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MIXING CHARACTERISTICS OF THE ATHABASCA RIVER BELOW THE PROPOSED ANC MILL

ALBERTA NEWSPRINT COMPANY LTD.

AUGUST, 1988

beak associates consulting ltd.

#300, 10160 - 112 Street
Edmonton, Alberta
Canada T5K 2L6

(403) 428-0003
Telex: 03-821172
Fax (403) 421-4300

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LETTER OF TRANSMITTAL

Mr. Bill Gunning
Nystrom, Lee, Kobayashi & Associates
2130 West 12 Avenue
Vancouver, B.C.
V6K 2N3

Dear Mr. Gunning:

Reference: Athabasca River Mixing Characteristics

The following report summarizes our assessment of the likely mixing characteristics of effluent from the Alberta Newsprint Company (ANC) newsprint mill in the Athabasca River. The study has been conducted as one component of the Environmental Impact Assessment (EIA) prepared by your firm for ANC, at the direction and request of Alberta Environment.

Sincerely yours,

BEAK ASSOCIATES CONSULTING LTD.

Brian F. Bietz, Ph.D.
Manager and Senior Scientist

BFB/tlz

Enclosure

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1.0 INTRODUCTION

Alberta Newsprint Company (ANC) is planning the construction of a 630 FMT/d newsprint mill adjacent to the Athabasca River about 11 km upstream of the Town of Whitecourt. As part of the effluent treatment and disposal system, a diffuser outfall structure will be constructed to discharge the effluent into the river. The environmental impact of this 0.17 m^3/s discharge has been previously addressed in Alberta Newsprint's Environmental Impact Assessment Report (ANC, 1988).

The conceptual design of the effluent diffuser was previously addressed by Northwest Hydraulics Consultants Ltd. (1988). This work was requested by Nystrom, Lee, Kobayashi and Associates Ltd. to better quantify the mixing zone characteristics downstream of the outfall. The complex morphology of the receiving stream, the non-uniformity of the river's cross-sections and the effects of ice-cover were to be considered to estimate the mixing zone for various flow conditions.

2.0 HYDROLOGY

The Alberta Newsprint Company (ANC) site is located about 17 km downstream of Water Survey of Canada's hydrometric station 7AE1 near Windfall. This station was operated continuously from 1960 to 1978. Since then, flow has been continuously monitored from the beginning of March until the end of October each year. Mean monthly flows reported by WSC are:

TABLE 1: Mean Monthly Flows at Windfall

Month	Condition	Flow (m^3/s)
January	ice-cover	53.7
February	ice-cover	50.2
March	ice-cover	48.7
April	break-up	103
May	open water	303
June	open water	664
July	open water	640
August	open water	454
September	open water	296
October	open water	184
November	freeze-up	93.6
December	ice-cover	65.1

Low flow hydrology for the Athabasca River has been addressed by both Alberta Environment (1984) and Alberta Newsprint Company (1988). The estimated 7 day duration low flow events at Windfall are:

TABLE 2: Low Flows at Windfall (m^3/s)

Return Period (years)	Alberta Environment	Alberta Newsprint
10	29.0	30.4
2	36.7	38.6

Allowing for tributary and diffuse inflow between the Windfall monitoring station and the ANC site, it is estimated that the 7Q10 flow at the ANC site is about 33.6 m^3/s.

3.0 RIVER MORPHOLOGY

In the reach between the ANC mill and Whitecourt, the Athabasca River has a sinuous and split channel configuration. The channel(s) have numerous side-channel and mid-channel bars and several mid-channel islands.

At high flows, the river occupies the many channels indicated on National Topographic System mapping (see Figure 1 - taken from Map 83J/4 at 1:50,000). Two sets of aerial photographs were obtained and examined to confirm this. Photographs dated 31 May 1977 (when the river flow at Windfall was 651 m^3/s) indicate that all sub-channels are conveying water. The flow is split about 1 km downstream of the ANC outfall site into two sub-channels which rejoin about 6 km further downstream. The flow is generally in multiple channels for a further 6 km to a point past the McLeod River confluence, the Millar Western Pulp Mill outfall and the Sakwatamau River confluence. For the next 10 km, the river is generally confined to a single channel with several mid-channel islands. This channel flow pattern was also observed on aerial photographs dated 29 May 1983 (when the flow at Windfall was 318 m^3/s).

At low flows, the river tends to flow in a single channel although minor amounts of water would also be conveyed in the sub-channels. During these conditions the flow remains in the north sub-channel for the 6 km down to the confluence with the south sub-channel. From here, the river tends to remain in a single channel past the McLeod River confluence, the Millar Western Pulp Mill outfall and the Sakwatamau River confluence. This was confirmed by aerial photographs dated 14 October 1987 (125 m^3/s at Windfall). Thus, for typical low flow conditions during the open water season (i.e. early spring and late fall) the Athabasca River could be considered a single channel river in this reach.

Calculations, based on the main channel of Section 14 from Northwest Hydraulics Consultants Inc. (1988), indicate that an open water flow rate of about 125 m^3/s corresponds to an ice-cover flow rate of 78 m^3/s (in terms of river width and depth). Thus, since most winter flows are less than 80 m^3/s, the Athabasca River could again be considered a single channel river for typical ice cover flow conditions.

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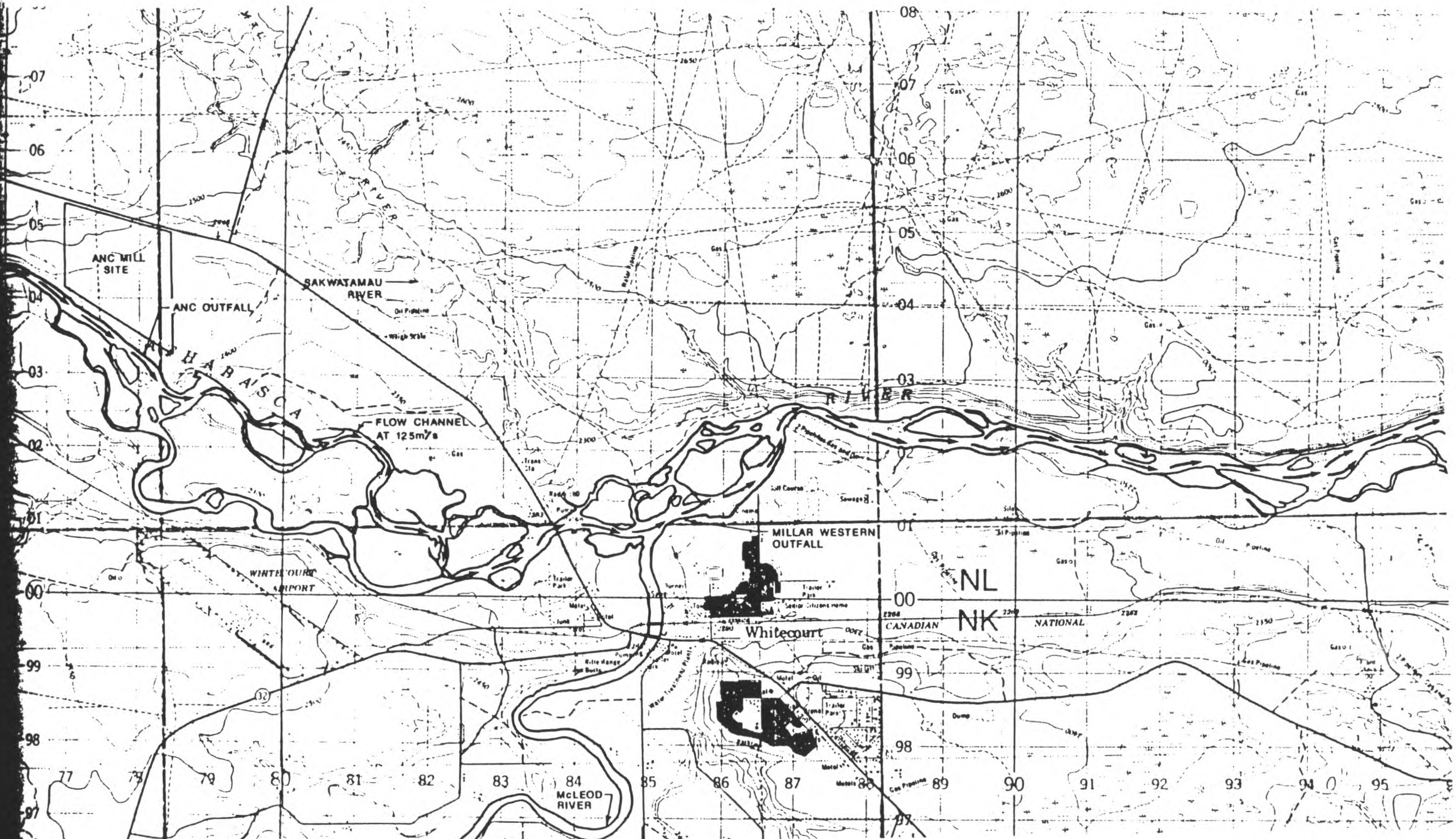


Figure 1

4.0 HYDRAULIC PARAMETERS

Six cross-sections of the Athabasca River in the vicinity of the ANC site were presented by Northwest Hydraulics Consultants Inc. (1988). These sections, obtained from Alberta Environment, were surveyed when the river flow was about 220 m^3/s. In addition, a single cross-section (corresponding, more or less, to Section 14 at the outfall site) was surveyed on 11 March 1988 by Beak. For the March survey, there was a flow of 53 m^3/s under an ice-cover which was about 0.7 m thick (Figure 2).

The cross-section at the proposed outfall site is not representative of the Athabasca River downstream. It is wider than typical and is affected by the mid-channel bar that separates the north and south sub-channels. Although the river is fairly uniform in depth at the outfall site, the velocities are not uniform across the width of the stream (Figure 2). High velocities were measured near the river's left bank and decrease to levels much less than expected towards the right bank. Flow calculations indicated that there was likely no flow in the south sub-channel.

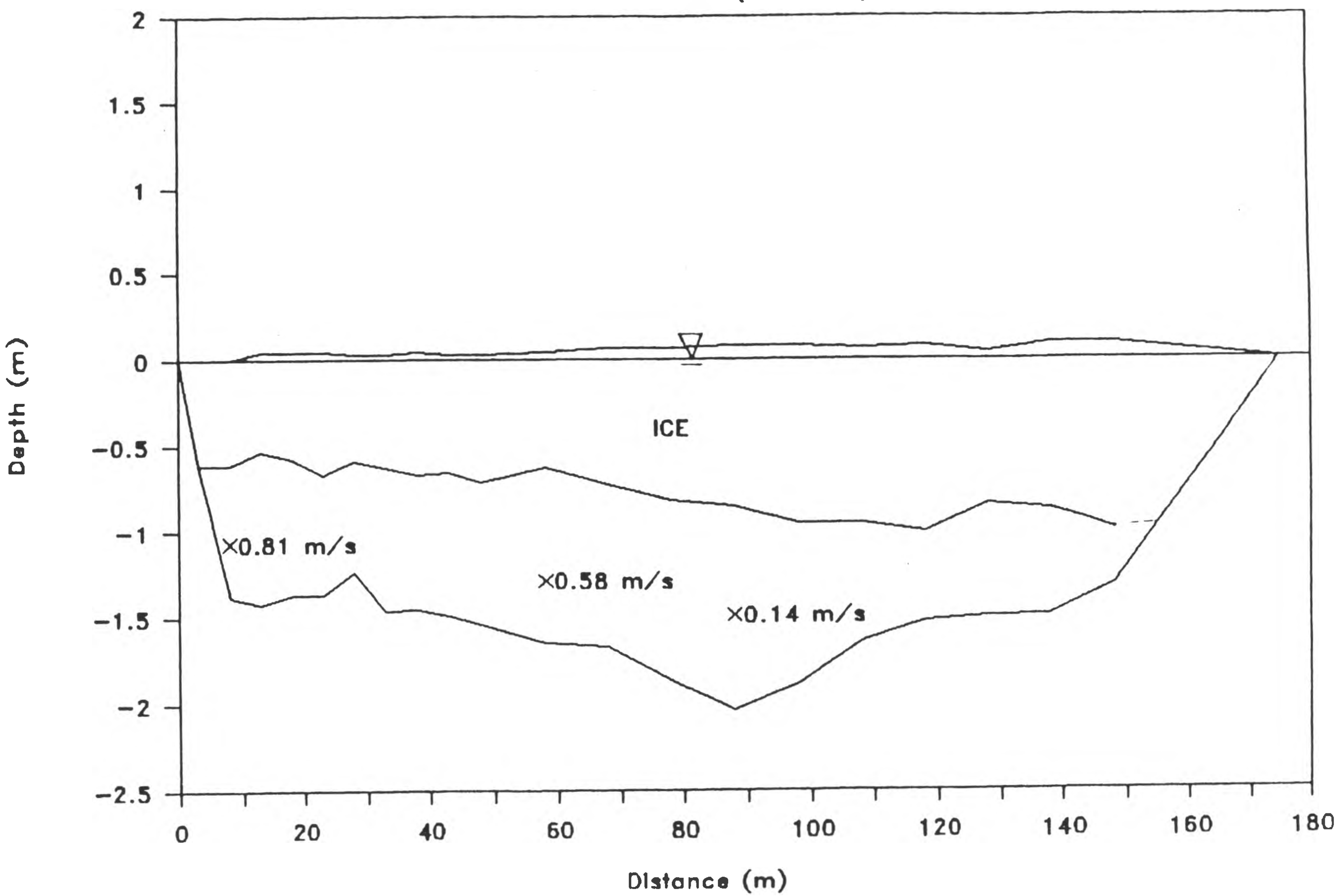
Typical hydraulic characteristics for the 7 km reach downstream of the outfall to the confluence of the two sub-channels were estimated based on the measured cross-sections and measurements taken from the 14 October 1987 aerial photographs. The following hydraulic parameters were estimated to be representative of the reach:

TABLE 3: Hydraulic Parameters Downstream of ANC

Flow	(m^3/s)	125	78	33.6
Flow Condition		open water	ice-cover	ice-cover
Width	(m)	79	79	76
Depth	(m)	1.11	1.11	0.69
Velocity	(m/s)	1.43	0.89	0.64

Figure 2 – Section Near Outfall Site

11 March 1988 (57 m3/s)



Information from other sources was used to obtain other hydraulic parameters:

Slope	0.0013	Kellerhals et al (1972)
Shape Velocity Factor (ψ)	2.0	Beltaos (1978) & cross-section data
$K_z = e_z/(RV_*)$	0.6	Beltaos (1978) & Fischer et al (1979)

Based on these, the transverse mixing coefficients for the three flow conditions were estimated from the equation:

$$E_z = \psi K_z R V_*$$

and the vertical mixing coefficient from Fischer et al. (1979):

$$e_y = 0.067 \ HV_*$$

The estimated mixing coefficients are as follows:

TABLE 4: Estimated Mixing Coefficients (m^2/s)

Flow Condition	e_y	E_z
Open Water (125 m^3/s)	0.0089	0.159
Ice-Cover (78 m^3/s)	0.0062	0.056
Ice-Cover (33.6 m^3/s)	0.0031	0.027

5.0 MIXING ZONE CHARACTERISTICS

5.1 PROPOSED DIFFUSER

The Northwest Hydraulics Consultants Ltd. report recommended that a subsurface diffuser be constructed to evenly disperse the effluent over the majority of the width of the river. This structure was tentatively, to extend into the river for a distance of 60 m. At high (greater than 300 m^3/s) river flows this would be less than 50% of the river width. However, at low river flows (less than 80 m^3/s under ice-cover) the diffuser would occupy almost all of the active flow area.

If the outfall is constructed as indicated, then mixing will be within a few kilometers at low flows as the flow is confined to the north sub-channel. This explains the estimated mixing zone length of "a few kilometers" indicated in the Environmental Impact Assessment (ANC, 1988). When the flow is high and occupying both sub-channels, the majority of the effluent will be evenly mixed in the north sub-channel; when the sub-channels rejoin, the two flows would mix within the few kilometers before the McLeod River confluence (this is exemplified by the 31 May 1977 aerial photographs where the McLeod River can be seen as mixing with the Athabasca River within 3 km of their confluence).

5.2 SHORTENED DIFFUSER

It may be desirable to shorten the diffuser to about one half its length in order to generate mixing in a more desirable fashion. In addition to lowering the capital cost, the shortened effluent diffuser would ensure that the effluent is only discharged into the north sub-channel. This configuration would occupy almost 50% of the flow width at the 7Q10 and allow for a "zone of passage" for fish at both low and high flow conditions.

Mixing lengths for this shortened diffuser outfall have been estimated using methods outlined in Transverse Mixing in Natural Streams (Beltaos, 1978) and A Review of Analytical Equations for Two Dimensional Dispersion (Hodgson, 1986). For single channel flow conditions (i.e. open water flows less than 125 m^3/s or ice-cover flows less than 80 m^3/s) a diffuser which extends to mid-stream (such as ANC's) has the following theoretical mixing lengths:

TABLE 5: Theoretical Mixing Zone Lengths

Condition	Flow (m^3/s)	Vertical Mixing Length (m)	Transverse Mixing Length (km)
Ice-Cover (7Q10)	33.6	10	45
Ice-Cover	78	18	33
Open Water	125	20	19

These estimates were based on prismatic single channel conditions (i.e. $X_m = 0.33\ UW^2/E_z$ and $X_v = 0.1\ UH^2/e_y$). The effects of side-channel and mid-channel bars in the north sub-channel would tend to shorten the transverse mixing lengths.

As the flow increases and occupies multiple channels, the mixing lengths would increase. However, due to the much higher flows, the amount of dilution achieved is superior even before complete mixing occurs (vertical mixing calculations indicates that initial dilutions in the order of 100 to 1 can be achieved in the first 20 m to 30 m downstream of the shortened diffuser for all flow conditions).

6.0 CONCLUSIONS AND RECOMMENDATIONS

1. The Athabasca River downstream of the Alberta Newsprint Company site occupies multiple channels during high (greater than 300 m^3/s) flows. At lower flows (less than 125 m^3/s for open water and 80 m^3/s for ice-cover), the river tends to occupy only one channel - the north sub-channel.

2. The 60 m long diffuser referenced in the Northwest Hydraulics Consultants (1988) report will produce complete mixing within a few kilometers of the outfall at low flows. At high flows complete mixing will occur within a few kilometers of the confluence of the two sub-channels (i.e. just before the McLeod River).

3. A shortened (about 30 m) diffuser would allow a "zone of passage" during low flows under ice-cover. The theoretical mixing lengths at low flows are in the order of 33 km 45 km.

4. A final survey of the outfall cross-section (with proper horizontal and vertical control) should be made prior to the generation of construction drawings. This should be done during winter when the river has an ice-cover. The survey should also include velocity measurements to ensure the identification of the streamflow pattern in the reach.

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APPENDIX A

CROSS-SECTION HYDRAULICS

JOB # 10-200-02-01 ALBERTA NEWSPRINT MILL SITE 2

FLOW (m3/s) = 54 FLOW CONDITION: UNDER ICE DATE: MAR 11/88

NOMINAL WATER LEVEL = 100.000 SLOPE = 0.001300 N = 0.038

STATION (m)	DIST (m)	ELEV (m)	ICE DEPTH (m)	WIDTH (m)	DEPTH (m)	AREA (m2)	VELOCITY (m/s)	FLOW (m3/s)	CUMULATIVE (m3/s)	CUMULATIVE FLOW (%)	WIDTH (%)
20.00		102.00									
22.00	0	100.000	0.00		0.00		0.00	LEFT BANK	0	0.0	0.0
25.00	5.50	99.39	0.61	5.50	0.00	0	0.00	0.00	0.00	0.0	3.2
30.00	10.50	98.62	0.61	5.00	0.77	4	0.81	3.12	3.12	5.8	6.0
35.00	15.50	98.57	0.49	5.00	0.94	5	0.79	3.72	6.84	12.7	8.9
40.00	20.50	98.63	0.53	5.00	0.84	4	0.77	3.24	10.08	18.8	11.7
45.00	25.50	98.63	0.62	5.00	0.75	4	0.75	2.82	12.90	24.1	14.6
50.00	30.50	98.76	0.56	5.00	0.68	3	0.73	2.50	15.40	28.7	17.5
55.00	35.50	98.54	0.59	5.00	0.87	4	0.72	3.11	18.51	34.5	20.3
60.00	40.50	98.54	0.62	5.00	0.84	4	0.70	2.92	21.43	39.9	23.2
65.00	45.50	98.51	0.62	5.00	0.87	4	0.68	2.94	24.38	45.4	26.1
70.00	53.00	98.46	0.69	7.50	0.85	6	0.66	4.19	28.57	53.3	30.4
80.00	63.00	98.35	0.58	10.00	1.07	11	0.62	6.63	35.21	65.6	36.1
90.00	73.00	98.33	0.67	10.00	1.00	10	0.58	5.80	41.01	76.4	41.8
100.00	83.00	98.14	0.76	10.00	1.10	11	0.43	4.73	45.74	85.3	47.6
110.00	93.00	97.96	0.78	10.00	1.26	13	0.28	3.53	49.26	91.8	53.3
120.00	103.00	98.11	0.88	10.00	1.01	10	0.14	1.41	50.68	94.5	59.0
130.00	113.00	98.36	0.90	10.00	0.74	7	0.12	0.90	51.58	96.1	64.8
140.00	123.00	98.47	0.93	10.00	0.60	6	0.10	0.62	52.20	97.3	70.5
150.00	133.00	98.50	0.79	10.00	0.71	7	0.09	0.61	52.81	98.4	76.2
160.00	143.00	98.51	0.78	10.00	0.71	7	0.07	0.48	53.30	99.3	81.9
170.00	174.50	98.69	0.90	31.50	0.41	7	0.05	0.35	53.65	100.0	100.0
196.50		100.000			0.00		0.00	RIGHT BANK			
198.50		102.00									
				174.5		114					

Hydraulic Depth =0.653
Hydraulic Width =174.5

Shear Velocity =0.064
Ave. Ice Depth =0.662

JOB # 10-200-02-01 ALBERTA NEWSPRINT MILL SECTION 14

FLOW (m3/s) = 78 FLOW CONDITION: ICE COVER DATE: OCT 14/87

WATER LEVEL = 703.330 SLOPE = 0.001300 N = 0.038

STATION (m)	DIST (m)	ELEV (m)	ICE DEPTH (m)	WIDTH (m)	DEPTH (m)	AREA (m2)	VELOCITY (m/s)	FLOW (m3/s)	CUMULATIVE FLOW (m3/s)	CUMULATIVE FLOW (%)	WIDTH (%)
20.00		704.31									
22.23	0	703.330	0.00		0.00		0.00	LEFT BANK	0	0.0	0.0
22.97	3.71	701.85	0.66	3.71	0.82	3	0.49	1.33	1.33	1.7	2.3
28.91	8.17	700.82	0.66	4.46	1.85	8	0.90	7.41	8.74	11.2	5.0
31.88	12.62	700.62	0.66	4.46	2.05	9	0.96	8.79	17.54	22.5	7.7
37.82	23.02	700.62	0.66	10.40	2.05	21	0.96	20.52	38.06	48.8	14.0
52.67	33.41	701.49	0.66	10.40	1.18	12	0.67	8.16	46.22	59.3	20.4
58.61	49.01	701.64	0.66	15.59	1.03	16	0.61	9.76	55.98	71.8	29.9
83.86	76.48	702.00	0.66	27.48	0.67	18	0.46	8.38	64.36	82.5	46.6
113.56	117.32	702.10	0.66	40.84	0.57	23	0.41	9.51	73.86	94.7	71.5
165.54	164.11	702.26	0.66	46.79	0.41	15	0.28	4.13	77.99	100.0	100.0
186.34		703.33			0.00		0.00	RIGHT BANK			
				164.11		126					

Hydraulic Depth = 0.768
Hydraulic Width = 164.11

Shear Velocity = 0.070