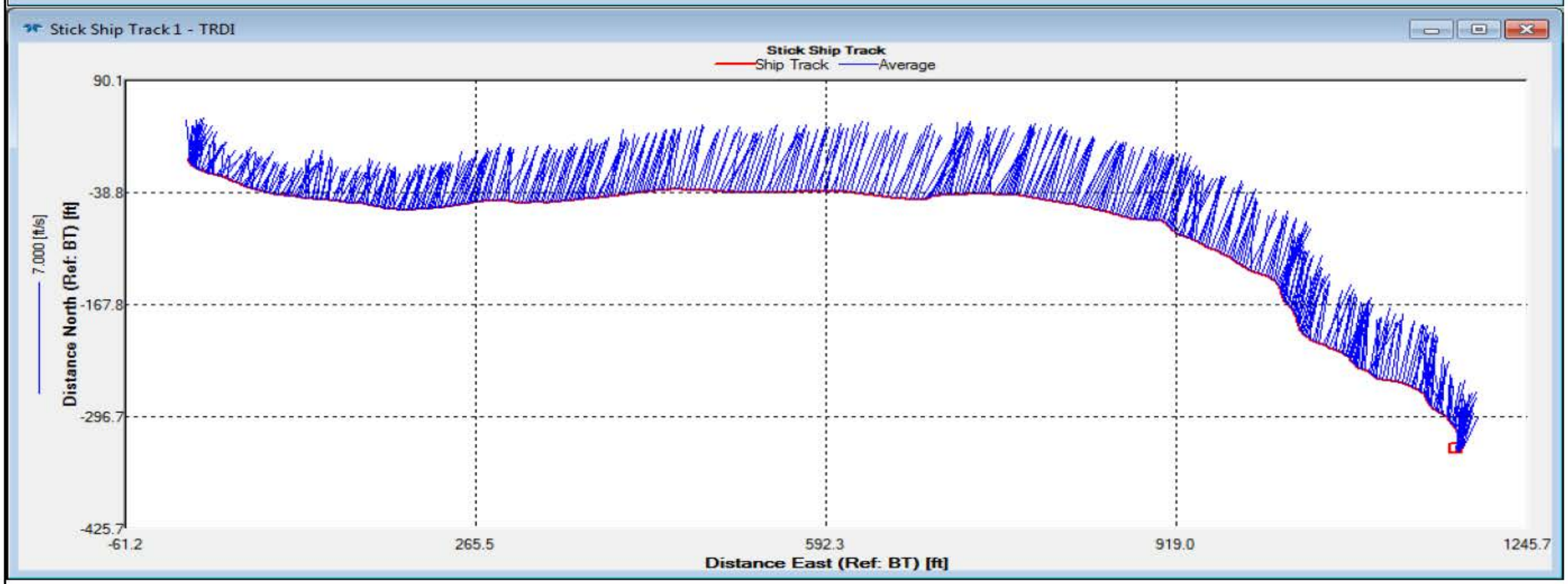


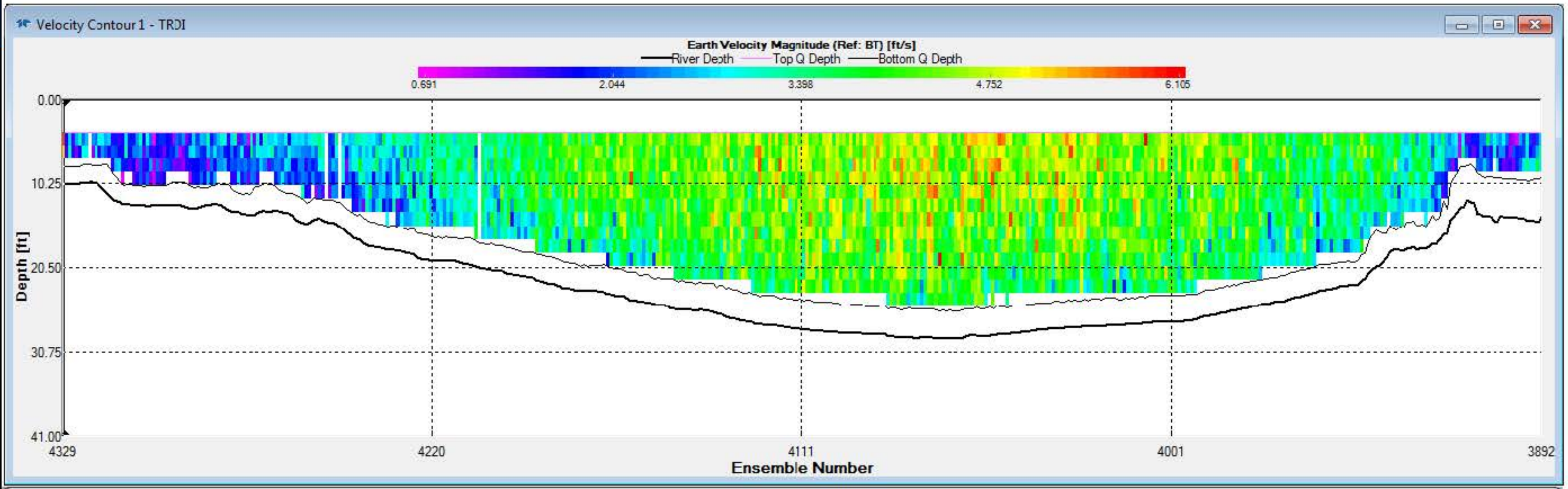
Stick Ship Track 1 - TRDI
Stick Ship Track
Ship Track
Average
Distance North (Ref: BT) [ft]
7.000 [ft/s]
84.5
-6.7
-97.9
189.0
-62.9
245.1
553.1
861.0
1169.0
Distance East (Ref: BT) [ft]

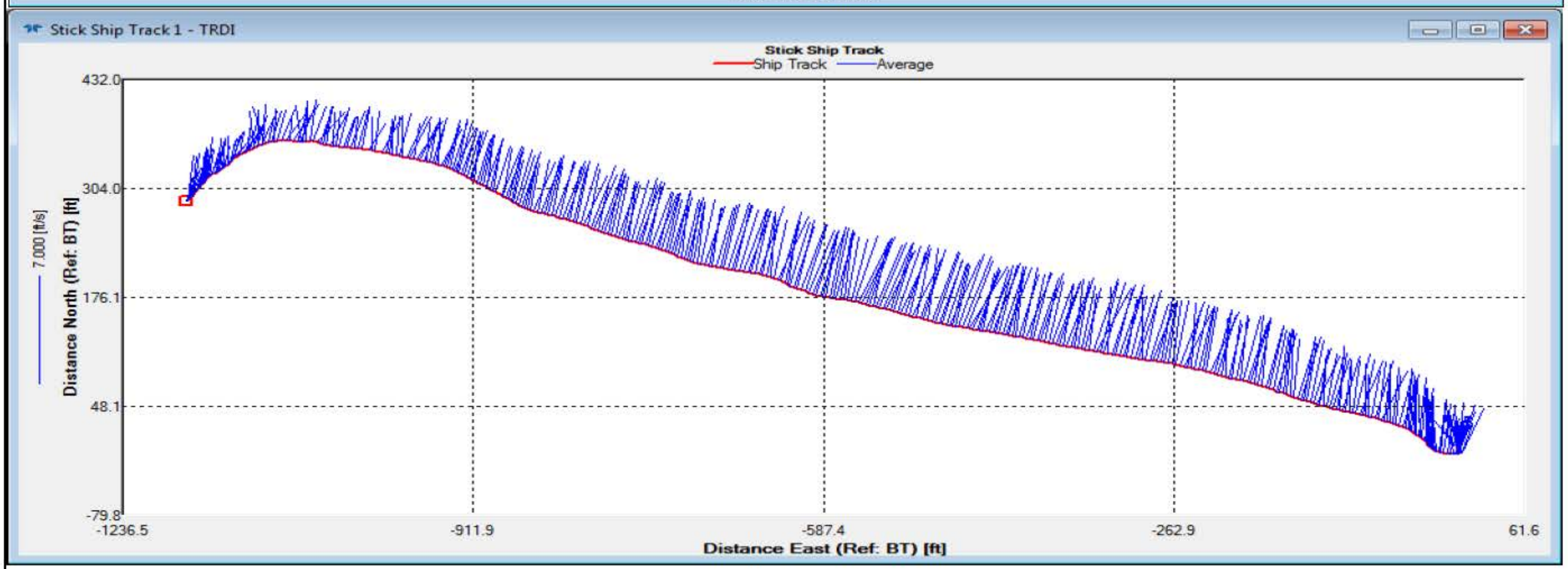

Velocity Contour 1 - TRDI
Earth Velocity Magnitude (Ref: BT) [ft/s]
River Depth
Top Q Depth
Bottom Q Depth
0.262
1.697
3.131
4.566
6.001
0.00
10.25
20.50
30.75
41.00
Depth [ft]
3235
3112
2989
2866
2743
Ensemble Number


Stick Ship Track 1 - TRDI
Stick Ship Track
Ship Track
Average
391.8
263.2
134.5
5.9
-122.8
Distance North (Ref: BT) [ft]
7.000 [ft/s]
-1243.3
-917.7
-592.1
-266.4
59.2
Distance East (Ref: BT) [ft]


Velocity Contour 1 - TRDI
Earth Velocity Magnitude (Ref: BT) [ft/s]
River Depth
Top Q Depth
Bottom Q Depth
0.295
1.846
3.397
4.948
6.500
0.00
10.25
20.50
30.75
41.00
Depth [ft]
3268
3403
3538
3673
3808
Ensemble Number

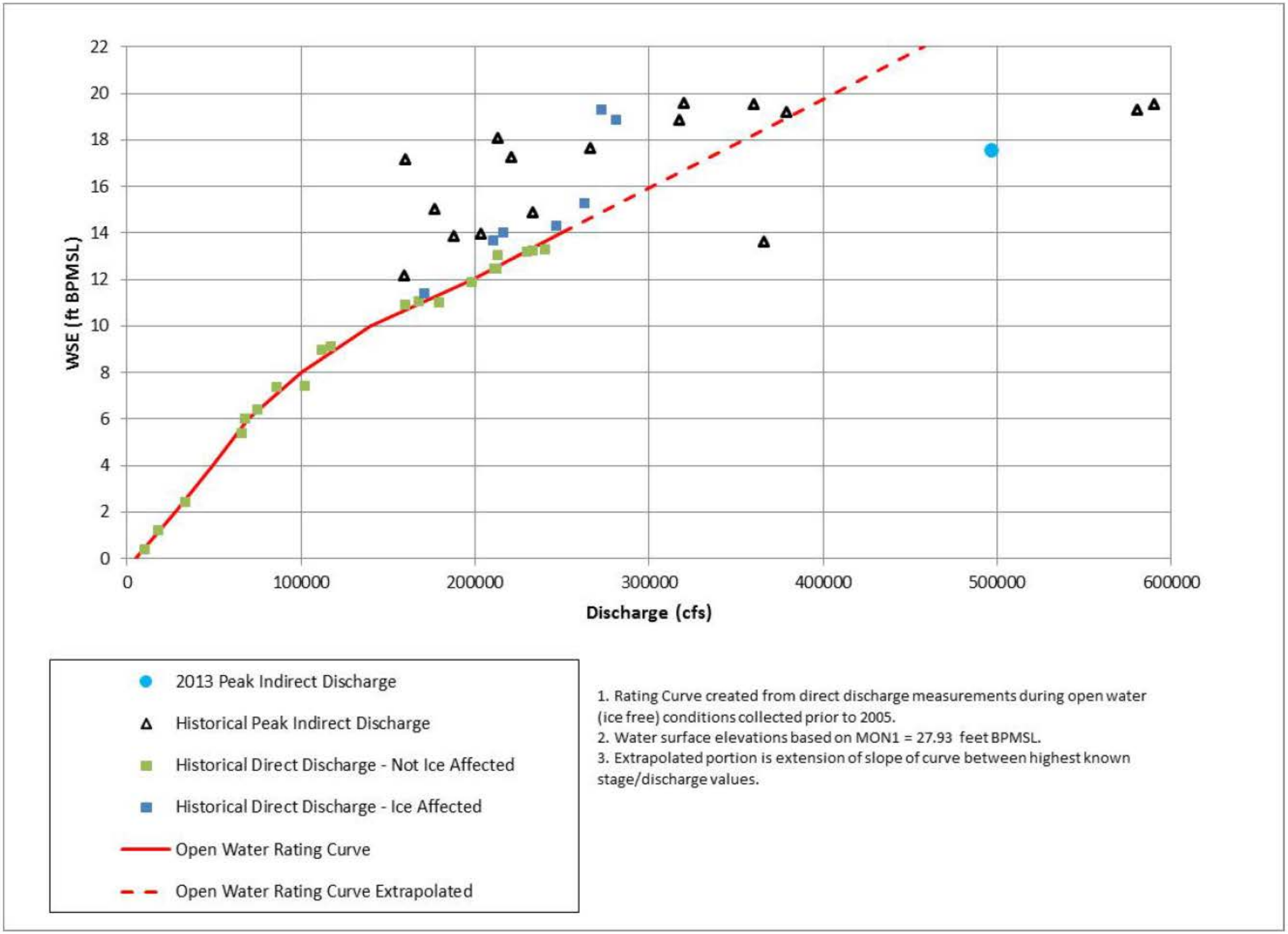

Stick Ship Track 1 - TRDI
Stick Ship Track
Ship Track
Average
90.1
-38.8
-167.8
-296.7
-425.7
Distance North (Ref: BT) [ft]
7.000 [ft/s]
-61.2
265.5
592.3
919.0
1245.7
Distance East (Ref: BT) [ft]


Velocity Contour 1 - TRDI
Earth Velocity Magnitude (Ref: BT) [ft/s]
River Depth
Top Q Depth
Bottom Q Depth
0.691
2.044
3.398
4.752
6.105
0.00
10.25
20.50
30.75
41.00
Depth [ft]
4329
4220
4111
4001
3892
Ensemble Number


Stick Ship Track 1 - TRDI
Stick Ship Track
Ship Track
Average
432.0
304.0
176.1
48.1
-79.8
Distance North (Ref: BT) [ft]
7.000 [ft/s]
-1236.5
-911.9
-587.4
-262.9
61.6
Distance East (Ref: BT) [ft]

APPENDIX C MON1 STAGE-DISCHARGE RATING CURVE WITH INDIRECT DISCHARGE

The MON1 stage-discharge rating curve, provided below, represents a comparison between ice-affected and non-ice-affected direct discharge measurements and historical peak indirect discharge values. These values represent the relationship between stage and discharge at lower-stage values when ice-free direct discharge measurements are possible. The stage-discharge rating curve may be used as a basis of comparison for the accuracy of indirect-discharge-calculated values. This curve does not account for ice effects on stage and discharge that are common during peak flow periods, as open-water conditions rarely occur at or near recorded historical peak stage levels. This rating curve was extrapolated beyond known values at lower stage-discharge periods. The extrapolation is based on the highest known values and is used as a general reference only.



1. Rating Curve created from direct discharge measurements during open water (ice free) conditions collected prior to 2005.
2. Water surface elevations based on MON1 = 27.93 feet BPMSL.
3. Extrapolated portion is extension of slope of curve between highest known stage/discharge values.

APPENDIX D 2013 ALPINE SWALE BRIDGES DIRECT DISCHARGE NOTES

Long Swale Bridge

Baker

Discharge Measurement Notes

Date: June 5, 2013
Computed By: GCY
Checked By: SMC

Location Name: Long Swale Bridge

Party: WAB, GCY, AW(ABR), SMC   Start: 12:30   Finish: 16:23

Temp: 28 °F   Weather: Overcast with snow; 10 mph NE wind; minimal waves

Channel Characteristics:

Width: 448 ft   Area: 2947 sq ft   Velocity: 2.47 fps   Discharge: 7286 cfs

Method: USGS Midsection   Number of Sections: 36   Count: N/A

Spin Test: Passed after 120 seconds   Meter: Price AA (MJBA01)

Meter: 0.6 ft above bottom of weight

Weight: 50 lbs

Wading **Cable** Ice Boat

Upstream or Downstream side of bridge

GAGE READINGS			
Gage	Start	Finish	Change
G3	9.90	9.83	0.07
G4	9.45	9.4	0.05

GPS Data: W Bridge Abutment

Left Edge of Water: N 70.33994 ° W 150.97575 °

Right Edge of Water: N 70.33964 ° W 150.97214 °

E Bridge Abutment

LE Floodplain: ° ' . "

RE Floodplain: ° ' . "

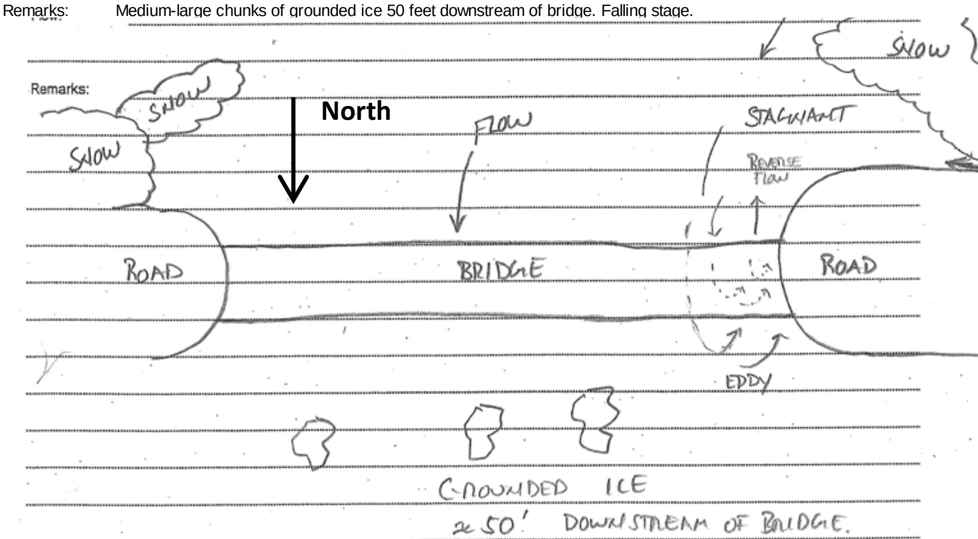
Measurement Rated: Excellent **Good** Fair Poor based on "Descriptions"

Descriptions:

Cross Section: No snow or ice under the bridge during discharge measurement.

Flow: South to north. A back eddy was present behind a large snow pile, upstream and on the west side of the bridge, causing flow reversal along the west abutment.

Remarks: Medium-large chunks of grounded ice 50 feet downstream of bridge. Falling stage.



Short Swale Bridge

Baker

Discharge Measurement Notes

Date: June 5, 2013
Computed By: GCY
Checked By: SMC

Location Name: Short Swale Bridge

Party: WAB, GCY, AW(ABR) Start: 17:30 Finish: 19:11

Temp: 32 °F Weather: High Overcast; 5-10 mph E wind; minimal waves

Channel Characteristics:

Width: 54 ft Area: 446 sq ft Velocity: 3.60 fps Discharge: 1608 cfs

Method: USGS Midsection Number of Sections: 21 Count: N/A

Spin Test: Passed after 120 seconds Meter: Price AA (MJBA01)

GAGE READINGS			
Gage	Start	Finish	Change
G3	9.81	9.69	0.12
G4	9.35	9.3	0.05

Meter: 0.6 ft above bottom of weight

Weight: 50 lbs

Wading **Cable** Ice Boat

Upstream or Downstream side of bridge

GPS Data: W Bridge Abutment

Left Edge of Water: N 70.33994 ° W 150.98467 °

Right Edge of Water: N 70.34003 ° W 150.98425 °

E Bridge Abutment

LE Floodplain: ° ' . "

RE Floodplain: ° ' . "

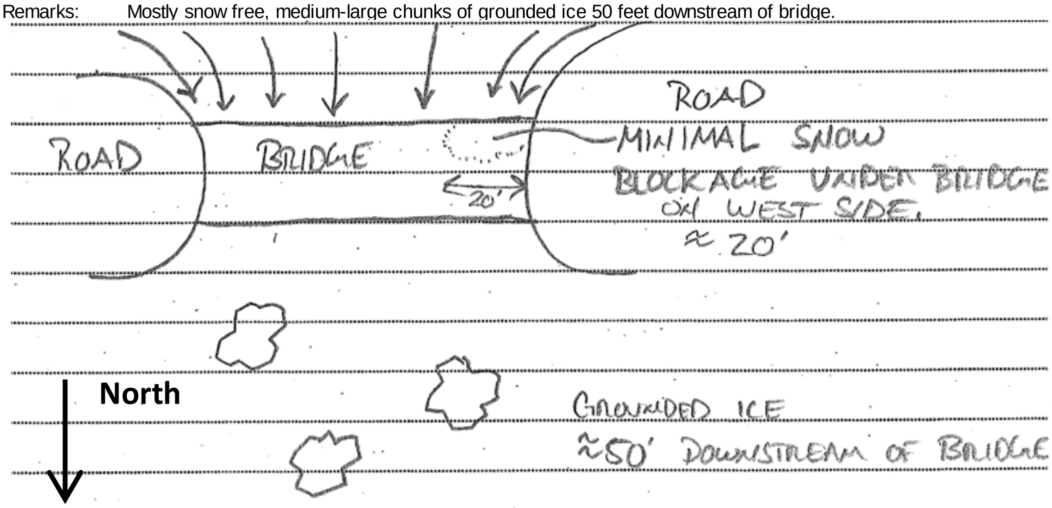
Measurement Rated: Excellent **Good** Fair Poor based on "Descriptions"

Descriptions:

Cross Section: Minimal snow blockage on the left bank (west abutment) protruding approximately 20 feet into the flow.

Flow: Smooth with small ripples

Remarks: Mostly snow free, medium-large chunks of grounded ice 50 feet downstream of bridge.



2013 Colville River Delta Spring Breakup Monitoring & Hydrologic Assessment