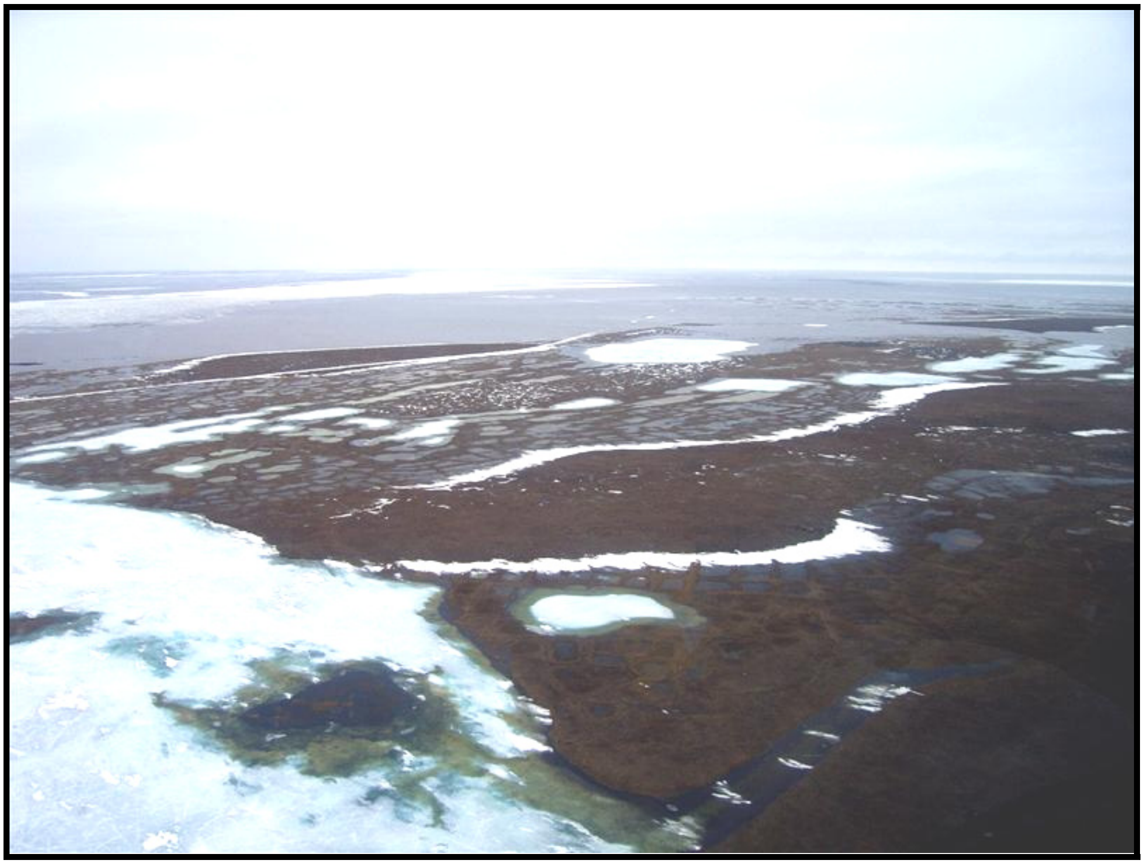
Fiord West 2008 CRD Breakup Assessment



Submitted to

ConocoPhillips

Submitted by

Baker

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

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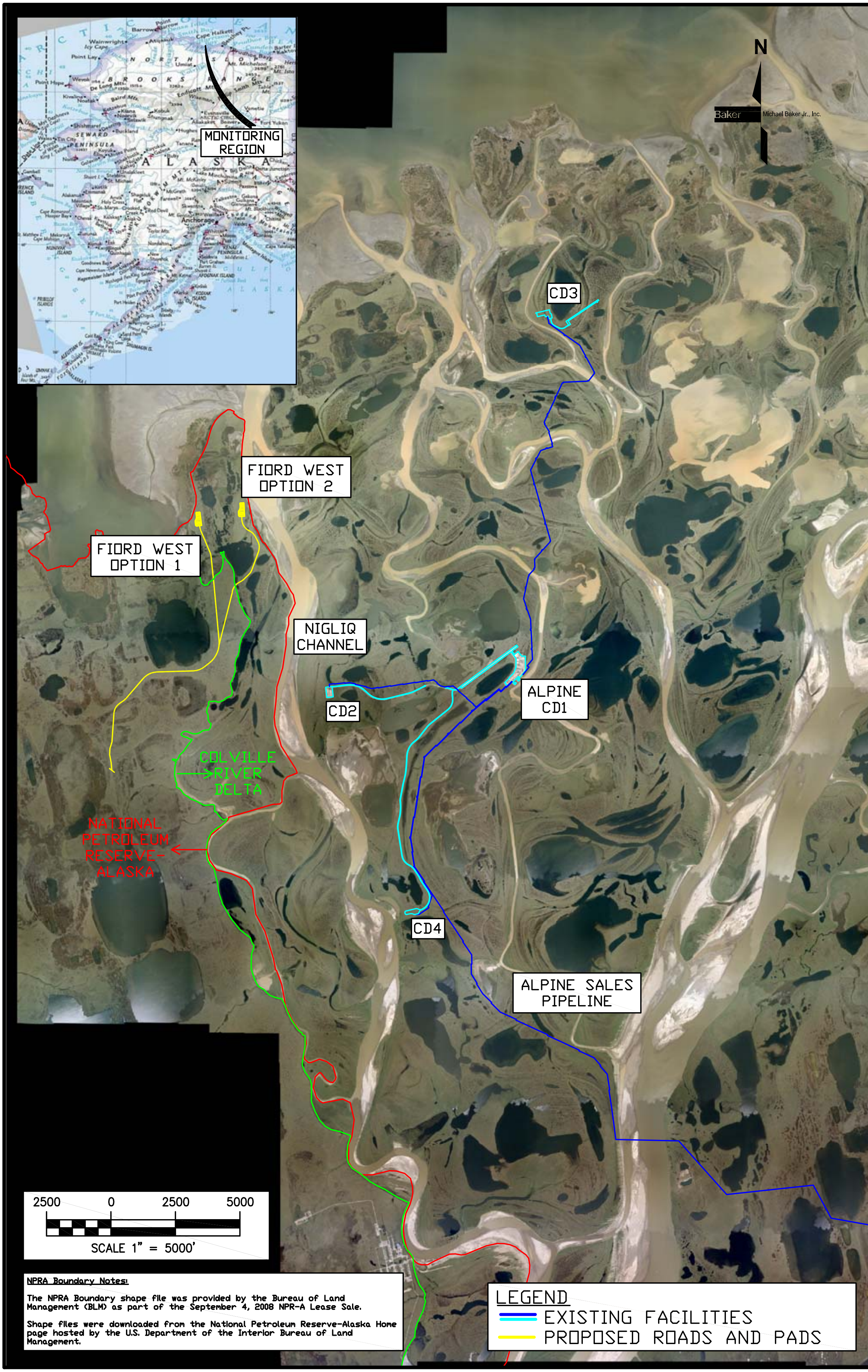
1.0 Introduction

ConocoPhillips, Alaska (CPAI) proposes to develop satellite-drilling pads west of existing Alpine facilities in the National Petroleum Reserve-Alaska (NPR-A), adjacent to the Colville River Delta (Delta or CRD). Two alternatives are currently under investigation in the Fiord West area (Figure 1-1). Proposed alternatives are for a single access road and oil production pad, originating on the eastern fringe of NPR-A from the planned CD5 facility extending to the northwestern corner of the CRD. This report presents a preliminary hydrologic assessment of the Fiord West area for proposed development alternatives.

Fiord West Option 1 consists of approximately 4.2 miles of gravel road terminating at a gravel pad of approximately 9 acres. The pad and nearly 1 mile of road are located in the CRD with the remaining section of road perched above the CRD. Option 2 follows an identical path as Option 1 for the first 2.9 miles before diverging to the northeast for an additional 2.2 miles, then terminating at the proposed pad. The last 1.3 miles of the Option 2 road and pad are located in the CRD. The gravel pad is similar in both size and orientation for both options.

Observations and measurements were recorded during the 2008 Alpine Facilities spring breakup program. Spring breakup flooding is the largest annual flooding event in the CRD and monitoring of this event is integral to understanding regional hydrology and local hydraulics. Such assessments are critical for design engineers to understand potential floodwater impacts and establish proper design criteria for structures to withstand design flood events.

An assessment of the hydrologic impacts from high magnitude floodwaters to the two proposed road and pad configurations was performed using the 2-dimensional surface water model already developed for the Colville River Delta.



NPRA Boundary Notes:

The NPRA Boundary shape file was provided by the Bureau of Land Management (BLM) as part of the September 4, 2008 NPR-A Lease Sale.

Shape files were downloaded from the National Petroleum Reserve-Alaska Home page hosted by the U.S. Department of the Interior Bureau of Land Management.

FIORD WEST
2008 BREAKUP HYDROLOGIC
ASSESSMENT OVERVIEW

FIGURE 1-1
(SHEET 1 OF 1)

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

Baker

ConocoPhillips
Alaska, Inc.

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2.0 Methods

The primary methods used during the 2008 spring breakup monitoring program included visual observations of flow distribution and measurements of water surface elevation (WSE) at representative locations. Observations were recorded using aerial photography collected during monitoring reconnaissance flights. Field methods were based on standard techniques proven to be safe, reliable, efficient, and accurate for the conditions found in the CRD during spring breakup.

The most recent version of the Colville River Delta 2-dimensional surface water model was used to estimate peak water surface elevations and flow velocities in the Fiord West area near the proposed road and pad configurations. As a preliminary analysis, the inclusion of proposed alternatives into the 2-dimensional model is not warranted at this time.

2.1 Visual Observations

Visual observations were conducted from the ground via Hägglund tracked vehicles between May 10 and May 20, and from the air via helicopter between May 21 and June 2, 2008. Observations and field surveys were recorded in field notebooks. Additionally, digital photographs were collected to document the extent of local conditions during and after peak breakup. Each photograph was electronically imprinted, with the horizontal position of the camera, date, and time at which the photograph was taken.

2.2 Water Surface Elevation

Water surface elevations were monitored at two locations in the Fiord West area using graduated stream staff gages. Placement of staff gages was based on local topography and proximity to proposed structures. The northern most gage (FWP) was placed in the vicinity of the Option 2 pad near the bank of the Nigliq Channel. Given local topography and predicted floodwater elevations this position would adequately capture floodwater conditions near both Option 1 (west) and Option 2 (east) pads. The second gage (FWR) was located near a prominent topographic depression crossed by the Option 2 access road. This depression links numerous lakes along the toe of the Delta’s western bluff and would likely convey a significant portion of floodwater in the Fiord West area. Additional gages, monitored as part of the Alpine spring breakup program, were located on the Nigliq Channel providing additional insight into floodwater impacts and overbank flow conditions in the Fiord West area. The timing of measurements was based on the hydrologic and hydraulic conditions present during breakup.

The elevation of each gage was surveyed to a local benchmark using optical differential level loop surveys. The basis of elevation for each gage and the horizontal position of associated benchmarks and gages are presented in Table 2-1. The most recent basis of elevation of vertical control, as of spring 2008, was used. Gages located on the Nigliq Channel were given the name of their associated benchmark monument. Surveys were completed on May 9 and May 14, 2008 prior to breakup. The gage locations relative to proposed configurations are presented in Figure 2-1.

Table 2-1 2008 Survey Control and Gage Summary

Gage Site	Latitude (NAD83)	Longitude (NAD83)	Basis of Elevation	Elevation (BPMSL - Feet)	Reference
Mounment 22	N 70° 19' 06.6"	W 151° 03' 17.6"	Monument 22	10.10	LCMF 2003
Monument 23	N 70° 16' 42.8"	W 150° 59' 55.0"	Monument 23	9.52	Baker 2008
FWR	N 70° 21' 39.4"	W 151° 06' 16.3"	NPRA-2	7.65	LCMF 2007
FWP	N 70° 22' 38.0"	W 151° 05' 51.4"	NPRA-2	7.65	LCMF 2007

Temporary staff gages consisted of one to five gage assemblies at each location. Gage assemblies consisted of a metal gage faceplate mounted on a two-by-four timber attached with U-bolts to 1.5-inch angle iron posts driven into the ground. Installation of each staff gage was completed prior to the arrival of breakup floodwater. The horizontal position of each gage was recorded using a handheld Garmin 60 GPS in North American Datum of 1983 (NAD 83). All elevations presented in this report are referenced to British Petroleum Mean Sea Level (BPMSL).

2.3 Colville River Delta 2-Dimensional Surface Water Model

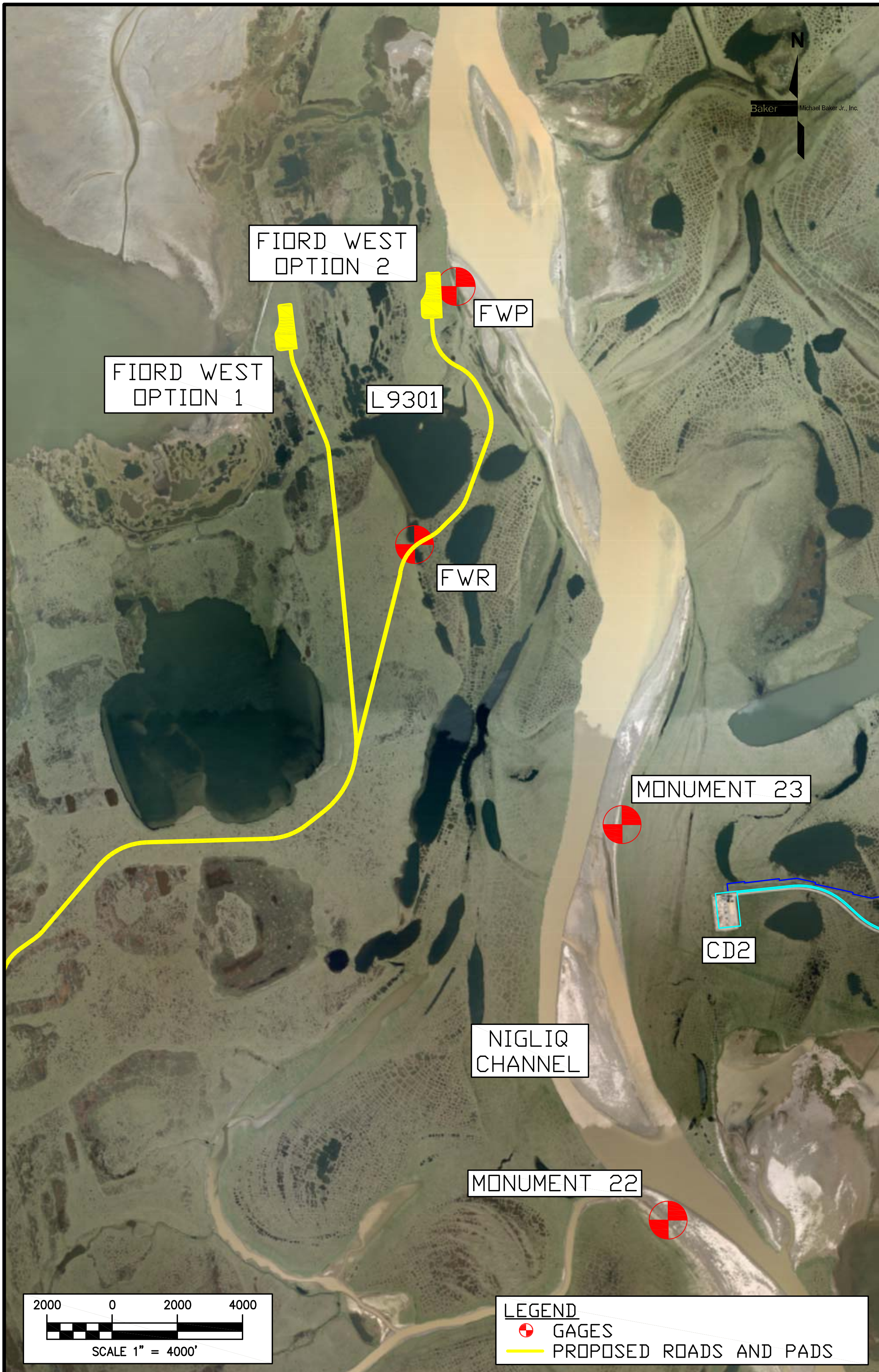
2.3.1 Modeling Software

The Colville River 2-dimensional (2D) surface water model was first developed in 1997 to estimate water surface elevations and velocities at the proposed Alpine Development Project Facilities locations. The model is a product of two computer programs. The finite element mesh was developed using software titled *Surface Water Modeling System* (SMS) developed by Brigham Young University (Brigham Young, 1994) and distributed by Environmental Modeling Systems, Inc. (EMS-I), recently merged with Aquaveo, LLC. The original model was developed using version 4.1. Subsequent analyses were developed using versions 6.0, 7.0, 9.0 and 10.0. The current project was developed using SMS 10.0 to refine the finite element mesh, analyze modeling results, and generate output graphics.

The computer program developed by the U.S. Geologic Survey (Froehlich, 1996), *Finite Element Surface Water Modeling System* (FESWMS), performs the numerical computations of the modeling system. The SMS includes an interface with the *Flow and Sediment Transport* (FST2DH) module of FESMWS.

2.3.2 Revision History

The model has undergone numerous revisions since the original 1997 version (Baker 1998). Proposed CD3 and CD4 satellite developments were incorporated in 2002, including additional floodplain



FIORD WEST
2008 SPRING BREAKUP
GAGE LOCATIONS

FIGURE 2-1
(SHEET 1 OF 1)

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

Baker

ConocoPhillips Alaska, Inc.

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topographic survey data (Baker 2002). In 2006, the model was once again modified to include as-built alignment conditions along the CD4 access road and pad and 2004/2005 survey data of the Nigliq Channel near Monument 23 (Baker 2006a). A supplemental analysis was also performed in 2006 to incorporate the proposed Qannik extension of the existing CD2 pad (Baker 2006b). The most recent modification was performed in 2008 to include additional floodplain topographic and channel bathymetric survey data.

2.3.3 Baseline Conditions and Modeling Results Output

Baseline modeling was performed using existing conditions (CD3 and CD4) facilities and the latest topographic and bathymetric data. The mesh was not modified to model anticipated future conditions resulting from either of the proposed Fiord West facilities. Preliminary results presented here should approximate those experienced post-construction given the location of proposed access road and pad alignments with respect to existing facilities and the Delta boundary. Baseline model runs for the 50- and 200-year flood events were used to estimate the associated hydrologic conditions in the Fiord West area. Resulting peak stage and velocities were extracted from the model at discrete locations near proposed pad and road alignments.

Element status, whether it is “on” or “off”, can yield data that is not truly representative of local conditions and must be reviewed to identify accurate results. The tolerance limits set to define when an element turns “on” or “off” has been unchanged through recent project updates. An element that is turned “on” is considered in the numerical computations while an element that is turned “off” is not. The tolerance limit has been set at one foot. Thus, if an element was already considered “on” it would be turned “off” when the water surface elevation fell one foot below the elevation of the highest node on that element. If an element were considered “off” it would be turned “on” when the water surface elevation was one foot higher than the highest node on that element.

Elements that are turned “off” are generally those that are dry or only partially covered with water. In some cases, an element that is considered “off” may in fact be completely covered with water, however, the water surface elevation is below the depth tolerance to turn the element on. For example, the elements to the west of the Nigliq Channel near the Option 2 pad are turned “off” during the 50-year flood condition. By examining ground and water surface elevations in this area, it can be seen that some of these elements are inundated with water but to depths below the 1-foot depth tolerance. Under these conditions water surface elevations and velocities are estimated from the nearest element that is “on” when deemed appropriate.

3.0 Results and Discussion

3.1 2008 Spring Breakup Hydrologic Observations

The 2008 spring breakup event was mild having an estimated return interval of approximately 3-years based on indirect discharge calculations and observed water surface elevations (Baker 2008). Floodwaters in the Nigliq Channel remained in-channel. All observed water in the Fiord West area was local snow melt (Figure 3-1). No flow was observed between water bodies or within natural topographic depressions that would likely convey water.

Water surface elevations from floodwater were only observed at Monument 22 and Monument 23. Ponding from local melt was observed at gage FWR and was hydraulically connected to Lake L9301 though no flow was observed. No measurable water surface elevation was recorded at gage FWP. Peak water surface elevations are presented in Table 3-1.

Table 3-1 2008 Peak Water Surface Elevations

Gage	Peak Water Surface Elevation (ft BPMSL)	Date	Observations
Monument 22	6.78	May 30	Highwater mark (Baker 2008)
Monument 23	5.79	May 30	Highwater mark (Baker 2008)
FWR	3.06	June 02	Direct measurement - no highwater mark
FWP	N/A	N/A	No measurable water present

3.2 Colville River Delta 2-Dimensional Surface Water Model

Since 1997, 2D surface water modeling has been used to predict water surface elevations and velocities in the Colville River Delta. The model has proven to be a reliable tool and has been integral in the design of all existing Alpine facilities, including roads, pads, and pipelines.

The finite element mesh on which the model relies has been built from a variety of sources of ground elevation and bathymetry. The Fiord West region of the model, located in the northwestern corner of the Delta, is based on little topographic data limiting detail in the mesh and in turn the model output for this area. The model does provide a high level understanding of local flood conditions and the limited topographic relief in the area allows us to further refine resulting data at specific locations. One such location is in the vicinity of the Option 2 pad, which is to be placed on high ground along the coast of Harrison Bay. Photogrametric data produced from 2004 aerial photography suggests a local ground elevation of 11 to 17 feet (Prudhoe Bay Mean Sea Level) beneath the proposed pad footprint (Figure 3-2). The finite element mesh does not capture this relatively small area of high ground; modeling it at an elevation of 4 to 5 feet. These differences in ground surface elevation are near the boundary of the CRD and have no impact on the overall accuracy of the model. Such differences in baseline data require

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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

FIORD WEST
2008 SPRING BREAKUP
AERIAL PHOTOGRAPHS (JUNE 1)

FIGURE 3-1
(SHEET 1 OF 1)

diligence in identifying erroneous model solutions at specific locations of interest and correctly presenting expected floodwater conditions. In this case, neighboring water surface elevations are presented for this location. Likewise, ground elevations and local water surface elevations must be reviewed to identify accurate conditions where elements may have been turned “off”. Floodwater is not represented in model output figures where elements have been turned “off” and should not be relied upon for expected conditions at precise locations without reviewing the tabulated data and topography.

Local topography and modeling results suggest that overbank flow in the Fiord West region would flow to the northwest as the bluff forming the western boundary of the Delta (Figure 3-2) moves westward and drops in elevation. Water surface elevations drop as floodwater from the Nigliq Channel go overbank and flow northwest, ultimately joining the outflow of Fish Creek Basin in Harrison Bay.

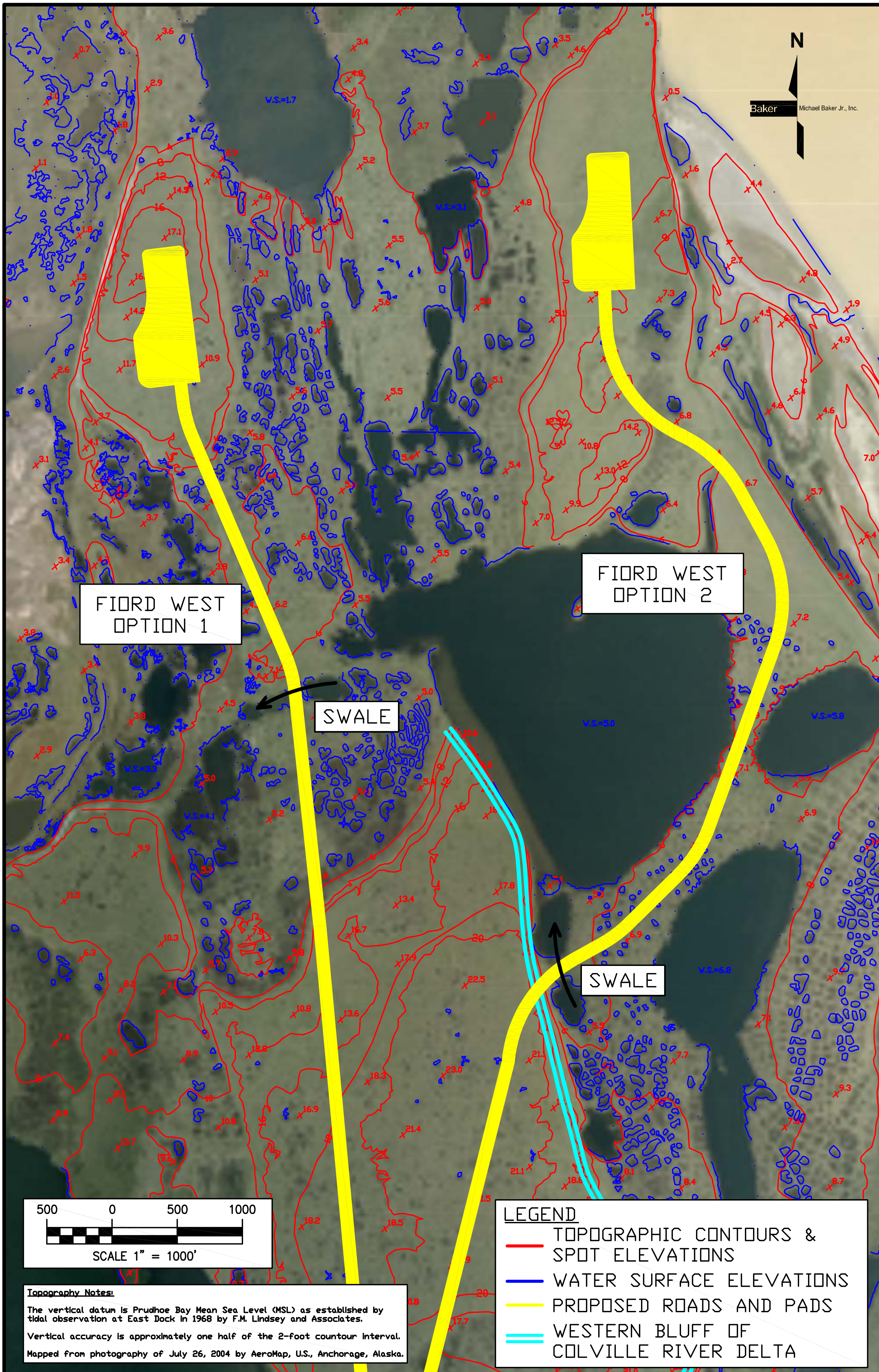
Preliminary findings of anticipated floodwater conditions for the 50-year and 200-year design conditions near the proposed Fiord West options are presented below. Table 3-2 presents water surface elevations and velocities at the 2008 gaging locations. Table 3-3 and Table 3-4 present data collected at explicit locations along Option 1 and Option 2 configurations, respectively. Model output figures are presented for the 50-year and 200-year flood conditions in Appendix A. An index of output figures is presented at the beginning of Appendix A.

Results are provided for baseline conditions only. The mesh has not been modified to model the presence of the proposed road and pad options.

Table 3-2 Water Surface Elevations and Velocities Near Staff Gages During 50- and 200-Year Floods

Location	State Plane Coordinates (1)			2008 Existing Facilities 50-Year Flood (3)		2008 Existing Facilities 200-Year Flood (5)	
	Northing	Easting	Approxiamte Ground Elevation (2)	Water Surface Elevation (2)	Velocity (4)	Water Surface Elevation (2)	Velocity (4)
Monument 22	5,967,152	1,510,286	5.2	11.9	2.0	14.1	1.7
Monument 23	5,976,250	1,509,226	8.2	10.2	1.9	12.1	3.0
FWR	5,982,691	1,504,453	2.9**	9.1*	-	10.5*	-
FWP	5,988,628	1,505,412	7.8	-	-	8.9	0.8

Notes:
1. All elevations are reported in BPMSL, and coordinates are reported in Alaska State Plane, Zone 4, NAD83.
2. Ground and water surface elevations are reported in feet, BPMSL.
3. 50-year water surface elevations and velocities based on 2008 model output: Q50_2008CD5_Pre_b(final).flo.
4. Flow velocities are reported in feet per second.
5. 200-year water surface elevations and velocities based on 2008 model output: Q200_2008CD5_Pre_b(final).flo.
6. Water surface elevations and velocities with an asterisk (*) represent values in the vicinity of the identified location. The element at the specified location is considered turned off by the model, however the ground surface elvation is lower than the local water surface elevation.
7. Ground elevations with a double asterisk (**) represent values in the vicinity of the identified location obtained during staff gage placement in spring 2008. This value is substituted for that assigned to the finite element mesh. Velocities in these areas cannot be estimated.
8. Empty cells are areas where the model indicates a water surface elevation below approximate ground elevation (dry ground).



FIORD WEST
2004 PHOTOGRAMETERIC
TOPOGRAPHY
FIGURE 3-2
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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

Baker

ConocoPhillips
Alaska, Inc.

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3.2.1 50-Year Flood Condition

Fiord West Option 1 runs along the top of the bluff forming the western boundary of the Delta before dropping to a minimum elevation of approximately 4 feet near Harrison Bay and the northern limits of the model. Water surface elevations predicted for the 50-year flood are not expected to reach Fiord West Option 1.

To the east, ground surface elevations and expected water surface elevations rise as shallow overbank flow exits the Nigliq Channel. The pad and northern section of the Fiord West Option 2 access road fall within 300 feet of the Nigliq Channel and are subject to this flow. Water depths are not expected to exceed 2.5 feet and are rarely greater than 1 foot. Velocities are also low, falling below 0.5 feet per second. With correct placement of drainage structures velocities and water surface elevations are not expected to increase significantly should the Option 2 configuration be constructed.

Floodwaters would likely be conveyed along the western bluff, flowing between neighboring lakes via topographic depressions (swales), though this is not represented in the model output. Approximate ground elevations obtained from field surveys and modeled water surface elevations are presented where the proposed road crosses this area (Table 3-2, Gage FWR and Table 3-4, Station 65+00).

3.2.2 200-Year Flood Condition

Floodwater from the 200-year condition is expected to inundate areas around the northern section of Fiord West Option 1 access road, unlike the 50-year condition, though depths are not expected to exceed 1.5 feet. Velocities are not expected to exceed 2 feet per second. Though the model output figures suggest that floodwater will reach the pad of Option 1 (Figure A-3), recent photogrametric topography places the pad well above the local water surface elevations, as presented in Figure 3-2 and Table 3-3. This topographic data also suggests that a swale located north of the bluff and south of the Option 1 pad, similar to that seen near Gage FWR, would likely convey a larger volume of flow than the surrounding floodplain.

During a 200-year flood event Option 2 would be surrounded by floodwater for its entire length east of the bluff. Expected water depths would range from 1-foot to 3-feet with a potential maximum depth of 7.5 feet in the swale along the western bluff (Table 3-2, Gage FWR). Velocities are also notably high with maximum modeled velocities of 2.0 feet per second.

Table 3-3 Water Surface elevations and Velocities Near Proposed Fiord West Option 1 Road and Pad Configuration During 50- and 200-Year Floods

Location	State Plane Coordinates (1)			2008 Existing Facilities 50-Year Flood (3)		2008 Existing Facilities 200-Year Flood (5)	
	Northing	Easting	Approxiamte Ground Elevation (2)	Water Surface Elevation (2)	Velocity (4)	Water Surface Elevation (2)	Velocity (4)
SW Corner Pad	5,987,168	1,501,319	11.0**	-	-	-	-
SE Corner Pad	5,987,199	1,501,755	10.5**	-	-	-	-
NW Corner Pad	5,988,189	1,501,319	17.0**	-	-	-	-
NE Corner Pad	5,988,229	1,501,615	16.0**	-	-	-	-
5+00	5,986,713	1,501,722	4.6	-	-	5.8	1.6
10+00	5,986,253	1,501,918	4.6	-	-	6.1	1.6
15+00	5,985,793	1,502,113	4.7	-	-	6.4	1.7
20+00	5,985,333	1,502,309	5.0	-	-	6.7*	1.4*
25+00	5,984,863	1,502,476	5.7	-	-	7.0*	0.6*
30+00	5,984,365	1,502,530	6.5	-	-	7.3*	0.2*

Notes:
1. All elevations are reported in BPMSL, and coordinates are reported in Alaska State Plane, Zone 4, NAD83.
2. Ground and water surface elevations are reported in feet, BPMSL.
3. 50-year water surface elevations and velocities based on 2008 model output: Q50_2008CD5_Pre_b(final).flo.
4. Flow velocities are reported in feet per second.
5. 200-year water surface elevations and velocities based on 2008 model output: Q200_2008CD5_Pre_b(final).flo.
6. Water surface elevations and velocities with an asterisk (*) represent values in the vicinity of the identified location. The element at the specified location is considered turned off by the model, however the ground surface elvation is lower than the water surface elevation.
7. Ground elevations with a double asterisk (**) represent values in the vicinity of the identified location obtained during staff gage placement in spring 2008. This value is substituted for that assigned to the finite element mesh. Velocities in these area cannot be estimated.
8. Empty cells are areas where the model indicates a water surface elevation below approximate ground elevation (dry ground).

Table 3-4 Water Surface elevations and Velocities Near Proposed Fiord West Option 2 Road and Pad Configuration During 50- and 200-Year Floods

Location	State Plane Coordinates (1)			2008 Existing Facilities 50-Year Flood (3)		2008 Existing Facilities 200-Year Flood (5)	
	Northing	Easting	Approxiamte Ground Elevation (2)	Water Surface Elevation (2)	Velocity (4)	Water Surface Elevation (2)	Velocity (4)
SW Corner Pad	5,987,917	1,504,648	7.2	-	-	8.3	0.7
SE Corner Pad	5,987,912	1,505,087	7.5	-	-	8.7	0.8
NW Corner Pad	5,988,929	1,504,726	6.8	-	-	8.4	1.2
NE Corner Pad	5,988,948	1,505,025	7.1	-	-	8.6	1.1
5+00	5,987,419	1,504,905	7.3	7.3*	0.1*	8.6	0.8
10+00	5,986,991	1,505,155	7.2	7.6*	0.1*	9.0	0.9
15+00	5,986,762	1,505,493	7.2	7.8*	0.2*	9.3	1.0
20+00	5,986,427	1,505,857	7.2	7.9*	0.2*	9.7	1.2
25+00	5,985,990	1,506,100	7.2	8.2*	0.2*	9.8	1.1
30+00	5,985,510	1,506,221	7.0	8.4*	0.3*	9.9	1.1
35+00	5,985,027	1,506,108	6.8	8.5*	0.4*	10.0	1.4
40+00	5,984,557	1,505,938	6.4	8.8*	0.4*	10.1	1.6
45+00	5,984,087	1,505,768	7.3	8.8*	0.4*	10.2	1.8
50+00	5,983,623	1,505,583	8.1	8.9*	0.4*	10.3	2.0
55+00	5,983,250	1,505,254	9.0	-	-	10.3	1.4
60+00	5,982,916	1,504,883	9.5	-	-	10.4	1.1
65+00	5,982,653	1,504,459	5.0**	9.1*	-	10.4*	-

Notes:
1. All elevations are reported in BPMSL, and coordinates are reported in Alaska State Plane, Zone 4, NAD83.
2. Ground and water surface elevations are reported in feet, BPMSL.
3. 50-year water surface elevations and velocities based on 2008 model output: Q50_2008CD5_Pre_b(final).flo.
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6. Water surface elevations and velocities with an asterisk (*) represent values in the vicinity of the identified location. The element at the specified location is considered turned off by the model, however the ground surface elvation is lower than the water surface elevation.
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8. Empty cells are areas where the model indicates a water surface elevation below approximate ground elevation (dry ground).

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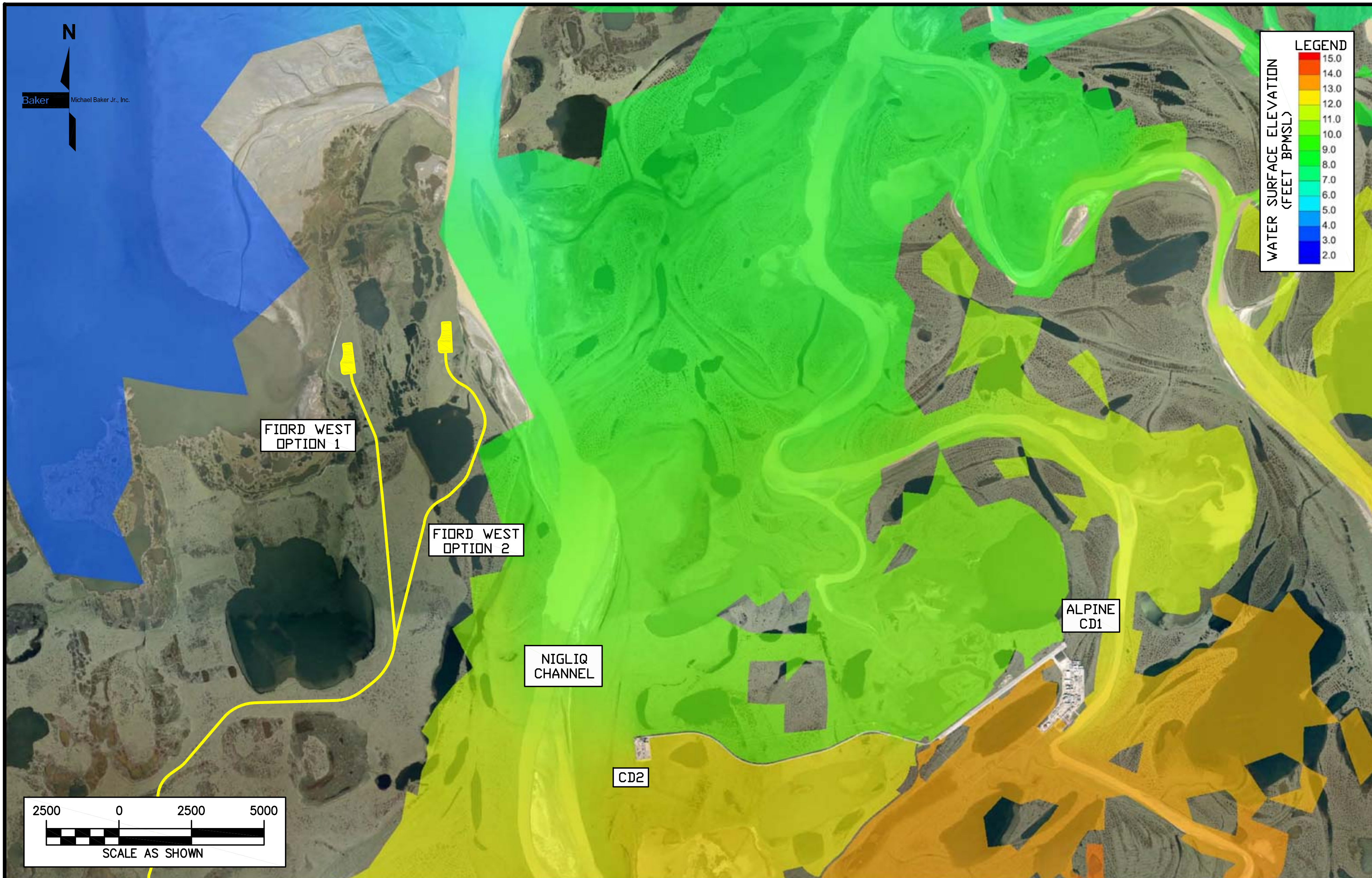
Appendix A SMS 2-Dimensional Model Output

Figure A-1 SMS Model Output 2008 Existing Conditions 50-Year Water Surface Elevations

Figure A-2 SMS Model Output 2008 Existing Conditions 50-Year Flow Velocities

Figure A-3 SMS Model Output 2008 Existing Conditions 200-Year Water Surface Elevations

Figure A-4 SMS Model Output 2008 Existing Conditions 200-Year Flow Velocities



ConocoPhillips
Alaska, Inc.

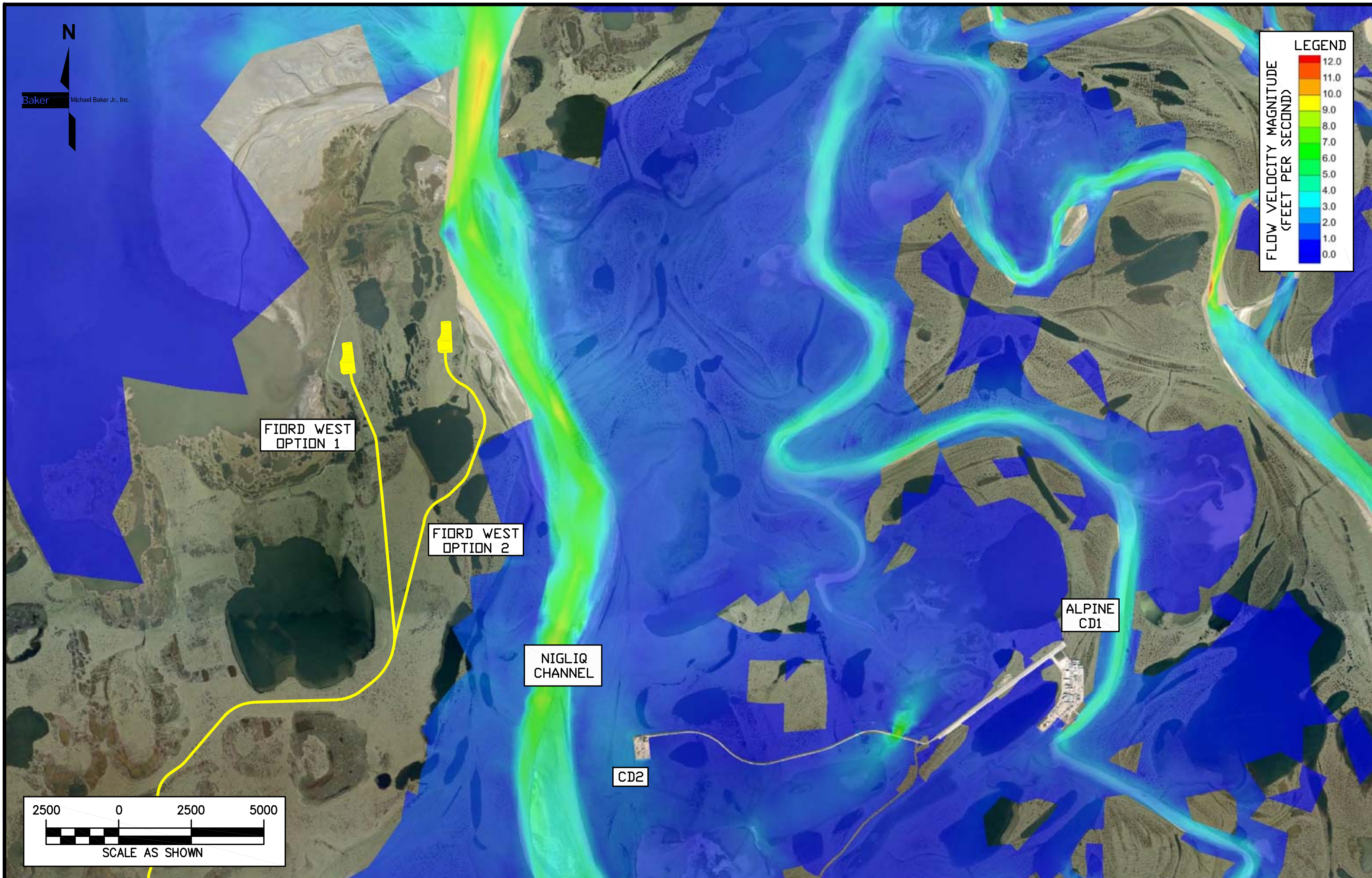
DATE:	10/02/08	PROJECT:	114717
DRAWN:	MDM	FILE:	SMS_OUTPUT.DWG
CHECKED:	OOO	SCALE:	AS SHOWN

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

SMS MODEL OUTPUT
2008 EXISTING CONDITIONS 50-YEAR
WATER SURFACE ELEVATIONS

FIGURE A-1
(SHEET 1 OF 1)



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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:	10/02/08	PROJECT:	114717
DRAWN:	MDM	FILE:	SMS_OUTPUT.DWG
CHECKED:	OOO	SCALE:	AS SHOWN

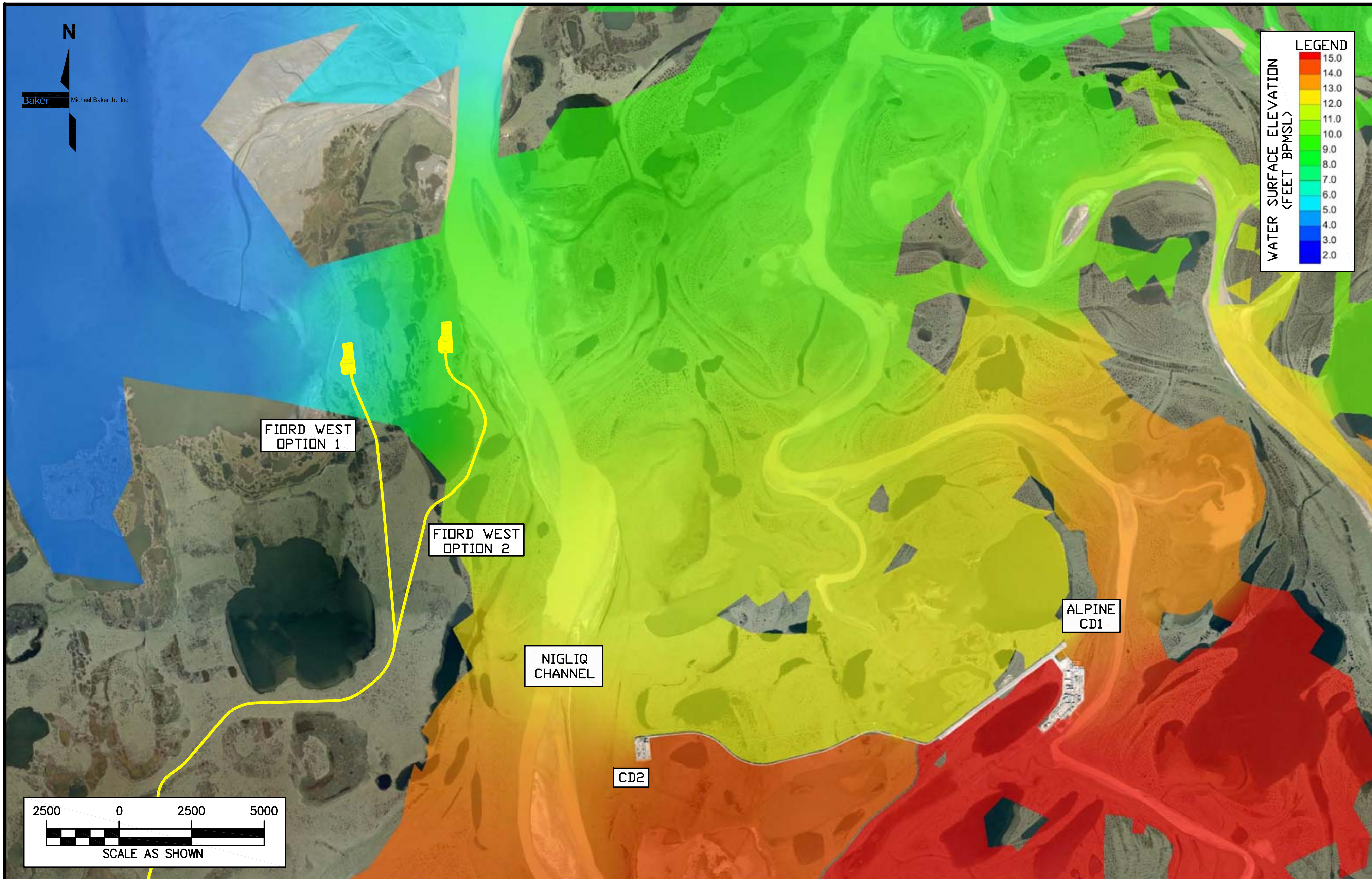
SMS MODEL OUTPUT

2008 EXISTING CONDITIONS 50-YEAR

FLOW VELOCITIES

FIGURE A-2

(SHEET 1 OF 1)



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Alaska, Inc.

DATE:	10/02/08	PROJECT:	114717
DRAWN:	MDM	FILE:	SMS_OUTPUT.DWG
CHECKED:	OOO	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

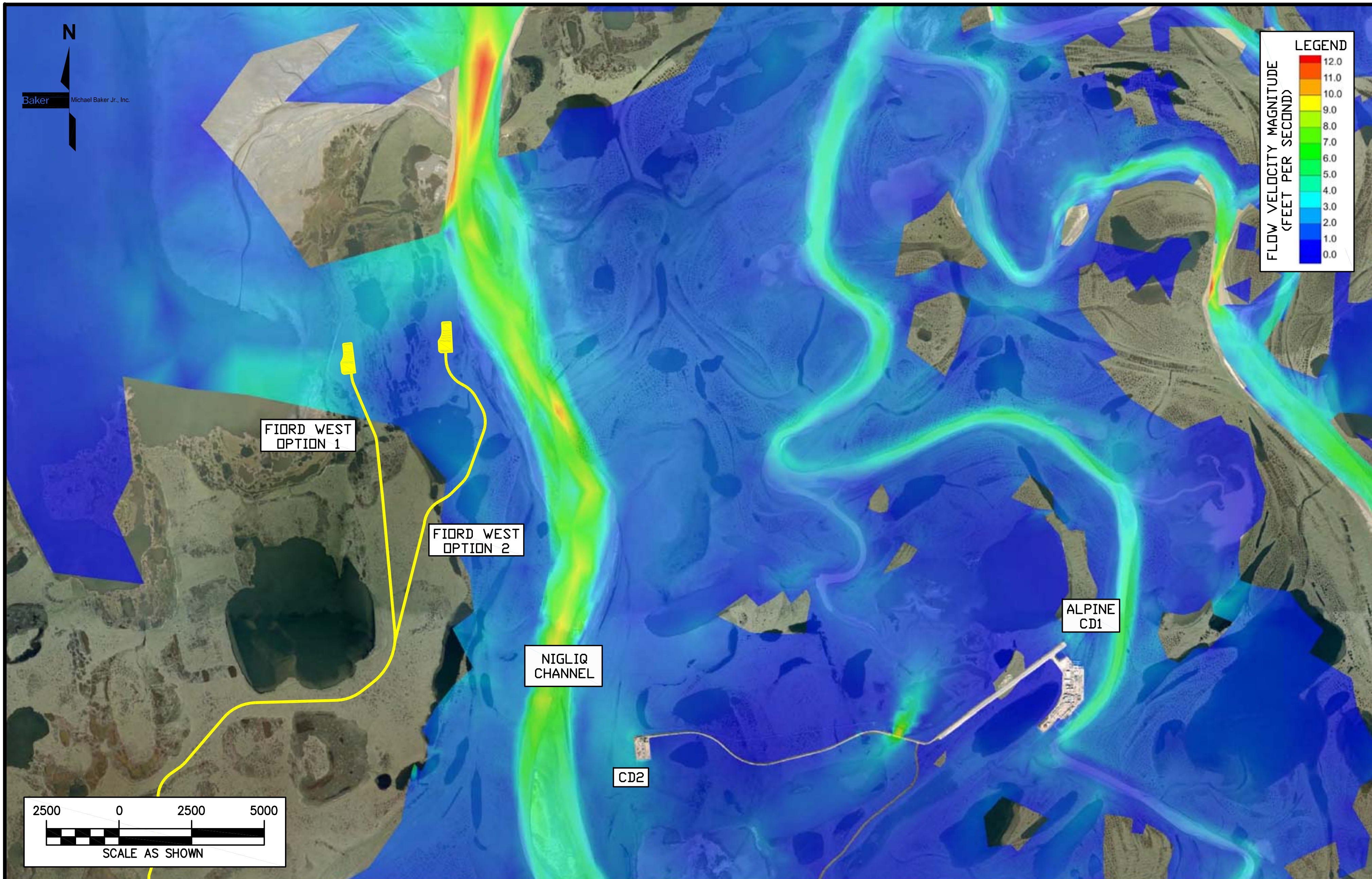
SMS MODEL OUTPUT

2008 EXISTING CONDITIONS 200-YEAR

WATER SURFACE ELEVATIONS

FIGURE A-3

(SHEET 1 OF 1)



ConocoPhillips Alaska, Inc.

DATE:	10/02/08	PROJECT:	114717
DRAWN:	MDM	FILE:	SMS_OUTPUT.DWG
CHECKED:	OOO	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

SMS MODEL OUTPUT
2008 EXISTING CONDITIONS 200-YEAR
FLOW VELOCITIES

FIGURE A-4
(SHEET 1 OF 1)