CD-North Satellite Development Bank Migration Analysis Report

Submitted to

PHILLIPS Alaska, Inc.
A Subsidiary of PHILLIPS PETROLEUM COMPANY

May 2002

By

Michael Baker Jr., Inc.
4601 Business Park Blvd., Suite 42
Anchorage, Alaska 99503
907-273-1600

25009-MBJ-RPT-001

CD-North Satellite Development Bank Migration Analysis Report

Submitted to

PHILLIPS Alaska, Inc.
A Subsidiary of PHILLIPS PETROLEUM COMPANY

May 2002

By

Michael Baker Jr., Inc.
4601 Business Park Blvd., Suite 42
Anchorage, Alaska 99503
907-273-1600

25009-MBJ-RPT-001

Contents

Section 1. Overview

A bank migration analysis was performed for the proposed CD-North Satellite Development project. The CD-North project consists of a facility pad, an airstrip, and an approximately 6.7-mile-long pipeline between the pad and the existing Alpine development. The pipeline alignment crosses three delta distributary channels. Pipeline bridges are proposed for the three crossings. A project overview is shown on the attached Figure 1.

Lounsbury & Associates provided the pad layout used in the analysis and NANA-Colt Engineering provided the pipeline layout.

The bank migration analysis focused on seven areas:

1. CD-North facility pad along the northeast bank of the West Ulamnigiaq Channel
2. The northeast end of the CD-North airstrip near the west bank of the East Ulamnigiaq Channel
3. Pipeline alignment along the northeast banks of the West Ulamnigiaq and Ulamnigiaq Channels
4. Pipeline bridge crossing of the Ulamnigiaq Channel (Crossing 5)
5. Pipeline bridge crossing of the Tamayagiaq Channel (Crossing 4)
6. Pipeline bridge crossing of the Sakoonang Channel (Crossing 2)
7. Pipeline alignment along the west bank of the Sakoonang Channel

The analysis was performed by comparing the position of channel bank lines on photography from July and August 1948, and June 30, 1999.

Section 2. Historical Observations of Bank Migration in the Colville River Delta

H.J. Walker and others have made observations and measurements of bank migration within the Colville River delta.[1] Bank erosion within the delta occurs almost entirely within a two- or three-week period during or shortly after the spring breakup flood. Maximum bank erosion often occurs during the recession of the breakup flood peak. Bank erosion proceeds through either sloughing of the thawed face of a permafrost bank, or through the block collapse of a thermoerosional niche. The undercutting of the frozen bank through thermal and mechanical processes produces a thermoerosional niche. Of the two processes, thermoerosional niches account for far higher magnitudes and rates of erosion. Niches as deep as 26 feet have been measured along the bank of the East Channel of the river.

The collapse of thermoerosional niches results in the occurrence of relatively large magnitudes of bank erosion within a very short period. The niche, however, may have been developing for a number of years with no change in the location of the edge of the bank. Bank erosion within the delta, therefore, often proceeds in abrupt steps separated by long periods of apparent stability. It has been suggested that long-term rates of erosion within arctic streams are relatively uniform in comparison to streams in nonpermafrost areas.[2] This apparent uniformity of long-term erosion rates gives an added degree of confidence in the average erosion rates calculated within the current analysis.

The majority of erosional banks within the Colville River delta are right banks (left and right banks are relative to an observer facing downstream) with the highest potential for erosion on banks facing to the west and south. This dominance of erosion on generally west- and south-facing banks reflects the importance of aspect on insolation (thermal input from the sun) reception of the banks. A recent example of this would be the ice wedge deterioration and erosion witnessed at the east bank of the East Channel near the HDD crossing site. Depositional banks most commonly face northeast, the dominant direction of wind-transported sediment, and the direction receiving lowest insolation. Dunes are commonly found on northeast-facing banks.

In the arctic, channels formed in cohesive fine-grained materials produce sinuous or meandering patterns and their banks are highly resistant to erosion. Channels formed in non-cohesive, coarse-grained sediments tend to form braided channels and are less resistant to erosion. Within the current study, all of the channels analyzed are either sinuous or meandering which suggests that underlying materials are likely cohesive and fine-grained.

---

1 Walker, H.J. and Arnborg, L. 1966. "Permafrost and Ice-wedge Effect on Riverbank Erosion," In *Proceedings, First International Permafrost Conference*, pp. 164-171; Ritchie, W. and Walker, H.J. 1974. "Riverbank Forms of the Colville River Delta," In Reed, J.C. Jr. and Sater, J.C., eds., *The Coast and Shelf of the Beaufort Sea: Arctic Institute of North America*, pp. 545-562; and Walker, H.J. et al. 1987. "Riverbank Erosion in the Colville Delta, Alaska," *Geografiska Annaler 69 A*, pp. 61-70

2 Scott, K.M. 1978. "Effects of Permafrost on Stream Channel Behavior in Arctic Alaska," *US Geological Survey Professional Paper 1068*

Walker and others measured bank erosion at a number of sites within the delta. Erosion was measured along the Nigliq Channel near the community of Nuiqsut. Erosion of a peat bank overlying a sand deposit at Nigilik, the site of a 19th century bartering station at the mouth of the channel, was also measured. A maximum one-year erosion rate of 36 feet was recorded at Nuiqsut. The long-term average at the site was approximately 3 feet per year. At Nigilik (near the mouth of the Nigliq Channel), a long-term average of approximately 4 feet per year was measured. Both of these sites are along high banks that are at least partially composed of unconsolidated and noncohesive sediments. The banks are high enough so that they do not flood during breakup but are subject to flows throughout the open water season.

Section 3. Analysis Methods

Aeromap U.S. provided the photography used in the analysis. The 1948 photography was provided as an uncontrolled digital photo mosaic while that from 1999 was provided as a digital orthophotograph. The highest resolution on the 1948 photography was a five-foot by five-foot pixel while that for the 1999 photography was a ten-foot by ten-foot pixel. Portions of the 1948 photography that covered the areas of interest were digitally cropped from the photo mosaic. The cropped photographs were then digitally "rubber sheeted" to the 1999 orthophotograph in order to match the scale and orientation of the two sets of photographic data.

Channel bank lines were digitized on both sets of photography. Channel bank lines represent the interpreted edge of vegetation. The edge of vegetation may not always coincide with what would be surveyed in the field as the top of the bank, particularly in areas such as point bars complexes on the inside of meander bends. However, in the absence of digital contour data, vegetation lines are felt to provide the best representation of bank lines.

Both the left and right banks were digitized in the areas of interest. Channels were then divided into reaches where similar types and magnitudes of bank migration processes were noted. Within each reach, five measurement sites were located along each bank. Included within each set of five sites was the point of maximum erosion (outboard retreat of the 1999 bank line relative to the 1948 bank line) along generally eroding banks, or maximum accretion (inboard advance of the 1999 bank line) along generally accreting banks. Measurements were also made at each bank of the three pipeline bridge crossing alignments.

Digitized ice wedge polygon boundaries were used to determine the "rubber sheeting" error near bank migration measurement locations. Correction factors were applied to the measurements to remove the "rubber sheeting" error. Positive values of bank migration denote erosion while negative values denote accretion. The resulting bank migration measurements are felt to be accurate to $\pm$10 ft (plus or minus the width of a single pixel on the 1999 photography) when differences in resolution, color, and quality between the two sets of photography are taken into account.

The average bank migration and bank migration rates, and maximum erosion and maximum erosion rates were estimated for each bank of each reach. Positive bank migration rates denote an eroding trend, while negative values denote an accreting trend. In this analysis, accreting banks are those which are interpreted to have been stabilized by the growth of vegetation (inboard of the 1948 vegetation line).

Average bank migration rates and maximum bank erosion rates were used to calculate predicted 30-year average bank migration and maximum erosion magnitudes based upon the assumed design life of the project.

A qualitative assessment of the general character of bank migration was developed for each bank of each reach. For average bank migration rates less than or equal to 0.3 feet per year (ft/yr) the bank is considered to have been "stable." Average rates between 0.4 and 1.0 ft/yr are considered to represent "minor erosion" while rates of greater than 1.0 ft/yr are considered to represent "moderate erosion." No banks measured within the analysis were considered to have experienced what would be qualitatively termed major erosion when compared to historical measurements of bank erosion within the Colville River delta.

Section 4. Analysis Results/Recommendations

The facility and pipeline layouts, 1948 and 1999 bank lines, channel reach delineations, and analysis results are presented on the attached Figures 2, 3, and 4. Recommended minimum facility and bridge abutment setbacks are based on estimated bank migration rates over 30 years, plus a one-time maximum erosion occurrence of either 9 or 18 feet (depending on the character of bank migration along a reach), plus an additional 10 feet to account for photogrammetric tolerances. The term "setback" as used in this report refers to a recommended minimum perpendicular distance that facilities should be placed away from the top of a given stream bank in order to account for bank migration.

No historical bank erosion measurements have been made along the distributary channels of interest. The one-time maximum erosion occurrence is a safety factor based upon a measurement by Walker[3] of 36 feet that resulted from the collapse of a thermoerosional niche. The 36-foot observation was made on the Nigliq Channel, which is a significantly larger and more active channel than the distributaries being analyzed for this project.

Characteristics of the channels crossed by the CD-North project are such that a one-time erosion occurrence is not likely to have the same magnitude as the larger channels of the delta. Further, some stream banks are unlikely to produce thermoerosional niches because of their geometry, aspect, position relative to bends, bank migration trends, or permafrost conditions. Such banks may still experience erosion over the life of the project, however, due to changes in the hydrologic, climatic, or geomorphic regimes of the delta. To account for these differences, a one-time erosion occurrence for reaches identified as having eroding bank migration trends has been set at 18 feet, based upon a one-time erosion occurrence for smaller distributaries (one half of the observed maximum occurrence on the Nigliq Channel). For reaches identified as having accreting bank migration trends, the one-time erosion occurrence has been set at 9 feet (one quarter of the observed maximum occurrence on the Nigliq Channel).

CD-North facility pad: The proposed CD-North facility pad is located on the inside of a bend on the right bank of the West Ulamnigiaq Channel (see Figure 2). The bank of the adjacent channel reach (WU2) has experienced an average of 38 feet of accretion over the analysis period with an average rate of –0.7 ft/yr. The bank adjacent to the pad would therefore be termed stable over the analysis period. Given the location on the inside of a bend, this stable or accreting trend is expected to continue over the life of the project.

Taking into account the importance of the pad integrity, the recommended facility pad setback is 35 feet from the right (northeast) bank along the reach WU2. This setback is based upon the maximum rate of erosion noted on an upstream reach of the West Ulamnigiaq Channel (over 30 years) plus a 9-foot one-time erosion occurrence, and a 10-foot tolerance. The use of the maximum erosion rate from an upstream reach (WU4) is felt to be appropriate given the apparent widening of the mouth of the channel at Reach WU5. This apparent widening may be signaling

[3] Walker et al. 1987

increased flood flows into the channel and the possible northward migration of eroding trends noted along the right banks of Reaches WU3 and WU4.

CD-North airstrip: The northeastern end of the proposed CD-North airstrip is located near the outside of a bend on the left bank of the East Ulamnigiaq Channel (see Figure 2). The bank of the adjacent channel reach (EU1) has experienced an average of 16 feet of erosion over the analysis period with an average rate of 0.3 ft/yr. A maximum of 29 feet of erosion was measured along the same bank, with a corresponding maximum rate of erosion of 0.6 ft/yr. Given the location on the outside of a bend, this eroding trend is expected to continue over the life of the project.

The recommended airstrip setback is 45 feet from the left (west) bank along the Reach EU1 (maximum erosion rate over 30 years, plus an 18-foot one-time erosion occurrence, and a 10-foot tolerance). The maximum erosion rate was used for developing the recommended setback because the section of the channel near the end of the airstrip is expected to continue to experience the highest rates of erosion along Reach EU1.

Pipeline alignment along the West Ulamnigiaq and Ulamnigiaq Channels: The proposed CD-North pipeline follows the right banks of the West Ulamnigiaq and Ulamnigiaq Channels for a distance of approximately 6,000 feet between the CD-North facility pad and the Ulamnigiaq Channel pipeline bridge (Crossing 2, see Figure 2). With the exception of a short reach (WU5) at the mouth of the West Ulamnigiaq Channel where the distributary channel leaves the Ulamnigiaq, the general character of bank migration of all the right banks of the reaches paralleled by the pipeline (WU2-4 and U3) was determined to have been stable over the analysis period.

The recommended pipeline setback is 44 feet from the right (northeast) bank along reaches WU2, WU3, WU4, and U3 (maximum rate for Reach WU4 over 30 years, plus an 18-foot one-time occurrence, plus a 10-foot tolerance). For this section of river, the maximum bank erosion rate was used rather than the average since the pipeline runs parallel to the channel and is more susceptible to fluctuations in erosion rates.

The right bank of Reach WU5 experienced a maximum of 172 feet of erosion over the analysis period, and a corresponding maximum erosion rate of 3.4 ft/yr. This widening of the head of the distributary channel appears to be the result of the 1999 bank line reoccupying a former pre-1948 bank line. As such, and without knowing when the bank line moved to its present location during the 51 years after 1948, the bank might actually be stable at this time. If this erosion trend is recent, however, then it must be assumed that such erosion will continue in the future. Thus, the recommended setback along this reach from the top of the right (east) bank is 129 feet (maximum erosion rate over 30 years, plus an 18-foot one-time occurrence, plus a 10-foot tolerance).

Pipeline bridge crossing of the Ulamnigiaq Channel (Crossing 5): The Ulamnigiaq Channel has been stable near the proposed pipeline bridge crossing site over the analysis period (see Figure 2). The left bank of the reach at the crossing (U4) has experienced an average of 16 feet of bank accretion over the analysis period, with an average migration rate of –0.3 ft/yr. The right bank of the reach at the crossing (U3) has experienced an average of 9 feet of erosion with an average rate of 0.2 ft/yr. At the bridge crossing alignment, one foot of accretion was measured at the left bank and 9 feet of erosion at the right bank. Based on average erosion rates over the design life of the project, 0 feet of erosion would be expected on the left bank at the bridge alignment and 5 feet of erosion would be expected on the right bank. Thus the recommended setbacks from the top of bank for the bridge abutments are: left (southwest) bank 19 feet (a 9-foot one-time erosion occurrence plus a 10-foot tolerance); and right (northeast) bank 33 feet (average erosion rate over 30 years, plus an 18-foot one-time erosion occurrence, plus a 10-foot tolerance).

Pipeline bridge crossing of the Tamayagiaq Channel (Crossing 4): The left bank of the reach at the proposed pipeline bridge crossing (T1) has been stable over the analysis period and has experienced an average of 10 feet of bank erosion, with an average migration rate of 0.2 ft/yr (see Figure 3). The right bank of the reach at the proposed crossing (T2) has experienced minor erosion over the analysis period with an average of 46 feet of erosion, and an average migration rate of 0.9 feet/yr. At the pipeline alignment, the left bank has experienced 6 feet of erosion and the right bank has experienced 17 feet. Based on average erosion rates over the design life of the project, 6 feet of erosion would be expected at the left bank at the bridge alignment and 27 feet of erosion would be expected on the right bank. Thus the recommended setbacks from the top of bank for the bridge abutments are: left (southeast) bank 34 feet (average erosion rate over 30 years, plus an 18-foot one-time erosion occurrence, plus a 10-foot tolerance); and right (northwest) bank 55 feet (average erosion rate over 30 years, plus an 18-foot one-time occurrence, plus a 10-foot tolerance).

Pipeline bridge crossing of the Sakoonang Channel (Crossing 2): The left bank of the reach at the proposed pipeline bridge crossing (S2) has been stable over the analysis period and has experienced an average of 6 feet of bank accretion, with an average migration rate of -0.1 ft/yr (see Figure 4). The right bank of the reach at the crossing (S2) has experienced minor erosion over the analysis period with an average of 20 feet of erosion, and an average migration rate of 0.4 feet/yr. At the pipeline alignment, the left bank has experienced 1 foot of erosion and the right bank has experienced 14 feet. Based on average erosion rates over the design life of the project, 0 feet of erosion would be expected at the left bank at the bridge alignment and 12 feet of erosion would be expected at the right bank. Thus the recommended setbacks from the top of bank for the bridge abutments are: left (southwest) bank 19 feet (a 9-foot one-time erosion occurrence, plus a 10-foot tolerance); and right (northeast) bank 40 feet (average erosion rate over 30 years, plus an 18 foot one-time erosion occurrence, plus a 10-foot tolerance).

Pipeline alignment along the left (west) bank of the Sakoonang Channel: After crossing the Sakoonang Channel, the CD-North pipeline follows the left bank of the channel for approximately 7,800 feet until it reaches the Alpine development (see Figure 4). The left bank of the channel along this portion of the pipeline route has been stable over the analysis period. The only identified erosion of the left bank is of the relatively short reach S4 that experienced an average of 12 feet of erosion. For most of the distance traversed by the pipeline between the Sakoonang Channel crossing and the Alpine development, the alignment is 400 to 800 feet away from the bank. In the last 1,400 feet before reaching the Alpine development, the pipeline comes to within 160 feet of the bank of the channel. Since the left bank of Reach S5 has been identified as accreting over the analysis period, the minimum recommended setback from the top of bank is 19 feet (a 9-foot one-time erosion occurrence, plus a 10-foot tolerance).

Setback recommendations are summarized in Table 1.

Table 1 CD-North Facility Setback Recommendations for Bank Migration

Facility	Channel	Bank	Setback
Facility Pad	West Ulamnigiaq	right	35 feet
Airstrip	East Ulamnigiaq	left	45 feet
Pipeline along West Ulamnigiaq and Ulamnigiaq Channels	West Ulamnigiaq and Ulamnigiaq (except Reach WU5)	right	44 feet
Pipeline along West Ulamnigiaq and Ulamnigiaq Channels	West Ulamnigiaq (Reach WU5)	right	129 feet
Pipeline Bridge (Crossing 5)	Ulamnigiaq	left	19 feet
Pipeline Bridge (Crossing 5)	Ulamnigiaq	right	33 feet
Pipeline Bridge (Crossing 4)	Tamayagiaq	left	34 feet
Pipeline Bridge (Crossing 4)	Tamayagiaq	right	55 feet
Pipeline Bridge (Crossing 2)	Sakoonang	left	19 feet
Pipeline Bridge (Crossing 2)	Sakoonang	right	40 feet
Pipeline Along Sakoonang Channel	Sakoonang	left	19 feet

It should be noted that the setback recommendations in this analysis are based strictly upon identified bank migration rates and trends. Other important design factors such as floodwater heights, ground elevations, and ice floe movements may govern final setback distances.

NOTES:
1. DIGITAL ORTHOPHOTO BASEMAPPING PROVIDED BY AEROMAP US, INC. FROM PHOTOGRAPHY FLOWN ON JUNE 30, 1999.
2. CD–NORTH PIPELINE ROUTE PROVIDED BY NANA–COLT ENGINEERING, APRIL 2002. CD–NORTH PAD LAYOUT PROVIDED BY LOUNSBURY AND ASSOCIATES, JANUARY 2002.

Baker Michael Baker Jr., Inc.

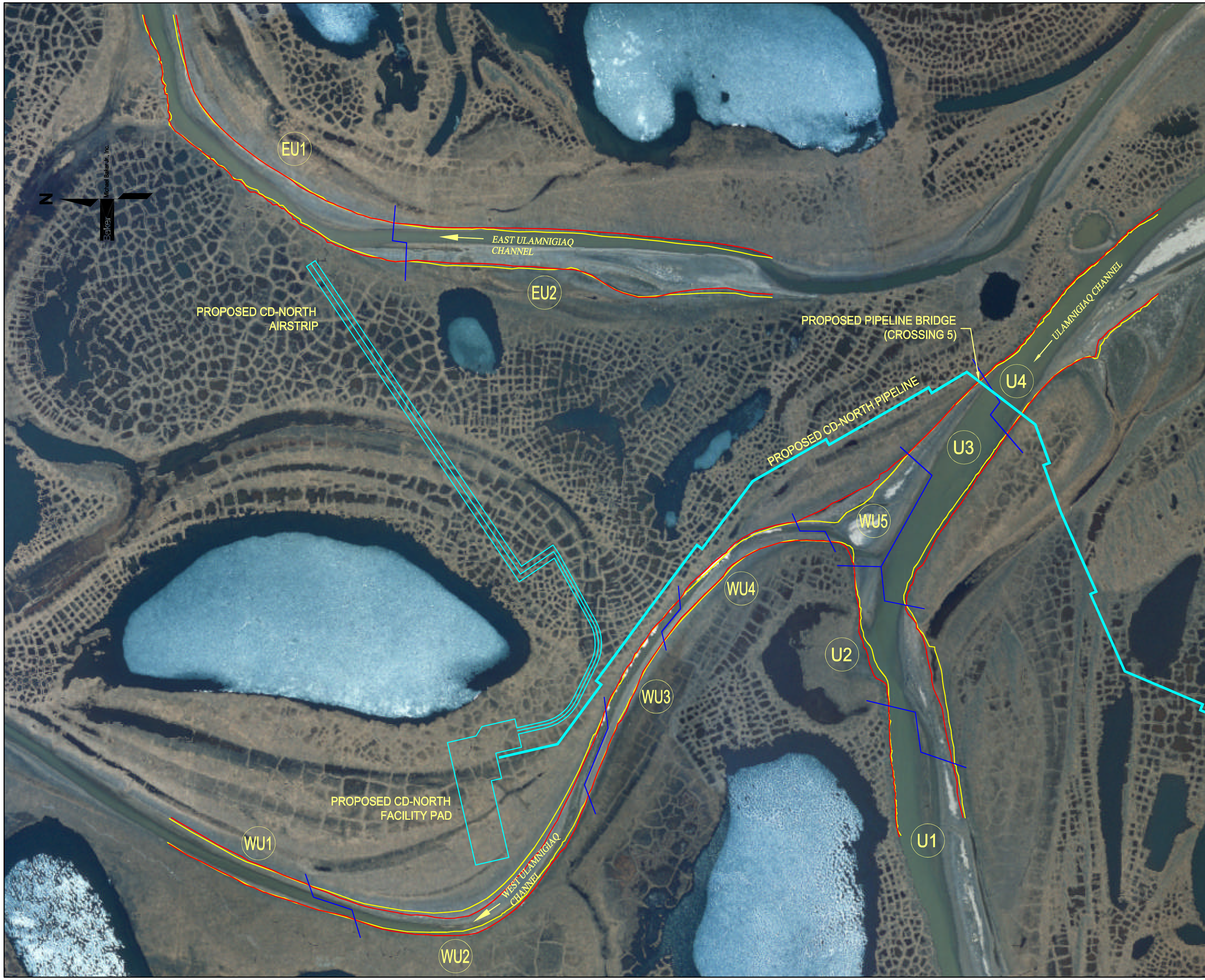
PHILLIPS Alaska, Inc.
A Subsidiary of PHILLIPS PETROLEUM COMPANY

1000 0 1000 2000
SCALE: 1" = 2000'

SCALE: AS SHOWN	DRAWN: TKM
DATE: 05/06/02	DESIGN: HRA
CADD FILE NO. BANKFIG1	CHECKED: JAB

CD–NORTH SATELLITE DEVELOPMENT
BANK MIGRATION ANALYSIS
PROJECT OVERVIEW

JOB NO:	DRAWING NO.	SHEET:
25009	FIGURE 1	1 OF 4



Reach	Bank	Maximum bank erosion [ft]	Maximum bank erosion rate [ft/yr]	Average bank migration [ft]	Average bank migration rate [ft/yr]	30-year predicted maximum bank erosion [ft]	30-year predicted average bank migration [ft]	General character of reach bank migration
WU1	left	5	0.1	-1	0.0	3	-1	stable
WU1	right	26	0.5	15	0.3	15	9	stable
WU2	left	52	1.0	30	0.6	31	18	minor erosion
WU2	right	0	0.0	-38	-0.7	0	-22	stable
WU3	left	12	0.2	-6	-0.1	7	-4	stable
WU3	right	26	0.5	17	0.3	15	10	stable
WU4	left	9	0.2	-3	-0.1	5	-2	stable
WU4	right	27	0.5	17	0.3	16	10	stable
WU5	left	52	1.0	27	0.5	31	16	minor erosion
WU5	right	172	3.4	87	1.7	101	51	moderate erosion
EU1	left	29	0.6	16	0.3	17	9	stable
EU1	right	40	0.8	11	0.2	24	7	stable
EU2	left	0	0.0	-45	-0.9	0	-26	stable
EU2	right	68	1.3	49	1.0	40	29	minor erosion
U1	left	0	0.0	-32	-0.6	0	-19	stable
U1	right	17	0.3	13	0.3	10	8	stable
U2	left	0	0.0	-62	-1.2	0	-36	stable
U2	right	79	1.5	38	0.7	46	22	minor erosion
U3	left	42	0.8	25	0.5	25	15	minor erosion
U3	right	12	0.2	9	0.2	7	5	stable
U4	left	3	0.1	-16	-0.3	2	-10	stable
U4	right	39	0.8	25	0.5	23	15	minor erosion
bridge	left	0	0.0	-1	0.0	0	-1	stable
bridge	right	9	0.2	9	0.2	5	5	stable

Notes:
1. Left and right banks are relative to an observer facing downstream.
2. Positive bank migration values denote erosion, that is, the 1999 bank line is located outboard of the 1948 bank line.
3. Negative bank migration values denote accretion, that is, the 1999 bankline is located inboard of the 1948 bank line.
4. The general character of reach bank migration is defined as "stable" for average migration rates of less than or equal to 0.3 ft/yr, "minor erosion" for rates of 0.4-1.0 ft/yr, and "moderate erosion" for rates greater than 1.0 ft/yr.
5. Digital orthophoto basemapping provided by Aeromap US, Inc., from photography flown June 30, 1999.
6. CD-North Pipeline route provided by NANA-Colt Engineering, April 2002. CD-North Pad layout provided by Lounsbury and Associates, January 2002.

Baker Michael Baker Jr., Inc.

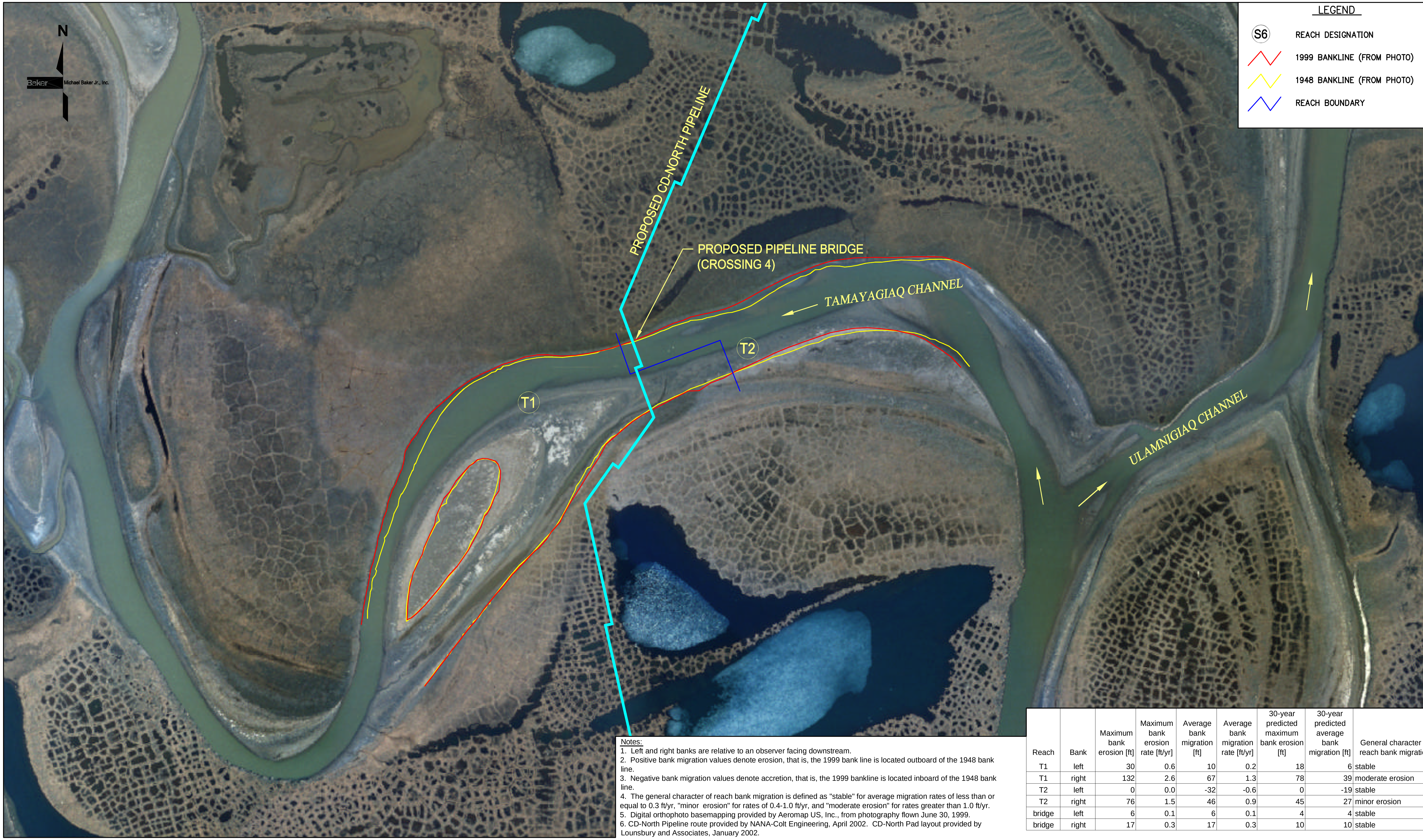
PHILLIPS 66 PHILLIPS Alaska, Inc.
A Subsidiary of PHILLIPS PETROLEUM COMPANY

500 0 500 1000
SCALE: 1" = 1000'

SCALE: AS SHOWN	DRAWN: TKM
DATE: 05/06/02	DESIGN: HRA
CADD FILE NO. BANKFIG2	CHECKED: JAB

CD-NORTH SATELLITE DEVELOPMENT
BANK MIGRATION ANALYSIS
ULAMNIGIAQ, AND EAST AND WEST ULAMNIGIAQ CHANNELS

JOB NO:	DRAWING NO.	SHEET:
25009	FIGURE 2	2 of 4



Notes:
1. Left and right banks are relative to an observer facing downstream.
2. Positive bank migration values denote erosion, that is, the 1999 bank line is located outboard of the 1948 bank line.
3. Negative bank migration values denote accretion, that is, the 1999 bankline is located inboard of the 1948 bank line.
4. The general character of reach bank migration is defined as "stable" for average migration rates of less than or equal to 0.3 ft/yr, "minor erosion" for rates of 0.4-1.0 ft/yr, and "moderate erosion" for rates greater than 1.0 ft/yr.
5. Digital orthophoto basemapping provided by Aeromap US, Inc., from photography flown June 30, 1999.
6. CD-North Pipeline route provided by NANA-Colt Engineering, April 2002. CD-North Pad layout provided by Lounsbury and Associates, January 2002.

Reach	Bank	Maximum bank erosion [ft]	Maximum bank erosion rate [ft/yr]	Average bank migration [ft]	Average bank migration rate [ft/yr]	30-year predicted maximum bank erosion [ft]	30-year predicted average bank migration [ft]	General character of reach bank migration
T1	left	30	0.6	10	0.2	18	6	stable
T1	right	132	2.6	67	1.3	78	39	moderate erosion
T2	left	0	0.0	-32	-0.6	0	-19	stable
T2	right	76	1.5	46	0.9	45	27	minor erosion
bridge	left	6	0.1	6	0.1	4	4	stable
bridge	right	17	0.3	17	0.3	10	10	stable

Baker Michael Baker Jr., Inc.

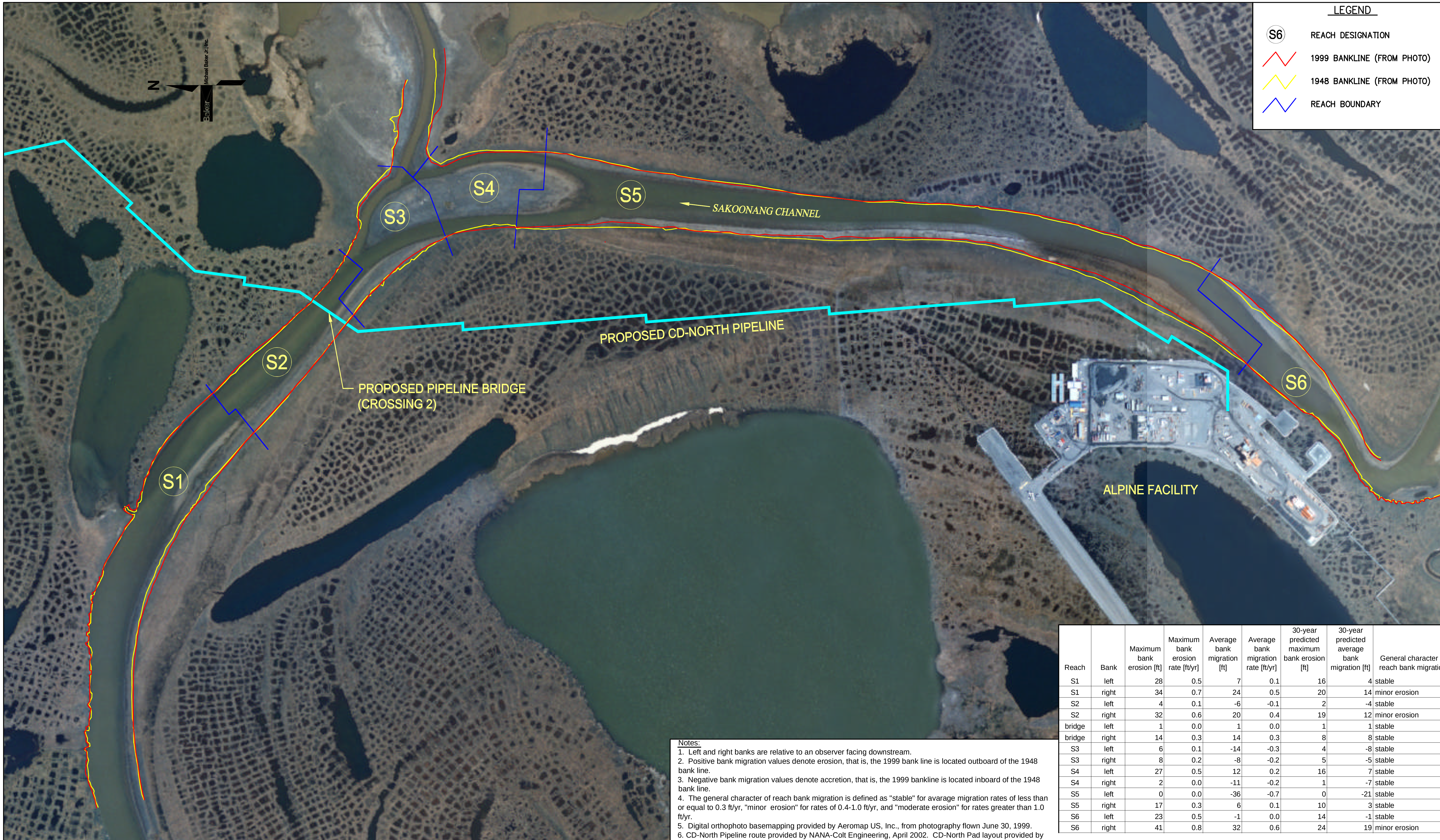
PHILLIPS Alaska, Inc.
A Subsidiary of PHILLIPS PETROLEUM COMPANY

400 0 400 800
SCALE: 1" = 800'

SCALE: AS SHOWN	DRAWN: TKM
DATE: 05/06/02	DESIGN: HRA
CADD FILE NO. BANKFIG3	CHECKED: JAB

CD–NORTH SATELLITE DEVELOPMENT
BANK MIGRATION ANALYSIS
TAMAYAGIAQ CHANNEL

JOB NO: 25009 DRAWING NO. FIGURE 3 SHEET: 3 OF 4



Reach	Bank	Maximum bank erosion [ft]	Maximum bank erosion rate [ft/yr]	Average bank migration [ft]	Average bank migration rate [ft/yr]	30-year predicted maximum bank erosion [ft]	30-year predicted average bank migration [ft]	General character of reach bank migration
S1	left	28	0.5	7	0.1	16	4	stable
S1	right	34	0.7	24	0.5	20	14	minor erosion
S2	left	4	0.1	-6	-0.1	2	-4	stable
S2	right	32	0.6	20	0.4	19	12	minor erosion
bridge	left	1	0.0	1	0.0	1	1	stable
bridge	right	14	0.3	14	0.3	8	8	stable
S3	left	6	0.1	-14	-0.3	4	-8	stable
S3	right	8	0.2	-8	-0.2	5	-5	stable
S4	left	27	0.5	12	0.2	16	7	stable
S4	right	2	0.0	-11	-0.2	1	-7	stable
S5	left	0	0.0	-36	-0.7	0	-21	stable
S5	right	17	0.3	6	0.1	10	3	stable
S6	left	23	0.5	-1	0.0	14	-1	stable
S6	right	41	0.8	32	0.6	24	19	minor erosion

Notes:
1. Left and right banks are relative to an observer facing downstream.
2. Positive bank migration values denote erosion, that is, the 1999 bank line is located outboard of the 1948 bank line.
3. Negative bank migration values denote accretion, that is, the 1999 bankline is located inboard of the 1948 bank line.
4. The general character of reach bank migration is defined as "stable" for avarage migration rates of less than or equal to 0.3 ft/yr, "minor erosion" for rates of 0.4-1.0 ft/yr, and "moderate erosion" for rates greater than 1.0 ft/yr.
5. Digital orthophoto basemapping provided by Aeromap US, Inc., from photography flown June 30, 1999.
6. CD-North Pipeline route provided by NANA-Colt Engineering, April 2002. CD-North Pad layout provided by Lounsbury and Associates, January 2002.

Baker Michael Baker Jr., Inc.

PHILLIPS Alaska, Inc.
A Subsidiary of PHILLIPS PETROLEUM COMPANY

400 0 400 800
SCALE: 1" = 800'

SCALE: AS SHOWN	DRAWN: TKM
DATE: 05/02/02	DESIGN: HRA
CADD FILE NO. BANKFIG4	CHECKED: JAB

CD-NORTH SATELLITE DEVELOPMENT
BANK MIGRATION ANALYSIS
SAKOONANG CHANNEL

JOB NO:	DRAWING NO.	SHEET:
25009	FIGURE 4	4 OF 4

Michael Baker Jr., Inc.
Anchorage, Alaska 99503
907-273-1600