1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT NORTH SLOPE, ALASKA

November 1996

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1.0 INTRODUCTION

This report summarizes the observations and measurements made on the Colville River Delta, and at stream crossings along the proposed pipeline route between the facilities area and DS-2M, during the 1996 spring breakup. These data provide hydrologic and hydraulic information required for pipeline and facilities design.

Our 1996 observations began on May 18 and continued through June 11. During this time water-surface elevations were measured throughout the delta, and discharge measurements were made at the head of the delta (Cross Section E27.09), in the Nechelik Channel (Cross Section N19.95), in the East Channel near the proposed pipeline crossing (E20.56), and in the Tamayayak (T12.62) and Sakoonang (S09.80) channels (Figure 1). These data were used to make estimates of the 1996 peak discharge at the head of the delta. Discharge measurements were also made in the Kachemach and Miluveach rivers at the proposed pipeline crossings. Suspended and bedload sediment samples were collected at E20.56 to provide data for scour estimates, which will be used to set the maximum top-of-pipe elevation within the pipeline crossing of the East Channel of the Colville River. Bed material samples were collected at the Nechelik Channel and Streams F, I, L, and X, as well as the Kachemach and Miluveach rivers. The bed material samples will be used to estimate hydraulic roughness and scour depth.

2.0 COLVILLE RIVER DELTA

2.1 Breakup Observations

During late April and early May 1996 average temperatures at both Anaktuvik Pass and Umiat were unusually cold and often below zero (Table 1). On May 5 the average daily temperature at Anaktuvik Pass rose above freezing for the first time in 1996. Warm weather continued through May 16, when the temperature cooled to several degrees below freezing for approximately a week. Between May 22 and May 27 a dramatic warming occurred, raising the average daily temperature to 51°F on May 24.

At Umiat the average daily temperature rose above freezing for the first time on May 6, and generally remained above freezing through the end of the month. The exceptions were May 19 and 20, when the average daily temperatures were slightly below freezing. A temperature of 76°F on May 25 set the all-time record high for the month of May.

The warm weather in the second week of May "ripened" the snowpack, and by May 13 water was flowing in the Colville River at Umiat. The warm weather continued through May 15, when reports indicated that the ice had "gone out" in Umiat, and water was flowing in the vicinity of Nuiqsut.

On May 19, when the field crew first arrived on site, water was flowing on the sandbar at E27.09 at the head of the delta (Appendix C, Photo C-1). No ice floes were observed in the river. However, there were many ice floes rafted on the sandbar. The ice cover over the deep water channel appeared intact and showed few signs of breaking up. The water-surface elevation (see Appendix D for methods) was 9.71 feet at 10:15 a.m. (Table 2). High-water marks measured at the time had an elevation of approximately 11.7 feet. The high water probably occurred on May 18. Ice floes that had broken free from the ice cover accumulated at a few locations within the delta, forming minor ice jams (Appendix C, Photos C-3 and C-4).

The water continued to fall through the week as the temperatures cooled (Figure 2). The lowest water-surface elevation was approximately 5.06 feet and occurred on May 23. The water began to rise again on May 24 (Appendix C, Photo C-2), and by the morning of May 25 had risen 4.5 feet (Figure 2). The water surface rose another 1.5 feet to reach an elevation of 11.0 feet by the afternoon of May 25. The ice over the deep-water channel remained intact.

By the morning of May 26, a large ice jam had formed at the inlet to the Nechelik Channel and extended across both the East and Nechelik channels. Upstream from the jam the ice cover had broken, and ice floes were continuing to pile up on the jam (Appendix C, Photo C-5). Downstream from the jam the ice cover over the deep channel remained in place (Appendix C, Photos C-6 and C-7). The water-surface elevation at E27.09 was 17.17 feet at 10:05 a.m. The water-surface elevation at about the midpoint of the jam (E24.92) was 11.83 feet at 10:55 a.m. The water-surface elevation below the jam (at about E22.75) was 11.41 feet at 12:15 p.m. Through midafternoon the water-surface elevation remained nearly constant at E27.09 (17.14 feet at 3:15 p.m.), and rose just less than 1.0 foot at E24.92 (12.73 feet by 3:30 p.m.).

By the morning of May 27 the channel upstream from E14.20 was generally clear of ice. The water-surface elevation at E27.09 had dropped nearly 4.5 feet to 12.55 feet by 12:10 p.m. During the following days, the ice jam continued to move downstream and the water level continued to fall at E27.09 (Figure 2).

The water-surface elevation near the ocean (Monuments 28 and 35) varied between 0 and 4.3 feet during the 1996 breakup (Table 2). In general the water-surface elevation decreased as breakup progressed. At Helmerick's Homestead (near MON35) the water-surface elevation varied between 2.6 and 1.9 feet during the period May 20 through May 30, and between 1.0 and 0.5 feet during the period June 6 through June 11 (Figure 3). The water-surface elevation at Monument 28 varied between 2.9 and 1.4 feet during the period May 19 through May 30, but dropped to as low as 0.1 feet in June (Table 2). An ice layer measured on May 19 at Monument 28 indicated that the water-surface elevation had been as high as 4.3 feet. Because the ice layer was not present when the monument was installed early this spring, it is thought that the ice layer probably formed during the initial flow of water in the Nechelik Channel. At that time the channel was probably substantially blocked by ice and snow.

The higher water-surface elevations at the onset of breakup are probably due to drifted snow and the ocean ice. When water first begins to flow down the river it spreads out over the drifted snow and shorefast ice, seeking a path to the ocean. Early in the breakup process there are relatively few leads into the ocean through the snow and ice. The area offshore acts as a bathtub, with the water-surface elevation increasing as the flow in the river increases. Although the high flow on May 18 was not the peak flow of the 1996 breakup, it did produce the highest water-surface elevation offshore. The highest water-surface elevation measured at Monument 28 was 2.85 feet on May 19. However on May 27, the date on which the 1996 peak discharge occurred at the head of the delta, the water-surface elevation at Monument 28 was only 2.50 feet. Although the river had continued to flow all that week, the water level at the ocean did not rise as high as on May 19. This was probably because additional leads had formed which allowed the water to discharge into the ocean. As breakup continued, the ocean ice gradually had less affect on the water-surface elevation. By June 11 the ocean ice had little or no affect on the water-surface elevation.

All of the water-surface elevations measured at E27.09 and E03.50, including those measured with the water level recorder, are presented in Tables 3 and 4, respectively. The 1995 water-surface elevation measurements adjusted to BPMSL datum are presented in Table 5. Because the elevation datum changed between 1995 and 1996 (from River to BPMSL), the water-surface elevations measured in 1995 required adjustment. A summary of the 1995 TBMs, for which there are adjusted elevations, are presented in Table 6.

2.1.1 Flow Directions

Arnborg et al. (1966) noted that the direction of flow in the Putu Channel depended on the river stage. According to Arnborg, the water flows from west to east at high stages and from east to west at low stages. This was generally observed in 1996.

A similar flow reversal condition was observed in the channel which connects the Tamayayak and East channels (downstream of the Tamayayak Channel). At high stages water flows from south to north, towards the East Channel. However, at low stages water flows from north to south, towards the Tamayayak Channel.

2.1.2 Ice Floe Thickness

Eleven ice floes which had rafted at the head of the sandbar at E27.09 were measured on May 20 (Appendix C, Photo C-8). The average maximum thickness of the ice was 5.2 feet, average minimum thickness was 4.6 feet, and the overall average thickness was 4.9 feet. The range in thickness was from 4.0 to 5.8 feet. The average dimension of the ice floes was 23 x 46 feet. The floes ranged in size from 8 to 40 feet wide and 25 to 75 feet long. Rafted ice floes measured in 1993 ranged in size from 7.5 to 13.5 feet wide, 12 to 26 feet long, and 2.5 to 5.5 feet thick (Shannon & Wilson, 1993). The temperature of the rafted ice floes measured on May 20th were 28 to 29°F, 6 inches into the side of the competent ice. It is believed that the ice floes were deposited on May 18. The air temperature was 22 to 26°F on May 20, and was similar on May 19.

2.2 Discharge

The discharge was measured at four cross sections: E20.56, N19.95, S09.80, and T12.62. The discharge at each of the above referenced cross sections, and the peak discharge during the 1996 spring breakup, are discussed below. The methods that were used to measure the discharge are discussed in Appendix D.

2.2.1 E27.09

The 1996 spring breakup hydrograph at the head of the Colville River Delta, and concurrent water-surface elevations, are shown in Figure 2. The peak water-surface elevation is also shown on cross section E27.09 (Figure 4), and the water-surface elevation data are summarized in Table 3.

The peak discharge at E27.09 occurred on May 26, at a water-surface elevation of 17.19 feet (Figure 2). At the time of the peak discharge, an ice jam was located immediately downstream from E27.09. Due to the effect of the ice jam on water-surface elevations, the open water stage-discharge relationship that has been developed based on past discharge measurements (Figure 5) could not be used to estimate the discharge. Therefore, the peak discharge was estimated using normal-depth computations, a measured water-surface slope, and estimates of the discharge at downstream cross sections.

Based on the available data, the peak discharge was estimated to be 160,000 cfs. The computation suggests an average main channel velocity of about 2.9 fps. This compares well with measurements of ice floe velocities made on May 26 at 12:00 p.m. at a location immediately upstream from E27.09, which varied between 2.4 and 2.9 fps. The open-water velocity-discharge relationship developed for E27.09 is presented in Figure 6. The methods used to develop the stage-discharge and velocity-discharge relationships are discussed in Appendix D.

The 1996 peak discharge is the second lowest annual peak discharge which has been observed. This is probably due to two main factors. First, the overall snowpack for the North Slope appears to have been below normal. Although the water-equivalent snow depths at Prudhoe Bay and Toolik River were at or above normal, the remaining five North Slope stations averaged about 75 percent of normal (NRSC, 1996). Second, much of the snowpack was depleted in the first melt/runoff episode which peaked on May 18.

2.2.2 E20.56 and N19.95

2.2.2.1 Peak Discharge and Flow Distribution

The peak discharge at N19.95 occurred on May 26, the same day as the peak discharge at E27.09, and is estimated to be 54,000 cfs (Table 7). The peak discharge at E20.56 occurred on May 27 and is estimated to be 128,000 cfs (Table 7).

On the day of the peak discharge at E27.09 and N19.95 (May 26) approximately 68 percent of the total flow in the Colville River passed down the East channel, while the remaining 32 percent passed down the Nechelik channel. The next day, the day of the peak at E20.56, approximately 76 percent of the total flow passed down the East Channel, and the remaining 24 percent passed down the Nechelik Channel. The increased percentage of flow in the Nechelik Channel on May 26 was due to the location of the ice jam on May 26. The ice jam was located primarily in the East Channel, below the inlet of the Nechelik Channel. This caused more water to be diverted into the Nechelik Channel than would normally occur without an ice jam. On May 29 and May 30 the percentage of the total flow in the East Channel was approximately 80 percent. This percentage increases as the total flow decreases. By June 4, 87 percent of the total flow passed down the East Channel.

Generally, the sum of the estimated discharges at E20.56 and N19.95 differs slightly from the estimated discharge at E27.09 for the May estimates (Table 7). This difference is probably due to the dynamic conditions caused by the presence of the ice jam in the upper end of the delta on May 26, and the rapidly changing stages as the ice jam moved downstream. However, relatively stable stages occurred in June. For the June estimates, the sum of the estimated flows at E20.56 and N19.95 more closely matched the estimated flow at E27.09. Thus, it is important to note that the stage-discharge relationships presented in Figures 5, 8, 11, 14, and 17 are primarily applicable to open-water conditions.

2.2.2.2 Discharge Measurement and Stage-Discharge-Velocity Relationships for E20.56

A discharge measurement was made at E20.56 on May 29, 1996, at an average water-surface elevation of 6.38 feet (Figure 7). The discharge was estimated to be 92,100 cfs. Based on this discharge measurement, a discharge measurement made in 1995 (ABR, Inc. and Shannon & Wilson, Inc., 1996), and normal depth computations, stage-discharge and velocity-discharge relationships were developed. The open-water stage-discharge relationship is presented in Figure 8, and the velocity-discharge relationship is presented in Figure 9. The methods used to develop the stage-discharge and velocity-discharge relationships are presented in Appendix D.

2.2.2.3 Discharge Measurement and Stage-Discharge-Velocity Relationships for N19.95

A discharge measurement was made at N19.95 on May 30, 1996, at an average water-surface elevation of 6.02 feet (Figure 10). The discharge was estimated to be 20,500 cfs. Based on this discharge measurement, a discharge measurement made in 1962 (Arnborg et al., 1966), and normal depth computations, stage-discharge and velocity-discharge relationships were developed. The open-water stage-discharge relationship is presented in Figure 11, and the velocity-discharge relationship is presented in Figure 12. The methods used to develop the stage-discharge and velocity-discharge relationships are presented in Appendix D.

2.2.3 Evaluation of Stage-Discharge Relationship at the Head of the Delta

Because most of the data used to compute the stage-discharge relationships were collected at relatively low water-surface elevations, it was desirable to check the accuracy of the relationships at higher water-surface elevations. This was accomplished by reading the flow from each stage-discharge relationship, at three high water-surface elevations, and comparing the sum of the flows at E20.56 and N19.95 to the flow at E27.09 (Table 8). The water-surface elevations at E20.56 and N19.95 associated with a given water-surface elevation at E27.09 were estimated using the slope of the water surface between E27.09 and the ocean.

Because of the variability and the sparseness of the ocean water-surface elevation data, and because large flood events will likely be the result of spring breakup, we used two water-surface elevations at the ocean: 2 and 4 feet. When the water-surface elevation was assumed to be 2 feet at the ocean, the maximum percent difference between the discharge at E27.09 and the sum of the discharges at E20.56 and N19.95 was approximately 7 percent. When the water-surface elevation was assumed to be 4 feet at the ocean, the maximum percent difference was approximately 2 percent. Based on the stage-discharge relationships, it is estimated that approximately 68 percent of the bankfull flow at E27.09 (385,000 cfs) passes down the East Channel and approximately 32 percent passes down the Nechelik Channel. The percentage of flow down the East Channel increases as the total flow decreases, and approaches 100 percent at low stages.

2.2.4 S09.80

Because the peak water-surface elevation was affected by an ice jam, the peak discharge was not estimated at this location. However, high-water marks were measured on the left bank at an elevation of approximately 5.7 feet.

A discharge measurement was made on May 31, 1996. The discharge was estimated to be 1,590 cfs at an average water-surface elevation of 3.23 feet (Figure 13). Based on this discharge measurement, a discharge measurement made in 1995 (ABR, Inc. and Shannon & Wilson, Inc., 1996), a discharge measurement made in 1962 (Arnborg et al., 1966), and normal depth computations, stage-discharge and velocity-discharge relationships were developed. The open-water stage-discharge relationship is presented in Figure 14, and the velocity-discharge relationship is presented in Figure 15. The methods used to develop the stage-discharge and velocity-discharge relationships are presented in Appendix D.

2.2.5 T12.62

Because the peak water-surface elevation was affected by an ice jam, the peak discharge was not estimated at this location. However, the peak water-surface elevation measured at the crest gage was 9.37 feet.

A discharge measurement was made on June 1, 1996. The discharge was estimated to be 4,230 cfs at an average water-surface elevation of 3.43 feet (Figure 16). Based on this discharge measurement, a discharge measurement made in 1962 (Arnborg et al., 1966), and normal depth computations, stage-discharge and velocity-discharge relationships were developed. The open-water stage-discharge relationship is presented in Figure 17, and the velocity-discharge relationship is presented in Figure 18. The methods used to develop the stage-discharge and velocity-discharge relationships are presented in Appendix D.

2.2.6 Hydraulic Roughness Values

The hydraulic roughness at the time of each discharge measurement was calculated based on the measured discharge and the associated water-surface elevation and slope. For computational purposes, the main channel within each cross section was divided into subsections based on the criteria presented by Davidian (1984; pages 20-26). A summary of the hydraulic roughness values computed for 1996, as well as those computed from discharge measurements made in previous years, is presented in Table 9.

2.3 Sediment Measurements

2.3.1 Suspended Sediment Measurements

Suspended sediment samples were collected from three locations along Cross Section E20.56 on June 2 at approximately 7:00 p.m. (see Appendix D for methods). A sample collected above the sandbar contained 200 mg/l suspended sediment (Figure 7). A composite sample collected at two locations in the low-water channel contained a suspended sediment concentration of 150 mg/l. The water-surface elevation at the time of sampling was 4.44 feet, which corresponds to a discharge of approximately 59,400 cfs. Based on the location of the samples and on the distribution of flow within the cross section, it is estimated that 18 percent of the flow had a suspended sediment concentration of 200 mg/l, and 82 percent of the flow had a suspended sediment concentration of 150 mg/l. Therefore, it is estimated that the average suspended sediment concentration was 159 mg/l. The total suspended load carried by the river under these conditions is estimated to be 25,000 tons/day.

2.3.2 Bedload Measurements

Bedload was measured at Cross Section E20.56 on June 2 between 11:20 a.m. and 6:05 p.m. (see Appendix D for methods). The average water-surface elevation during the bedload sampling was 4.63 feet, which corresponds to a discharge of approximately 61,700 cfs. Twenty locations along the cross section were sampled (Table 10). The total load is estimated to be 12.3 kg/sec, which is approximately equivalent to 1171 tons/day. Based on a discharge of 61,700 cfs, the concentration of the bedload is approximately 7.0 mg/l.

2.3.3 Bed Material Gradations

Bed material samples were collected at three locations within the low-water channel along Cross Section N19.95 (Stations 28+97, 31+53, and 33+40 in Figure 10). Based on the grain size distribution of the samples collected, the bed material in the low-water channel can be classified as fine sand or silty fine sand. The results of the sieve analysis are presented in Figure 19 and Table 11. Details of the sampling method are presented in Appendix D.

3.0 STREAMS ALONG THE PROPOSED PIPELINE ROUTE

The proposed pipeline route discussed herein is based on the proposed pipeline alignment shown on the December 13, 1995, preliminary alignment drawings provided by Michael Baker Jr. Inc., and shown herein on Figure 20. The route extends from the proposed facilities area within the Colville River Delta to DS-2M.

Prior to the 1996 field effort, 24 potential pipeline stream crossings were identified on U.S. Geological Survey 1:63,360 scale quadrangle maps and aerial photographs, between the proposed facilities area and DS-2M. Each stream was identified by a letter designation and is shown on Figure 20. Although the East Channel of the Colville River is a major pipeline crossing, it is not discussed in this section. Breakup on the East Channel, as well as other locations within the Colville River Delta, is discussed in Chapter 2.

The purpose of the 1996 spring breakup observations was to determine which of the 24 streams identified above will require additional information and hydraulic analyses for the design of the proposed pipeline. Based on the field observations, six streams were identified as requiring additional information and hydraulic analyses. The six streams are: Streams F, I (Kachemach River Tributary), L, O (Kachemach River), R (Miluveach River), and X. Additional information (which included discharge, velocity, water-surface slope, and/or bed material samples) was collected at these six streams during the site visit. Each of the 24 streams is described in Appendix E, and a summary of the characteristics associated with each stream is presented in Table 12. Photographs of selected streams are presented in Appendix C. Observations and additional information collected at selected streams are described in the following sections.

3.1 Breakup Observations

3.1.1 General Observations

Prior to breakup the stream channels were full of drifted snow, making many of the smaller channels virtually indistinguishable from the surrounding terrain. These smaller channels were not visible until water began flowing in them. Breakup proceeded in a south-to-north direction, beginning with the upstream reaches and proceeding downstream. Because the channels were clogged with drifted snow, the initial breakup flows occurred on top of the snow. As breakup proceeded, the water eroded and/or melted through the drifted snow, forming channels within the drifted snow.

As described in section 2.2.1, breakup was fairly minor, with the peak flow in the Colville River being the second lowest peak in seven years of observations. However, the streams along the pipeline route only experienced one peak discharge, whereas the Colville River had two peak discharges.

Although it did not happen this year, Streams A through E, may be affected by flood waters from the Sakoonang Channel. During periods of high water-surface elevations on the Sakoonang, the amount of water in these streams may be more a function of the water level in the Sakoonang than the amount of runoff generated from the drainage basin typically associated with these streams.

3.1.2 Breakup Observations at the Kachemach and Miluveach Rivers

The first signs of flow in the three largest streams along the proposed pipeline route were observed on the evening of May 24, 1996. The flow appeared to be on top of windblown snowdrifts in the Tributary to the Kachemach River and the Kachemach River. Water was ponded on snowdrifts within the Miluveach River channel, but did not appear to be flowing.

By the afternoon of May 25, water had eroded a channel through the snowdrifts. The highest water-surface elevations measured at the Kachemach and Miluveach Rivers occurred on that day (Table 13). By the afternoon of May 28, the water surface had dropped only about 1.2 feet in the Kachemach River and 0.9 feet in the Miluveach River. At this time, a large snowdrift covered the east bank of the Kachemach River in the vicinity of the proposed pipeline crossing, extending perhaps 70 feet into the low-water channel. The snowdrift was nearly gone by June 4. On May 28th, the Miluveach River channel banks were virtually free of snow in the vicinity of the proposed pipeline crossing, although a portion of the bed was still covered with snow/ice.

Snowdrifts were still present upstream, and numerous compacted-snow floes[1] were observed in the afternoon. Water-surface elevations at both the Kachemach and Miluveach had dropped on the order of 4 feet by June 4.

As discussed in Section 3.1.1, the spring flood water often has to erode through the snow before it can flow freely. Thus the drifted snow may restrict the channel, causing the water-surface elevation and velocity to be higher than in an unrestricted channel. Because of the loss of flow area caused by the wind-compacted snow, the peak discharge may not be associated with the highest water-surface elevation.

3.2 Discharge and Floe Velocity Measurements at the Kachemach and Miluveach Rivers

Discharge and compacted-snow floe velocities were measured at the Kachemach and Miluveach rivers along the proposed pipeline route. The methods used to measure discharge are discussed in Appendix D.

Compacted-snow floe velocities provide an estimate of the surface velocity, which can be used to verify discharge estimates based on water-surface elevation and slope measurements. At the Kachemach River on May 25 at about 4:00 p.m., compacted-snow floe velocities in the center of the stream averaged 5.1 fps. Compacted-snow floe velocities on the east side of channel averaged 4.7 fps. Compacted-snow floe velocities were also measured on May 27 at about 12:10 p.m. These velocities also averaged about 5.1 fps. At the Miluveach River on May 25 compacted-snow floe velocities on the east side of the channel averaged about 6.4 fps. Compacted-snow floes in the center of the channel averaged 7.3 fps. Peak discharge estimates were not made at the Kachemach and Miluveach rivers because it was felt that the high-water marks were due to flow over snow.

A discharge measurement was made at the Kachemach River on May 27, at an average water-surface elevation of 31.63 feet (BPMSL datum), about 1.4 feet below the water level measured

[1]Wind-blown snow accumulates within the stream channels in winter. During breakup the compacted snow is eroded by the rising flood water. Small floes of compacted snow are thus formed.

on May 25. The discharge was estimated to be 1,970 cfs. At the time of the discharge measurement, the snowdrift described in Section 3.1.2 covered the east bank of the Kachemach River. This snowbank may have reduced the flow area of the channel on the order of 30 to 40 percent. The maximum depth measured during the discharge measurement was 4.45 feet at the edge of the snowbank. The average velocity was 4.6 fps. The maximum point velocity was 5.8 fps.

A discharge measurement was made at the Miluveach River on May 28, at an average water-surface elevation of 46.91 feet (BPMSL datum). The maximum depth during the discharge measurement was 3.77 feet. The discharge was estimated to be 1,260 cfs. The average velocity was 4.2 fps. The maximum point velocity was 6.5 fps. At the time of the discharge measurement the river banks were free of compacted snow, but snow/ice covered approximately two-thirds of the channel bed.

3.3 Bed Material Samples

Bed material samples were collected at the larger stream crossings along the proposed pipeline route (see Appendix D for methods). Samples collected at Steams F and I consisted primarily of silt with fine roots. These samples were not analyzed beyond visual inspection. Samples collected from Streams L and X are classified as fine gravelly sands (Figure 21), based on the Unified Soil Classification System (ASTM D2487-85). Samples collected from the Kachemach and Miluveach rivers are classified as gravelly sands (Figure 22). A summary of the bed material gradations and the percentage passing each sieve size are summarized in Table 14.

4.0 CONCLUSION

This data report summarizes breakup conditions observed in the Colville River and nearby streams in 1996. This data, combined with additional data collected in 1996 (Shannon & Wilson, 1996) and in previous years (ABR, Inc. and Shannon & Wilson, Inc., 1996; Shannon & Wilson, 1993), will be used to set up and calibrate a two-dimensional surface water model of the Colville River Delta and used to facilitate the design of stream crossings along the entire pipeline route. Set up and calibration of the two-dimensional surface water model, and the design of stream crossings along the entire pipeline route, will be discussed in subsequent reports.

Sincerely,

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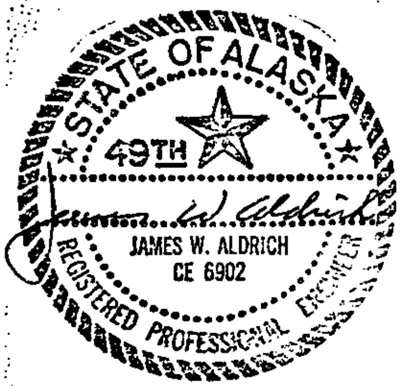

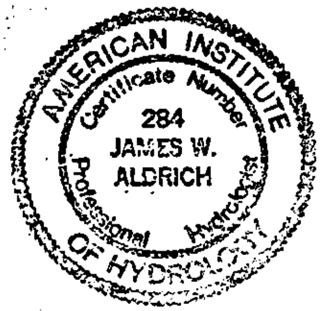

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APPENDIX A
TABLES

LIST OF TABLES

Table 1: Average Daily Temperature For Anaktuvuk Pass And Umiat.

May 1996 Day Of Month	Average Daily Temperatures Anaktuvuk Pass (°F)	Umiat (°F)
1	3	-4
2	8	0
3	16	6
4	22	10
5	33	27
6	35	37
7	37	32
8	36	38
9	38	39
10	40	42
11	40	39
12	38	42
13	41	40
14	33	37
15	36	39
16	29	33
17	25	32
18	26	32
19	21	31
20	21	29
21	21	32
22	41	49
23	46	59
24	51	58
25	45	52
26	43	42
27	50	50
28	43	52
29	47	57
30	46	53
31	41	53

Notes:
1. Data provided by the National Weather Service, Anchorage, AK.

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Table 2: 1996 Water Surface Elevations Based On 1996 British Petroleum Mean Sea Level (BPMSL) Datum

Date	Time	Location (see Figure 1)	Water-Surface Elevation (feet)	Reference Monument
20-May-96	17:15	E03.00	2.63	MON35
22-May-96	9:35	"	1.93	MON35
22-May-96	11:35	"	1.90	MON35
29-May-96	18:15	"	2.63	MON35
30-May-96	14:24	"	2.15	MON35
11-Jun-96	9:50	"	0.71	MON35
29-May-96	18:45	E09.76	4.17	MON33
9-Jun-96	17:00	"	1.30	MON33
3-Jun-96	13:35	E11.98	2.35	MON30
8-Jun-96	20:25	"	1.28	MON30
9-Jun-96	13:50	"	1.37	MON30
19-May-96	13:00	E14.20	5.91	MON17
24-May-96	16:10	"	2.80	MON17
29-May-96	15:40	E14.39	5.13	MON18
7-Jun-96	17:45	"	1.62	MON18
7-Jun-96	18:30	"	1.57	MON18
8-Jun-96	18:40	"	1.42	MON18
9-Jun-96	10:05	"	1.50	MON18
29-May-96	15:00	E16.32	5.44	TBM27P
19-May-96	12:20	"	6.54	MON14
29-May-96	15:19	"	5.57	MON14
29-May-96	17:50	"	5.49	MON13
1-Jun-96	9:57	"	4.33	MON15
1-Jun-96	18:08	"	4.15	MON15
4-Jun-96	10:40	"	2.78	MON15
7-Jun-96	10:35	"	1.29	MON15
7-Jun-96	16:10	"	1.72	MON13
7-Jun-96	16:45	"	1.69	MON13
8-Jun-96	16:35	"	1.52	MON13
29-May-96	12:20	E18.47	5.94	MON07
29-May-96	17:25	"	5.75	MON07
7-Jun-96	10:15	"	1.75	MON07
8-Jun-96	10:15	"	1.75	MON07
8-Jun-96	13:30	"	1.57	MON07
21-May-96	15:30	E20.56	5.04	MON09
24-May-96	15:30	"	3.94	MON09
26-May-96	12:45	"	9.89	MON09
26-May-96	15:45	"	10.25	MON09
1996 High Water Mark		"	16.5	MON09
27-May-96	12:55	"	11.16	MON09
29-May-96	11:40	"	6.41	MON09
29-May-96	12:35	"	6.50	MON06
29-May-96	16:20	"	6.44	MON06
29-May-96	16:55	"	6.33	MON09

Table 2: 1996 Water Surface Elevations Based On 1996 British Petroleum Mean Sea Level (BPMSL) Datum (continued)

Date	Time	Location (see Figure 1)	Water-Surface Elevation (feet)	Reference Monument
29-May-96	20:50	E20.56	6.38	MON06
31-May-96	12:35	"	6.39	MON09
31-May-96	17:16	"	6.22	MON09
31-May-96	18:30	"	6.22	MON09
1-Jun-96	9:07	"	5.52	MON09
1-Jun-96	18:30	"	5.31	MON09
2-Jun-96	10:45	"	4.82	MON09
2-Jun-96	19:46	"	4.44	MON09
8-Jun-96	10:35	"	1.91	MON06
11-Jun-96	14:30	"	3.71	MON09
26-May-96	12:15	E22.75	11.41	MON05
27-May-96	12:45	"	11.80	MON05
29-May-96	12:55	"	7.24	MON05
29-May-96	16:05	"	7.20	MON05
30-May-96	12:30	"	7.30	MON05
2-Jun-96	13:00	"	5.50	MON05
26-May-96	10:55	E24.92	11.83	MON03
26-May-96	15:30	"	12.73	MON03
27-May-96	12:35	"	12.15	MON03
30-May-96	12:18	"	7.88	MON03
30-May-96	18:10	"	7.94	MON03
2-Jun-96	10:50	"	6.08	MON03
19-May-96	10:15	E27.09	9.71	MON01
20-May-96	9:40	"	8.15	MON01
20-May-96	15:30	"	7.71	MON01
21-May-96	10:30	"	6.74	MON01
22-May-96	13:00	"	5.63	MON01
23-May-96	14:55	"	5.06	MON01
24-May-96	11:25	"	5.37	MON01
24-May-96	17:55	"	5.94	MON01
25-May-96	10:20	"	9.57	MON01
25-May-96	16:40	"	11.02	MON01
26-May-96	10:05	"	17.17	MON01
26-May-96	10:14	"	17.25	TBM13
26-May-96	10:25	"	16.63	TBM12
26-May-96	11:15	"	17.19	MON02
26-May-96	15:15	"	17.14	MON01
27-May-96	12:10	"	12.55	MON01
28-May-96	~20:00	"	9.07	MON01
29-May-96	15:05	"	8.26	MON02
30-May-96	11:55	"	8.54	MON01
30-May-96	17:00	"	8.56	MON02
31-May-96	11:40	"	8.54	MON02
2-Jun-96	10:30	"	6.59	MON02

Table 2: 1996 Water Surface Elevations Based On 1996 British Petroleum Mean Sea Level (BPMSL) Datum (continued)

Date	Time	Location (see Figure 1)	Water-Surface Elevation (feet)	Reference Monument
6-Jun-96	10:30	K11.65	3.70	MON02
19-May-96	14:30	"	4.82	MON32
24-May-96	16:25	"	2.39	MON32
29-May-96	17:58	"	4.26	MON32
9-Jun-96	14:15	"	1.53	MON32
10-Jun-96	10:05	"	1.59	MON32
11-Jun-96	9:00	"	1.72	MON32
11-Jun-96	17:20	"	2.14	MON32
9-Jun-96	10:30	K14.01	1.29	MON31
10-Jun-96	10:50	"	1.76	MON31
27-May-96	15:05	KACHEMACH R.	9.45	MON19
29-May-96	15:31	"	5.59	MON19
8-Jun-96	19:00	"	1.41	MON19
27-May-96	15:20	MILUVEACH R.	5.26	MON34
29-May-96	18:56	"	3.93	MON34
3-Jun-96	11:05	"	1.47	MON34
19-May-96	16:00	N02.03	2.85	MON28
20-May-96	12:10	"	2.67	MON28
21-May-96	17:10	"	2.10	MON28
23-May-96	17:10	"	1.42	MON28
24-May-96	17:10	"	1.21	MON28
25-May-96	17:45	"	1.83	MON28
27-May-96	15:35	"	2.50	MON28
29-May-96	16:30	"	2.27	MON28
30-May-96	13:55	"	1.59	MON28
1-Jun-96	14:10	"	1.00	MON28
11-Jun-96	9:10	"	0.05	MON28
30-May-96	13:41	N05.42	2.25	MON29
1-Jun-96	16:35	"	1.63	MON29
19-May-96	16:25	N07.46	4.08	MON23
24-May-96	17:25	"	1.72	MON23
29-May-96	16:12	"	3.08	MON23
30-May-96	13:25	"	2.43	MON23
1-Jun-96	13:20	"	1.66	MON23
1-Jun-96	17:45	"	1.87	MON23
1-Jun-96	17:45	"	1.87	MON23
30-May-96	13:10	N09.47	2.80	MON22
31-May-96	18:00	"	2.71	MON22
1-Jun-96	10:50	"	2.07	MON22
1-Jun-96	11:45	"	2.10	MON22
24-May-96	17:35	N12.88	2.45	MON20
29-May-96	14:39	"	4.44	MON20
30-May-96	12:56	"	3.88	MON20
31-May-96	15:25	"	3.76	MON20

Table 2: 1996 Water Surface Elevations Based On 1996 British Petroleum Mean Sea Level (BPMSL) Datum (continued)

Date	Time	Location (see Figure 1)	Water-Surface Elevation (feet)	Reference Monument
1-Jun-96	9:25	N15.07	3.09	MON20
30-May-96	12:45	"	4.65	MON12
31-May-96	13:25	"	4.58	MON12
31-May-96	14:20	"	4.52	MON12
30-May-96	11:35	N17.80	5.31	MON11
30-May-96	19:30	"	5.40	MON11
31-May-96	12:40	"	5.30	MON11
19-May-96	18:10	N19.95	7.71	MON10
21-May-96	11:35	"	5.18	MON10
24-May-96	15:15	"	4.05	MON10
26-May-96	14:25	"	11.50	MON10
26-May-96	20:30	"	12.06	MON10
1996 High Water Mark		"	12.11	MON10
27-May-96	13:00	"	11.16	MON10
29-May-96	15:35	"	6.12	MON10
30-May-96	12:30	"	6.02	MON10
30-May-96	15:10	"	6.03	MON10
30-May-96	17:46	"	6.07	MON10
30-May-96	19:20	"	6.08	MON10
31-May-96	9:40	"	6.05	MON10
31-May-96	10:00	"	6.04	MON10
31-May-96	18:45	"	5.81	MON10
1-Jun-96	8:55	"	5.14	MON10
1-Jun-96	18:45	"	4.81	MON10
2-Jun-96	10:10	"	4.32	MON10
2-Jun-96	16:05	"	4.03	MON10
3-Jun-96	12:00	"	3.19	MON10
4-Jun-96	11:00	"	2.68	MON10
26-May-96	14:50	N22.65	12.24	MON04
27-May-96	13:15	"	11.70	MON04
30-May-96	13:00	"	7.30	MON04
30-May-96	19:05	"	7.07	MON04
31-May-96	10:10	"	7.02	MON04
19-May-96	15:25	S01.38	3.21	MON24
20-May-96	11:45	"	2.79	MON24
24-May-96	16:55	"	1.41	MON24
29-May-96	17:03	"	2.86	MON24
31-May-96	17:45	"	1.65	MON24
4-Jun-96	17:25	"	0.45	MON24
20-May-96	11:20	S05.07	2.76	MON27
31-May-96	13:05	"	2.23	MON27
31-May-96	18:07	"	2.15	MON27
4-Jun-96	18:30	"	0.74	MON27
6-Jun-96	17:30	"	0.46	MON27

Table 2: 1996 Water Surface Elevations Based On 1996 British Petroleum Mean Sea Level (BPMSL) Datum (continued)

Date	Time	Location (see Figure 1)	Water-Surface Elevation (feet)	Reference Monument
7-Jun-96	17:35	S05.07	0.46	MON27
19-May-96	16:50	S09.80	3.22	MON16
20-May-96	11:05	"	2.63	MON16
21-May-96	15:55	"	2.40	MON16
24-May-96	15:45	"	1.78	MON16
1996 High Water Mark		"	5.70	MON16
29-May-96	14:51	"	4.63	MON16
31-May-96	14:55	"	3.25	MON16
31-May-96	17:37	"	3.20	MON16
6-Jun-96	16:05	"	0.47	MON16
20-May-96	10:40	S13.07	6.19	MON21
31-May-96	12:15	"	4.33	MON21
31-May-96	18:15	"	4.21	MON21
6-Jun-96	14:15	"	0.89	MON21
19-May-96	17:50	S16.52	7.01	MON08
20-May-96	10:10	"	6.24	MON08
29-May-96	17:15	"	6.18	MON08
31-May-96	17:25	"	5.93	MON08
6-Jun-96	12:10	"	1.72	MON08
19-May-96	15:10	T08.20	4.66	MON25
24-May-96	16:45	"	1.94	MON25
29-May-96	17:24	"	3.32	MON25
4-Jun-96	14:20	"	0.91	MON25
7-Jun-96	14:00	"	0.46	MON25
29-May-96	15:52	T11.48	4.41	MON26
1-Jun-96	10:38	"	3.30	MON26
1-Jun-96	17:52	"	3.13	MON26
4-Jun-96	12:20	"	1.78	MON26
7-Jun-96	12:25	"	0.60	MON26
19-May-96	17:15	T12.62	5.66	TBM50
21-May-96	16:45	"	3.85	TBM50
24-May-96	16:00	"	2.77	TBM50
1996 High Water Mark		"	9.37	TBM50
1-Jun-96	13:23	"	3.48	TBM50
1-Jun-96	16:55	"	3.40	TBM50
4-Jun-96	12:00	"	1.98	TBM50
7-Jun-96	12:05	"	0.63	TBM50

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Table 3: 1996 Water-Surface Elevations At E27.09

Day (1996)	Time	Elevation (ft)	Day (1996)	Time	Elevation (ft)
~ 18 May	HWM	11.7	30-May	1:00	8.28
19-May	10:15	9.71	30-May	1:30	8.29
20-May	9:40	8.15	30-May	2:00	8.29
20-May	15:30	7.71	30-May	2:30	8.30
21-May	10:30	6.74	30-May	3:00	8.31
22-May	13:00	5.63	30-May	3:30	8.32
23-May	14:55	5.06	30-May	4:00	8.33
24-May	11:25	5.37	30-May	4:30	8.34
24-May	17:55	5.94	30-May	5:00	8.34
25-May	10:20	9.57	30-May	5:30	8.35
25-May	16:40	11.02	30-May	6:00	8.38
26-May	10:05	17.17	30-May	6:30	8.39
26-May	11:15	17.19	30-May	7:00	8.40
26-May	15:15	17.14	30-May	7:30	8.42
27-May	12:10	12.55	30-May	8:00	8.43
28-May	~20:00	9.07	30-May	8:30	8.46
29-May	15:00	8.26	30-May	9:00	8.47
29-May	15:30	8.25	30-May	9:30	8.48
29-May	16:00	8.26	30-May	10:00	8.50
29-May	16:30	8.25	30-May	10:30	8.51
29-May	17:00	8.25	30-May	11:00	8.51
29-May	17:30	8.25	30-May	11:30	8.53
29-May	18:00	8.25	30-May	12:00	8.54
29-May	18:30	8.24	30-May	12:30	8.55
29-May	19:00	8.25	30-May	13:00	8.56
29-May	19:30	8.25	30-May	13:30	8.55
29-May	20:00	8.26	30-May	14:00	8.55
29-May	20:30	8.25	30-May	14:30	8.56
29-May	21:00	8.26	30-May	15:00	8.57
29-May	21:30	8.25	30-May	15:30	8.57
29-May	22:00	8.26	30-May	16:00	8.58
29-May	22:30	8.26	30-May	16:30	8.56
29-May	23:00	8.27	30-May	17:00	8.56
29-May	23:30	8.27	30-May	17:30	8.56
30-May	0:00	8.28	30-May	18:00	8.57
30-May	0:30	8.27	30-May	18:30	8.56

Table 3: 1996 Water-Surface Elevations At E27.09 (continued)

Day (1996)	Time	Elevation (ft)	Day (1996)	Time	Elevation (ft)
30-May	19:00	8.57	31-May	13:00	8.51
30-May	19:30	8.57	31-May	13:30	8.50
30-May	20:00	8.57	31-May	14:00	8.48
30-May	20:30	8.57	31-May	14:30	8.46
30-May	21:00	8.57	31-May	15:00	8.44
30-May	21:30	8.57	31-May	15:30	8.42
30-May	22:00	8.57	31-May	16:00	8.40
30-May	22:30	8.56	31-May	16:30	8.38
30-May	23:00	8.57	31-May	17:00	8.35
30-May	23:30	8.57	31-May	17:30	8.32
31-May	0:00	8.57	31-May	18:00	8.31
31-May	0:30	8.58	31-May	18:30	8.29
31-May	1:00	8.58	31-May	19:00	8.26
31-May	1:30	8.58	31-May	19:30	8.23
31-May	2:00	8.59	31-May	20:00	8.20
31-May	2:30	8.60	31-May	20:30	8.17
31-May	3:00	8.59	31-May	21:00	8.14
31-May	3:30	8.59	31-May	21:30	8.12
31-May	4:00	8.60	31-May	22:00	8.09
31-May	4:30	8.61	31-May	22:30	8.06
31-May	5:00	8.60	31-May	23:00	8.03
31-May	5:30	8.60	31-May	23:30	7.99
31-May	6:00	8.60	1-Jun	0:00	7.97
31-May	6:30	8.60	1-Jun	0:30	7.93
31-May	7:00	8.60	1-Jun	1:00	7.90
31-May	7:30	8.59	1-Jun	1:30	7.87
31-May	8:00	8.59	1-Jun	2:00	7.84
31-May	8:30	8.59	1-Jun	2:30	7.81
31-May	9:00	8.59	1-Jun	3:00	7.78
31-May	9:30	8.59	1-Jun	3:30	7.74
31-May	10:00	8.57	1-Jun	4:00	7.72
31-May	10:30	8.57	1-Jun	4:30	7.70
31-May	11:00	8.56	1-Jun	5:00	7.67
31-May	11:30	8.55	1-Jun	5:30	7.64
31-May	12:00	8.54	1-Jun	6:00	7.61
31-May	12:30	8.53	1-Jun	6:30	7.58

Table 3: 1996 Water-Surface Elevations At E27.09 (continued)

Day (1996)	Time	Elevation (ft)	Day (1996)	Time	Elevation (ft)
1-Jun	7:00	7.55	2-Jun	1:00	7.01
1-Jun	7:30	7.53	2-Jun	1:30	6.99
1-Jun	8:00	7.51	2-Jun	2:00	6.98
1-Jun	8:30	7.49	2-Jun	2:30	6.96
1-Jun	9:00	7.46	2-Jun	3:00	6.94
1-Jun	9:30	7.44	2-Jun	3:30	6.92
1-Jun	10:00	7.42	2-Jun	4:00	6.90
1-Jun	10:30	7.40	2-Jun	4:30	6.88
1-Jun	11:00	7.38	2-Jun	5:00	6.85
1-Jun	11:30	7.35	2-Jun	5:30	6.83
1-Jun	12:00	7.33	2-Jun	6:00	6.80
1-Jun	12:30	7.32	2-Jun	6:30	6.78
1-Jun	13:00	7.31	2-Jun	7:00	6.76
1-Jun	13:30	7.29	2-Jun	7:30	6.74
1-Jun	14:00	7.28	2-Jun	8:00	6.71
1-Jun	14:30	7.27	2-Jun	8:30	6.68
1-Jun	15:00	7.25	2-Jun	9:00	6.67
1-Jun	15:30	7.24	2-Jun	9:30	6.64
1-Jun	16:00	7.24	2-Jun	10:00	6.62
1-Jun	16:30	7.23	2-Jun	10:30	6.59
1-Jun	17:00	7.23	2-Jun	11:00	6.55
1-Jun	17:30	7.23	2-Jun	11:30	6.52
1-Jun	18:00	7.22	2-Jun	12:00	6.50
1-Jun	18:30	7.22	2-Jun	12:30	6.47
1-Jun	19:00	7.21	2-Jun	13:00	6.43
1-Jun	19:30	7.18	2-Jun	13:30	6.41
1-Jun	20:00	7.16	2-Jun	14:00	6.38
1-Jun	20:30	7.15	2-Jun	14:30	6.36
1-Jun	21:00	7.14	2-Jun	15:00	6.33
1-Jun	21:30	7.14	2-Jun	15:30	6.30
1-Jun	22:00	7.13	2-Jun	16:00	6.27
1-Jun	22:30	7.10	2-Jun	16:30	6.24
1-Jun	23:00	7.08	2-Jun	17:00	6.22
1-Jun	23:30	7.06	2-Jun	17:30	6.20
2-Jun	0:00	7.05	2-Jun	18:00	6.18
2-Jun	0:30	7.03	2-Jun	18:30	6.15

Table 3: 1996 Water-Surface Elevations At E27.09 (continued)

Day (1996)	Time	Elevation (ft)	Day (1996)	Time	Elevation (ft)
2-Jun	19:00	6.13	3-Jun	13:00	5.39
2-Jun	19:30	6.11	3-Jun	13:30	5.39
2-Jun	20:00	6.08	3-Jun	14:00	5.33
2-Jun	20:30	6.05	3-Jun	14:30	5.35
2-Jun	21:00	6.04	3-Jun	15:00	5.35
2-Jun	21:30	6.01	3-Jun	15:30	5.33
2-Jun	22:00	5.97	3-Jun	16:00	5.35
2-Jun	22:30	5.94	3-Jun	16:30	5.35
2-Jun	23:00	5.90	3-Jun	17:00	5.36
2-Jun	23:30	5.88	3-Jun	17:30	5.37
3-Jun	0:00	5.87	3-Jun	18:00	5.30
3-Jun	0:30	5.86	3-Jun	18:30	5.31
3-Jun	1:00	5.85	3-Jun	19:00	5.34
3-Jun	1:30	5.82	3-Jun	19:30	5.36
3-Jun	2:00	5.79	3-Jun	20:00	5.41
3-Jun	2:30	5.77	3-Jun	20:30	5.31
3-Jun	3:00	5.75	3-Jun	21:00	5.33
3-Jun	3:30	5.72	3-Jun	21:30	5.35
3-Jun	4:00	5.70	3-Jun	22:00	5.36
3-Jun	4:30	5.67	3-Jun	22:30	5.34
3-Jun	5:00	5.64	3-Jun	23:00	5.33
3-Jun	5:30	5.62	3-Jun	23:30	5.32
3-Jun	6:00	5.60	4-Jun	0:00	5.28
3-Jun	6:30	5.57	4-Jun	0:30	5.30
3-Jun	7:00	5.55	4-Jun	1:00	5.28
3-Jun	7:30	5.52	4-Jun	1:30	5.28
3-Jun	8:00	5.49	4-Jun	2:00	5.27
3-Jun	8:30	5.47	4-Jun	2:30	5.26
3-Jun	9:00	5.45	4-Jun	3:00	5.26
3-Jun	9:30	5.42	4-Jun	3:30	5.23
3-Jun	10:00	5.38	4-Jun	4:00	5.25
3-Jun	10:30	5.38	4-Jun	4:30	5.22
3-Jun	11:00	5.41	4-Jun	5:00	5.21
3-Jun	11:30	5.35	4-Jun	5:30	5.20
3-Jun	12:00	5.39	4-Jun	6:00	5.19
3-Jun	12:30	5.38	4-Jun	6:30	5.17

Table 3: 1996 Water-Surface Elevations At E27.09 (continued)

Day (1996)	Time	Elevation (ft)	Day (1996)	Time	Elevation (ft)
4-Jun	7:00	5.18	5-Jun	1:00	5.07
4-Jun	7:30	5.18	5-Jun	1:30	5.07
4-Jun	8:00	5.16	5-Jun	2:00	5.05
4-Jun	8:30	5.16	5-Jun	2:30	5.04
4-Jun	9:00	5.16	5-Jun	3:00	5.04
4-Jun	9:30	5.16	5-Jun	3:30	5.03
4-Jun	10:00	5.15	5-Jun	4:00	5.02
4-Jun	10:30	5.13	5-Jun	4:30	5.00
4-Jun	11:00	5.13	5-Jun	5:00	4.99
4-Jun	11:30	5.13	5-Jun	5:30	4.97
4-Jun	12:00	5.12	5-Jun	6:00	4.96
4-Jun	12:30	5.11	5-Jun	6:30	4.95
4-Jun	13:00	5.11	5-Jun	7:00	4.94
4-Jun	13:30	5.11	5-Jun	7:30	4.92
4-Jun	14:00	5.11	5-Jun	8:00	4.91
4-Jun	14:30	5.11	5-Jun	8:30	4.88
4-Jun	15:00	5.11	5-Jun	9:00	4.86
4-Jun	15:30	5.11	5-Jun	9:30	4.85
4-Jun	16:00	5.10	5-Jun	10:00	4.82
4-Jun	16:30	5.11	5-Jun	10:30	4.80
4-Jun	17:00	5.10	5-Jun	11:00	4.78
4-Jun	17:30	5.11	5-Jun	11:30	4.76
4-Jun	18:00	5.11	5-Jun	12:00	4.74
4-Jun	18:30	5.11	5-Jun	12:30	4.71
4-Jun	19:00	5.11	5-Jun	13:00	4.68
4-Jun	19:30	5.11	5-Jun	13:30	4.66
4-Jun	20:00	5.11	5-Jun	14:00	4.64
4-Jun	20:30	5.11	5-Jun	14:30	4.61
4-Jun	21:00	5.11	5-Jun	15:00	4.58
4-Jun	21:30	5.11	5-Jun	15:30	4.56
4-Jun	22:00	5.10	5-Jun	16:00	4.53
4-Jun	22:30	5.10	5-Jun	16:30	4.51
4-Jun	23:00	5.09	5-Jun	17:00	4.48
4-Jun	23:30	5.09	5-Jun	17:30	4.45
5-Jun	0:00	5.09	5-Jun	18:00	4.43
5-Jun	0:30	5.08	5-Jun	18:30	4.40

Table 3: 1996 Water-Surface Elevations At E27.09 (continued)

Day (1996)	Time	Elevation (ft)	Day (1996)	Time	Elevation (ft)
5-Jun	19:00	4.38	6-Jun	3:00	4.03
5-Jun	19:30	4.36	6-Jun	3:30	4.00
5-Jun	20:00	4.34	6-Jun	4:00	3.98
5-Jun	20:30	4.34	6-Jun	4:30	3.96
5-Jun	21:00	4.31	6-Jun	5:00	3.93
5-Jun	21:30	4.29	6-Jun	5:30	3.91
5-Jun	22:00	4.26	6-Jun	6:00	3.89
5-Jun	22:30	4.24	6-Jun	6:30	3.87
5-Jun	23:00	4.21	6-Jun	7:00	3.85
5-Jun	23:30	4.18	6-Jun	7:30	3.84
6-Jun	0:00	4.17	6-Jun	8:00	3.81
6-Jun	0:30	4.15	6-Jun	8:30	3.79
6-Jun	1:00	4.12	6-Jun	9:00	3.77
6-Jun	1:30	4.10	6-Jun	9:30	3.75
6-Jun	2:00	4.08	6-Jun	10:00	3.73
6-Jun	2:30	4.05	6-Jun	10:30	3.70

Notes:

1. Water surface elevation datum is based on British Petroleum Mean Sea Level (BPMSL).
2. Water surface elevation data from 29 May to 6 June were recorded with a water-level recorder at E27.09. Elevations prior to those dates were measured with a rod and level.

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Table 4: 1996 Water-Surface Elevations At E03.50

Day (1996)	Time	Elevation (ft)	Day (1996)	Time	Elevation (ft)
20-May	17:15	2.63	7-Jun	14:30	0.69
22-May	9:35	1.93	7-Jun	15:00	0.72
22-May	11:35	1.90	7-Jun	15:30	0.75
29-May	18:15	2.63	7-Jun	16:00	0.80
30-May	14:24	2.15	7-Jun	16:30	0.87
6-Jun	23:00	0.75	7-Jun	17:00	0.91
6-Jun	23:30	0.74	7-Jun	17:30	0.95
7-Jun	0:00	0.70	7-Jun	18:00	1.00
7-Jun	0:30	0.68	7-Jun	18:30	1.05
7-Jun	1:00	0.66	7-Jun	19:00	1.07
7-Jun	1:30	0.65	7-Jun	19:30	1.09
7-Jun	2:00	0.64	7-Jun	20:00	1.08
7-Jun	2:30	0.64	7-Jun	20:30	1.06
7-Jun	3:00	0.64	7-Jun	21:00	1.04
7-Jun	3:30	0.66	7-Jun	21:30	1.03
7-Jun	4:00	0.70	7-Jun	22:00	0.99
7-Jun	4:30	0.73	7-Jun	22:30	0.97
7-Jun	5:00	0.79	7-Jun	23:00	0.94
7-Jun	5:30	0.83	7-Jun	23:30	0.88
7-Jun	6:00	0.87	8-Jun	0:00	0.83
7-Jun	6:30	0.90	8-Jun	0:30	0.79
7-Jun	7:00	0.94	8-Jun	1:00	0.76
7-Jun	7:30	0.94	8-Jun	1:30	0.74
7-Jun	8:00	0.92	8-Jun	2:00	0.71
7-Jun	8:30	0.91	8-Jun	2:30	0.69
7-Jun	9:00	0.89	8-Jun	3:00	0.68
7-Jun	9:30	0.85	8-Jun	3:30	0.67
7-Jun	10:00	0.83	8-Jun	4:00	0.67
7-Jun	10:30	0.80	8-Jun	4:30	0.70
7-Jun	11:00	0.76	8-Jun	5:00	0.72
7-Jun	11:30	0.73	8-Jun	5:30	0.74
7-Jun	12:00	0.71	8-Jun	6:00	0.76
7-Jun	12:30	0.69	8-Jun	6:30	0.78
7-Jun	13:00	0.68	8-Jun	7:00	0.82
7-Jun	13:30	0.68	8-Jun	7:30	0.85
7-Jun	14:00	0.67	8-Jun	8:00	0.86

Table 4: 1996 Water-Surface Elevations At E03.50 (continued)

Day (1996)	Time	Elevation (ft)	Day (1996)	Time	Elevation (ft)
8-Jun	8:30	0.86	9-Jun	2:30	0.59
8-Jun	9:00	0.84	9-Jun	3:00	0.56
8-Jun	9:30	0.83	9-Jun	3:30	0.54
8-Jun	10:00	0.81	9-Jun	4:00	0.53
8-Jun	10:30	0.79	9-Jun	4:30	0.54
8-Jun	11:00	0.77	9-Jun	5:00	0.55
8-Jun	11:30	0.75	9-Jun	5:30	0.58
8-Jun	12:00	0.71	9-Jun	6:00	0.61
8-Jun	12:30	0.69	9-Jun	6:30	0.67
8-Jun	13:00	0.66	9-Jun	7:00	0.72
8-Jun	13:30	0.63	9-Jun	7:30	0.76
8-Jun	14:00	0.62	9-Jun	8:00	0.80
8-Jun	14:30	0.60	9-Jun	8:30	0.84
8-Jun	15:00	0.60	9-Jun	9:00	0.86
8-Jun	15:30	0.60	9-Jun	9:30	0.86
8-Jun	16:00	0.60	9-Jun	10:00	0.87
8-Jun	16:30	0.64	9-Jun	10:30	0.85
8-Jun	17:00	0.68	9-Jun	11:00	0.85
8-Jun	17:30	0.71	9-Jun	11:30	0.83
8-Jun	18:00	0.76	9-Jun	12:00	0.82
8-Jun	18:30	0.77	9-Jun	12:30	0.80
8-Jun	19:00	0.80	9-Jun	13:00	0.79
8-Jun	19:30	0.83	9-Jun	13:30	0.77
8-Jun	20:00	0.85	9-Jun	14:00	0.75
8-Jun	20:30	0.84	9-Jun	14:30	0.73
8-Jun	21:00	0.87	9-Jun	15:00	0.71
8-Jun	21:30	0.87	9-Jun	15:30	0.70
8-Jun	22:00	0.86	9-Jun	16:00	0.67
8-Jun	22:30	0.83	9-Jun	16:30	0.66
8-Jun	23:00	0.79	9-Jun	17:00	0.66
8-Jun	23:30	0.76	9-Jun	17:30	0.67
9-Jun	0:00	0.74	9-Jun	18:00	0.67
9-Jun	0:30	0.71	9-Jun	18:30	0.69
9-Jun	1:00	0.68	9-Jun	19:00	0.68
9-Jun	1:30	0.65	9-Jun	19:30	0.71
9-Jun	2:00	0.62	9-Jun	20:00	0.73

Table 4: 1996 Water-Surface Elevations At E03.50 (continued)

Day (1996)	Time	Elevation (ft)	Day (1996)	Time	Elevation (ft)
9-Jun	20:30	0.76	10-Jun	14:30	0.80
9-Jun	21:00	0.78	10-Jun	15:00	0.81
9-Jun	21:30	0.79	10-Jun	15:30	0.78
9-Jun	22:00	0.82	10-Jun	16:00	0.76
9-Jun	22:30	0.83	10-Jun	16:30	0.74
9-Jun	23:00	0.82	10-Jun	17:00	0.74
9-Jun	23:30	0.80	10-Jun	17:30	0.73
10-Jun	0:00	0.80	10-Jun	18:00	0.74
10-Jun	0:30	0.79	10-Jun	18:30	0.73
10-Jun	1:00	0.77	10-Jun	19:00	0.72
10-Jun	1:30	0.75	10-Jun	19:30	0.72
10-Jun	2:00	0.73	10-Jun	20:00	0.73
10-Jun	2:30	0.72	10-Jun	20:30	0.74
10-Jun	3:00	0.69	10-Jun	21:00	0.73
10-Jun	3:30	0.68	10-Jun	21:30	0.75
10-Jun	4:00	0.67	10-Jun	22:00	0.76
10-Jun	4:30	0.67	10-Jun	22:30	0.79
10-Jun	5:00	0.66	10-Jun	23:00	0.80
10-Jun	5:30	0.65	10-Jun	23:30	0.78
10-Jun	6:00	0.65	11-Jun	0:00	0.78
10-Jun	6:30	0.66	11-Jun	0:30	0.78
10-Jun	7:00	0.66	11-Jun	1:00	0.79
10-Jun	7:30	0.69	11-Jun	1:30	0.76
10-Jun	8:00	0.72	11-Jun	2:00	0.74
10-Jun	8:30	0.76	11-Jun	2:30	0.71
10-Jun	9:00	0.79	11-Jun	3:00	0.70
10-Jun	9:30	0.81	11-Jun	3:30	0.71
10-Jun	10:00	0.85	11-Jun	4:00	0.70
10-Jun	10:30	0.85	11-Jun	4:30	0.71
10-Jun	11:00	0.86	11-Jun	5:00	0.69
10-Jun	11:30	0.86	11-Jun	5:30	0.70
10-Jun	12:00	0.87	11-Jun	6:00	0.69
10-Jun	12:30	0.87	11-Jun	6:30	0.68
10-Jun	13:00	0.85	11-Jun	7:00	0.67
10-Jun	13:30	0.83	11-Jun	7:30	0.70
10-Jun	14:00	0.81	11-Jun	8:00	0.71

Table 4: 1996 Water-Surface Elevations At E03.50 (continued)

Day (1996)	Time	Elevation (ft)	Day (1996)	Time	Elevation (ft)
11-Jun	8:30	0.73	11-Jun	15:30	1.01
11-Jun	9:00	0.76	11-Jun	16:00	1.00
11-Jun	9:30	0.80	11-Jun	16:30	0.95
11-Jun	10:00	0.80	11-Jun	17:00	0.99
11-Jun	10:30	0.82	11-Jun	17:30	1.01
11-Jun	11:00	0.89	11-Jun	18:00	0.99
11-Jun	11:30	0.93	11-Jun	18:30	0.90
11-Jun	12:00	1.01	11-Jun	19:00	0.97
11-Jun	12:30	1.04	11-Jun	19:30	0.94
11-Jun	13:00	1.01	11-Jun	20:00	1.00
11-Jun	13:30	0.99	11-Jun	20:30	0.99
11-Jun	14:00	1.01	11-Jun	21:00	0.95
11-Jun	14:30	1.00	11-Jun	21:30	0.79
11-Jun	15:00	0.99			

Notes:

1. Water surface elevation datum is based on British Petroleum Mean Sea Level (BPMSL).
2. Water surface elevation data from 6 June to 11 June were recorded with a water-level recorder at E03.50. Elevations prior to those dates were measured with a rod and level at E3.00.

Table 5: 1995 Water Surface Elevations Based On 1996 British Petroleum Mean Sea Level (BPMSL) Datum

Date	Time	Location (see Figure 1)	Water-Surface Elevation (feet)	Reference Monument
14-May-95		E27.68	13.49	TBM 13
15-May-95	12:30	"	14.65	"
11-Jun-95	12:00	"	6.71	"
11-Jun-95	18:15	"	6.76	"
12-Jun-95	18:40	"	6.7	"
11-May-95	15:30	E27.09	7.06	USGS
12-May-95	18:35	"	11.94	"
14-May-95	14:00	"	13.12	"
15-May-95	13:00	"	14.28	"
15-May-95	18:20	"	14.36	"
1995 High Water Mark		"	14.88	"
18-May-95	10:00	"	11.38	"
19-May-95	12:30	"	8.97	"
3-Jun-95	18:40	"	8.05	TBM 1P
4-Jun-95	10:45	"	7.26	"
5-Jun-95	10:50	"	5.74	"
6-Jun-95	10:40	"	4.43	"
6-Jun-95	19:30	"	4.13	"
7-Jun-95	11:15	"	3.93	"
7-Jun-95	21:16	"	4.36	"
8-Jun-95	11:15	"	4.96	"
8-Jun-95	19:00	"	5.53	"
9-Jun-95	13:45	"	6.39	"
10-Jun-95	12:45	"	6.43	"
11-Jun-95	11:45	"	6.29	"
12-Jun-95	12:10	"	6.26	"
12-Jun-95	16:50	"	6.24	"
12-Jun-95	18:00	"	6.43	TMB 5
12-Jun-95	21:00	"	6.22	TBM 1P
13-Jun-95	10:30	"	6.25	"
13-Jun-95	16:30	"	6.61	"
13-Jun-95	17:00	"	6.73	"
15-Jun-95	10:20	"	6.30	"
16-Jun-95	9:40	"	5.51	"
17-Jun-95	10:15	"	5.14	"
18-Jun-95	10:15	"	6.97	"
18-Jun-95	18:00	"	7.37	"
18-Jun-95	23:00	"	7.47	"
19-Jun-95	8:20	"	7.26	"
19-Jun-95	21:20	"	7.33	"
15-Jul-95		"	1.92	"
31-Jul-95	14:30	"	1.41	"
1-Aug-95	18:35	"	1.02	"

Table 5: 1995 Water Surface Elevations Based On 1996 British Petroleum Mean Sea Level (BPMSL) Datum (continued)

Date	Time	Location (see Figure 1)	Water-Surface Elevation (feet)	Reference Monument
2-Aug-95	13:37	E27.09	1.37	TBM 1P
3-Aug-95	11:28	"	1.92	"
22-Aug-95	17:03	"	3.25	"
25-Aug-95	10:27	"	2.20	"
26-Aug-95	10:42	"	2.05	"
26-Aug-95	20:16	"	1.95	"
28-Aug-95	18:38	"	1.65	"
29-Aug-95	14:19	"	1.87	"
14-May-95	14:30	E26.66	12.88	TBM 12
15-May-95		"	13.98	"
11-Jun-95	12:15	"	6.43	"
11-Jun-95	18:40	"	6.46	"
13-Jun-95	11:15	"	6.50	"
5-Jun-95	14:30	E20.56	4.26	TBM 60P
6-Jun-95	10:50	"	3.32	"
6-Jun-95	19:50	"	3.10	"
7-Jun-95	11:30	"	2.88	"
7-Jun-95	21:29	"	3.19	"
8-Jun-95	11:35	"	3.72	"
8-Jun-95	18:40	"	4.09	"
9-Jun-95	14:05	"	4.79	"
10-Jun-95	14:00	"	4.84	"
10-Jun-95	14:35	"	4.71	TBM 65P
11-Jun-95	10:20	"	4.72	TBM 60P
11-Jun-95	18:00	"	4.68	"
12-Jun-95	12:25	"	4.70	"
12-Jun-95	16:30	"	4.70	"
13-Jun-95	17:30	"	4.99	"
13-Jun-95	18:00	"	5.00	"
14-Jun-95	10:45	"	5.17	"
14-Jun-95	21:35	"	5.10	"
15-Jun-95	10:50	"	4.87	"
15-Jun-95	21:10	"	4.59	"
16-Jun-95	9:55	"	4.08	"
16-Jun-95	21:05	"	3.70	"
17-Jun-95	12:35	"	3.72	"
17-Jun-95	15:35	"	3.82	"
17-Jun-95	23:00	"	4.35	"
18-Jun-95	22:40	"	5.00	"
19-Jun-95	17:25	"	5.20	"
1-Aug-95	17:57	"	0.73	"
2-Aug-95	14:01	"	0.68	"
3-Aug-95	11:48	"	1.08	"

Table 5: 1995 Water Surface Elevations Based On 1996 British Petroleum Mean Sea Level (BPMSL) Datum (continued)

Date	Time	Location (see Figure 1)	Water-Surface Elevation (feet)	Reference Monument
3-Aug-95	14:48	E20.56	1.04	TBM 60P
4-Aug-95	11:50	"	1.30	"
8-Aug-95		"	1.83	"
9-Aug-95		"	1.86	"
14-Aug-95		"	1.85	"
22-Aug-95	16:14	"	2.13	"
25-Aug-95	12:39	"	1.23	"
26-Aug-95	10:17	"	1.17	"
26-Aug-95	20:36	"	1.12	"
28-Aug-95	16:33	"	0.93	"
28-Aug-95	19:13	"	1.16	"
29-Aug-95	15:32	"	1.26	"
14-May-95	18:25	E16.46	9.41	TBM 28
15-May-95	14:55	"	10.43	"
19-Jun-95	19:00	"	3.89	"
12-May-95	14:50	E16.32	7.31	TBM 25
12-May-95	15:20	"	7.68	TBM 27
14-May-95	18:15	"	9.31	TBM 27
14-May-95	18:35	"	9.25	TBM 25
15-May-95	14:40	"	10.35	TBM 27
15-May-95	15:30	"	10.46	TBM 25
1995 High Water Mark		"	11.03	TBM 25
1995 High Water Mark		"	11.04	TBM 27
18-May-95	11:00	"	8.32	TBM 25
8-Jun-95	18:25	"	3.40	TBM 20
14-Jun-95	12:00	"	3.82	TBM 27
15-Jun-95	16:45	"	3.84	TBM 25
15-Jun-95	19:30	"	3.86	TBM 20
19-Jun-95	19:10	"	3.87	TBM 27
19-Jun-95	20:30	"	4.17	TBM 20
25-Aug-95	14:17	"	1.20	"
26-Aug-95	10:04	"	0.96	"
26-Aug-95	20:52	"	0.93	"
27-Aug-95	16:43	"	0.95	"
28-Aug-95	11:54	"	0.56	"
28-Aug-95	19:34	"	1.16	"
29-Aug-95	16:51	"	1.45	"
14-May-95	18:00	E16.14	9.12	TBM 29
15-May-95	15:15	"	10.30	"
19-Jun-95	19:15	"	3.83	"
14-May-95	18:50	E14.20	8.35	TBM 1CP
15-May-95	18:00	"	9.19	"
1995 High Water Mark		"	9.39	"

Table 5: 1995 Water Surface Elevations Based On 1996 British Petroleum Mean Sea Level (BPMSL) Datum (continued)

Date	Time	Location (see Figure 1)	Water-Surface Elevation (feet)	Reference Monument
18-May-95	15:00	E14.20	7.74	TBM 1CP
6-Jun-95		N08.09	1.27	TBM 46
7-Jun-95	12:25	"	0.88	"
7-Jun-95	20:20	"	0.8	"
19-Jun-95	10:30	"	1.52	"
26-Aug-95		"	0.35	"
14-May-95	15:15	N08.08	6.35	TBM 42
15-May-95		"	7.06	"
14-May-95	15:00	N07.46	6.14	TBM40P
15-May-95	16:00	"	6.83	"
18-May-95	12:05	"	>5.51	"
6-Jun-95	17:45	"	1.14	TBM 45
7-Jun-95	12:05	"	0.82	"
7-Jun-95	13:20	"	0.81	"
7-Jun-95	15:00	"	0.80	"
7-Jun-95	17:20	"	0.79	"
7-Jun-95	18:00	"	0.77	"
7-Jun-95	19:00	"	0.76	"
8-Jun-95	10:30	"	0.85	"
8-Jun-95	20:00	"	0.99	"
9-Jun-95	13:00	"	1.26	"
10-Jun-95	9:15	"	1.36	"
10-Jun-95		"	1.35	"
11-Jun-95	9:40	"	1.28	"
11-Jun-95	19:30	"	1.25	"
12-Jun-95	11:20	"	1.24	"
12-Jun-95	18:00	"	1.23	"
18-Jun-95	13:15	"	1.14	"
18-Jun-95	16:40	"	1.24	"
19-Jun-95	9:00	"	1.44	"
19-Jun-95	9:10	"	1.44	"
19-Jun-95	12:00	"	1.43	"
19-Jun-95	12:30	"	1.52	TBM 40P
29-Jul-95	20:05	"	-0.05	TBM 45
31-Jul-95	9:45	"	0.43	"
31-Jul-95	18:00	"	0.39	"
1-Aug-95	10:31	"	-0.09	"
1-Aug-95	10:40	"	-0.09	"
1-Aug-95	19:20	"	0.41	"
2-Aug-95	10:15	"	-0.07	"
2-Aug-95	17:02	"	0.10	"
3-Aug-95	10:45	"	0.05	"
3-Aug-95	12:04	N07.46	-0.08	TBM 45

Table 5: 1995 Water Surface Elevations Based On 1996 British Petroleum Mean Sea Level (BPMSL) Datum (continued)

Date	Time	Location (see Figure 1)	Water-Surface Elevation (feet)	Reference Monument
22-Aug-95	18:19	N07.46	0.62	"
26-Aug-95	12:05	"	0.30	"
6-Jun-95	18:00	N07.17	1.12	TBM 47
7-Jun-95	12:15	"	0.82	"
7-Jun-95	20:10	"	0.75	"
19-Jun-95	9:30	"	1.42	"
26-Aug-95	12:25	"	0.42	"
14-May-95	15:30	N07.00	5.75	TBM 43
15-May-95		"	6.58	"
1995 High Water Mark		S09.80	6.85	TBM30P
14-May-95	16:00	"	3.96	"
15-May-95	17:00	"	5.15	"
18-May-95	13:00	"	6.52	"
4-Jun-95	13:45	"	3.77	TBM 35
4-Jun-95		"	3.75	"
4-Jun-95	20:14	"	3.29	"
10-Jun-95	17:00	"	2.02	"
12-Jun-95	12:50	"	1.95	"
12-Jun-95	15:50	"	1.94	"
14-May-95		S09.30	3.96	TBM 32
15-May-95		"	5.16	"
4-Jun-95	19:00	"	3.24	"
12-Jun-95	13:00	"	1.87	"
12-Jun-95	16:00	"	1.83	"
14-May-95		T13.30	8.72	TBM 53
15-May-95		"	9.08	"
19-Jun-95	18:05	"	3.34	"
1995 High Water Mark		T12.62	9.84	TBM50
14-May-95	16:45	"	8.58	"
15-May-95	17:30	"	8.72	"
18-May-95	14:30	"	6.75	"
14-Jun-95	18:10	"	3.38	"
19-Jun-95	18:35	"	3.23	"
14-May-95		T12.15	8.12	TBM 52
19-Jun-95	18:45	"	3.18	"

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Table 6: Tempoary Bench Marks (TBMs) Surveyed In Both 1995 And 1996

Cross Section	TBM	1992 TBM Elevation (feet)	1995 TBM Elevation Based On RIVER (feet)	1996 TBM Elevation Based On BPMSL (feet)	Reference Monument	Reference Monument Elevation Based On BPMSL (feet)
E27.09	USGS REBAR		30.96	29.97	MON01	27.74
"	5		16.08	15.07	MON01	"
"	6		30.52	29.53	MON01	"
"	6P		30.47	29.48	MON01	"
"	10		28.67	27.68	MON01	"
"	13		29.61	28.62	MON01	"
"	12		32.24	31.25	MON01	"
"	1P		21.96	20.83	MON02	21.29
"	1		21.51	20.35	MON02	"
E20.56	65		28.03	27.21	MON09	25.03
"	65P		27.92	26.97	MON09	
"	60		19.32	18.66	MON06	18.3
"	60P		18.86	18.11	MON06	"
"	61		18.89	18.25	MON06	"
E16.32	20		15.28	14.99	MON13	13.75
"	20P		15.17	14.95	MON13	"
"	21		14.85	14.66	MON13	"
"	22		15.42	15.09	MON13	"
"	25		23.42	22.44	MON14	20.52
"	25P		22.77	23.09	MON14	"
"	27		17.9	17.6	MON15	19.49
"	27A		18.04	17.75	MON15	"
"	27P		21.2	20.81	MON15	"
E14.2	1CP		28.57	28.45	MON17	26.28
K10.69	3A	7.46 [1]			DUNE	35.56
N07.46	40		10.27	9.86	MON23	9.53
"	40P		10.15	9.72	MON23	"
"	41		10.33	9.99	MON23	"
S09.80	30		12.19	11.84	MON16	12.12
"	30P		12.33	12.03	MON16	"
T12.62	50		14.14	13.99	MON26	14.07
"	55		24.31	23.46	MON26	"

Notes:
1. K10.69 was measured in 1992 and was based on monument "DUNE" at an elevation of 36 feet.

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Table 7: Flow Estimates At Cross Sections E27.09, E20.56, And N19.95 During The 1996 Spring Breakup

Date	Parameter	Cross Section			Sum Of E20.56 And N19.95	Percent Difference From E27.09
		E27.09	E20.56	N19.95		
26 May	WSE (ft)	17.19	10.25	12.11		
	Q (cfs)	160,000	115,000	54,000	169,000	+5.6
27 May	WSE (ft)	12.55	11.16	11.16		
	Q (cfs)	149,000	128,000	39,700	167,700	+12.6
29 May	WSE (ft)	8.26	6.33	6.12		
	Q (cfs)	105,000	83,400 [3]	21,500	104,900	-0.1
30 May	WSE (ft)	8.56	6.34 [4]	6.08		
	Q (cfs)	111,000	83,500	21,000 [5]	104,500	-5.9
1 June (~0900)	WSE (ft)	7.46	5.52	5.14		
	Q (cfs)	91,200	73,000	17,000	90,000	-1.3
1 June (~1800)	WSE (ft)	7.22	5.31	4.81		
	Q (cfs)	87,400	70,000	15,500	85,500	-2.2
2 June (~1030)	WSE (ft)	6.59	4.82	4.32		
	Q (cfs)	78,200	64,000	13,300	77,300	-1.2
2 June (~1800)	WSE (ft)	6.18	4.44	4.03		
	Q (cfs)	72,800	69,000	12,000	71,000	-2.5
4 June	WSE (ft)	5.13	3.71	2.68		
	Q (cfs)	60,600	50,500	7,400	57,900	-4.5

Notes:
1. The discharge estimates for May 26 and 27 are based on normal depth computations.
2. The discharge estimates for May 29 through June 4 are based on the stage-discharge curves developed for each cross section.
3. The discharge measured on this date was 92,100 cfs.
4. The discharge measured on this date was 20,500 cfs.
5. The water-surface elevation was not measured at E20.56 on 30 May. This elevation is based on an extrapolation of the water-surface elevations measured at Mon01 and Mon05.

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Table 8: Comparison Of Estimated Flow At The Head Of The Delta (E27.09) With The Sum Of The Flow In The East Channel (E20.56) And The Nechelik Channel (N19.95) For Relatively High Water-Surface Elevations (WSE)

Condition	Parameter	Cross Section			Sum Of E20.56 And N19.95	Percent Difference From E27.09
		E27.09	E20.56	N19.95		
WSE = 2 feet at Ocean	WSE (ft)	12.00	9.59	10.05		
	Q (cfs)	195,000	134,000	47,000	181,000	-7.1
WSE = 2 feet at Ocean	WSE (ft)	18.00	14.20	14.94		
	Q (cfs)	345,000	228,000	100,000	338,000	-2.0
WSE = 2 feet at Ocean	WSE (ft)	19.40	15.19	16.01		
	Q (cfs)	385,000	246,000	118,000	364,000	-5.5
WSE = 4 feet at Ocean	WSE (ft)	12.00	10.07	10.44		
	Q (cfs)	195,000	142,000	50,000	192,000	-1.5
WSE = 4 feet at Ocean	WSE (ft)	18.00	14.62	15.68		
	Q (cfs)	345,000	232,000	112,000	344,000	-0.3
WSE = 4 feet at Ocean	WSE (ft)	19.40	15.68	16.39		
	Q (cfs)	385,000	258,000	123,000	381,000	-1.0

Notes:

1. All discharge estimates are based on the stage-discharge curves for each cross section (Figures 5, 8, and 11).
2. The water-surface elevations at E20.56 and N19.95 are based on the slope between E27.09 and the ocean. It was assumed that the slope was the same for both the upper East and Nechelik Channels.

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Table 9: Summary Of Hydraulic Roughness Values For The Colville River Delta Based On Discharge Measurements

Cross Section	Date	Water-Surface Elevation (feet)	Measured Discharge (cfs)	Measured Slope (ft/ft)	Hydraulic Roughness	
					Low-Water Channel	Sandbar
E27.09	2-Jun-93	13.33	239,000	0.000105	0.0240	0.0219
	11-Jun-95	6.42	74,600	0.000053	0.0287	0.0202
E20.56	8-Jun-95	3.86	48,400	0.000039	0.0263	0.0307
	29-May-96	6.38	92,100	0.000061	0.0249	0.0315
N19.95	30-May-96	6.02	20,500	0.000077	0.0199	0.0164 (south bar) 0.0173 (north bar)
S09.80	31-May-96	3.23	1,590	0.000049	0.0248	0.0156
T12.62	1-Jun-96	3.43	4,290	0.000042	0.0456 [2]	0.0233

Notes:

1. Water-Surface Elevations are based on BPMSL datum.
2. The channel hydraulic roughness value for the Tamayayak Channel is high relative to the values calculated at other sites. This may be due to uncertainties associated the surface water slope measurement. A change in the measured water surface elevations, of less than the measurement accuracy, could result in a slope which would yield a channel hydraulic roughness value of 0.03. Additionally, the measurement accuracy was affected by wind waves.

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Table 10: Bedload Data Collected At E20.56 On 2 June 1996.

Station (ft)	Depth (ft)	Width (ft)	Sampling Time	Sample Number	Time (Minutes)	Sediment Weight (grams)	Sample Load (g/m)	Section Load (g/s)	Load (Tons/day)
5638	REW								
5624	4.5	59.5	13:35	---	5	0	0	0.00	0.00
5533	9.3	128.5	15:05	11	10	0	0	0.00	0.00
5367	6.8	127.5	14:35	12	10	0	0	0.00	0.00
5278	7.5	141.5	15:55	10	5	0	0	0.00	0.00
5084	10.5	181	14:00	13	6	27.3	4.6	55	5.2
4916	14	129	16:15	9	5	40.6	8.1	70	6.7
4826	16	89	13:42	14	3	58	19	115	11
4738	15.9	98.5	16:30	8	5	35.7	7.1	47	4.5
4629	15.5	83	17:00	6	1	36.4	36	201	19
4572	15.5	88.5	13:20	15	3	733.4	244	1442	137
4452	16.3	101	13:00	16	3	258.2	86	580	55
4370	10.5	85.5	17:22	4	1	68.9	69	393	37
4281	16.3	106	17:12	5	1	191.9	192	1356	129
4158	15.5	132.5	12:40	17	3	686.8	229	2022	193
4016	13	99	17:45	3	1.5	774.7	516	3409	325
3960	13.4	81.5	12:25	18	3	650.5	217	1178	112
3853	12.2	104	11:55	20	3	148.9	50	344	33
3752	8.5	335	12:12	19	4	192.9	48	1077	103
3183	3	636.5	18:05	2	10	0	0	0.00	0.00
2479	2.7	642	11:22	21	5	0	0	0.00	0.00
2189	LEW								
TOTAL		**3449**						**12289**	**1171**

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Table 11. Summary of Bed Material Data For N19.95

River Location	Sample Location	Date	D(25) (mm)	D(50) (mm)	D(75) (mm)	Percent Greater Than 0.062 mm	U. S. Standard Sieve No.	U. S. Standard Sieve Size (mm)	Percent Passing By Weight	Description
N19.95	Cross Section Station 2897	03-Jun-96	0.08	0.12	0.17	82	#10	2.00	100.0	Silty Fine SAND
							#20	0.85	99.9	
							#40	0.425	99.5	
							#60	0.250	97.8	
							#100	0.150	69.4	
							#200	0.075	22.2	
N19.95	Cross Section Station 3153	03-Jun-96	0.28	0.34	0.40	100	#4	4.75	100.0	Fine SAND
							#10	2.00	98.5	
							#20	0.85	96.9	
							#40	0.425	83.7	
							#60	0.250	12.7	
							#100	0.150	0.9	
							#200	0.075	0.6	
N19.95	Cross Section Station 3340	03-Jun-96	0.27	0.33	0.04	99	#10	2.00	100.0	Fine SAND
							#20	0.85	99.9	
							#40	0.425	93.3	
							#60	0.250	16.1	
							#100	0.150	2.4	
							#200	0.075	1.0	

Notes:
1. River location is based on river miles measured from the mouth of the Nechelik Channel.
2. D(25), D(50), and D(75) refer to the particle size for which 25, 50, and 75 percent, respectively, of the material by weight is finer.

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Table 12 : Summary Of Channel Characteristics And Stream Flow Observations For Streams Along The Proposed Pipeline Route

Approximate Stream Location	Map Desig-nation	Approximate Drainage Basin Area (square miles)	Typical Channel Width: Bankfull (feet)	Typical Channel Width: Observed Water Surface Width (feet) (1)	Typical Depth: At Bankfull (feet)	Typical Depth: Observed Water Depth (feet) (1)	Surface Velocity (fps) (2)	Water Suface Slope (ft/ft)	Date of Observation	Description
1.0 Mile East Of Alpine Well	A	0.53		210 to 230		2.5 to 3			June 3 & 7	Grass-lined swale with small channel.
1.5 Miles East Of Alpine Well	B	0.35		8 to 12	3	0.3 to 0.6			June 3 & 7	Grass-lined swale with small channel.
2.0 Miles East Of Alpine Well	C	5.50	100	2.5	13	0.5			June 3	Incised channel of significant width at mouth.
Station 210+00	D	0.67							June 7	Grass-lined swale without a continuous channel.
Station 290+00	E	1.08							June 2 & 3	Grass-lined swale without a well defined channel.
Station 515+00	F	3.64		8 to 11	2.9 to 6.6	2.5 to 5.6 (3.2 avg)	1.4	0.0018	May 31 & June 1	Beaded stream in a grass-lined swale.
Station 585+00	G	2.45		3 to 7 (3 avg)	2 to 2.5	0.5 to 2.3 (0.85 avg)	1.4		May 31	Small stream in a wide, flat, grassed area between two lakes.
Station 615+00	H	1.23				2.5			May 31	Grass-lined swale with a small channel.
Tributary To Kachemach River	I	24.6		30 to 60		4.4 to 9+	2.3 to 2.8	0.00028	May 31, June 1 & 2	Meandering, beaded channel in a wide grass-lined swale.
Station 747+00	J	0.07							May 31	Grass-lined swale without a well defined channel.
Station 771+00	K	1.45		3 to 6	2	0.5 to 1			May 31 & June 7	Small beaded stream flowing in polygonal troughs.
Station 782+00	L	0.85		3 to 30 (14 avg)		0.4 to 2.6 (0.9 avg)	1.4	0.0047	May 31 & June 3	Small beaded stream in grass-lined swale.
Station 830+00	M	2.18	5 to 8	6 to 8	1 to 1.5	1 to 1.5			May 31 & June 7	Small stream in a wide, flat, grassed area between two lakes.
Station 923+00	N	1.14		2.5 to 9	1.5	0.2 to 0.5			May 31 & June 7	Small stream flowing in polgonal troughs.
Kachemach River	O	137	200	138	5 to 6	4.5	4.5 to 5.3	0.00081 to 0.00093	May 25, 27, 28, 29 & 31	Medium-size, meandering river.
Station 1070+00	P								May 31 & June 12	Probably does not exist or is not a significant stream.
Station 1119+00	Q	0.11		3 to 5	1.5	0.5 to 0.7			May 31 & June 7	Small stream flowing in polygonal troughs.
Miluveach River	R	101	130	118	3.3 to 6.4	3.77	6.4 to 7.4	0.00074 to 0.0011	May 25, 28 & June 4	Medium-size, meandering river.
Station 1146+00	S	0.04	2 to 5		0.5 to 1.5		1 to 3		May 28	Small stream flowing in polygonal troughs.
Station 1243+00	T	2.15							May 28	Small stream in a wide, shallow swale between two lakes.
Station 1263+00	U	0.19							May 28	Basin U is drained by multiple channels. One drainage noted was a wide, shallow swale.
Station 1310+00	V	0.54		3 to 5		0.2 to 0.5			May 28	Basin V is drained by multiple channels. Small streams or ponded water within grass-lined swales.
Station 1362+00	W	0.02	1 to 2		0.5 to 1				May 28	Small stream flowing in polgonal troughs.
Station 1400+00	X	7.33	80 to 100	8 to 33	15+	0.5 to 3.5 (1.3 avg)	3 to 4	0.0026	May 28 & June 2	Meandering stream within incised channel.

Notes:

1. Width, depth, and slope observations were generally made between May 28 and June 7, 1996 by Shannon & Wilson, Inc.
2. Velocity is the surface velocity based on timing of a buoy, or, for the Kachemach and Miluveach Rivers, timing of compacted-snow floes.
3. Station locations are along the pipeline alignment shown on the preliminary Michael Baker Jr., Inc. drawings provided to Shannon & Wilson, Inc. on 13 December 1995 and titled "Alternative-A X14, Above Ground Pipeline, No Permanent Road."
4. Drainage basin area was evaluated based on USGS 1:63,360 scale quadrangle maps and one or more of the following aerial photographic flights: 1:63,360 scale July 1982 Color IR, 1:18,000 scale September 1988 Color, and 1:18,000 scale July 1992 Color IR. Note that the 1992 photography covers only the portion of the alignment west of the Kachemach River, the 1988 photopraphy covers only the portion of the alignment east of the Kachemach River, and the 1982 photography covers approximately the entire alignment. Drainage basin area is based on the pipeline crossing location as indicated on the 13 December 1995 drawings.

Table 13: 1996 Water-Surface Elevations At The Kachemach And Miluveach Rivers At The Proposed Pipeline Crossings

Date	Time	Location	Water-Surface Elevation (feet) (1)	Reference TBM
25-May-96	16:00	Kachemach River	32.91	KACH-1
26-May-96	16:05	"	32.12	"
27-May-96	12:10	"	31.54	"
"	18:28	"	31.59	"
"	19:47	"	31.67	"
28-May-96	10:30	"	30.65	"
"	20:00	"	31.7	See Note 2
29-May-96	14:00	"	30.8	See Note 2
25-May-96	15:00	Miluveach River	47.97	MILU-1
28-May-96	15:30	"	46.84	"
"	18:00	"	47.08	"
4-Jun-96	13:30	"	43.82	"

Notes:

1. Water surface elevation datum is based on British Petroleum Mean Sea Level (BPMSL).
2. Water-surface elevations at TBM KACH-1 on these dates are based on linear interpolation using water surface-elevations measured 730 feet upstream and 999 feet downstream from KACH-1.

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Table 14: Summary of Bed Material Data For Selected Streams Along The Proposed Pipeline Route

River Location	Sample Location	Date	D(25) (mm)	D(50) (mm)	D(75) (mm)	Percent Greater Than 0.062 mm	U. S. Standard Sieve No.	U. S. Standard Sieve Size (mm)	Percent Passing By Weight	Description/Comments
Stream F	Near Left Edge Of Water	05-Jun-96								SILT and Fine Roots The sample was collected from a narrow channel between beads. The channel bottom was covered with a dense root mat, and felt frozen below 0.2- to 0.4-feet depth. The sample was not analyzed beyond a visual inspection.
Stream I	Near Left Edge Of Water	05-Jun-96								SILT and Fine Roots The sample was collected from a 3 to 3.5-foot-deep channel between beads. The channel bottom was covered with a dense root mat, and felt frozen below 0.5 feet. The sample was not analyzed beyond a visual inspection. Based on probing with a survey rod on June 2, the channel bottom may be unvegetated and sandy in places.
Stream L	Near Right Edge Of Water	05-Jun-96	0.40	2.28	4.57	98	3/4	19.05	100	Fine Gravelly SAND
							3/8	9.53	97.4	
							#4	4.75	77.0	
							#10	2.00	46.9	
							#20	0.85	34.7	
							#40	0.425	27	
							#60	0.250	13	
							#100	0.150	4.5	
							#200	0.075	2.2	
Kachemach River	Near Left Edge Of Water	04-Jun-96	0.84	4.39	9.63	100	1 1/2	38.1	100.0	Gravelly SAND The sample collected was representative of the bed material within the low-water channel. The water level was approximately 4 feet below the top of the bank at the time that the sample was collected. The surface of the gravel bar on the west bank consisted of material that was coarser than that in the low-water channel. Six-inch high dunes on the gravel bar were armored with a coarse sandy gravel with occasional cobbles up to 4 inches in diameter.
							1	25.4	96.7	
							3/4	19.05	91.5	
							3/8	9.53	74.8	
							#4	4.75	52.4	
							#10	2.00	34.2	
							#20	0.85	25.4	
							#40	0.425	13.3	
							#60	0.250	1.5	
							#100	0.150	0.3	
							#200	0.075	0.2	

Notes:
1. D(25), D(50), and D(75) refer to the particle size for which 25, 50, and 75 percent, respectively, of the material by weight is finer.

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Table 14: Summary of Bed Material Data For Selected Streams Along The Proposed Pipeline Route (continued)

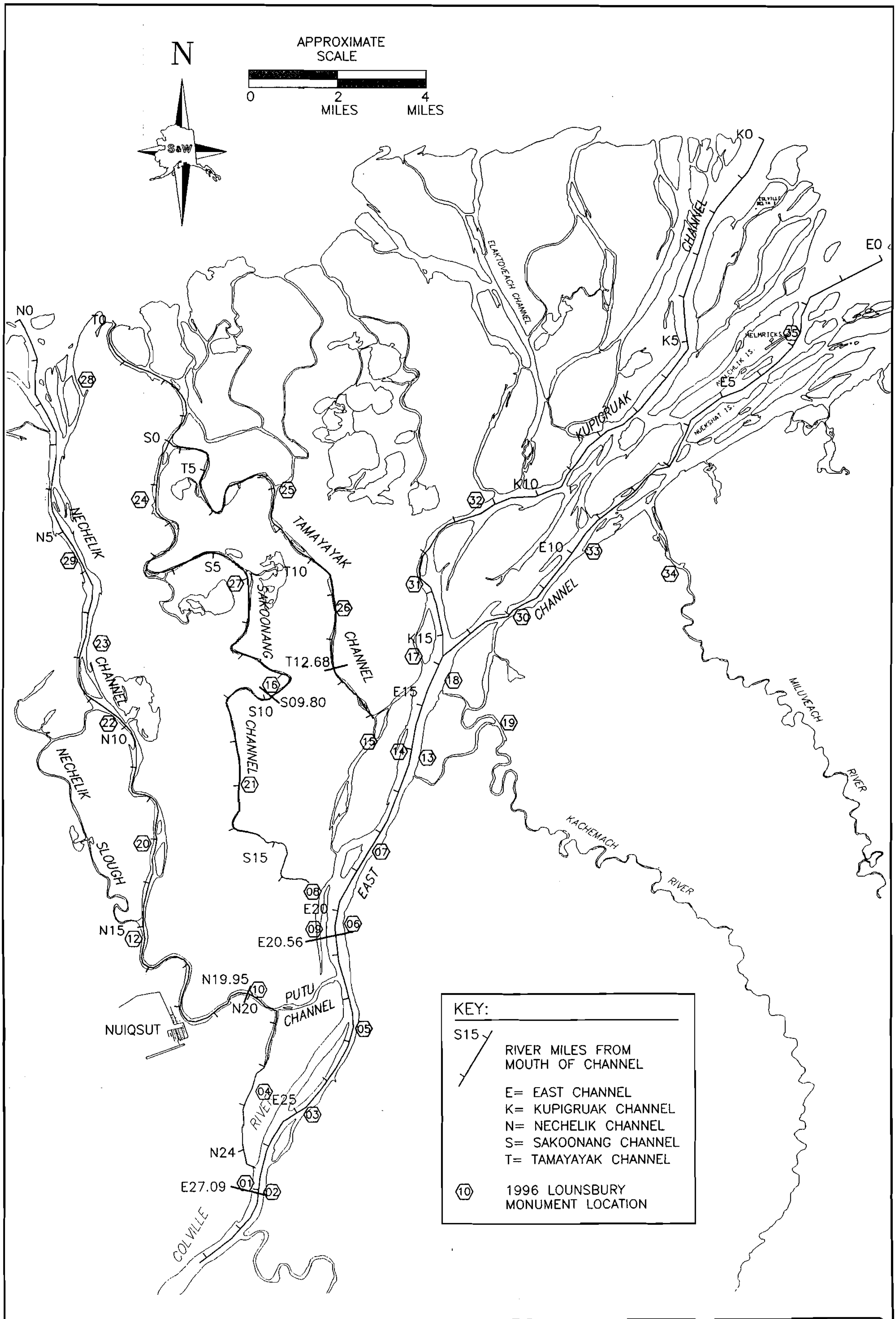
River Location	Sample Location	Date	D(25) (mm)	D(50) (mm)	D(75) (mm)	Percent Greater Than 0.062 mm	U. S. Standard Sieve No.	U. S. Standard Sieve Size (mm)	Percent Passing By Weight	Description
Miluveach River	Near Left Edge Of Water	04-Jun-96	0.69	4.50	15.17	99	2	50.8	100	Gravelly SAND
							1 1/2	38.1	92.7	
							1	25.4	85.3	
							3/4	19.05	79.4	
							3/8	9.53	67.2	
							#4	4.75	51.3	
							#10	2.00	36.9	
							#20	0.85	28	
							#40	0.425	20.1	
							#60	0.250	8.8	
							#100	0.150	2.8	
							#200	0.075	1	
Stream X	Near Channel Center	05-Jun-96	0.27	2.34	5.39	99	3/4	19.05	100	Fine Gravelly SAND
							3/8	9.53	94.5	
							#4	4.75	72.0	
							#10	2.00	46.9	
							#20	0.85	40.4	
							#40	0.425	36.1	
							#60	0.250	23.3	
							#100	0.150	6.7	
							#200	0.075	1.1	

Notes:
1. D(25), D(50), and D(75) refer to the particle size for which 25, 50, and 75 percent, respectively, of the material by weight is finer.

HYDROLIB\PROJECTS\L-1259\REPORT\TABLES\BED MATERIAL.XLS

APPENDIX B
FIGURES

LIST OF FIGURES



SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	7/2/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	L1259F-1.DWG
CHECKED:	SRR	SCALE:	1" = 2 MILES

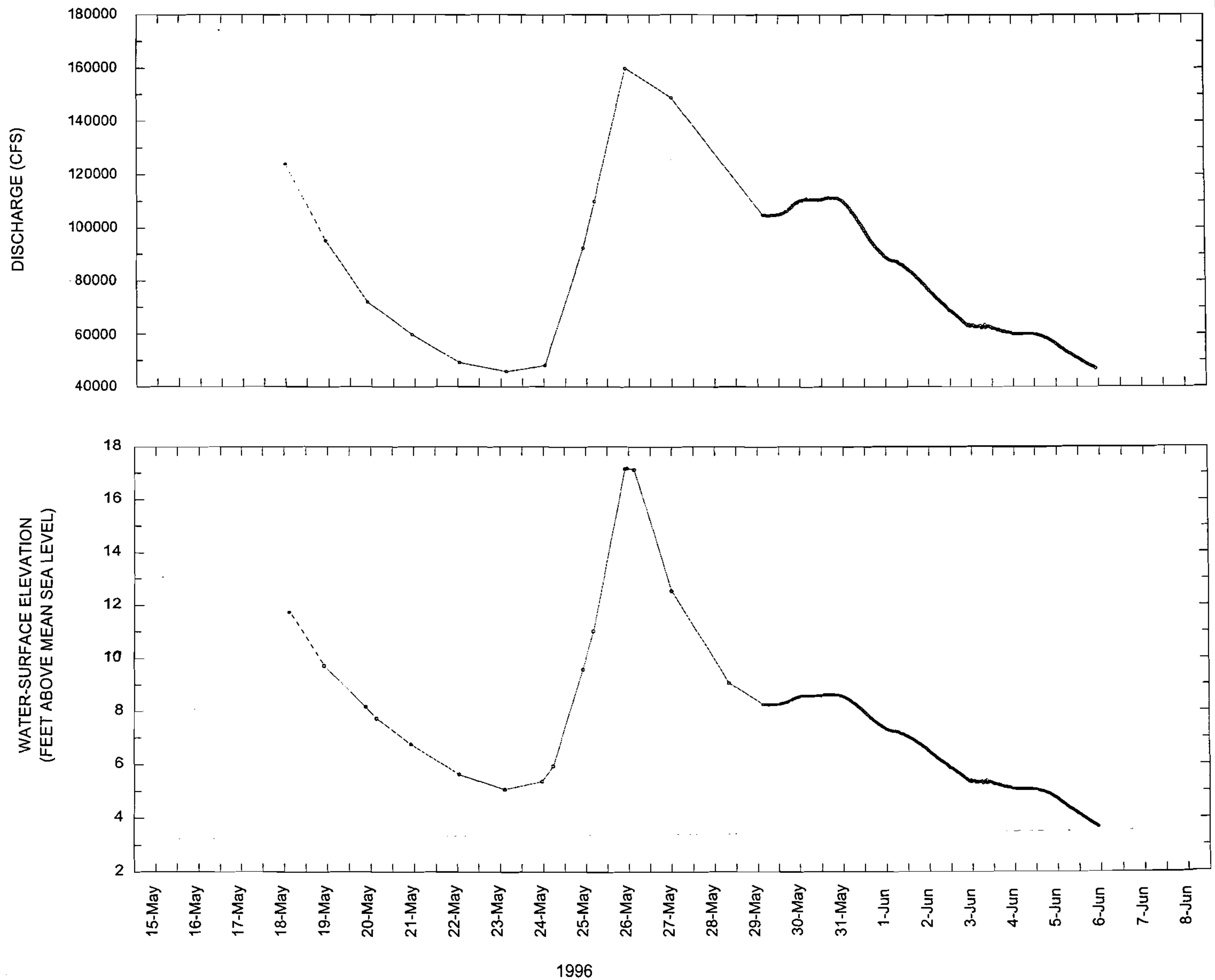
PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: RIVER CHANNEL CROSS SECTION LOCATIONS
COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

REVISION

NO.:	DATE:	BY:

FIGURE: 1



NOTES:

1. DATA WERE OBTAINED USING A WATER-LEVEL RECORDER FROM 29-MAY TO 6-JUN. OTHER DATA POINTS WERE MEASURED WITH A ROD AND LEVEL ON THE SPECIFIED DAY.
2. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).
3. THE DATE LABELS REPRESENT NOON OF THAT DAY.

NO	DATE:	REVISION:	BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

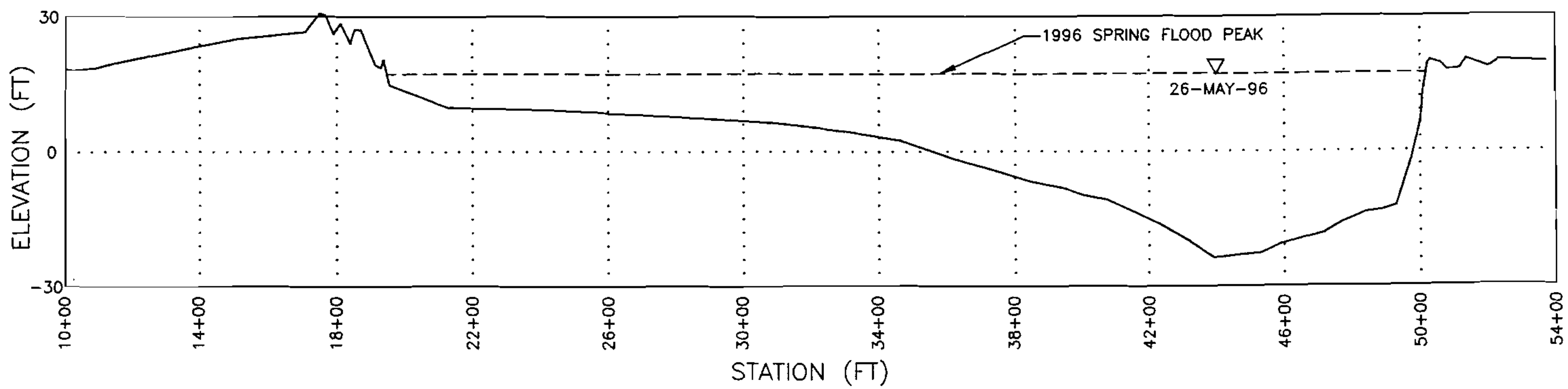
SUBJECT: HYDROGRAPH AND WATER-SURFACE ELEVATIONS AT E27.09 COLVILLE RIVER, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE: 30 SEP 1996
DRAWN: SWT
CHECKED: SRR
PROJECT: L-1259
FILE: FIGURE 2.CH4
SCALE:

FIGURE
2

CROSS SECTION E27.09 (EAST CHANNEL)



NOTES:

1. THE 1996 SPRING FLOOD PEAK DISCHARGE OCCURRED ON 26 MAY 1996 AND HAD AN ELEVATION OF 17.19 FEET.
2. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).
3. CROSS SECTION IS PRESENTED LOOKING DOWNSTREAM.
4. CROSS SECTION IS NAMED BASED ON RIVER MILES FROM THE MOUTH OF THE CHANNEL.

NO.	DATE	REVISION	BY

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

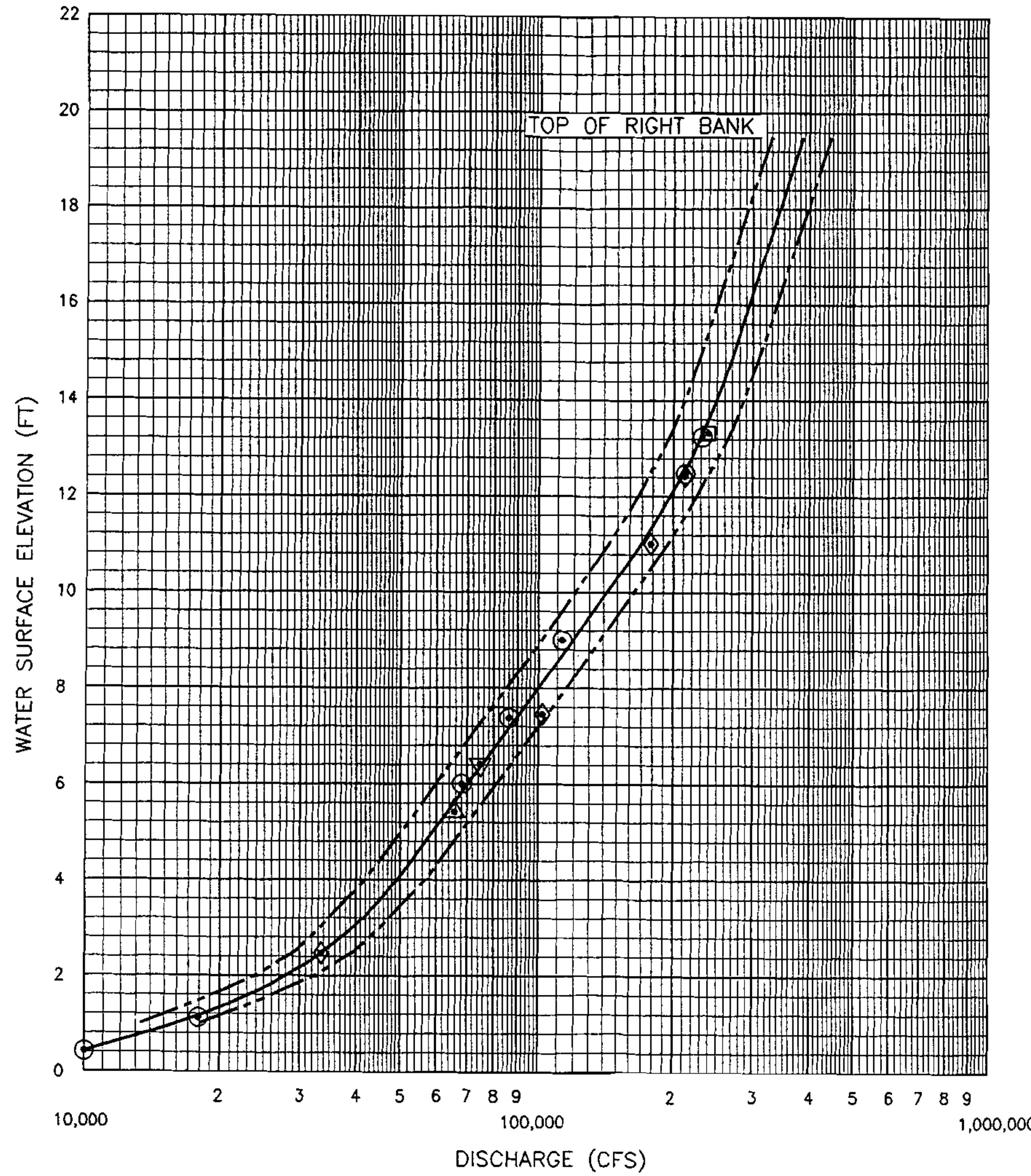
LOCATION: RIVER CHANNEL CROSS SECTION AT E27.09 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	7/2/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	L1259F-4.DWG
CHECKED:	SRR	SCALE:	VARIES

FIGURE: 4

EAST CHANNEL- E27.09



- ⊡ BASED ON THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 2 JUNE 1993 (JORGENSON et al. 1994).
- ▽ BASED ON THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 11 JUNE 1995.
- ⊙ BASED ON THE DISCHARGE MEASUREMENTS MADE BY THE USGS IN 1977.
- △ BASED ON THE DISCHARGE MEASUREMENT MADE BY ARCTIC HYDROLOGIC CONSULTANTS ON 10 JUNE 1992 (JORGENSON et al. 1993).
- ◈ BASED ON THE DISCHARGE MEASUREMENTS MADE IN 1962 (ARNBORG et al. 1966).

——— THE MOST LIKELY DISCHARGE RATING CURVE.
— - - — THE UPPER AND LOWER LIMITS OF THE MOST LIKELY DISCHARGE RATING CURVE.

NOTES:
1. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).

REVISION		
NO.	DATE:	BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

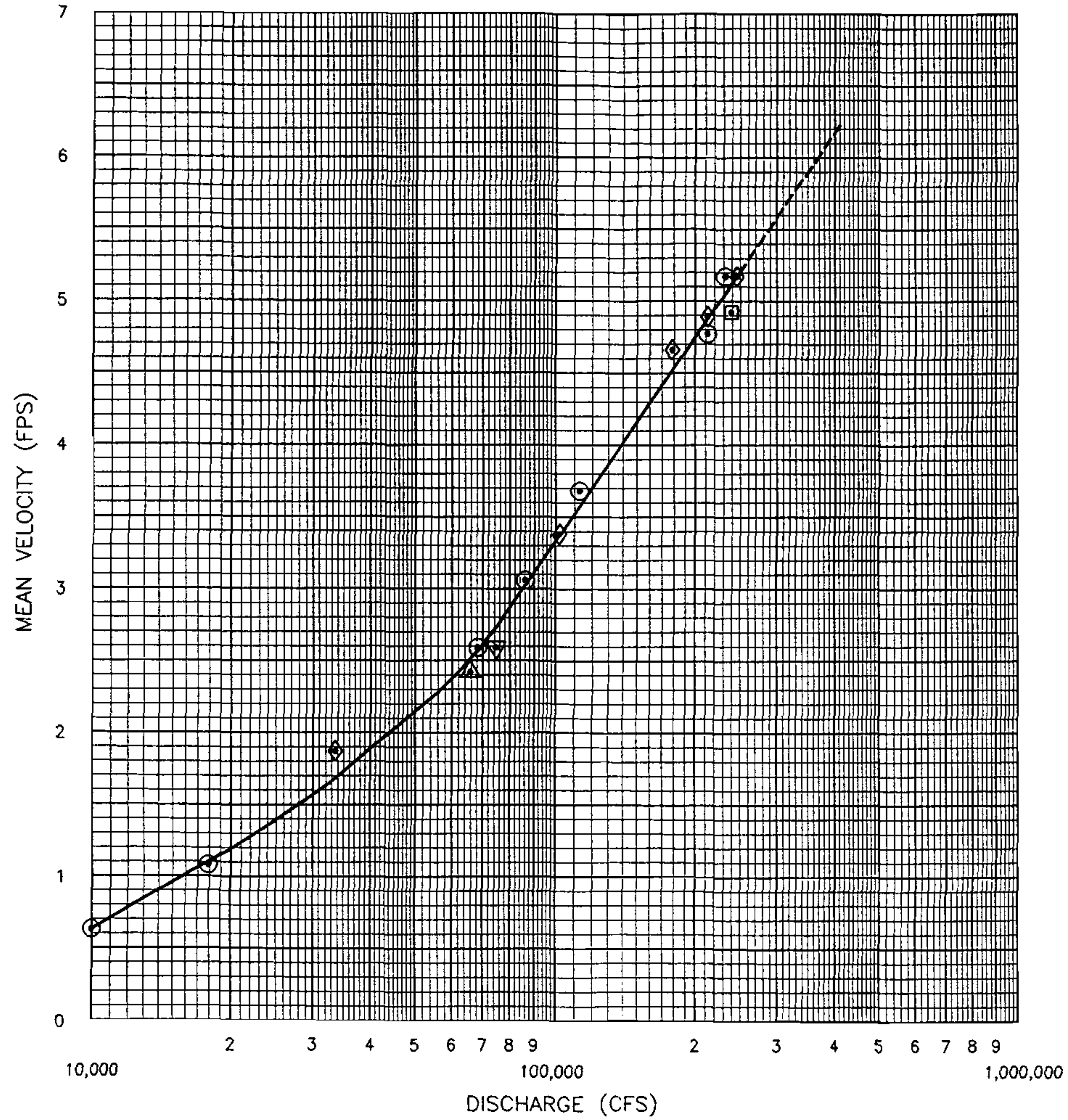
SUBJECT: STAGE-DISCHARGE RELATIONSHIP FOR CROSS SECTION E27.09 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	8/26/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	L1259F-5.DWG
CHECKED:	SRR	SCALE:	VARIES

FIGURE: 5

EAST CHANNEL– E27.09



- ⊡ BASED ON THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 2 JUNE 1993 (JORGENSON et al. 1994).
- ▽ BASED ON THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 11 JUNE 1995.
- ⊙ BASED ON THE DISCHARGE MEASUREMENTS MADE BY THE USGS IN 1977.
- △ BASED ON THE DISCHARGE MEASUREMENT MADE BY ARCTIC HYDROLOGIC CONSULTANTS ON 10 JUNE 1992 (JORGENSON et al. 1993).
- ◈ BASED ON THE DISCHARGE MEASUREMENTS MADE IN 1962 (ARNBORG et al. 1966).

REVISION		
NO	DATE:	BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

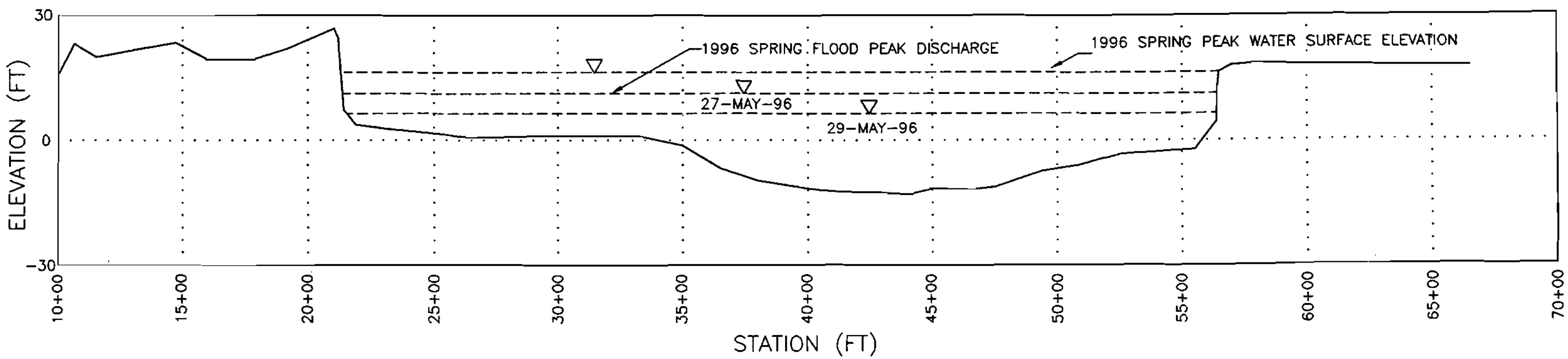
SUBJECT: VELOCITY–DISCHARGE RELATIONSHIP FOR CROSS SECTION E27.09 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	8/26/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	L1259F-6.DWG
CHECKED:	SRR	SCALE:	VARIES

FIGURE: 6

CROSS SECTION E20.56 (EAST CHANNEL)



NOTES:

1. THE 1996 SPRING FLOOD PEAK DISCHARGE PROBABLY OCCURRED ON 27 MAY 1996 AND HAD AN ELEVATION OF 11.16 FEET.
2. THE SPRING PEAK WATER-SURFACE ELEVATION (16.5 FEET) WAS DUE TO BACKWATER FROM AN ICE JAM.
3. A DISCHARGE MEASUREMENT WAS MADE ON 29 MAY 1996 AT AN ELEVATION OF 6.38 FEET.
4. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).
5. CROSS SECTION IS PRESENTED LOOKING DOWNSTREAM.
6. CROSS SECTION IS NAMED BASED ON RIVER MILES FROM THE MOUTH OF THE CHANNEL.

NO.: DATE: REVISION BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

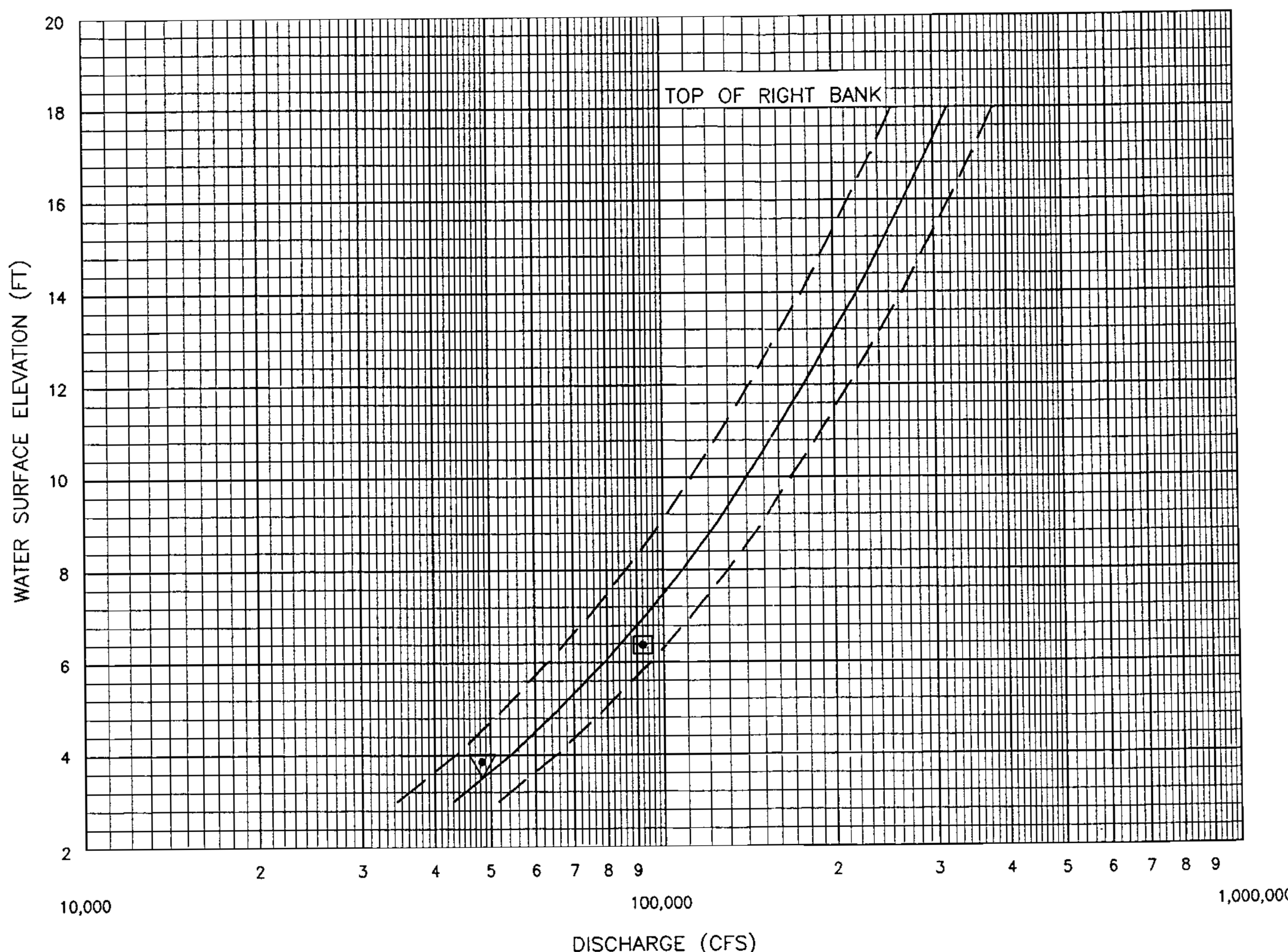
SUBJECT: RIVER CHANNEL CROSS SECTION AT E20.56 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE: 7/2/96 | PROJECT: L-1259
DRAWN: BC | FILE: L1259F-7.DWG
CHECKED: SRR | SCALE: VARIES

FIGURE: 7

EAST CHANNEL–E20.56



⊡ DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 29 MAY 1996.

▽ DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 8 JUNE 1995.

——— THE MOST LIKELY DISCHARGE RATING CURVE.

— — THE UPPER AND LOWER LIMITS OF THE MOST LIKELY DISCHARGE RATING CURVE.

NOTES:
1. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).

REVISION		
NO.:	DATE:	BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

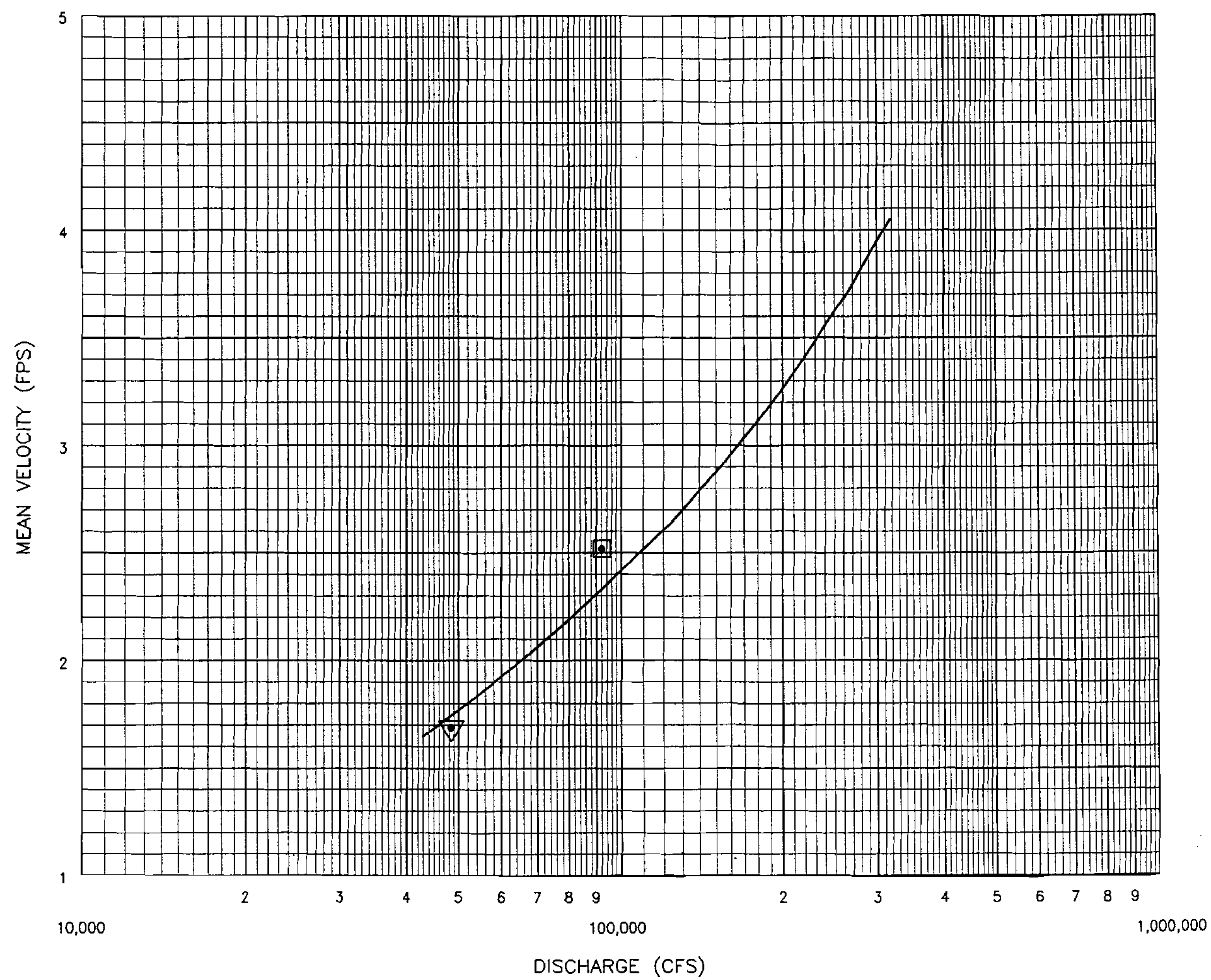
SUBJECT: STAGE–DISCHARGE RELATIONSHIP FOR CROSS SECTION E20.56 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	8/26/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	E20-568.DWG
CHECKED:	SRR	SCALE:	VARIES

FIGURE: 8

EAST CHANNEL–E20.56



▣ THE AVERAGE VELOCITY MEASUREMENT MADE BY SHANNON & WILSON ON 29 MAY 1996.

▽ THE AVERAGE VELOCITY MEASUREMENT MADE BY SHANNON & WILSON ON 8 JUNE 1995.

REVISION		
NO.:	DATE:	BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

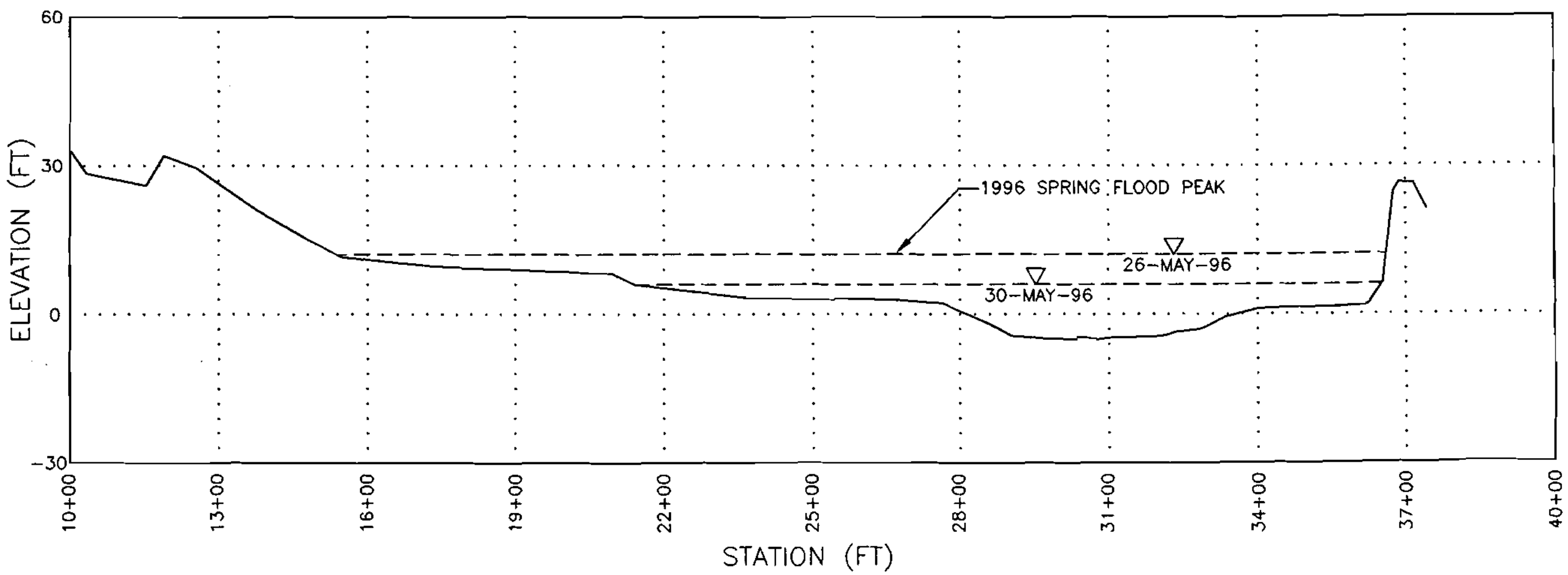
SUBJECT: VELOCITY–DISCHARGE RELATIONSHIP FOR CROSS SECTION E20.56 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	8/26/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	E20-56.DWG
CHECKED:	SRR	SCALE:	VARIES

FIGURE: 9

CROSS SECTION N19.95 (NECHELIK CHANNEL)



NOTES:

1. THE 1996 SPRING FLOOD PEAK DISCHARGE PROBABLY OCCURRED ON 26 MAY 1996 AND HAD AN ELEVATION OF 12.11 FEET.
2. A DISCHARGE MEASUREMENT WAS MADE ON 30 MAY 1996 AT AN ELEVATION OF 6.02 FEET.
3. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).
4. CROSS SECTION IS PRESENTED LOOKING DOWNSTREAM.
5. CROSS SECTION IS NAMED BASED ON RIVER MILES FROM THE MOUTH OF THE CHANNEL.

NO. | DATE: | REVISION | BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

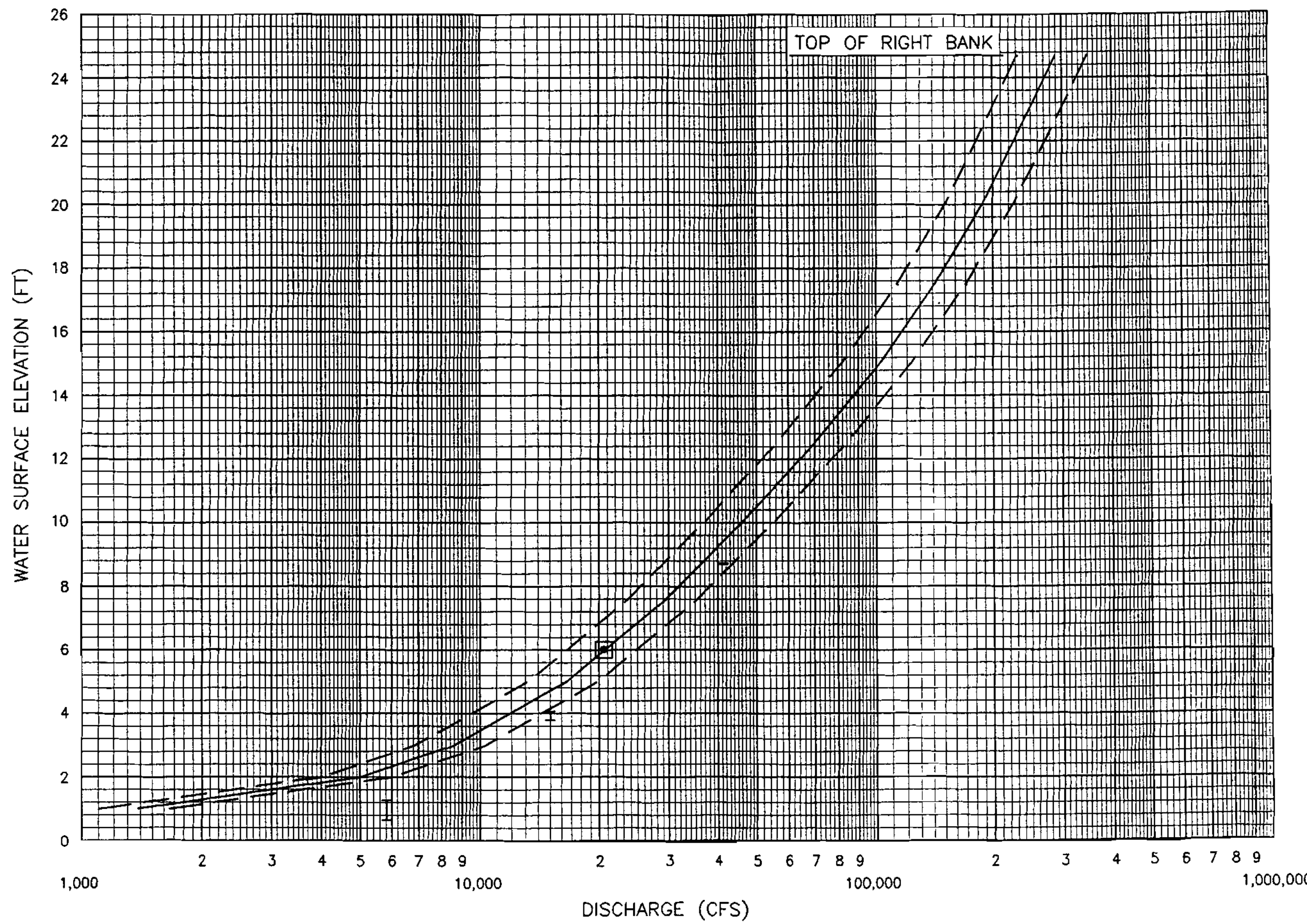
SUBJECT: RIVER CHANNEL CROSS SECTION AT N19.95 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE: 7/2/96 | PROJECT: L-1259
DRAWN: BC | FILE: L1259F10.DWG
CHECKED: SRR | SCALE: VARIES

FIGURE: 10

NECHELIK CHANNEL– N19.95



⊡ THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 30 MAY 1996.

I BASED ON THE DISCHARGE MEASUREMENTS MADE IN 1962 AT A CROSS SECTION 2.15 MILES DOWNSTREAM (ARNBORG ET AL. 1966).

——— THE MOST LIKELY DISCHARGE RATING CURVE.

— — THE UPPER AND LOWER LIMITS OF THE MOST LIKELY DISCHARGE RATING CURVE.

NOTES:

1. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).

REVISION			
NO.:	DATE:		BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STAGE–DISCHARGE RELATIONSHIP FOR CROSS SECTION N19.95 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	8/26/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	N19-958.DWG
CHECKED:	SRR	SCALE:	VARIES

FIGURE: 11

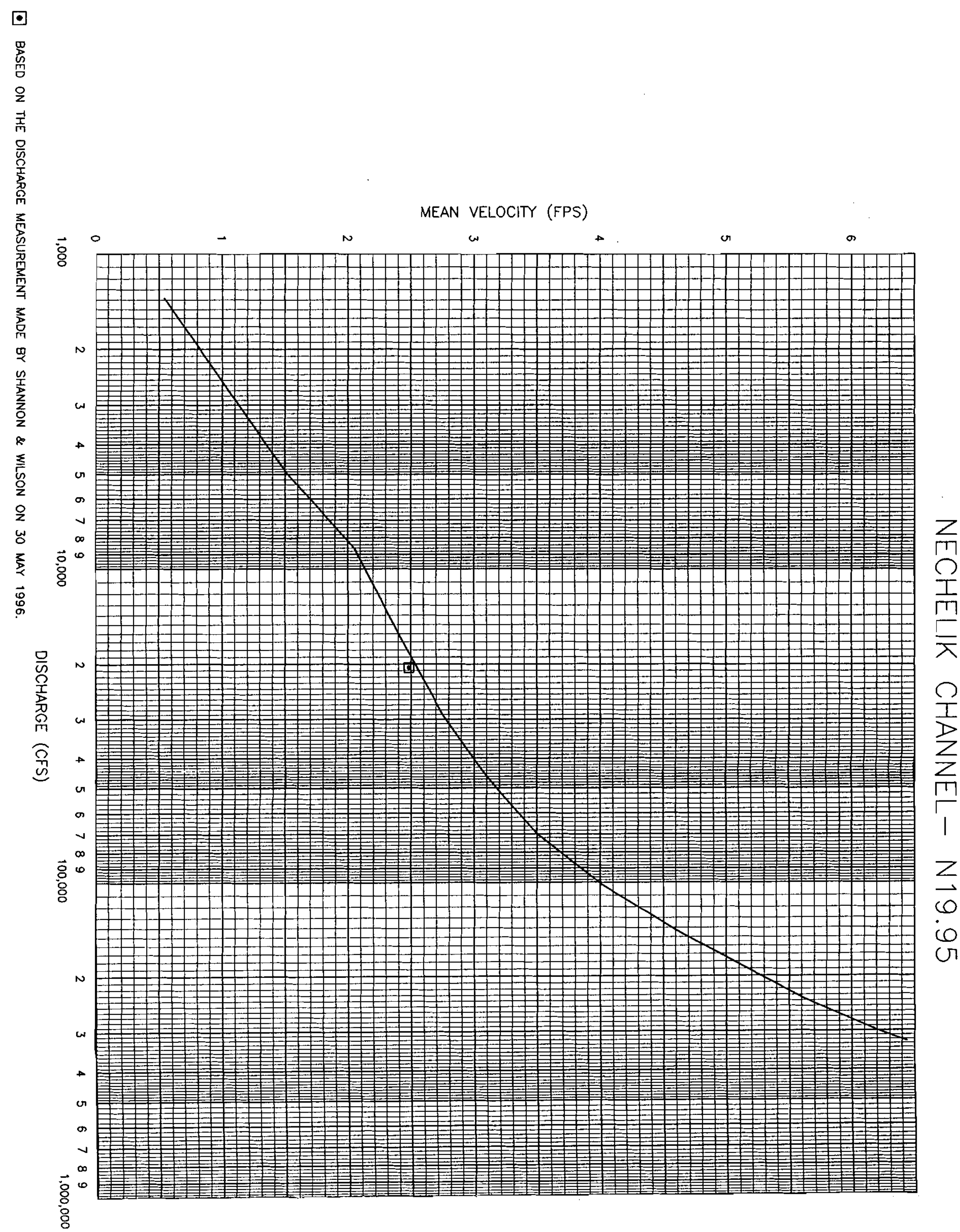
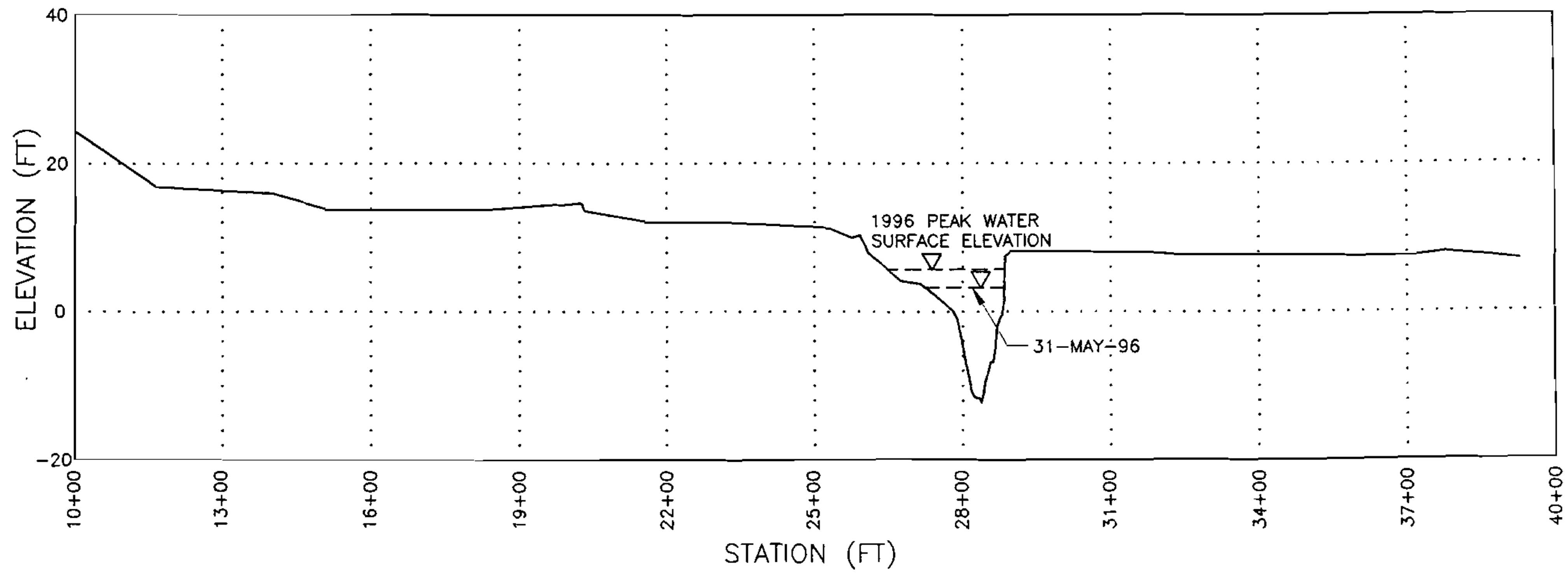


FIGURE: 12	SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS	PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT	REVISION
	DATE: 8/26/96 — PROJECT: L-1259	SUBJECT: VELOCITY-DISCHARGE RELATIONSHIP FOR CROSS SECTION N19.95 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA	NO. DATE: BY:
	DRAWN: BC — FILE: N19-95S.DWG		
	CHECKED: SRR — SCALE: VARIES		

CROSS SECTION S09.80 (SAKOONANG CHANNEL)



NOTES:

1. THE 1996 SPRING FLOOD PEAK DISCHARGE WAS NOT ESTIMATED AT THIS CROSS SECTION.
2. THE 1996 SPRING PEAK WATER-SURFACE ELEVATION (5.7 FEET) WAS DUE TO BACKWATER FROM AN ICE JAM.
3. A DISCHARGE MEASUREMENT WAS MADE ON 31 MAY 1996 AT AN ELEVATION OF 3.23 FEET.
4. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).
5. CROSS SECTION IS PRESENTED LOOKING DOWNSTREAM.
6. CROSS SECTION IS NAMED BASED ON RIVER MILES FROM THE MOUTH OF THE CHANNEL.

REVISION		
NO.	DATE	BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

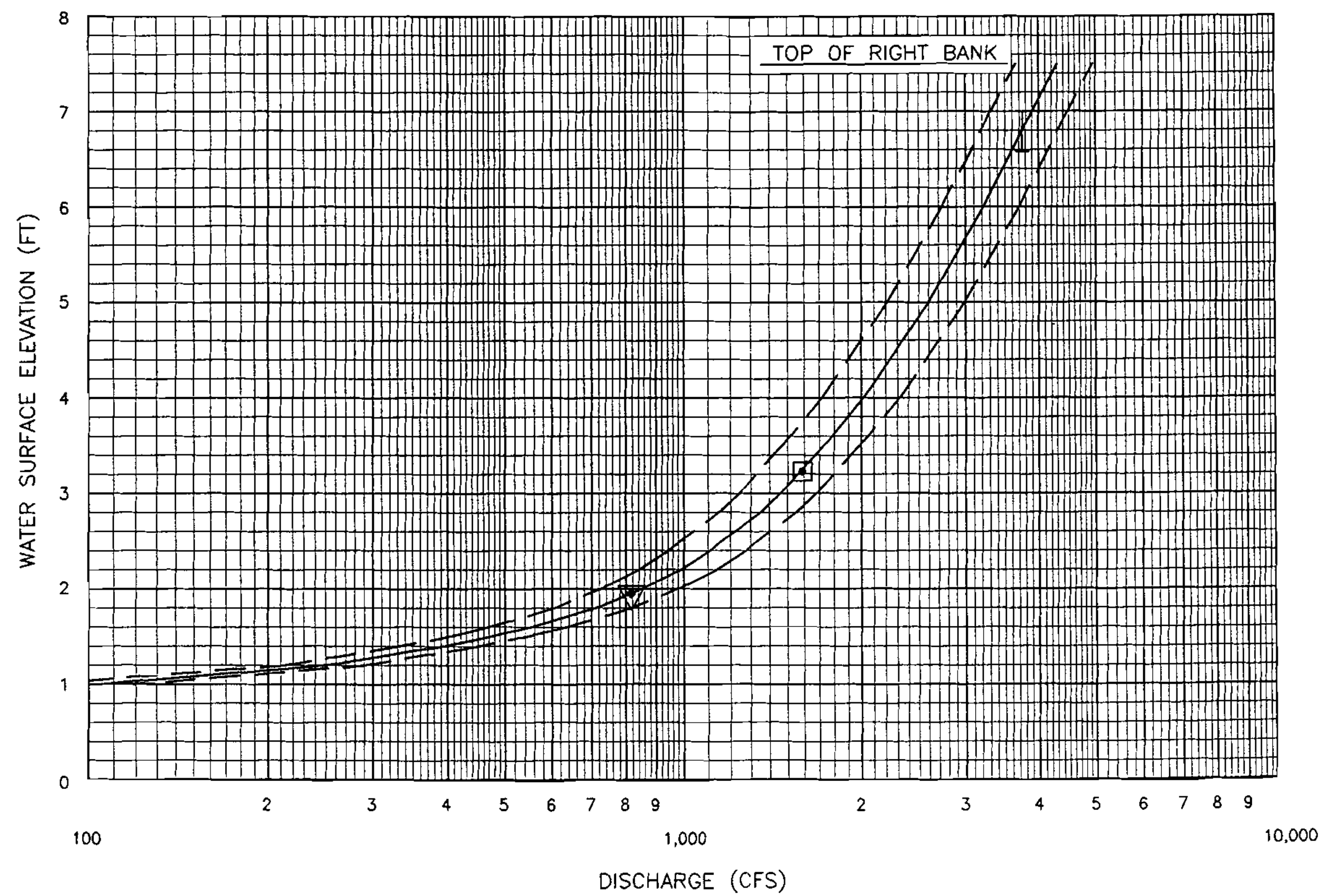
SUBJECT: RIVER CHANNEL CROSS SECTION AT S09.80 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	7/2/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	L1259F13.DWG
CHECKED:	SRR	SCALE:	VARIES

FIGURE: 13

SAKOONANG CHANNEL– S09.80



THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 31 MAY 1996.

THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 12 JUNE 1995.

BASED ON THE DISCHARGE MEASUREMENT MADE IN 1962 AT A CROSS SECTION APPROXIMATELY 6 MILES UPSTREAM (ARNBORG ET AL. 1966).

THE MOST LIKELY DISCHARGE RATING CURVE.

THE UPPER AND LOWER LIMITS OF THE MOST LIKELY DISCHARGE RATING CURVE.

NOTES:

1. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).

PROJECT:	1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT
SUBJECT:	STAGE–DISCHARGE RELATIONSHIP FOR CROSS SECTION S09.80 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

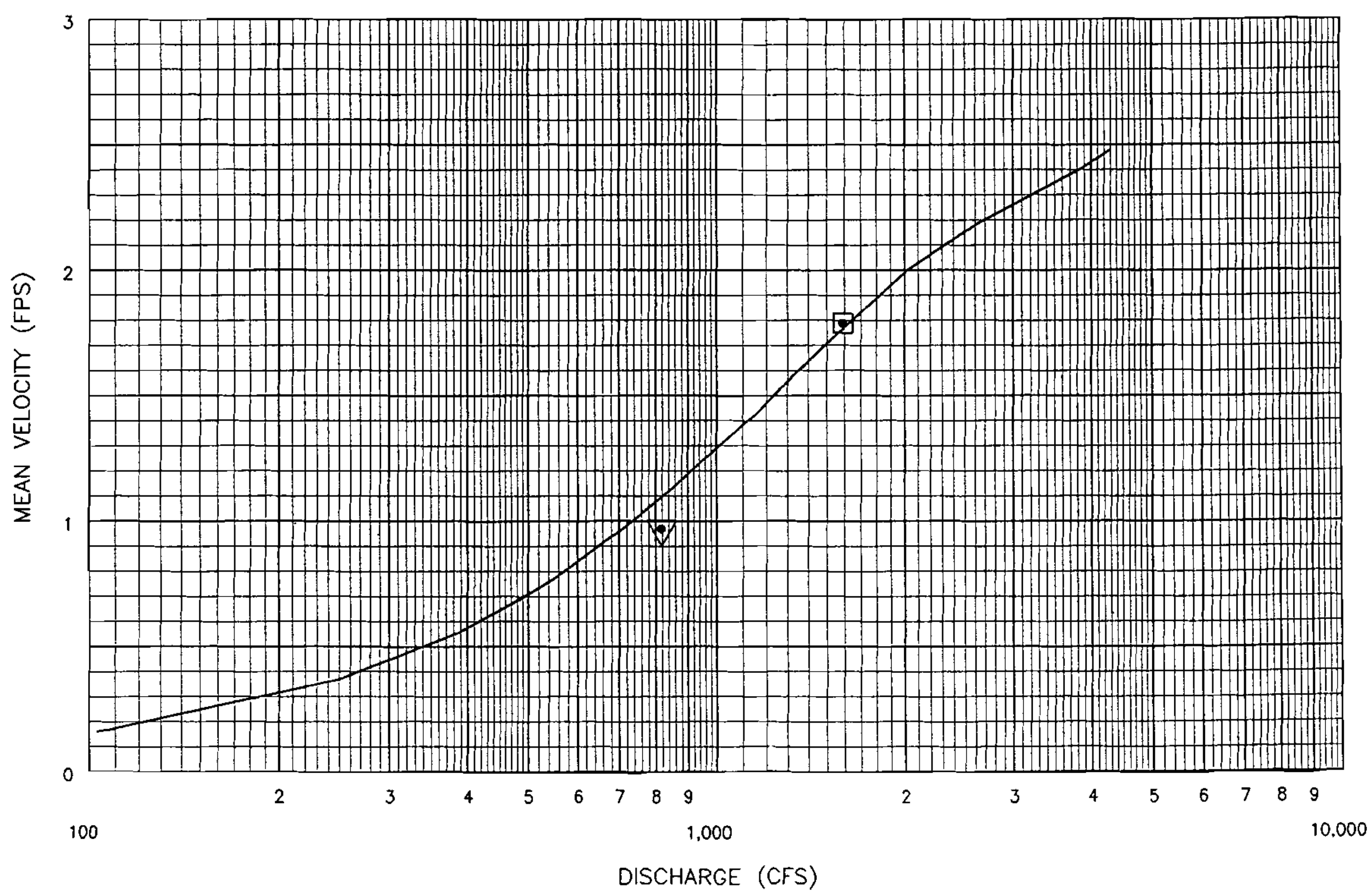
SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	8/26/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	L1259F14
CHECKED:	SRR	SCALE:	VARIES

FIGURE: 14

NO.	DATE:	REVISION	BY:

SAKOONANG CHANNEL- S09.80



⊡ BASED ON THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 31 MAY 1996.

▽ BASED ON THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 12 JUNE 1995.

NO.:	DATE:	REVISION	BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

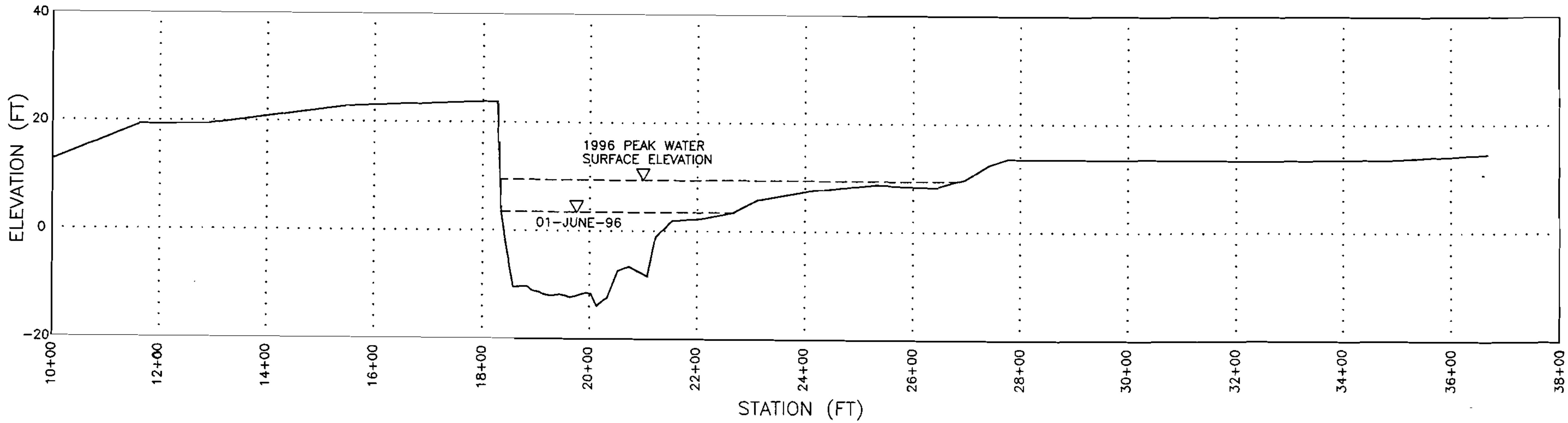
SUBJECT: VELOCITY-DISCHARGE RELATIONSHIP FOR CROSS SECTION S09.80 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	8/26/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	L1259F15.DWG
CHECKED:	SRR	SCALE:	VARIES

FIGURE: 15

CROSS SECTION T12.62 (TAMAYAYAK CHANNEL)



NOTES:

1. THE 1996 SPRING FLOOD PEAK DISCHARGE WAS NOT ESTIMATED AT THIS CROSS SECTION.
2. THE 1996 SPRING PEAK WATER-SURFACE ELEVATION (9.37 FEET) WAS DUE TO BACKWATER FROM AN ICE JAM.
3. A DISCHARGE MEASUREMENT WAS MADE ON 01 JUNE 1996 AT AN ELEVATION OF 3.43 FEET.
4. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).
5. CROSS SECTION IS PRESENTED LOOKING DOWNSTREAM.
6. CROSS SECTION IS NAMED BASED ON RIVER MILES FROM THE MOUTH OF THE CHANNEL.

NO.	DATE:	REVISION	BY:

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

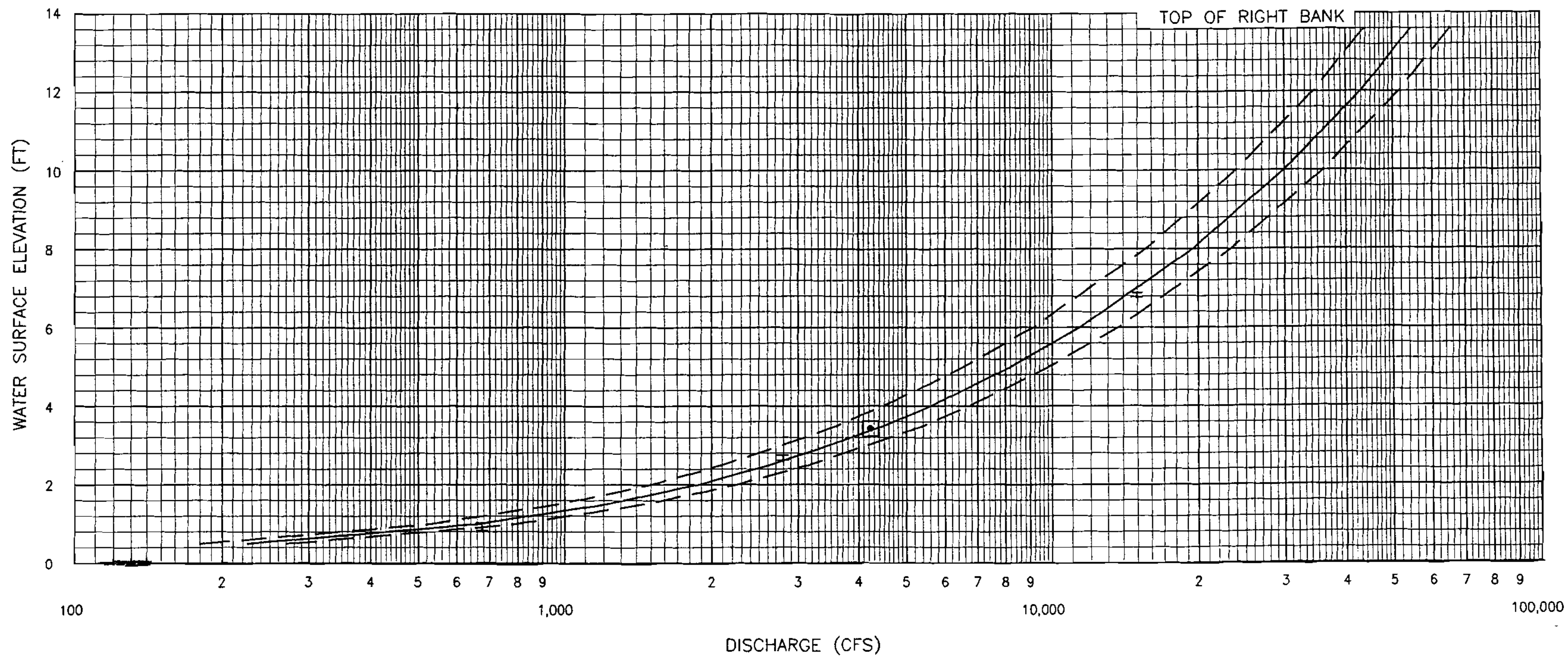
SUBJECT: RIVER CHANNEL CROSS SECTION AT T12.62 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE: 7/2/96 | PROJECT: L-1259
DRAWN: BC | FILE: L1259F16.DWG
CHECKED: SRR | SCALE: VARIES

FIGURE 16

TAMAYAYAK CHANNEL–T12.62



THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 01 JUNE 1996.

BASED ON DISCHARGE MEASUREMENTS MADE IN 1962 AT A CROSS SECTION APPROXIMATELY 1 MILE UPSTREAM (ARNBORG ET AL. 1966).

—— THE MOST LIKELY DISCHARGE RATING CURVE.

— — THE UPPER AND LOWER LIMITS OF THE MOST LIKELY DISCHARGE RATING CURVE.

NOTES:

1. ELEVATION DATUM IS BASED ON BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL).

PROJECT:	1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT
SUBJECT:	STAGE–DISCHARGE RELATIONSHIP FOR CROSS SECTION T12.62 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

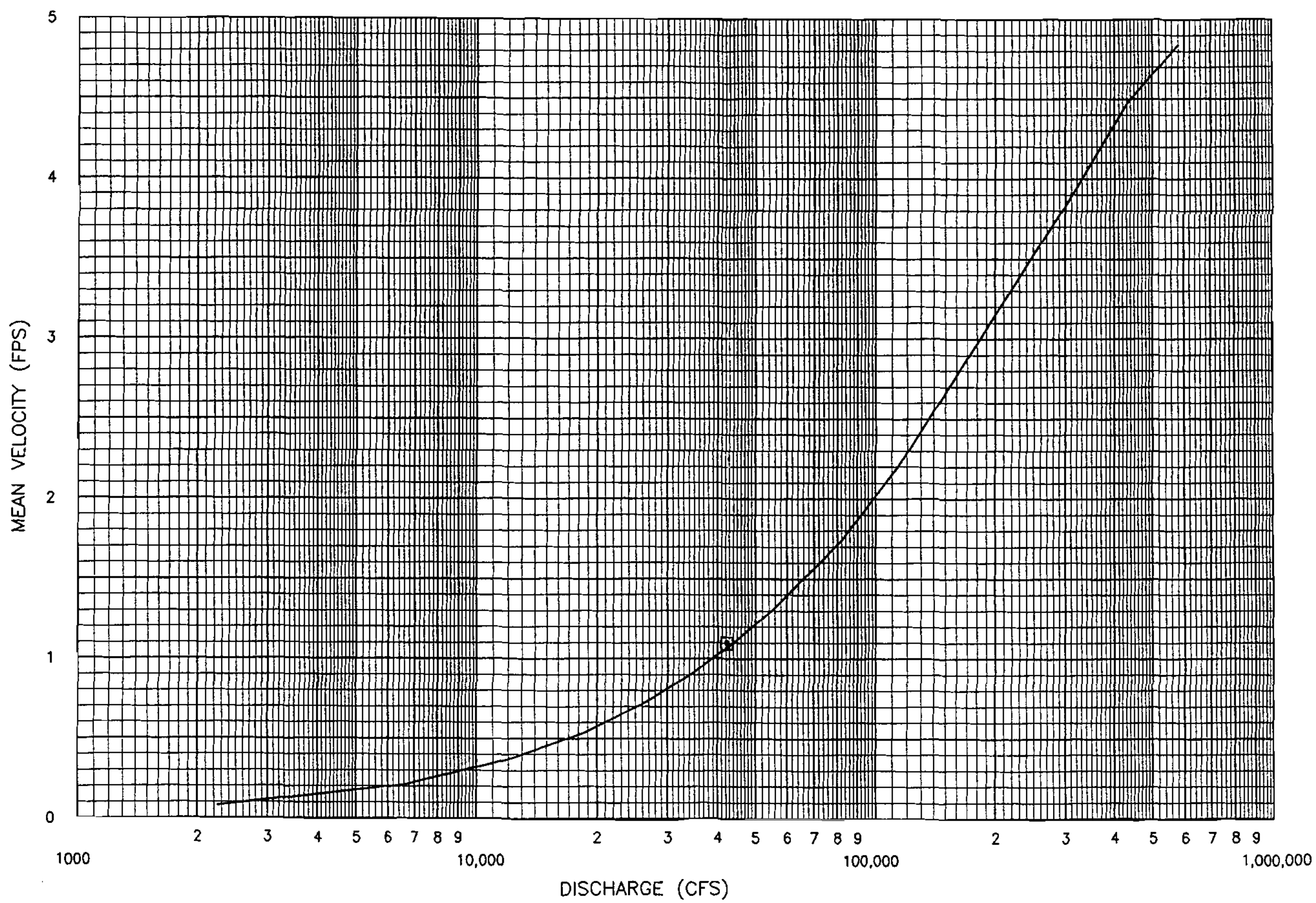
DATE:	8/26/96	PROJECT:	L-1259
DRAWN:	BC	FILE:	L1259F17.DWG
CHECKED:	SRR	SCALE:	VARIES

FIGURE: 17

REVISION

NO.:	DATE:		BY:

TAMAYAYAK CHANNEL–T12.62



▣ BASED ON THE DISCHARGE MEASUREMENT MADE BY SHANNON & WILSON ON 01 JUNE 1996.

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS	
DATE: 8/26/96	PROJECT: L-1259
DRAWN: BC	FILE: L1259F18.DWG
CHECKED: SRR	SCALE: VARIES

PROJECT: 1996 COLVILLE RIVER SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

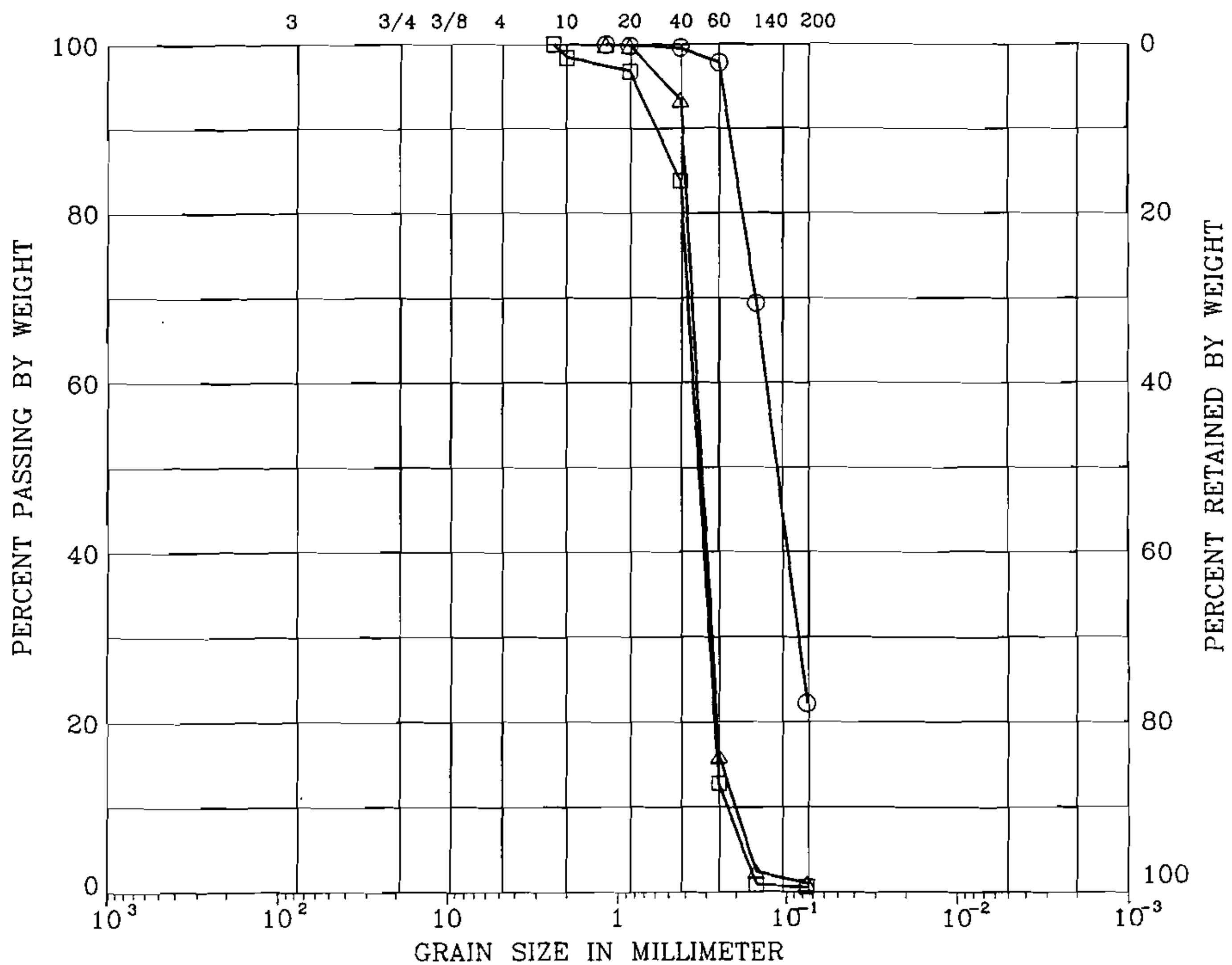
SUBJECT: VELOCITY-DISCHARGE RELATIONSHIP FOR CROSS SECTION T12.62 COLVILLE RIVER DELTA, NORTH SLOPE, ALASKA

REVISION		
NO.:	DATE:	BY:

FIGURE: 18

UNIFIED SOIL CLASSIFICATION

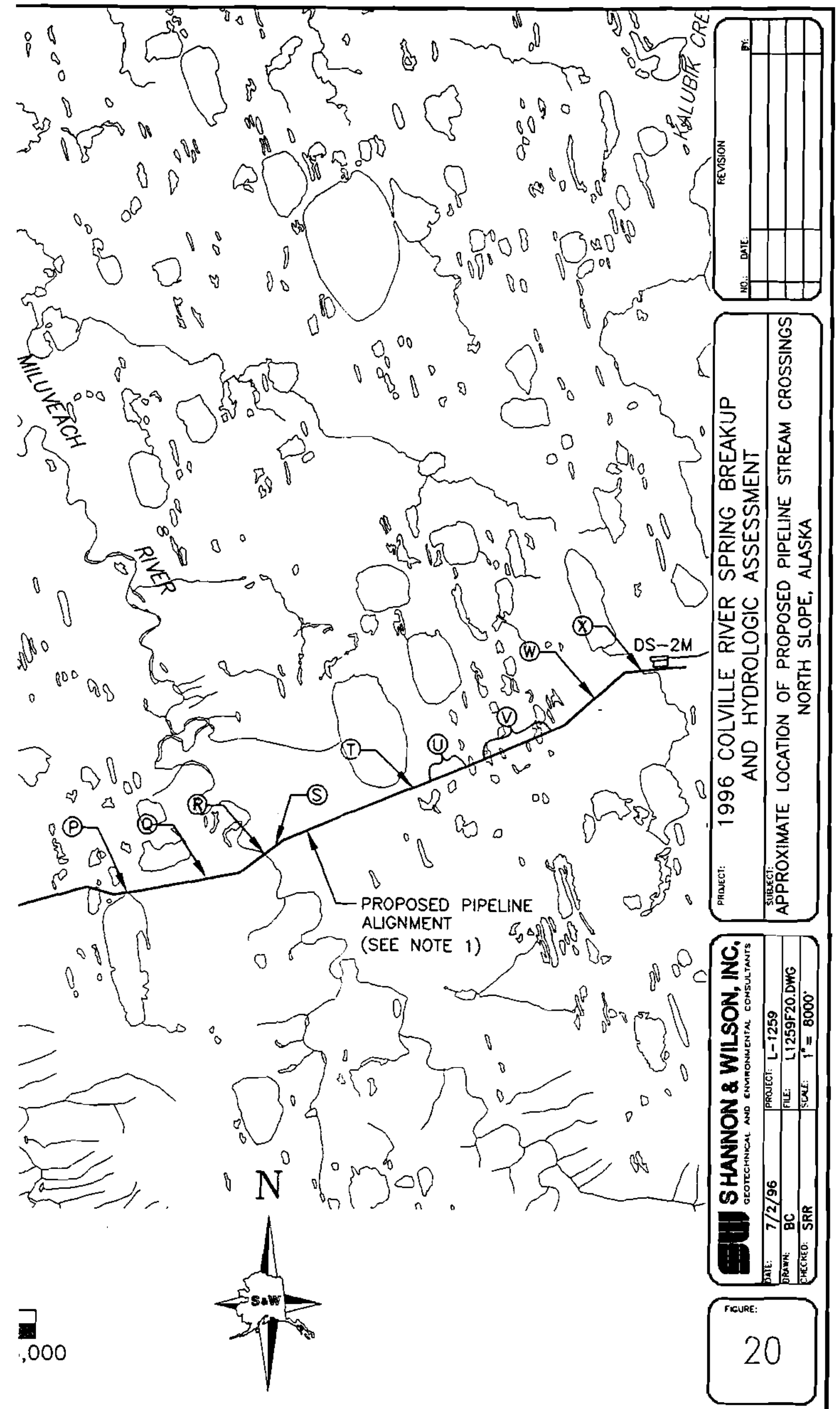
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER

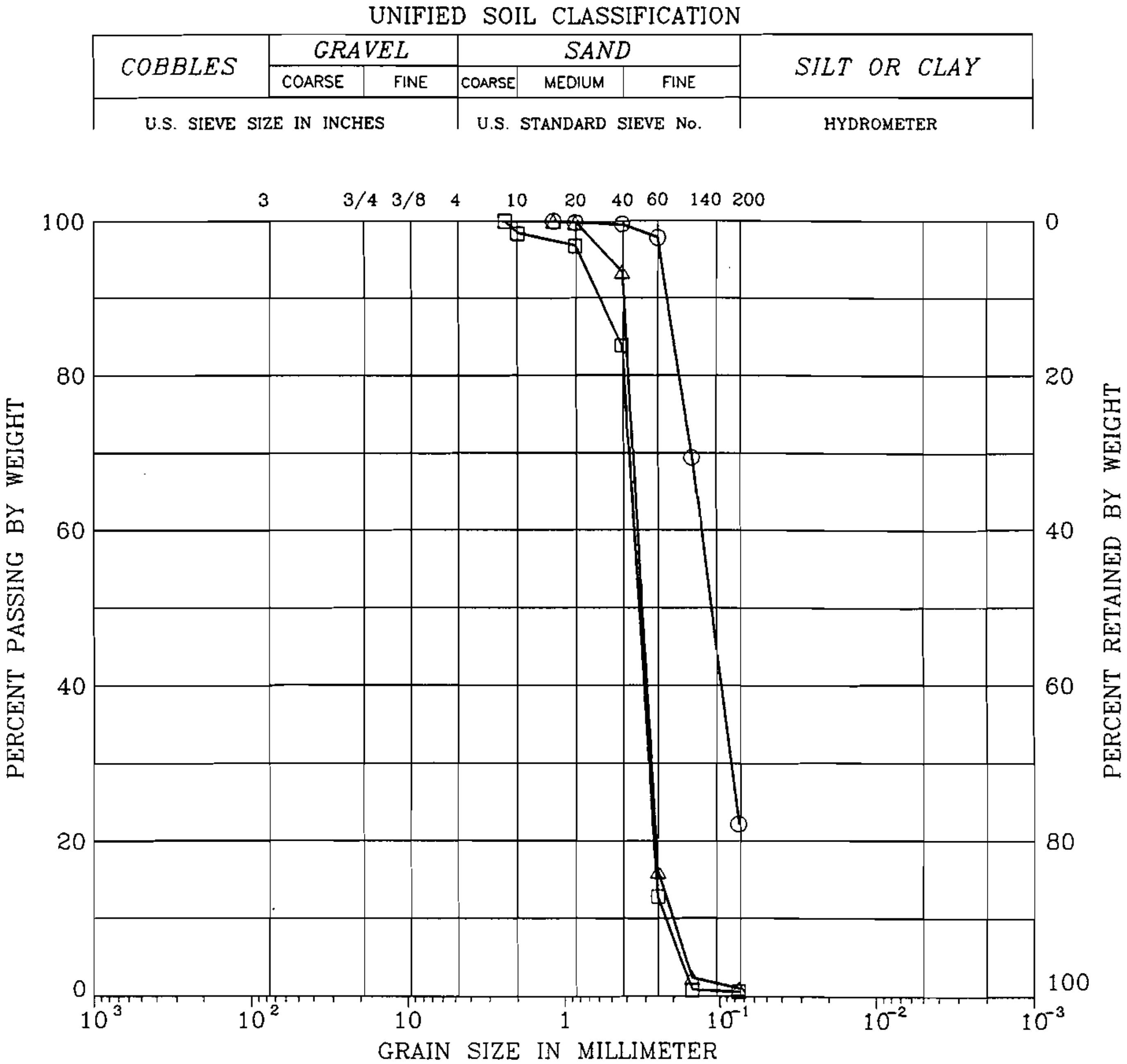


SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	BM-1				Bed Material Sample at Station 2897
□	BM-2				Bed Material Sample at Station 3153
△	BM-3				Bed Material Sample at Station 3340

Remark : Cross Section N19.95 Bed Material Samples

Project No. L-1259	1996 Colville River Hydrological Assessment
Shannon & Wilson, Inc. Geotechnical Consultants	GRAIN SIZE DISTRIBUTION Figure No. 19

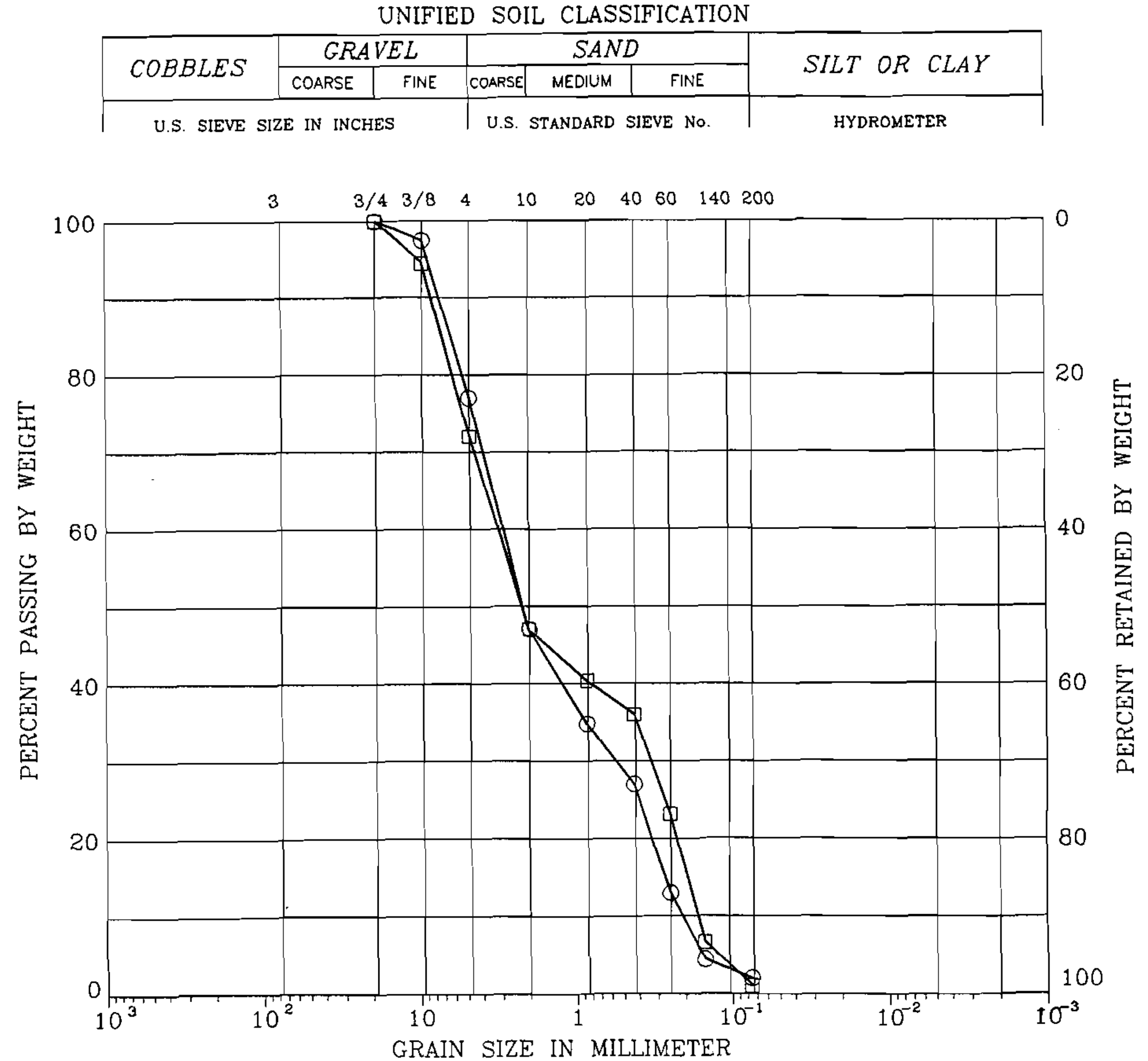




SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	BM-1				Bed Material Sample at Station 2897
□	BM-2				Bed Material Sample at Station 3153
△	BM-3				Bed Material Sample at Station 3340

Remark : Cross Section N19.95 Bed Material Samples

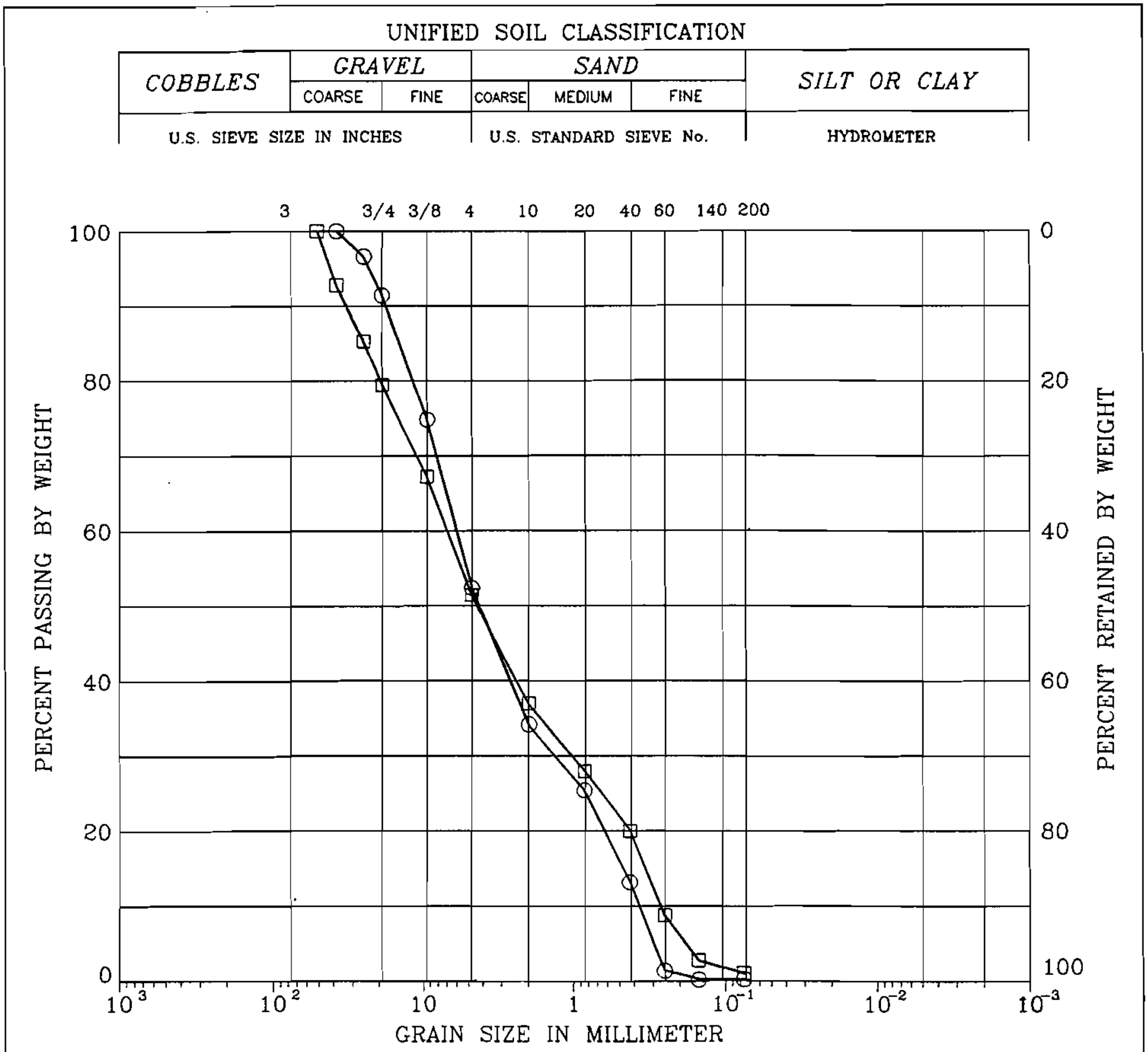
Project No. L-1259	1996 Colville River Hydrological Assessment
Shannon & Wilson, Inc. Geotechnical Consultants	**GRAIN SIZE DISTRIBUTION** Figure No. 19



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	Stream L				Stream L Bed Material Sample
□	Stream X				Stream X Bed Material Sample

Remark : Samples taken at proposed pipeline crossing

Project No. L-1259	1996 Colville River Hydrologic Assessment
Shannon & Wilson, Inc. Geotechnical Consultants	GRAIN SIZE DISTRIBUTION Figure No. 21



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	Kach-1				Kachemach River Bed Material Sample
□	Milu-1				Miluveach River Bed Material Sample

Remark : Samples taken at proposed pipeline crossing

Project No. L-1259	1996 Colville River Hydrologic Assessment
Shannon & Wilson, Inc. Geotechnical Consultants	GRAIN SIZE DISTRIBUTION Figure No. 22

APPENDIX C
PHOTOGRAPHS

LIST OF PHOTOGRAPHS

LIST OF PHOTOGRAPHS (cont.)

*Note that the date shown on the photo is incorrect for the following photographs: C-17, C-23, C-26, C-27, C-34, C-36.

Photo C-1: 19 May 96
Looking upstream from E27.09, showing initial spring runoff event.
Ice is over the low-water channel.

Photo C-2: 24 May 96
Looking upstream from E27.09, showing the drop in the water level after the initial spring runoff event.
Ice is over the low-water channel.

NO.	DATE:	REVISION:	BY:

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: COLVILLE RIVER DELTA

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	14 OCT 1996	PROJECT:	L-1259
DRAWN:	CJH	FILE:	C-1_C-2.DS4
CHECKED:	JWA	SCALE:	

Photo C-3: 19 May 96
Looking southwest at the Nechelik Channel from the vicinity of river mile N19. Nuiqsut is visible in the upper right hand corner on the west bank.

Photo C-4: 20 May 96
Looking north at the Sakoonang Channel from the vicinity of river mile S12.

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DATE	14 OCT 1996	PROJECT	L-1259
DRAWN	CJH	FILE	C-3-4.DS4
CHECKED	JWA	SCALE	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: COLVILLE RIVER DELTA

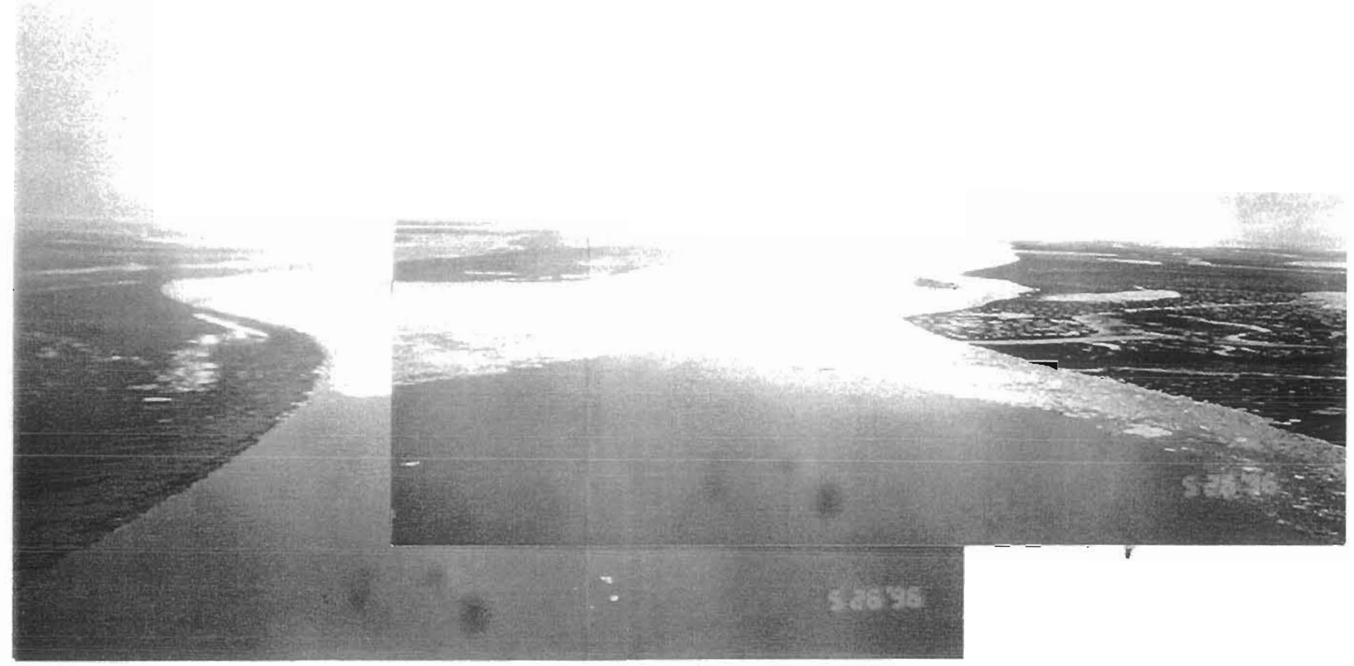

Photo C-5: 26 May 96
Looking at the upstream end of the ice jam in the Colville River from the vicinity of river mile E27.
The ice jam is at the upstream end of the Nechelik Channel and is in both the Nechelik and East Channels.

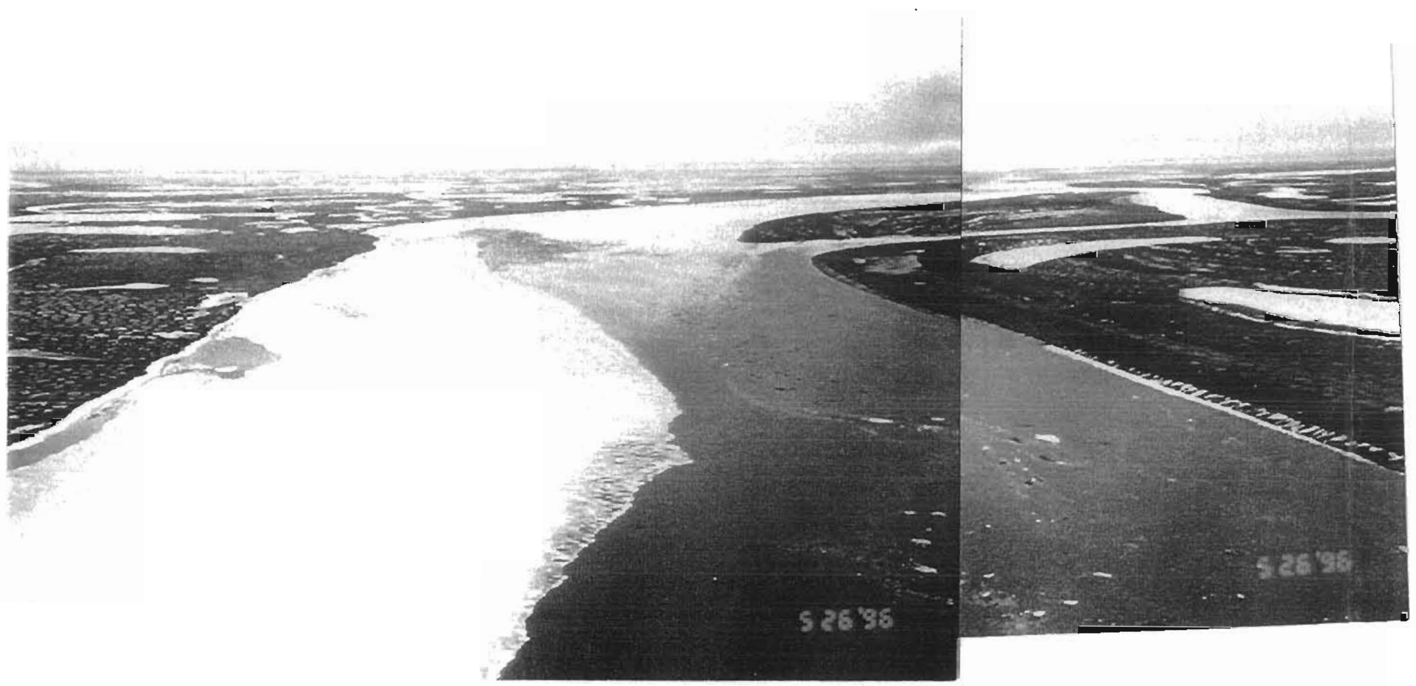

Photo C-6: 26 May 96
Looking upstream from E20.56 at the downstream end of the ice jam in the Colville River.
The ice at E20.56 is over the low-water channel.

Photo C-7: 26 May 96
Looking downstream from E20.56.
The ice is over the low water channel.

NO.	DATE:	REVISION:	BY:

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: COLVILLE RIVER DELTA

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DATE:	14 OCT 1996	PROJECT:	L-1259
DRAWN:	CJH	FILE:	C-5-6-7.DS4
CHECKED:	JWA	SCALE:	

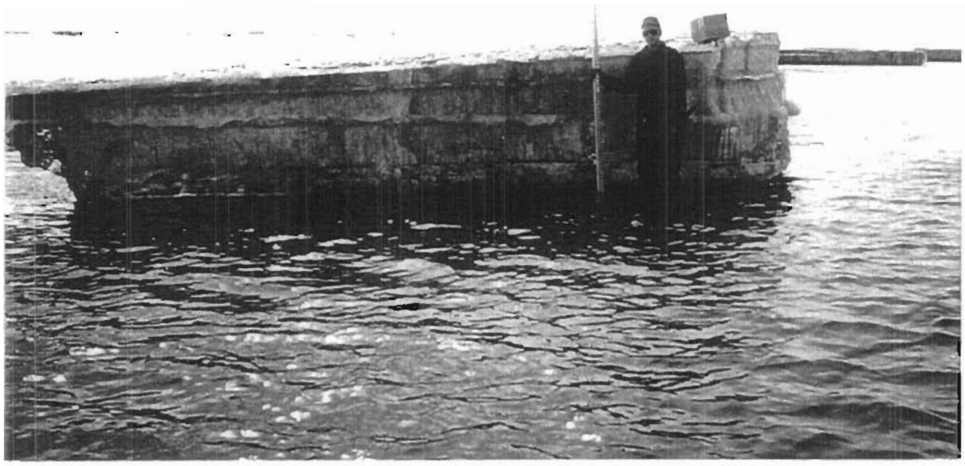

Photo C-8: 20 May 96
Rafted ice floe at E27.09.

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DATE	14 OCT 1996	PROJECT	L-1259
DRAWN	CJH	FILE	C-8.DS4
CHECKED	JWA	SCALE	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: COLVILLE RIVER DELTA

Photo C-9: 3 June 96
Looking south at Stream A.

Photo C-10: 3 June 96
Looking south at Stream B.

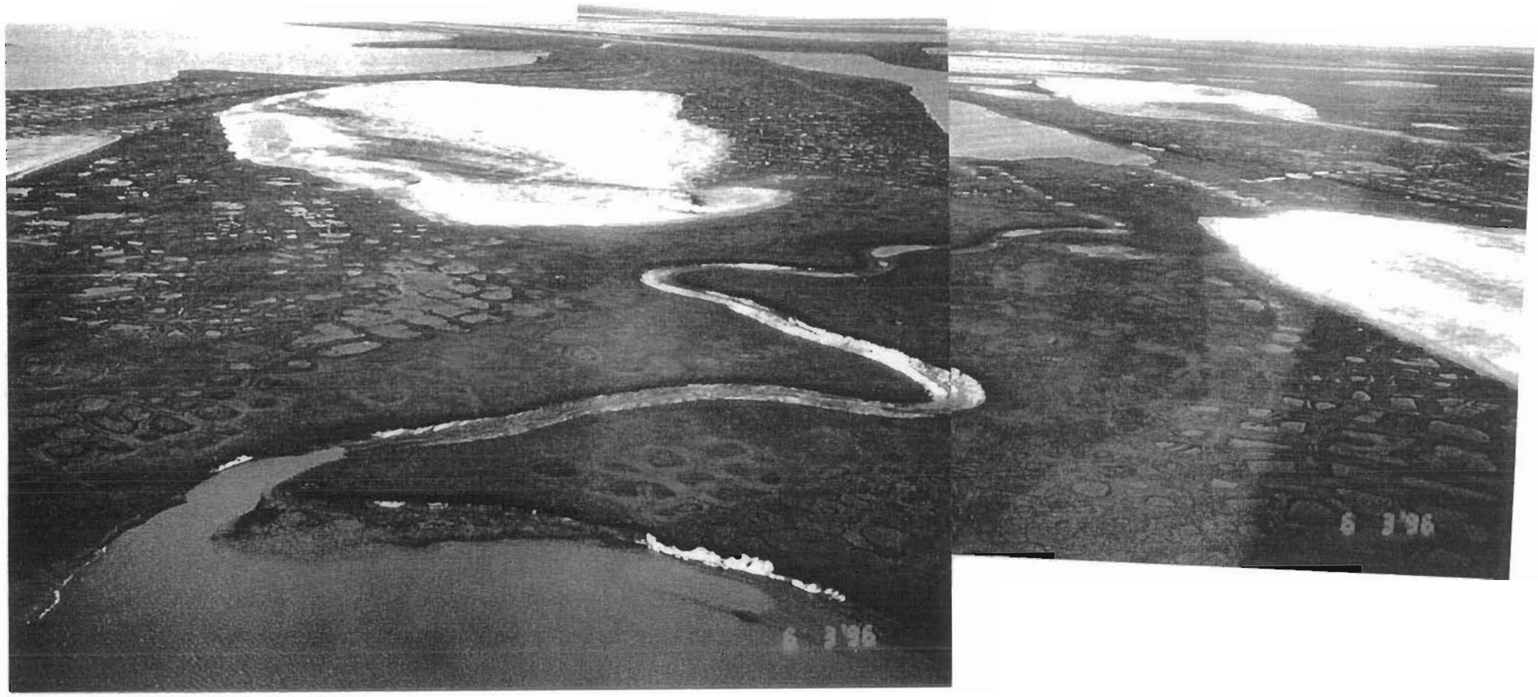

Photo C-11: 3 June 96
Looking south at Stream C.

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS	
DATE: 14 OCT 1996	PROJECT: L-1259
DRAWN: CJH	FILE: C-11.DS4
CHECKED: JWA	SCALE:

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

REVISION			
NO.	DATE		BY:

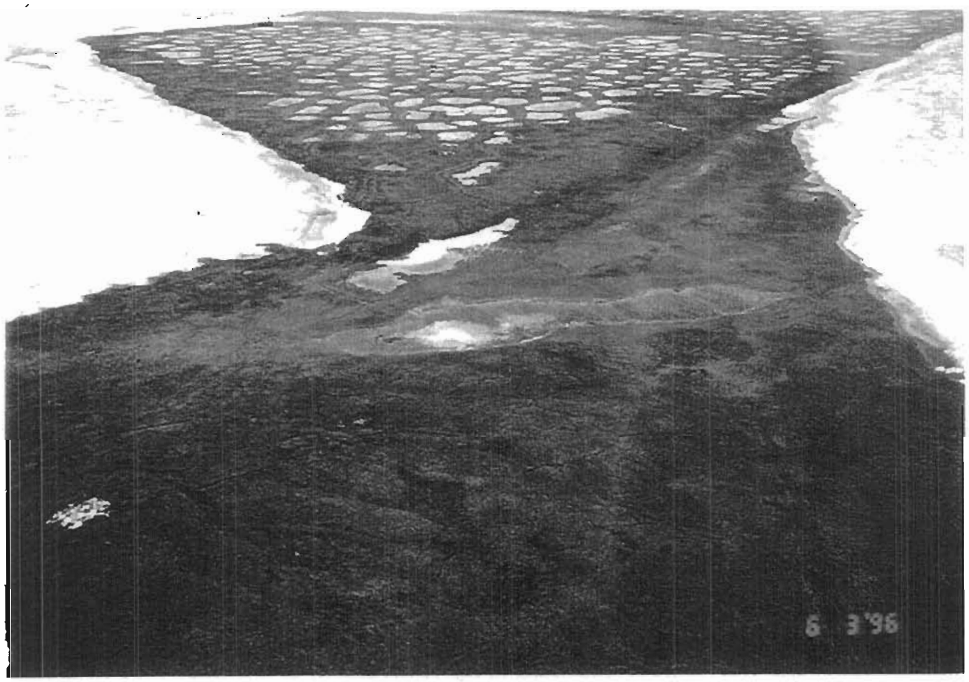

Photo C-12: 3 June 96
Looking west at Stream E.

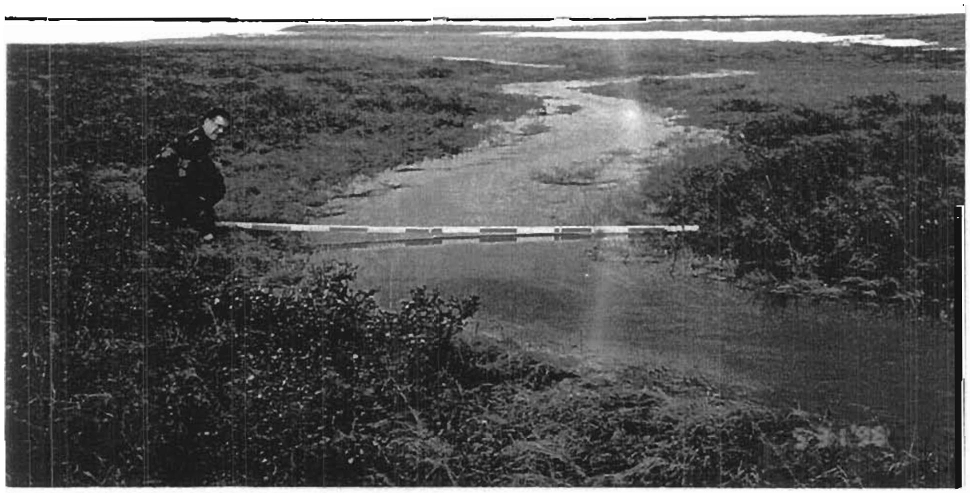

Photo C-13: 31 May 96
Looking downstream at Stream F.

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE	14 OCT 1996	PROJECT	L-1259
DRAWN	CJH	FILE	C-12-13.DS4
CHECKED	JWA	SCALE	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

Photo C-14: 31 May 96
Looking downstream at Stream G.

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE	14 OCT 1996	PROJECT	L-1259
DRAWN	CJH	FILE	C-14.DS4
CHECKED	JWA	SCALE	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

Photo C-15: 31 May 96
Looking upstream at Stream H.

Photo C-16: 31 May 96
Looking upstream at Stream H from about
400 feet upstream from the lake.

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE	14 OCT 1996	PROJECT	L-1259
DRAWN	CJH	FILE	C-15-16.DS4
CHECKED	JWA	SCALE	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

Photo C-17: 31 May 96
Looking upstream from the vicinity of the proposed pipeline crossing at the Tributary to the Kachemach River (Stream I).

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE	14 OCT 1996	PROJECT	L-1259
DRAWN	CJH	FILE	C-17.DS4
CHECKED	JWA	SCALE	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

Photo C-18: 1 June 96
Looking north (downstream) at Stream K.

Photo C-19: 1 June 96
Looking downstream at Stream K from the vicinity of the proposed pipeline crossing.

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS	
DATE 14 OCT 1996	PROJECT L-1259
DRAWN CJH	FILE C-18-19.DS4
CHECKED JWA	SCALE

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

Photo C-20: 1 June 96
Looking north (downstream) at Stream L.

Photo C-21: 1 June 96
Looking upstream at Stream L from the vicinity of the proposed pipeline crossing.

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE	14 OCT 1996	PROJECT	L-1259
DRAWN	CJH	FILE	C-20-21.DS4
CHECKED	JWA	SCALE	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

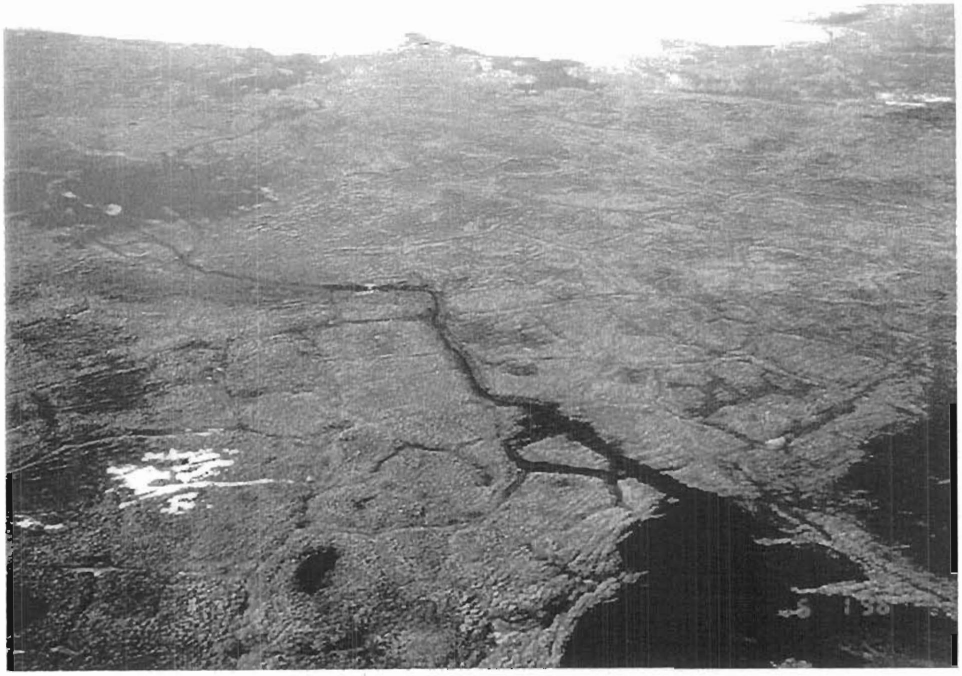

Photo C-22: 1 June 96
Looking north at
Stream M.

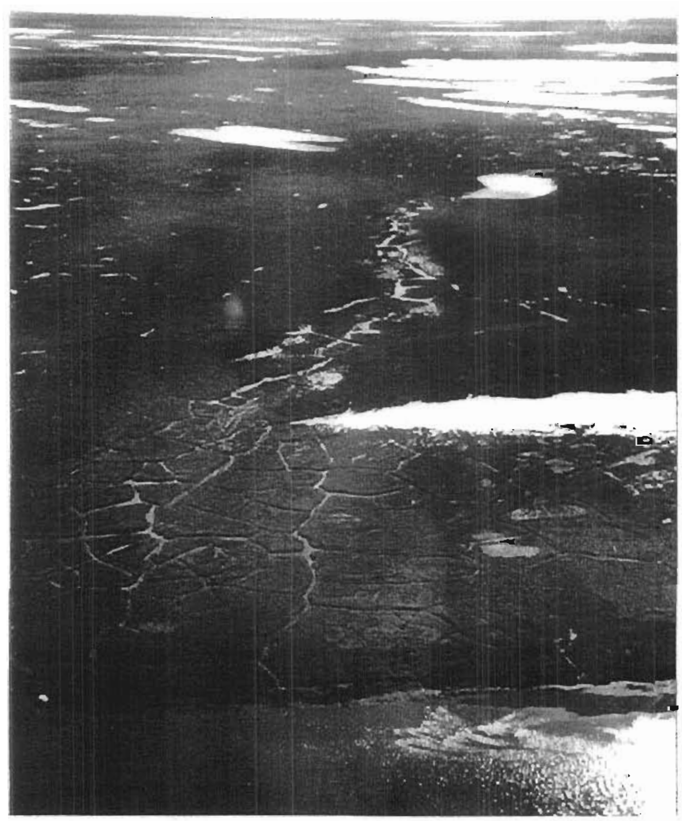

Photo C-23: 31 May 96
Looking southwest (upstream) at
Stream N.

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE	14 OCT 1996	PROJECT	L-1259
DRAWN	CJH	FILE	C-22-23.DS4
CHECKED	JWA	SCALE	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

Photo C-24: 26 May 96
Looking north (downstream) at the Kachemach River
in the vicinity of the proposed pipeline crossing.

Photo C-25: 26 May 96
Looking downstream at the Kachemach River
toward the proposed pipeline crossing.

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS				PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT
DATE	14 OCT 1996	PROJECT	L-1259	SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE
DRAWN	CJH	FILE	C-24-25.DS4	
CHECKED	JWA	SCALE		

Photo C-26: 31 May 96
Looking southwest at Stream P.
Flow in polygonal troughs may not be continuous between the lake in the foreground and the lake in the upper left portion of the photograph.

Photo C-27: 31 May 96
Looking southwest (upstream) at Stream Q.

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS			
DATE	14 OCT 1996	PROJECT	L-1259
DRAWN	CJH	FILE	C-26-27.DS4
CHECKED	JWA	SCALE	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

Photo C-28: 29 May 96
Looking north (downstream) at the Miluveach River
in the vicinity of the proposed pipeline crossing.

Photo C-29: 25 May 96
The Miluveach River. Windblown snow is
visible in the bottom of the channel.

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS		PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT
DATE: 14 OCT 1996	PROJECT: L-1259	SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE
DRAWN: CJH	FILE: C-28-29.DS4	
CHECKED: JWA	SCALE:	

Photo C-30: 29 May 96
Looking upstream at Stream S.

Photo C-31: 29 May 96
Looking upstream at Stream T.

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE	14 OCT 1996	PROJECT	L-1259
DRAWN	CJH	FILE	C-30-31.DS4
CHECKED	JWA	SCALE	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

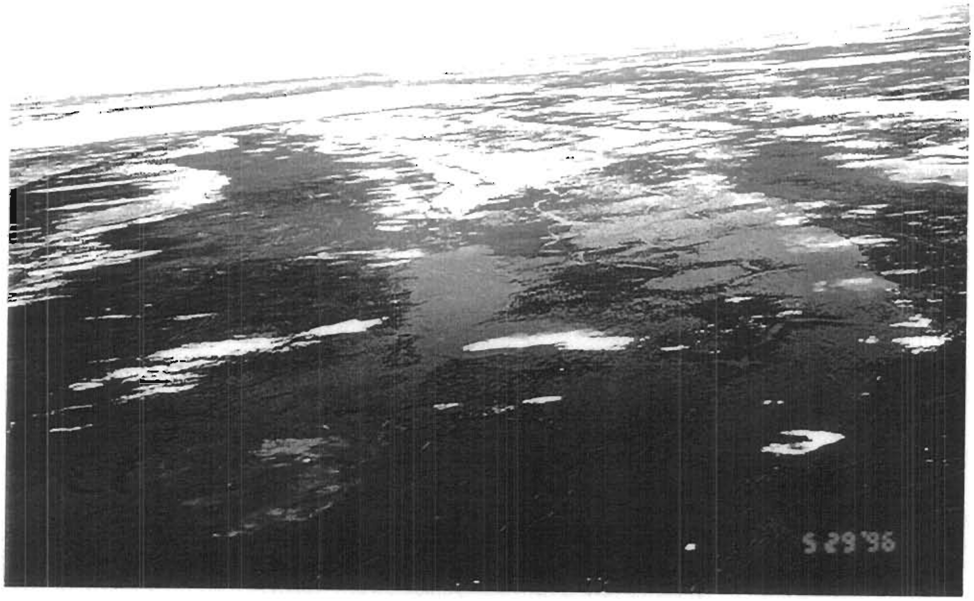

Photo C-32: 29 May 96
Looking downstream at Basin U.

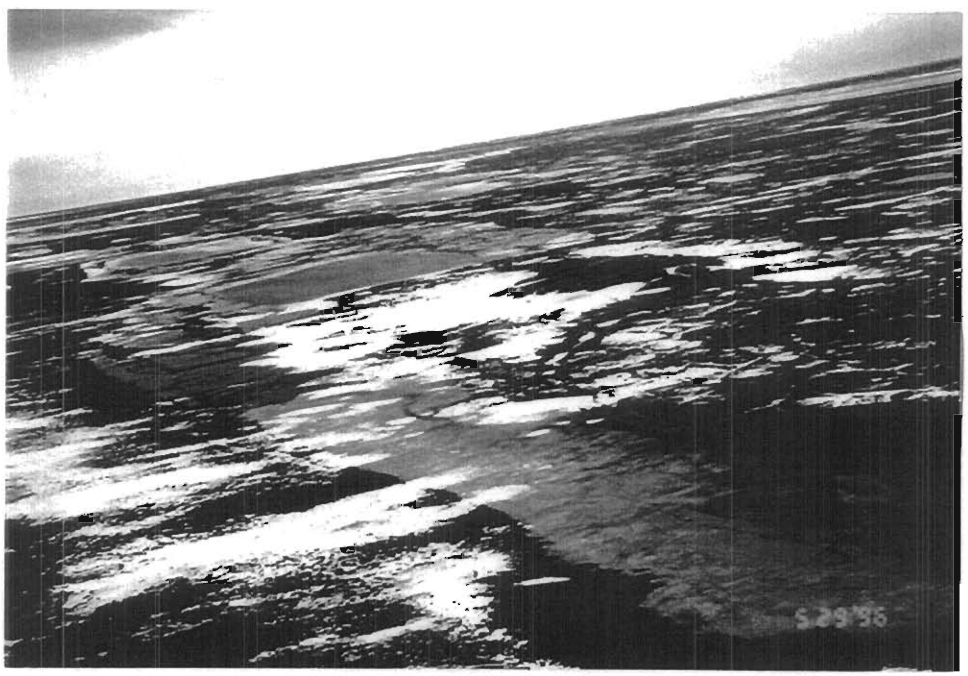

Photo C-33: 29 May 96
Looking east at Basin V.

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	14 OCT 1996	PROJECT:	L-1259
DRAWN:	CJH	FILE:	C-32-33.DS4
CHECKED:	JWA	SCALE:	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

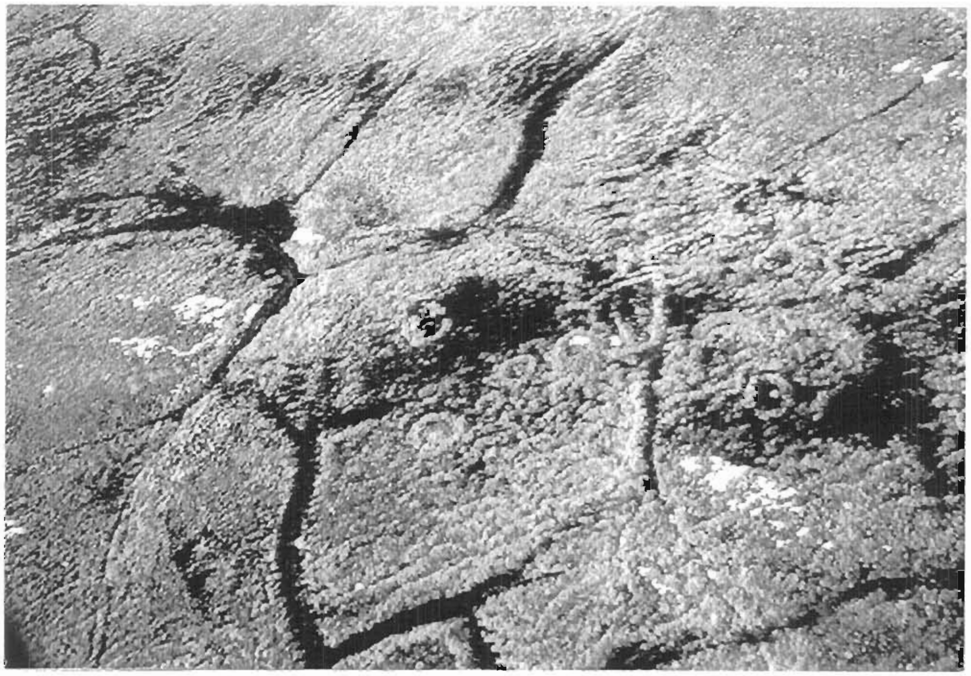

Photo C-34: 28 May 96
Looking west (downstream) at Stream W.

Photo C-35: 29 May 96
Looking downstream at Stream W.

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE:	14 OCT 1996	PROJECT:	L-1259
DRAWN:	CJH	FILE:	C-34-35.DS4
CHECKED:	JWA	SCALE:	

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

Photo C-36: 28 May 96
Looking upstream at Stream X.

Photo C-38: 2 June 96
Looking downstream at Stream X from the proposed pipeline crossing.
The water has eroded through the windblown snow.

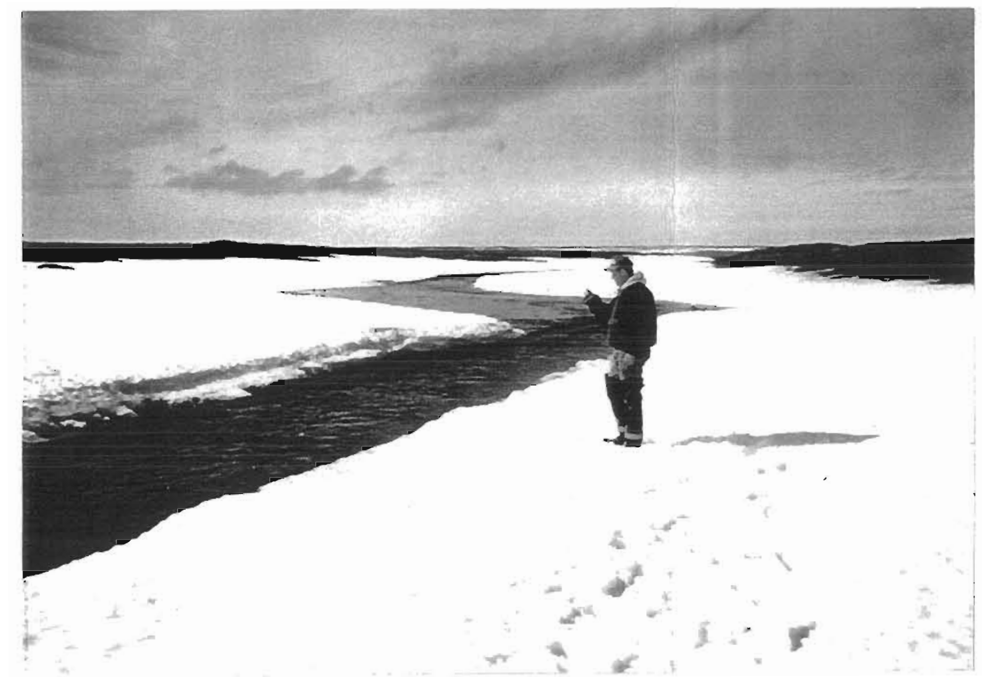

Photo C-37: 28 May 96
Looking downstream at Stream X.
The water was flowing on windblown snow.

NO.	DATE:	REVISION:	BY:

PROJECT: 1996 COLVILLE RIVER DELTA SPRING BREAKUP AND HYDROLOGIC ASSESSMENT

SUBJECT: STREAMS ALONG THE PROPOSED PIPELINE ROUTE

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DATE: 14 OCT 1996	PROJECT: L-1259
DRAWN: CJH	FILE: C-36-38.DS4
CHECKED: JWA	SCALE:

APPENDIX D
METHODS

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Water-Surface Elevation Measurements

Water-surface elevations were measured at selected locations throughout the delta during the period May 18 to June 11. The elevations were based on monuments that were installed in April 1996 by Lounsbury and Associates (Shannon & Wilson, 1996). The location of the monuments is shown on Figure 1. The elevation datum is British Petroleum Mean Sea Level (BPMSL). Selected temporary benchmarks (TBMs) used in 1995 were also tied to this datum. A rod and automatic level were typically used to make the water surface elevation measurements.

A Campbell CR-21 data logger with a NWI-2000 pressure transducer was installed to collect continuous water-surface elevations at two locations. From May 29 through June 6 the data logger was at E27.09. From June 6 through June 11 the data logger was at the Helmerick's Homestead (E3.50). The recorder collected water-surface elevation data every half hour.

Discharge Measurements

Discharge measurements were made in the delta at Cross Sections E20.56, N19.95, S09.80, and T12.62, and at the Kachemach and Miluveach rivers along the proposed pipeline route. In general, the techniques described in *Discharge Measurements at Gaging Stations* (USGS, 1984) were used to make the discharge measurements. The purpose of the discharge measurements was to provide data that can be used to estimate: channel hydraulic roughness, distribution of flow between the distributaries, and stage-discharge and velocity-discharge relationships. The discharge measurements were made from a boat with a Price AA current meter. In the Kachemach and Miluveach Rivers the current meter was suspended from a wading rod. In all other rivers the current meter was suspended from a bridge reel, using a 75-pound weight. At Cross Sections E20.56 and N19.95, the horizontal position of the boat was estimated using a theodolite to measure the angle between a TBM on the river bank and the boat. At Cross Sections S09.80 and T12.62 and at the Kachemach & Miluveach Rivers, a tag line was used to determine the location of the measurement along the cross section. The water-surface elevation was recorded periodically during the discharge measurements, and a weighted-average water-surface elevation was used as the water-surface elevation corresponding to the discharge measurement. The water-surface slope was measured prior to, and immediately after, the discharge measurement.

Sediment Sampling

Sediment samples were collected to assist in the analysis of scour. Samples were collected for suspended sediment, bedload, and bed material. The collection of each type of sample is described below.

Suspended Sediment

Suspended sediment samples were collected at Cross Section E20.56 using techniques described by Guy and Norman (1970). The samples were collected using a U.S. D-49 depth-integrated sampler suspended from a bridge reel at the front of a boat. Each sample was collected by lowering and raising the sampler at a constant rate. The nozzle and sampling rate were selected such that the sample bottle would not overfill during the sampling. The same sampling rate and nozzle were used at all locations within the cross section. Because of insufficient time, only three samples were collected.

Bedload Sediment

Bedload samples were collected at E20.56 using a 65-lb Helley-Smith sampler (3-inch by 3-inch opening) suspended from a bridge reel at the front of a boat. The mesh size of the sediment collection bag was 0.25 mm. Samples were collected at intervals which were approximately the same as those used for the discharge measurement. Two traverses across the channel were made, with half the intervals being sampled on each traverse. The length of time the sampler remained on the riverbed was set such that the sediment-collection bag was not filled to greater than 50 percent of capacity during any individual measurement. The maximum length of time the sampler remained on the riverbed at any single location was 10 minutes. The samples were individually dried, weighed, and stored. The total load was computed by summing the load calculated in each section. The steps of the calculation are shown in Table 10.

Bed Material

Bed material samples were taken in the delta at Cross Section N19.95 using a pipe dredge and a boat. Bed material samples were also collected along the proposed pipeline route at the tributary to the Kachemach River (Stream I), the Kachemach River, the Miluveach River, and Streams F, L, and X. These samples were collected within the low-water channel using a shovel. Grain-size analyses were conducted with the washed-sieve method (ASTM D-422-72) on all samples, except those collected from Streams F and I. Samples F and I were assessed visually.

Preparation of Stage-Discharge-Velocity Relationships

Stage-discharge and velocity-discharge relationships were developed for E27.09, E20.56, N19.95, S09.08, and T12.62 using the data collected in 1996, 1995, 1993, 1992, 1977, and 1962. The methods used to develop the relationships at each site are discussed below.

E27.09

The open-water stage-discharge relationship and velocity-discharge relationship for E27.09 were developed by Shannon & Wilson in March of 1996, using data collected at the head of the delta since 1962 (ABR, Inc. and Shannon & Wilson, Inc., 1996). The relationships presented in this report are the same as those developed in March except that they have been adjusted to the

BPMSL datum. Minimal and maximal likely stage-discharge relationships, based on ±15 percent of the most likely stage-discharge relationship, have also been added to the stage-discharge relationship.

E20.56

The open-water stage-discharge relationship and velocity-discharge relationship for E20.56 were based on discharge measurements made by Shannon & Wilson in 1996 and 1995, and normal-depth computations. The hydraulic roughness used in the computations was the average of the hydraulic roughness estimates from the 1995 and 1996 discharge measurements. The slope of the water surface used in the computations was varied with water-surface elevation. The relationship between the water-surface slope and the water-surface elevation was developed from the 1995 and 1996 water-surface elevation measurements in the vicinity of E20.56 (Tables 2 and 5). Because the final curve does not pass through the discharge measurements made in 1995 and 1996, there are slight differences between those discharge measurements and the discharge estimates based on the stage-discharge relationship (Table 7). Minimal and maximal likely stage-discharge relationships, based on ±20 percent of the most likely stage-discharge relationship, are shown to represent uncertainty in the stage-discharge relationship.

N19.95

The open-water stage-discharge relationship (Figure 11) and velocity-discharge relationship (Figure 12) for N19.95 were based on: normal-depth computations, a discharge and water-surface elevation measurement made for this project in 1996, and two discharge and water-surface elevation measurements made by Arnborg et al. (1966) in 1962. The 1962 discharge measurements were made near N17.8, approximately 2.15 miles downstream from Cross Section N19.95. The 1962 discharge measurements were adjusted to the BPMSL datum and for the difference in location on the channel, based on estimated water-surface slopes along the channel. The 1962 discharge measurements are plotted on Figure 11 as bars, to show the possible range in estimated water-surface elevation resulting from projecting the elevations upstream to N19.95.

The shape of the stage-discharge relationship (Figure 11) between the lowest and highest 1962 discharge measurements is based on a best-fit line passing through the measurements. However, the line through the 1962 measurements does not pass through the 1996 discharge measurement. Because the upper Nechelik and Putu channels are undergoing increased sedimentation (Walker, 1994), the channels probably carry less water at a given elevation than in 1962. It is therefore likely that the stage-discharge relationship has shifted towards the left, and now passes through the 1996 discharge measurement. The curve above the highest 1962 measurement is based on normal-depth computations using hydraulic roughness values calculated from the 1996 discharge measurement and adjusted for bedform. Because large flood events are likely to occur during spring breakup, the slope is based on the difference between the water-surface elevations at the cross section and the ocean (assuming the water-surface elevation at the ocean is approximately 2 feet during breakup). The portion of the curve below the lowest 1962 discharge measurement is based on a stage-discharge relationship developed by Arnborg et al. (1966) for cross section N17.8, approximately 2.15 miles downstream. Minimal and maximal likely stage-discharge relationships, based on ±20 percent of the most likely stage-discharge relationship, are shown to represent uncertainty in the stage-discharge relationship.

S09.80

The open-water stage-discharge relationship (Figure 14) and velocity-discharge relationship (Figure 15) for S09.80 were based on: normal-depth computations, discharge and water-surface elevation measurements made by Shannon & Wilson in 1996 and 1995, and a discharge and water-surface elevation measurement made by Arnborg et al. (1966) in 1962. The 1962 discharge and water-surface elevation measurement were made approximately 6 miles upstream from S09.80. The 1962 measurements were adjusted to the BPMSL datum and adjusted for the difference in location on the channel, based on estimated water-surface slopes along the channel. The 1962 discharge measurement is plotted on Figure 14 as a bar, to show the possible range in estimated water-surface elevation resulting from projecting the measured water-surface elevation downstream to S09.80.

The stage-discharge relationship, at water-surface elevations higher than the 1995 discharge measurement, was estimated by extending a curve through the 1995 and 1996 discharge measurements. The upper end of the relationship was established as the average of the 1962 discharge measurement and a normal-depth computation. The normal-depth computation used the hydraulic roughness from the 1996 discharge measurement and a slope based on a regression equation developed with 1996, 1995, and 1962 data. The lower end of the curve, at water-surface elevations below the 1995 discharge measurement, is based on the thalweg elevation (0.6 feet) at the inlet to the Sakoonang Channel (S16.52). This is the approximate elevation at which flow ceases to enter the Sakoonang Channel. When adjusted for slope, the elevation of zero flow at S09.80 is approximately 0.4 feet. Minimal and maximal likely stage-discharge relationships, based on ±15 percent of the most likely stage-discharge relationship, are shown to represent uncertainty in the stage-discharge relationship.

T12.62

The open-water stage-discharge relationship (Figure 17) and velocity-discharge relationship (Figure 18) for T12.62 were based on: normal-depth computations, a discharge and water-surface elevation measurement made by Shannon & Wilson in 1996, and three discharge and water-surface elevation measurements made by Arnborg et al. (1966) in 1962. The 1962 discharge and water-surface elevation measurements were made approximately 1 mile upstream from T12.62. The 1962 measurements were adjusted to the BPMSL datum and adjusted for the difference in location on the channel, based on estimated water-surface slopes along the channel. The 1962 discharge measurements are plotted on Figure 17 as bars, to show the possible range in estimated water-surface elevation resulting from projecting the measured water-surface elevation downstream to T12.62.

The stage-discharge relationship (Figure 17) was developed by passing a best-fit line through the discharge measurements made in 1996 and 1962. The curve above the highest discharge measurement is based on normal-depth computations. The hydraulic roughness values used in the computations were derived from the 1996 discharge measurement and adjusted for bedform. Because large flood events are likely to occur during spring breakup, the water-surface slopes used in the normal depth computations were based on the difference between the water-surface elevations at the cross section and the coast (assuming that the water-surface elevation at the coast was approximately 2 feet). The portion of the curve below the lowest discharge measurement is based on a stage-discharge relationship developed by Arnborg et al. (1966) at a cross section approximately 1 mile upstream. Minimal and maximal likely stage-discharge relationships, based on ± 20 percent of the most likely stage-discharge relationship, are shown to represent uncertainty in the stage-discharge relationship.

APPENDIX E
DESCRIPTIONS OF STREAMS ALONG THE PROPOSED PIPELINE ROUTE

A brief description of the characteristics of each stream is presented below. A summary of the characteristics is presented in Table 12, and photographs of the streams are presented in Appendix C. Unless stated otherwise, the stream depth reported in this section is the depth at the thalweg.

Stream A can be characterized as a shallow grass-lined swale with a small channel, which flows between lakes on the upstream and downstream sides of the proposed pipeline route (Appendix C, Photo C-9). The drainage basin appears to be limited to the area in the immediate vicinity of the upstream lake, and is estimated to be 0.53 square miles in size. In general, the channel consists of two long deep pools connected by broad shallow reaches. On June 7 the water surface width and depth in the broad shallow reaches was approximately 210 to 230 feet and 2.5 to 3.0 feet, respectively. If the discharge increases from what it was on June 7, the water will spread out over a large area. Thus, the stream can probably accommodate a much larger flow with a relatively small increase in water surface elevation.

Stream B can be characterized as a grass-lined swale with a small channel, which flows between lakes on the upstream and downstream sides of the proposed pipeline route (Appendix C, Photo C-10). The drainage basin appears to be limited to the area in the immediate vicinity of the upstream lake, and is estimated to be 0.35 square miles in size. On June 7 water was flowing from the north lake to the south lake. The observed water surface width was typically 8 to 12 feet, but in places the water surface widened to between 50 and 70 feet. The depth of flow was generally 0.3 to 0.6 feet. Most of the flow passed within a 1-foot-wide portion of the densely grassed swale. Flows up to 3 feet deep might be contained by the mounds within the swale. Thus, even at a flow depth of 3 feet, the water surface might only be 50 to 100 feet wide.

Stream C is an incised channel of significant width at the mouth, where it flows into the Sakoonang Channel (Appendix C, Photo C-11). The drainage basin is estimated to be 5.5 square miles in size. The top width of the stream, several hundred feet from the Sakoonang Channel, is on the order of 100 feet. The depth from the top of the bank to the thalweg is on the order of 13 feet. On June 3 the stream was approximately 2.5 feet wide and 0.4 feet deep. The water course was not continuous between the mouth and the lakes, but would be at high water. The width and depth of this stream at the mouth is probably due more to the fluctuations in the water surface elevation within the Sakoonang Channel than to the amount of runoff generated from the drainage basin. It is also possible that water from the Sakoonang Channel gets into Stream C and contributes to the flow within this channel.

Stream D is a grass-lined swale without a channel. The feature identified as Stream D on the aerial photographs is a polygonal trough extending between two lakes. However, the trough is actually an extension of one of the lakes rather than a channel. On June 7 there was no water between the two lakes.

Stream E is a grass-lined swale without a well-defined channel, which flows between lakes on the upstream and downstream sides of the proposed pipeline route (Appendix C, Photo C-12). The drainage basin appears to be limited to the area in the immediate vicinity of the upstream lake, and is estimated to be 1.08 square miles in size. On June 2 and 3 water was not continuous between the two lakes. If the water depth increases, it will spread out over a large area. An old high water channel of the East Channel of the Colville River may flow into the lake on the upstream side of the proposed pipeline crossing at high-water surface elevations on the East Channel.

Stream F is a beaded stream within a grass-lined swale, which flows between lakes on the upstream and downstream sides of the proposed pipeline route (Appendix C, Photo C-13). The drainage basin is estimated to be 3.64 square miles in size, and the channel is approximately 940 feet long. On June 1 there was a difference in water-surface elevation from the upstream to the downstream lake of 1.67 feet, resulting in an average water-surface slope of about 0.0018 feet/foot. The water surface width and depth varied between 8 to 11 feet and 2.5 to 5.6 feet, respectively. The deepest portions of the stream are within the beads. The average surface velocity was about 1.4 fps. Within the bottom of the channel there is an average width of approximately 2 to 3 feet that is not covered by vegetation. The bankfull elevation is approximately 1 foot higher than the water surface observed on June 1. Most flows will probably be contained within an area equal to the width of the lakes at the upstream and downstream ends of the channel. The vegetation on the floodplain consists of grass and medium dense willows with a height of about 1 foot. The willows were not leafed out on June 1.

Stream G can be characterized as a small stream in a low flat floodplain, which flows between lakes on the upstream and downstream sides of the proposed pipeline route (Appendix C, Photo C-14). The drainage basin is estimated to be 2.45 square miles in size. On May 31 the average water surface width and depth were approximately 3 feet and 0.8 feet, respectively. The water surface depth varied from 0.5 to 2.2 feet, and the average surface velocity was 1.4 fps. If the water surface rose 1 to 1.5 feet above that observed on May 31, it would spread out over a very wide area.

Stream H can be characterized as a grass-lined swale with a small channel (Appendix C, Photos C-15 and C-16). The drainage basin is estimated to be 1.23 square miles in size. The stream flows into a lake on the downstream side of the proposed alignment, and becomes more incised as it approaches the lake. For the first 400 feet upstream from the lake, the deepest part of the stream is not covered by vegetation. On May 31 the depth was about 2.5 feet within this reach. There was a small waterfall with a drop of about 1 foot located immediately upstream from this reach. The depth was shallower upstream from the waterfall. During an inspection of the stream channel only one hole was identified, which was about 3 feet deep.

Stream I is a tributary to the Kachemach River (Appendix C, Photo C-17). It has a meandering, beaded channel which flows within a wide, grass-lined swale. The drainage basin is estimated to be 24.6 square miles in size. On June 2 the stream width and depth varied from 30 to 60 feet and 4.4 to 9.0 feet, respectively. The water surface velocity was about 2.6 fps, and the water surface slope was about 0.00028 feet/foot. Probing the thalweg indicated that the bottom may be sand, at least at some locations. Ice appeared to line the sides of deep holes. The floodplain is grass covered with mild undulations, averaging about 9 inches in height. Although willows are not present close to the channel, sparse willows were observed within the meander width. The willows were about 9 inches in height. The willows were not leafed out on June 2.

Stream J is a grass-lined swale without a well-defined channel. It appears that the channel contains water only in the spring. The drainage basin is estimated to be 0.07 square miles in size.

Stream K can be characterized as a beaded stream flowing in polygonal troughs (Appendix C, Photos C-18 and C-19). On June 7 the stream width and depth varied from 2 to 6 feet and 0.5 to 1 foot, respectively. The channel is completely vegetated within the shallow areas, but has no vegetation on the bottom of the deeper beads. The drainage basin is estimated to be 1.45 square miles in size.

Stream L is a small beaded stream in a grass-lined swale, which flows into Stream K (Appendix C, Photos C-20 and C-21). The drainage basin is estimated to be 0.85 square miles in size. On June 3 the stream width and depth varied from 3 to 30 feet and 0.4 to 1.6 feet, respectively. The average stream width and depth were 14 feet and 0.9 feet, respectively. The water surface velocity was about 1.4 fps, and the water surface slope was about 0.0047 feet/foot. Although the channel is grass-lined, the grass cover is less dense within the deepest part of the channel. For a width of about 5 feet, in the deepest part of the channel, the soil is exposed between the sparse clumps of grass. Probing the thalweg indicated that there may be ice in the deepest beads. The floodplain is grass covered with no willows. Ground undulations are on the order of 9 to 12 inches. It appeared that windblown snow may fill or partially fill the stream channel.

Stream M is a small stream in a wide grassed floodplain, which flows between lakes on the upstream and downstream sides of the proposed pipeline route (Appendix C, Photo C-22). The drainage basin is estimated to be 2.18 square miles in size. The peak water surface this year appeared to be 8 to 10 feet wide and 1.5 to 2 feet deep. If the water surface rises from what it was this year, a large area would be inundated.

Stream N is a small stream flowing in one or two polygonal troughs, within a 40- to 50-foot-wide swale (Appendix C, Photo C-23). The drainage basin is estimated to be 1.14 square miles in size. On June 7 the stream width and depth varied from 2.5 to 9 feet and 0.2 to 0.5 feet, respectively. Flow depths on the order of 1.5 feet could be contained within the troughs. The channel width was greater than 9 feet at polygon intersections.

Stream O is also known as the Kachemach River (Appendix C, Photos C-24 and C-25). It is a medium-sized meandering river with a sand and gravel bed. The drainage basin is estimated to be 137 square miles in size. Compacted-snow floe velocities on May 25 averaged about 5.1 fps in the center of the channel and 4.7 fps on the east side of the channel. Compacted-snow floe velocities on May 27 averaged about 5.1 fps. On May 27 the stream width and depth were about 138 feet and 4.5 feet, respectively. The water surface slope varied between 0.00081 and 0.00093 feet/foot during the spring breakup observations. The bankfull width and depth are about 200 feet and 5 to 6 feet, respectively. Throughout the breakup observations the east side of the river was blocked by a windblown snowdrift.

Stream P probably does not exist or is not a significant stream (Appendix C, Photo C-26). A feature that looked like it might contain a stream was observed on the aerial photographs and designated as Stream P, prior to going to the field. However, in the field water, was observed only in polygonal troughs and did not appear to be either continuous or moving.

Stream Q is a small stream flowing in polygonal troughs (Appendix C, Photo C-27). The drainage basin is estimated to be 0.11 square miles in size. On June 7 flow within the individual troughs was generally 3 to 5 feet wide and 0.5 to 0.7 feet deep. At polygon intersections the flow was typically 6 to 10 feet wide and 0.2 to 0.4 feet deep. In general, flow depths of 1.5 feet could be contained within the troughs.

Stream R is also known as the Miluveach River (Appendix C, Photos C-28 and C-29). It is a medium-sized meandering river with a sand and gravel bed. The drainage basin is estimated to be 101 square miles in size. On May 25 the water was flowing through windblown snowdrifts. Compacted-snow floe velocities averaged about 7.3 fps in the center of the channel and 6.4 fps on the east side of the channel. On May 28 the stream width and depth were about 118 feet and 3.8 feet, respectively. The water surface slope varied between 0.0011 and 0.00074 feet/foot during the spring breakup observations. The bankfull width and depth are about 130 feet and 3 to 6 feet, respectively.

Stream S is a small stream flowing in grass-lined polygonal troughs (Appendix C, Photo C-30). The drainage basin is estimated to be 0.04 square miles in size. On May 28 the stream width and depth were 2 to 5 feet and 0.5 to 1.5 feet, respectively. The velocity of the water was about 1 to 3 fps. Once the water surface elevation is above the top of the polygonal troughs, the water will spread out over a very wide area.

Stream T is a small stream channel within a wide shallow swale, which flows between lakes on the upstream and downstream sides of the proposed pipeline route (Appendix C, Photo C-31). The drainage basin is estimated to be 2.15 square miles in size. On May 28 the water had no apparent velocity at the pipeline crossing. Downstream from the pipeline crossing, where the stream empties into a lake, the channel is narrower and more defined than at the proposed pipeline crossing. There may be a little head-cutting taking place, but it is probably not occurring very fast.

Drainage Basin U is drained by multiple channels at the proposed pipeline crossing (Appendix C, Photo C-32). In general, the channels can be characterized as a wide, shallow, grass-lined swale. On May 28 there was no apparent velocity at the proposed pipeline crossing. The drainage basin is estimated to be 0.19 square miles in size.

Drainage Basin V is drained by multiple channels at the pipeline crossing (Appendix C, Photo C-33). In general, the channels can be characterized as grass-lined swales. On May 28 the ponded water was 50 to 100 feet wide and 1 to 3 feet deep. The proposed pipeline crossing appears to be within a swampy area. The drainage basin is estimated to be 0.54 square miles in size.

Stream W is a small stream flowing in grass-lined polygonal troughs (Appendix C, Photos C-34 and C-35). The drainage basin is estimated to be 0.02 square miles in size. The bankfull width and depth are 1 to 2 feet and 0.5 to 1 foot, respectively.

Stream X is an incised meandering channel, which flows between lakes on the upstream and downstream sides of the proposed pipeline route (Appendix C, Photos C-36, C-37, and C-38). The drainage basin is estimated to be 7.33 square miles in size. On May 28 the channel was nearly completely full of windblown snow, and water was flowing on the top of the snow. The flow width was about 8 feet and the flow depth was about 3.5 feet. The flow velocity was about 3.8 fps. By June 2 the stream had eroded through the windblown snow and was at an elevation that may have been on the order of 5 to 10 feet below what it was on May 28. On June 2 the stream width and depth were 9 to 33 feet and 0.5 to 2.4 feet, respectively. The water surface velocity was about 3 fps, and the water surface slope was about 0.0026 feet/foot. The channel bottom is gravelly sand. Ground ice was exposed in one of the banks. The bankfull width is probably on the order of 80 to 100 feet. The bankfull depth may be on the order of 15 feet. The floodplain consists of grass, with ground undulations on the order of 0.75 to 1 foot high.