APPENDIX B

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northwest hydraulic consultants

Ref. No. 16987

May 11, 2011

Canadian Zinc Corporation
Suite 1710 - 650 West Georgia Street
Vancouver, BC
V6B 4N9

Attention: David Harpley

Via email: david@canadianzinc.com

Re: Mixing analysis for exfiltration trench outfall to Prairie Creek - UPDATED

Dear Mr. Harpley:

1.0 INTRODUCTION

The water management plan proposed by Canadian Zinc Corporation (CZN) for operation of the Prairie Creek mine involves treating mine drainage water and mill process water to reduce metal concentrations, then discharging excess treated water to Prairie Creek. A NHC letter report dated September 9, 2010 presented a preliminary review of outfall alternatives. A diffuser was ruled out because of the lack of a suitably deep channel. NHC recommended a simple pipe outlet from the bank of Prairie Creek in order to minimize construction impacts.

The results of mixing analysis for this pipe outfall presented in a letter dated October 22, 2010 and subsequent discussions with regulators resulted in the abandonment of the pipe outfall alternative and the selection of an exfiltration trench outfall as a more viable alternative. A preliminary design of this exfiltration trench outfall was presented in a letter report dated December 22, 2010. The design of the exfiltration trench was refined in the course of the present mixing analysis presented herein.

This report presents the results of a mixing analysis performed to quantify mixing in Prairie Creek in the reach downstream of the outfall. The exfiltration trench will discharge the treated water over a width of stream bed to increase mixing in the near field or vertical mixing zone. Once vertical mixing is complete further mixing occurs laterally in the far field or transverse mixing zone. The results from this report are presented as dimensionless concentrations and dilutions relative to initial outfall concentrations and are intended to be utilized by others to assess various water quality parameters to ensure that they meet water quality instream targets.

2.0 CHANNEL HYDRAULIC CHARACTERISTICS

Figure 1 shows Prairie Creek below the outfall location based on a 1994 orthophoto at the mine site and 1:50,000 scale topographic map developed from aerial photos taken in 1969. Photos 1 and 2 show the location of the proposed outfall and downstream reach as observed in 2010. These photos show the stream conditions for a discharge of 12 m^3/s, which is similar to the mean open water flow.

Channel hydraulic characteristics for the reach downstream of the outfall were estimated using a HEC-RAS hydraulic model. Available survey information consists of channel cross sections, thalweg and water surface profiles surveyed in August 1980 and in August 2010. The 2200 m reach length surveyed in August 1980 ends about 1000 m downstream of the Harrison Creek confluence and provides good information on the overall channel profile and representative channel sections. The 350 m reach length surveyed upstream of the Harrison Creek confluence in August 2010 provides current cross section information in the reach where the outfall is proposed, and confirmation that the current water surface slope is consistent with the slope surveyed in 1980. Representative cross sections surveyed in 1980 and 2010 were transposed to the locations shown in Figure 1 reach based on the general channel profile and the location of riffle sections as seen in the 2010 photographs.

The HEC-RAS model was run to determine channel hydraulic conditions for both open-water and ice-cover conditions. Open-water conditions typically occur from May to October and ice-cover conditions typically occur from November to April. Three monthly discharges (maximum, mean and minimum) were selected to represent the range of hydraulic characteristics for each of these conditions. Discharges were determined by analysis of monthly flow data from Water Survey of Canada (WSC) records for Prairie Creek at Cadillac Mine for the period October 1974 through December 1990. These WSC discharges were increased by a factor of 2% to account for the difference in drainage area between the WSC gauge and the reach downstream of the outfall. The hydraulic characteristics at the outfall for the six selected stream discharges are listed in Table 1.

Table 1 Summary of hydraulic characteristics at outfall

Flow Condition	Discharge (m^3/s)	Top Width (m)	Mean Velocity (m/s)	Mean Depth (m)	Maximum Depth (m)
Open-water (May-Oct)					
Maximum Monthly	38.2	60.1	1.70	0.37	1.00
Mean Monthly	10.2	24.0	1.16	0.37	0.64
Minimum Monthly	1.57	12.3	0.65	0.20	0.31
Ice-cover (Nov-Apr)					
Maximum Monthly	4.43	22.8	0.62	0.31	0.57
Mean Monthly	0.71	11.8	0.36	0.17	0.27
Minimum Monthly	0.039	6.4	0.10	0.06	0.12

3.0 OUTFALL CHARACTERISTICS

Figure 2 shows the proposed location and extent of the exfiltration trench within Prairie Creek. The exfiltration trench will contain two lengths of perforated pipe, one 8 m long and the other 6 m long. The 8 m pipe will be operated during open water conditions and the 6 m pipe will be operated during ice-cover conditions when the channel width is smaller. The dual pipe system also provides some redundancy and backup capability in the event that there is a problem with one of the pipes.

Figure 3 shows design details of the discharge section of the exfiltration trench which will be located under the low flow channel to facilitate rapid mixing of the effluent with stream flows under low flow conditions. The design includes air backwash pipes to help clear the trench of any fine sediment which may potentially be deposited in the backfill material. To minimize impacts, backwashing should be done at high flows when suspended sediment naturally occurs in the water column.

The outfall will discharge a mixture of treated process water and treated mine drainage water. The release of treated process water is proposed to be managed on the basis of the flow in Prairie Creek and its corresponding dilution capacity to meet the instream objectives. Mine drainage water will reflect the groundwater flow into the mine, and the rate of flow is expected to vary both annually and seasonally as a function of antecedent climatic conditions. Four alternate effluent discharge scenarios were considered to evaluate a range of possible mine drainage conditions. These scenarios include the best (most likely) estimate of outfall discharge, low and high estimates of groundwater flow into the mine and an extreme scenario of high groundwater flow which includes flow from the Prairie Creek aquifer. Two total discharges are provided for each scenario, one for a standard rate of process water discharge and the other for a reduced rate of process water discharge when Prairie Creek flows are too low to accommodate the standard rate. Note that in February and March the two discharge scenarios are the same because no process water will be released during these months. The effluent discharge rates were determined by Canadian Zinc and are summarized on a monthly basis in Table 2.

Table 2 Summary of monthly total outfall discharge scenarios

	Total Outfall Discharge Scenario							
	Low Estimate (m^3/s)		Best Estimate (m^3/s)		High Estimate (m^3/s)		Extreme Estimate (m^3/s)	
Month	Standard Process Water	Reduced Process Water	Standard Process Water	Reduced Process Water	Standard Process Water	Reduced Process Water	Standard Process Water	Reduced Process Water
Jan	0.0055	0.0048	0.0090	0.0083	0.0110	0.0103	0.0940	0.0933
Feb	0.0020	0.0020*	0.0030	0.0030*	0.0060	0.0060*	0.0860	0.0860*
Mar	0.0020	0.0020*	0.0030	0.0030*	0.0050	0.0050*	0.0710	0.0710*
Apr	0.0065	0.0052	0.0085	0.0072	0.0125	0.0112	0.1370	0.1357
May	0.0505	0.0505	0.0775	0.0775	0.1065	0.1065	0.2255	0.2255
Jun	0.0615	0.0615	0.0925	0.0925	0.1705	0.1705	0.2335	0.2335
Jul	0.0615	0.0615	0.0925	0.0925	0.1765	0.1765	0.2395	0.2395
Aug	0.0615	0.0604	0.0925	0.0914	0.1705	0.1694	0.2295	0.2284
Sep	0.0550	0.0525	0.0845	0.0820	0.1480	0.1455	0.2330	0.2305
Oct	0.0275	0.0256	0.0465	0.0446	0.0735	0.0716	0.2055	0.2036
Nov	0.0140	0.0132	0.0205	0.0197	0.0295	0.0287	0.1455	0.1447
Dec	0.0080	0.0070	0.0115	0.0105	0.0165	0.0155	0.0945	0.0935

* no process water will be released in February and March so the total discharge is the same for both standard and reduced process water scenarios.

4.0 VERTICAL MIXING

The exfiltration trench design will produce significant mixing in the near field zone where vertical mixing processes dominate, because the effluent will be discharged evenly over a 6 or 8 m width of the channel with shallow turbulent flow. Vertical mixing analysis was carried out analytically for all seven stream discharge scenarios presented in Section 2 combined with the four outfall discharge scenarios. The ice cover worst case water quality (WQ) scenario was selected to present the worst case water quality expected in April when process water discharged along with mine water under ice cover conditions. Each set of four outfall discharges were selected from the monthly outfall discharges in

Table 2 based on the month in which corresponding stream discharge would most likely to occur. These discharges are summarized in Table 3 along with the computed vertical mixing lengths and vertical dilutions for each scenario.

The vertical mixing length was defined as the distance downstream of the exfiltration trench where vertical variations in concentration would be less than ±2%. Vertical mixing lengths tend to increase with increased flow depth. Vertical mixing lengths varied from a minimum of 1.6 m during low flow ice-covered conditions to a maximum of 31 m during high flow open-water conditions.

Table 3 Summary of mixing characteristics for various discharge scenarios

Discharge Scenario	Open Water Monthly Max. Flow	Open Water Monthly Mean Flow	Open Water Monthly Min. Flow	Ice Cover Monthly Max. Flow	Ice Cover Monthly Mean Flow	Ice Cover Monthly Min. Flow	Ice Cover Worst Case WQ
Prairie Creek							
Discharge (m^3/s)	38.2	10.2	1.57	4.43	0.71	0.039	0.080
Month of most likely occurrence	Jun	Jul	Oct	Apr	Dec	Mar	Apr
Vertical mixing length (m)	30.6	22.1	10.2	16.1	7.4	1.6	2.5
Length of perforated pipe	8.0	8.0	8.0	6.0	6.0	6.0	6.0
Flow width in vertical mixing zone	13%	33%	65%	26%	51%	92%	73%
Flow area in vertical mixing zone	35%	51%	78%	43%	66%	97%	89%
Discharge in vertical mixing zone	45%	61%	85%	51%	74%	98%	95%
Low Estimate Outfall Discharge							
Outfall discharge (m^3/s)	0.0615	0.0615	0.0256	0.0065	0.0080	0.0020	0.0052
Mean vertical velocity at bed (m/s)	0.015	0.015	0.006	0.002	0.003	0.001	0.002
Increase in mean velocity	0.0%	0.2%	0.5%	0.1%	0.4%	2.0%	2.5%
Dilution after vertical mixing	280.4	101.4	52.6	350.9	66.8	20.1	15.6
Dilution after transverse mixing	622.1	166.9	62.2	682.5	89.8	20.5	16.5
Best Estimate Outfall Discharge							
Outfall Discharge (m^3/s)	0.0925	0.0925	0.0446	0.0085	0.0115	0.0030	0.0072
Mean vertical velocity at bed (m/s)	0.023	0.023	0.011	0.003	0.004	0.001	0.002
Increase in mean velocity	0.1%	0.3%	0.8%	0.1%	0.5%	2.2%	2.6%
Dilution after vertical mixing	186.6	67.6	30.6	268.5	46.7	13.7	11.5
Dilution after transverse mixing	414.0	111.3	36.2	522.2	62.7	14.0	12.2
High Outfall Discharge							
Outfall Discharge (m^3/s)	0.1705	0.1765	0.0716	0.0125	0.0165	0.0050	0.0112
Mean vertical velocity at bed (m/s)	0.043	0.044	0.018	0.004	0.006	0.002	0.004
Increase in mean velocity	0.1%	0.5%	1.3%	0.1%	0.7%	3.7%	4.0%
Dilution after vertical mixing	101.4	35.7	19.4	182.7	32.8	8.6	7.7
Dilution after transverse mixing	225.0	58.8	22.9	355.4	44.0	8.8	8.2
Extreme Outfall Discharge							
Outfall Discharge (m^3/s)	0.2335	0.2395	0.2036	0.1370	0.0945	0.0710	0.1357
Mean vertical velocity at bed (m/s)	0.058	0.060	0.051	0.046	0.032	0.024	0.045
Increase in mean velocity	0.2%	0.7%	3.7%	0.9%	3.8%	36.5%	34.6%
Dilution after vertical mixing	74.2	26.5	7.4	17.1	6.3	1.5	1.5
Dilution after transverse mixing	164.6	43.6	8.7	33.3	8.5	1.5	1.6

The percentage of the channel width and flow area occupied by the vertical mixing zone above the perforated pipes are also listed in Table 3 for each discharge scenario. The width of the vertical mixing zone ranges from 13% to 65% of the channel width during open water conditions and from 26% to 92% of the channel width during ice cover conditions. The flow area of the vertical mixing zone ranges from 35% to 78% of the channel area during open water conditions and from 43% to 97% of the channel width during ice cover conditions; however, much of this area will have lower than average concentrations due to incomplete vertical mixing.

Mean vertical velocities at the bed exiting the exfiltration trench presented in Table 3 were estimated for each of the flow scenarios, assuming a vertical spreading rate of 1:5 (H:V) which yields an average bed footprint width of about 0.5 m. In most cases, the vertical velocities are about 0.02 m/s or less; but, if extreme outfall discharges occur, vertical velocities of up to 0.06 m/s may occur.

The estimated increases in mean downstream velocities due to the addition of the outfall discharges are also listed in Table 3. The velocities were computed from the relationships between mean velocity and discharge established with the HEC-RAS model. The increases are generally less than 1% but for extreme outfall discharges and minimum channel discharges increases in mean velocity of up to 37% may occur. However, these velocities do not exceed naturally occurring velocities because the larger increases occur during periods with low channel flows.

Dilutions at the end of the vertical mixing zone were calculated assuming that the effluent concentration mixed completely with the percentage of the stream discharge flowing directly over top of the perforated pipe section of the exfiltration trench. The percentage of the stream discharge flowing over the exfiltration trench was determined from the distribution of unit discharge across the channel for the various stream discharges. These unit discharge distributions were calculated by multiplying the local velocities by the local depths and were estimated using the surveyed cross section (XS 20) shown in Figure 2. The lowest dilution of 1.5 was found to occur during low flow ice-covered conditions with the extreme outfall discharge for both the minimum flow and the worst case dilution scenario.

5.0 TRANSVERSE MIXING

The dilutions resulting from complete transverse mixing of effluent concentrations were calculated for all of the scenarios presented in Table 3. Very little increase in dilutions occurred for the minimum ice-covered discharge scenarios because mixing was already 98% complete in the vertical mixing zone.

Transverse mixing analyses were performed with the TRSMIX transverse mixing numerical model to determine the length of the transverse mixing zone and the distribution of concentrations within this zone. This model was developed at the University of Alberta to simulate mixing in natural streams with variable channel characteristics such as Prairie Creek. Model inputs include outfall characteristics and the stream hydraulic characteristics, as well as mixing characteristics.

Mixing characteristics are defined by dimensionless mixing coefficients. Dimensionless mixing coefficients in natural channels tend to range from 0.4 to 0.8, however values higher than 1.0 have been measured in some rivers. A value of 0.8 was selected for Prairie Creek. This value, on the high side of the normal range, was selected because the available hydraulic characteristics of the reach were limited to representative sections that would not capture all of the observed variations of the flow field such as the sinuosity of the channel.

Best estimate outfall discharges for the mean open-water and ice-covered flow conditions were selected for simulation with the transverse mixing model. These two scenarios represent the conditions which will occur most likely and most frequently. The minimum ice-covered discharge scenario was not simulated because transverse mixing would be almost complete at the end of the vertical mixing zone. As well, the minimum open-water discharge scenario was not simulated because the initial conditions were relatively similar to the mean ice-covered discharge scenario. Maximum discharge scenarios were not simulated because both near field and far field dilution rates are more than double the rates for the mean flow scenarios.

Figures 4 and 5 show the distributions of dimensionless concentrations obtained from the mixing model for the two mean flow scenarios. These dimensionless concentrations are defined as the fraction of concentration relative to the initial outfall concentration and are the inverse of dilution. Transverse distances are shown relative to the local stream width for ease of presentation. The following information is presented in each figure:

- Chart A shows the distribution of dimensionless concentration over a 2000 m reach downstream of the outfall.
- Chart B shows transverse sections of the plume as it spreads across the channel with increasing distance downstream from the outfall.
- Chart C shows the reduction in maximum concentration and concentration along each bank with distance downstream from the outfall.

The maximum concentration is within 3% of the mean concentration about 1700 m downstream of the outfall for the scenario with mean ice-covered discharge and the best estimate of outfall discharge. For the scenario with mean open-water discharge and the best estimate of outfall discharge, the maximum concentration is still 10% greater than the mean concentration at the end of the modeling reach 2000 m downstream of the outfall. Deviations in concentration of less than 2% are considered to be completely mixed so mixing for the mean ice-cover scenario is virtually complete. Deviations in concentration of 10% are not considered fully mixed but differences in concentrations may be difficult to detect when concentrations are low, given the variability in background concentrations and fluctuations in eddy size and intensity.

The mixing length required for any particular water quality constituent to meet the instream target levels can be determined by combining the mixing model dimensionless concentrations with the design concentrations in the effluent discharge and the background concentrations in the receiving water.

6.0 CLOSURE

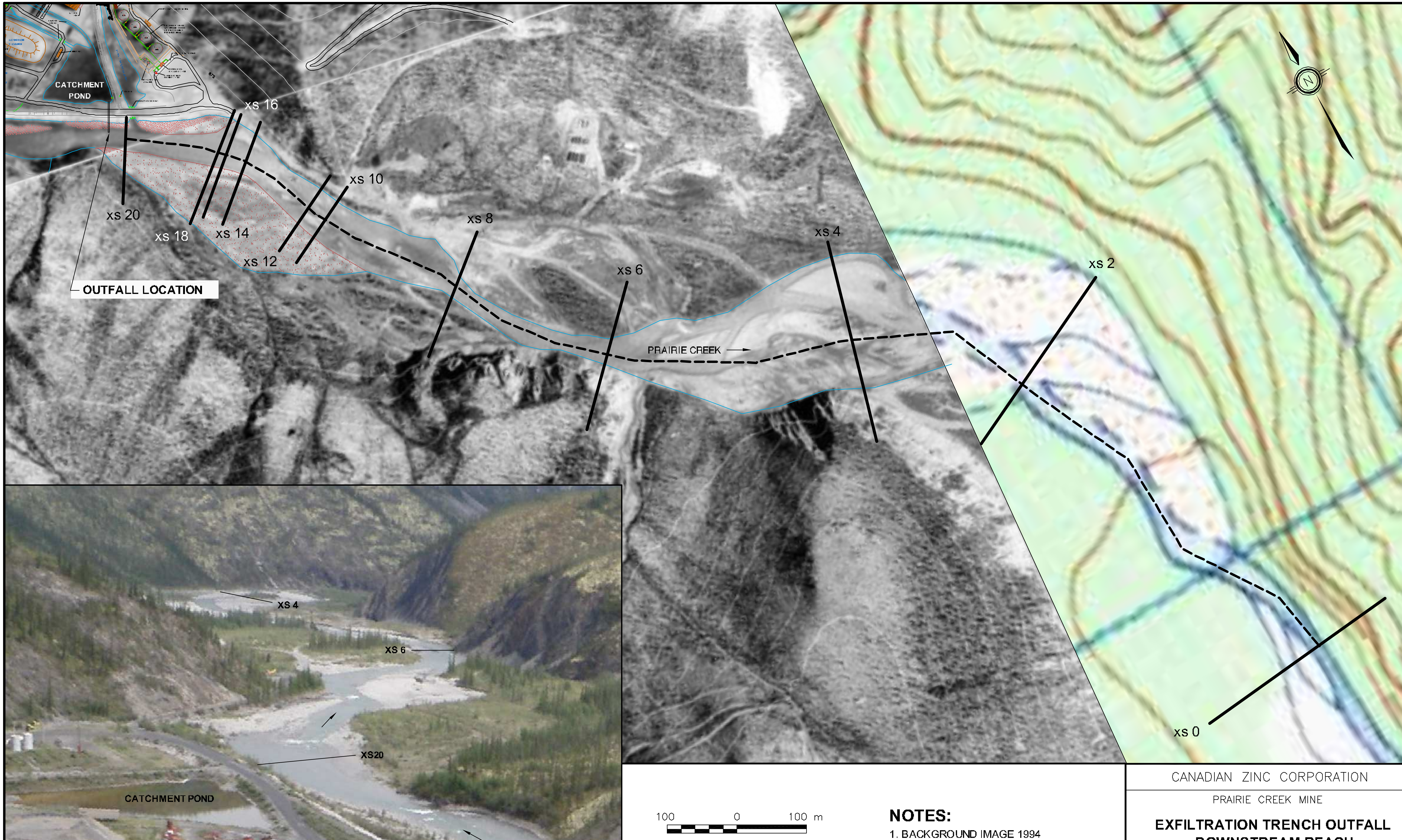
This report presents the results of a mixing analysis performed to quantify mixing in Prairie Creek in the reach downstream of the proposed exfiltration trench outfall. The results from this report are presented as dimensionless concentrations and dilutions relative to initial outfall concentrations and are intended to be utilized by others to assess various water quality parameters to ensure that they meet water quality in-stream targets.

We trust that the above assessment meets your immediate needs; please do not hesitate to call if there are any questions.

Respectfully submitted,

northwest hydraulic consultants ltd.

W.A. (Bill) Rozeboom, M.B.A., P.Eng. Senior Hydrologist	Gary Van Der Vinne, M.Sc., P.Eng. Principal



VIEW DOWNSTREAM TO PRAIRIE CREEK MIXING ZONE REACH, AUGUST 2010.

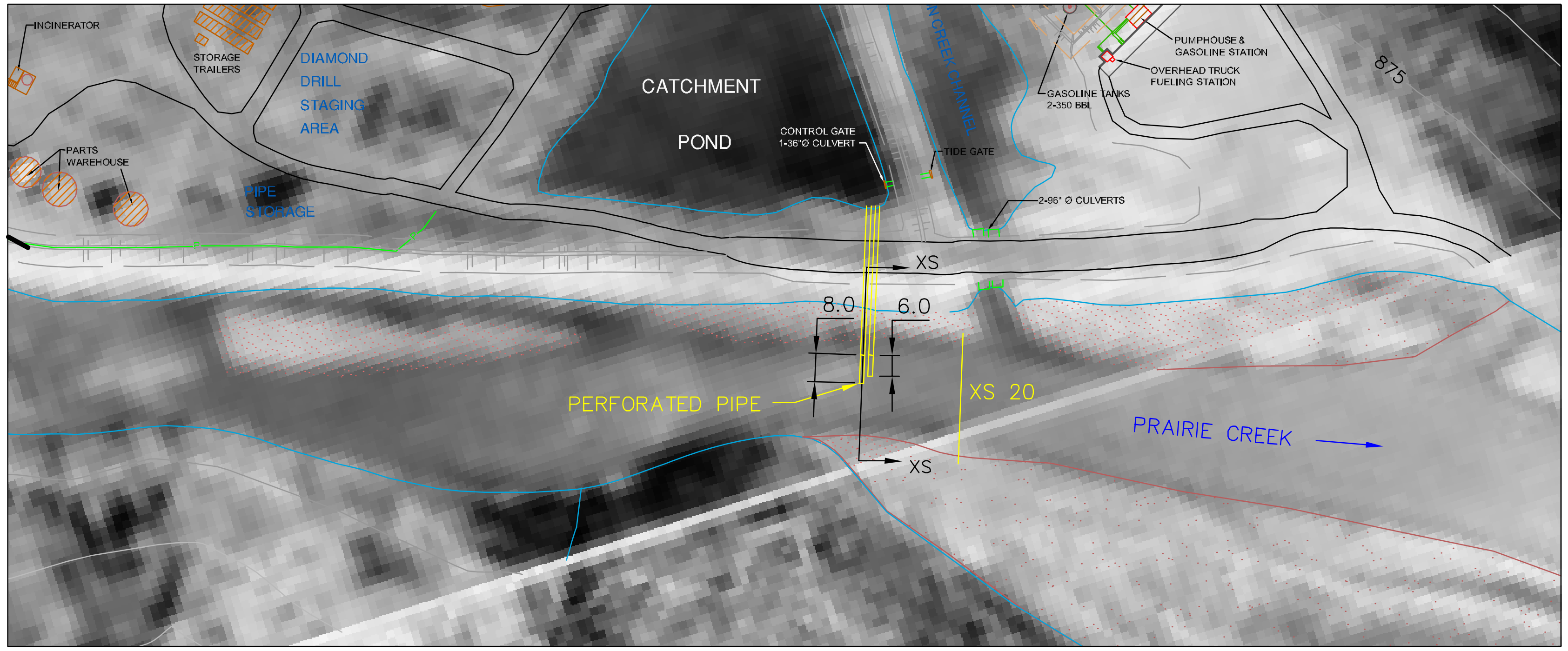
100 0 100 m

SCALE 1:5,000

NOTES:

1. BACKGROUND IMAGE 1994
2. MAP SOURCE: NTS 95F10, EDITION 1

CANADIAN ZINC CORPORATION		
PRAIRIE CREEK MINE		
EXFILTRATION TRENCH OUTFALL DOWNSTREAM REACH		
Dwg. 6987-003-R1	9 Feb 2011	**Figure 1**
northwest hydraulic consultants		



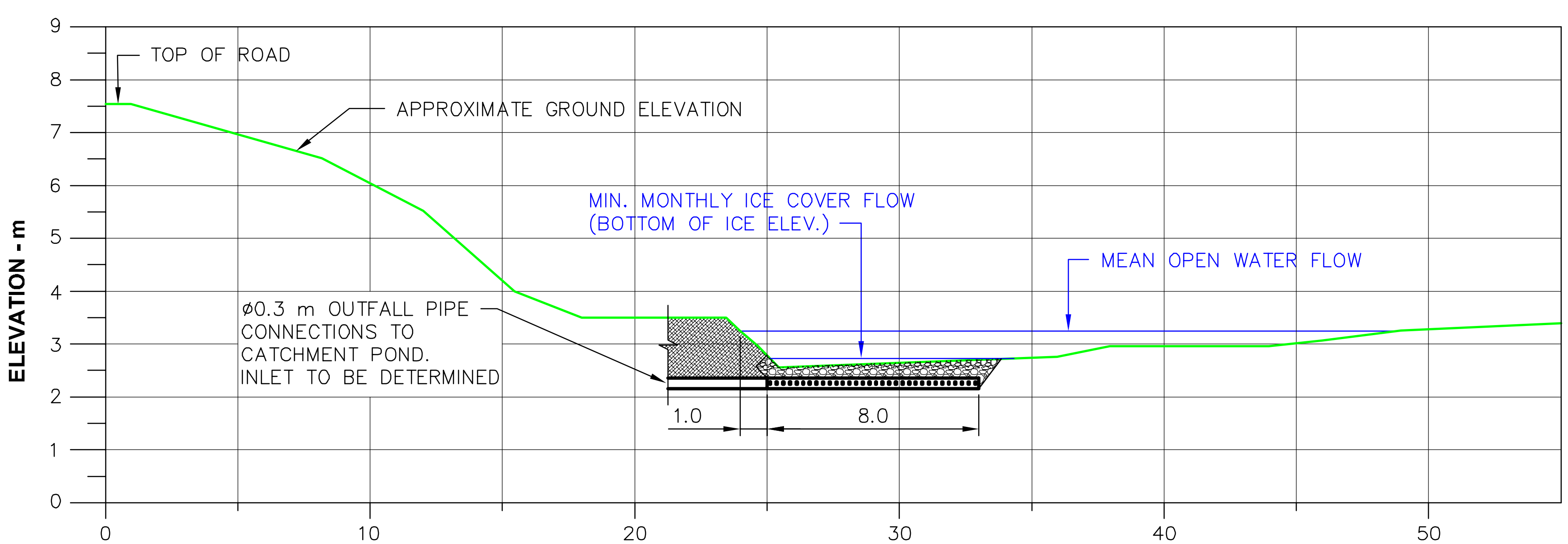
SITE PLAN WITH 1994 BACKGROUND IMAGE

50 0 50

SCALE 1:2,000

PHOTO 1. VIEW DOWNSTREAM
PHOTO DATE: AUGUST 9, 2010

PHOTO 2. EXFILTRATION TRENCH LOCATION
PHOTO DATE: AUGUST 9, 2010



ELEVATIONS ARE ASSUMED DATUM

DISTANCE - m

CROSS SECTION AT OUTFALL ALONG 8.0 m PIPE
(VIEWING DOWNSTREAM)

NOT FOR CONSTRUCTION

CANADIAN ZINC CORPORATION

PRAIRIE CREEK MINE

EXFILTRATION TRENCH OUTFALL CONCEPTUAL DESIGN

Dwg. 6987-006-R2	29 Apr 2011	**Figure 2**

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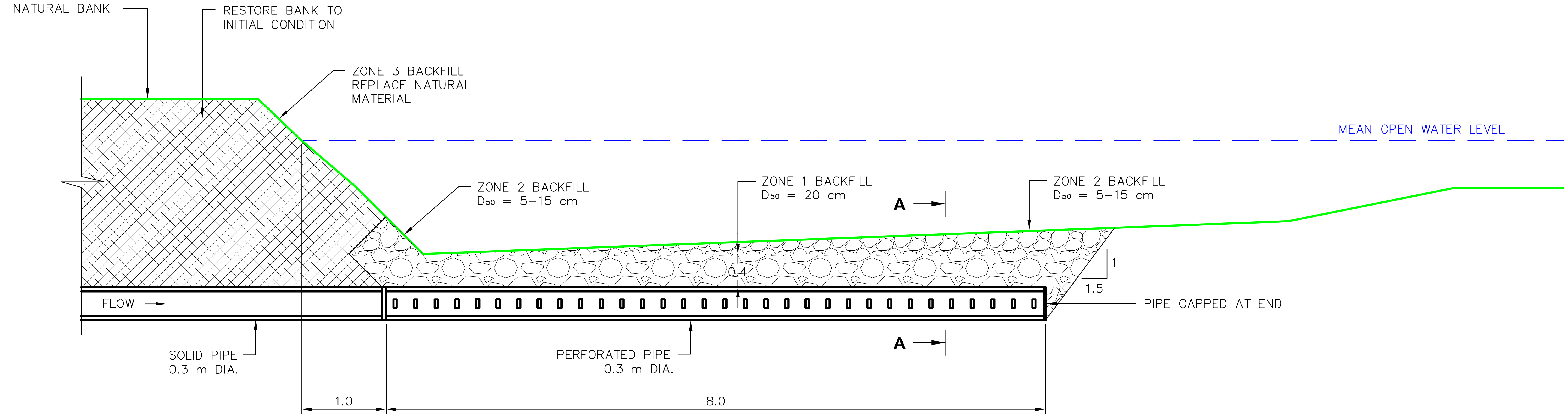
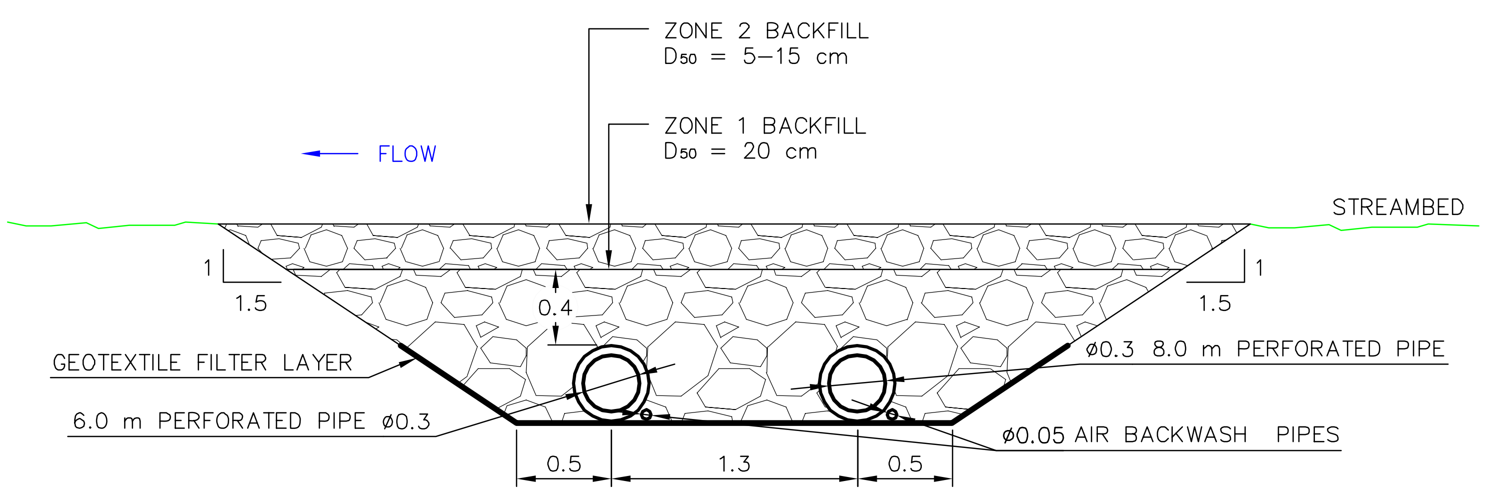
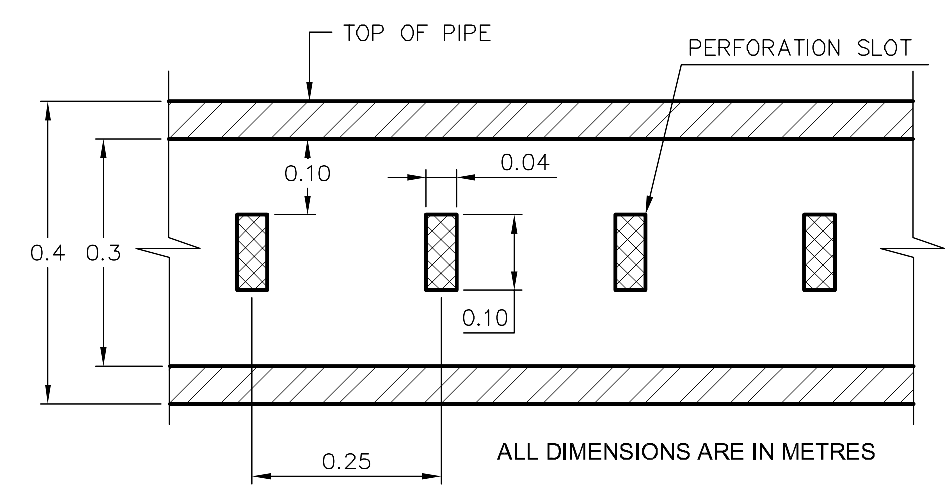


DETAIL 1
EXFILTRATION TRENCH ALONG 8.0 m PIPE
HORIZONTAL SCALE 1:50
VERTICAL SCALE 1:25



A-A
SCALE 1:40



ALL DIMENSIONS ARE IN METRES

DETAIL 2
PERFORATED PIPE ELEVATION
SCALE 1:10

NOT FOR CONSTRUCTION

CANADIAN ZINC CORPORATION
PRAIRIE CREEK MINE
EXFILTRATION TRENCH OUTFALL DETAILS

Dwg. 6987-006-R2	29 Apr 2011	**Figure 3**

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CHART A
CONCENTRATION CONTOUR PLAN

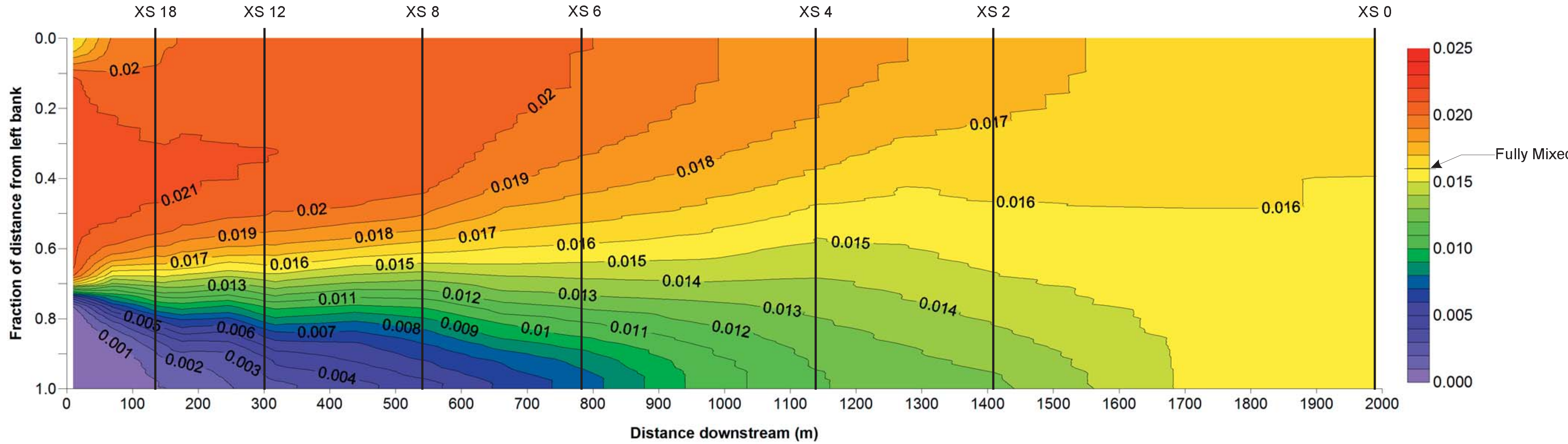


CHART B
TRANSVERSE CONCENTRATION PROFILES

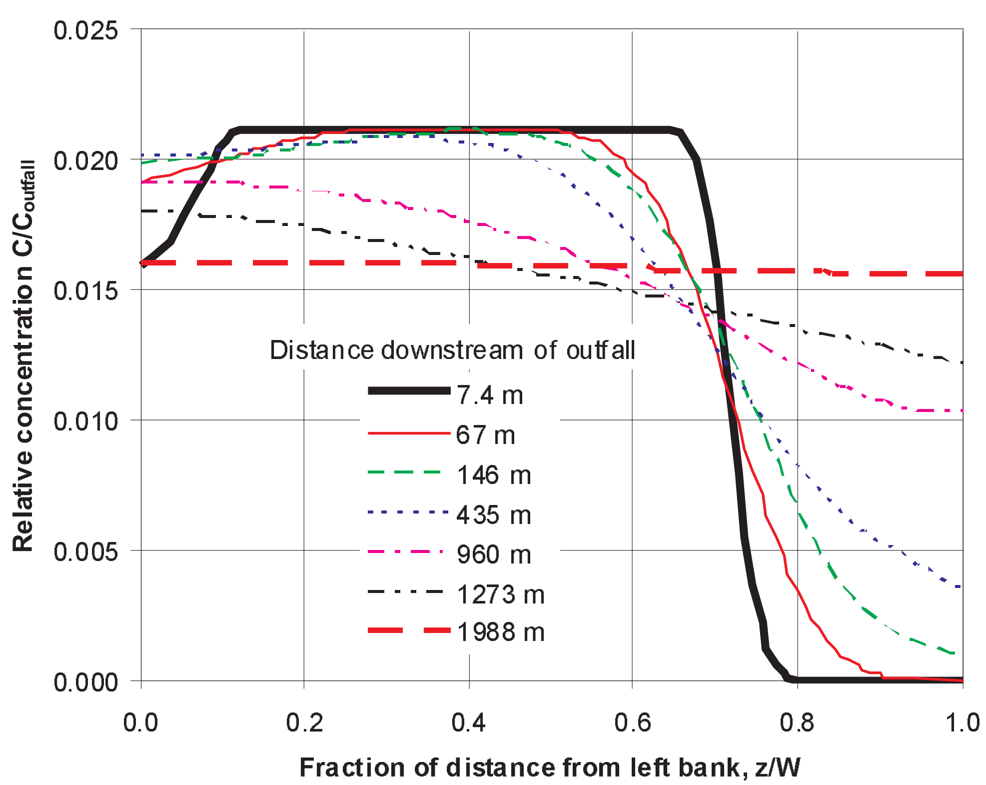
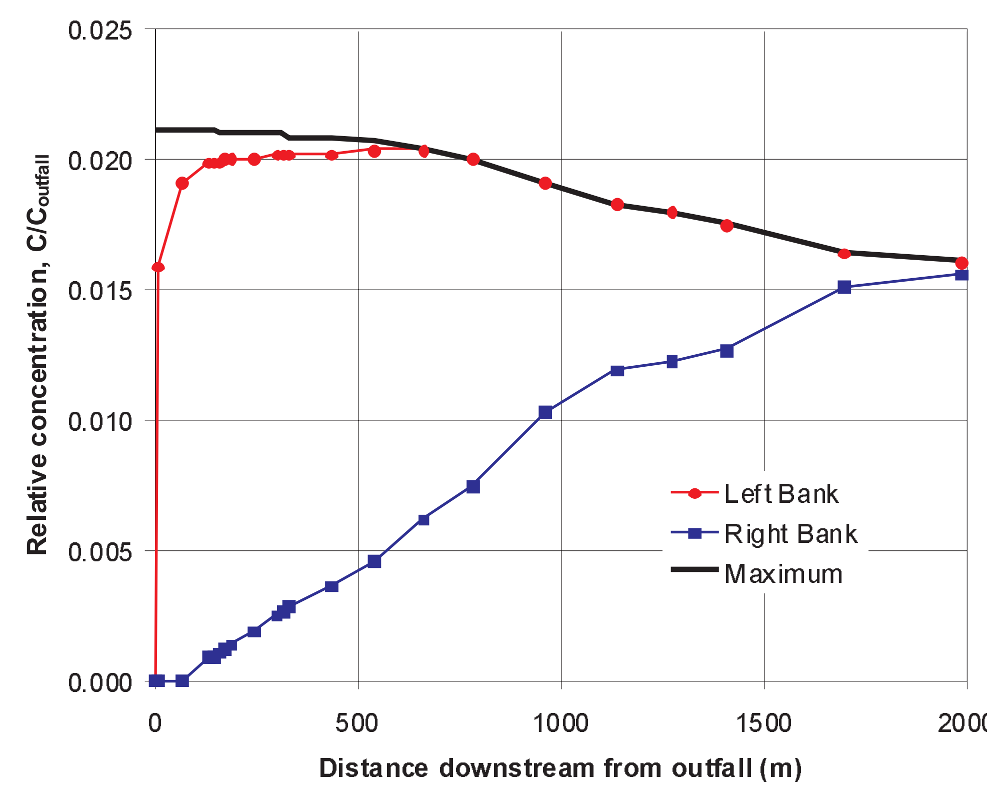


CHART C
LONGITUDINAL CONCENTRATION PROFILES



Prairie Creek Discharge	0.71 m^3/s
Outfall Discharge	0.0115 m^3/s
Vertical Mixing Length	7.1 m
Fully-mixed Dilution	62.7

CANADIAN ZINC CORPORATION
PRAIRIE CREEK MINE

EXFILTRATION TRENCH OUTFALL CONCENTRATION DISTRIBUTIONS FOR MEAN ICE-COVERED CONDITIONS

Project 16987	29 Apr 2011	**Figure 4**

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CHART A
CONCENTRATION CONTOUR PLAN

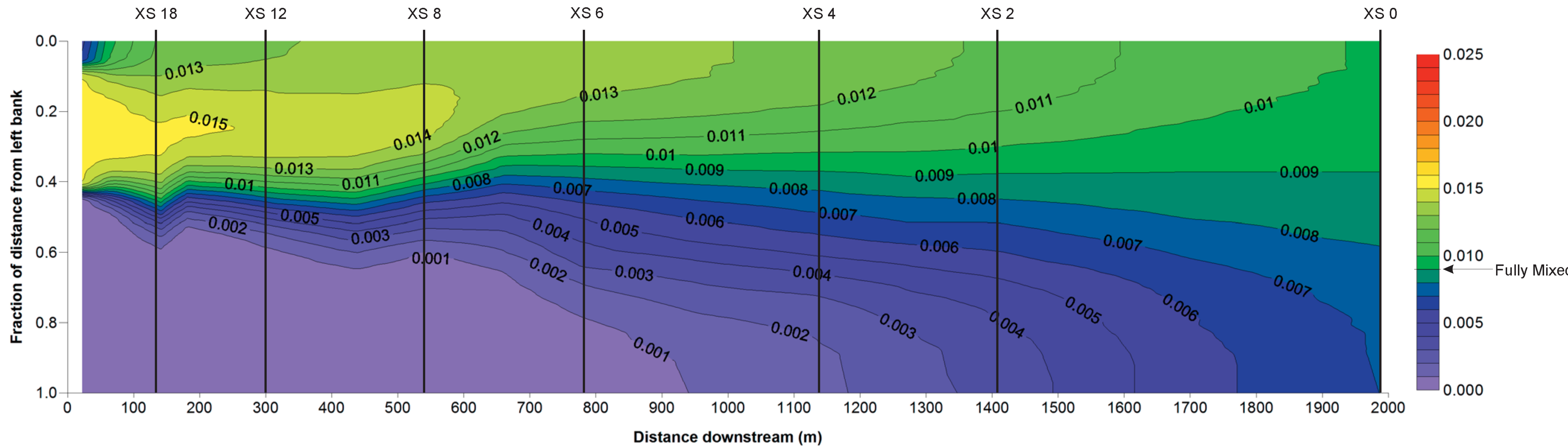


CHART B
TRANSVERSE CONCENTRATION PROFILES

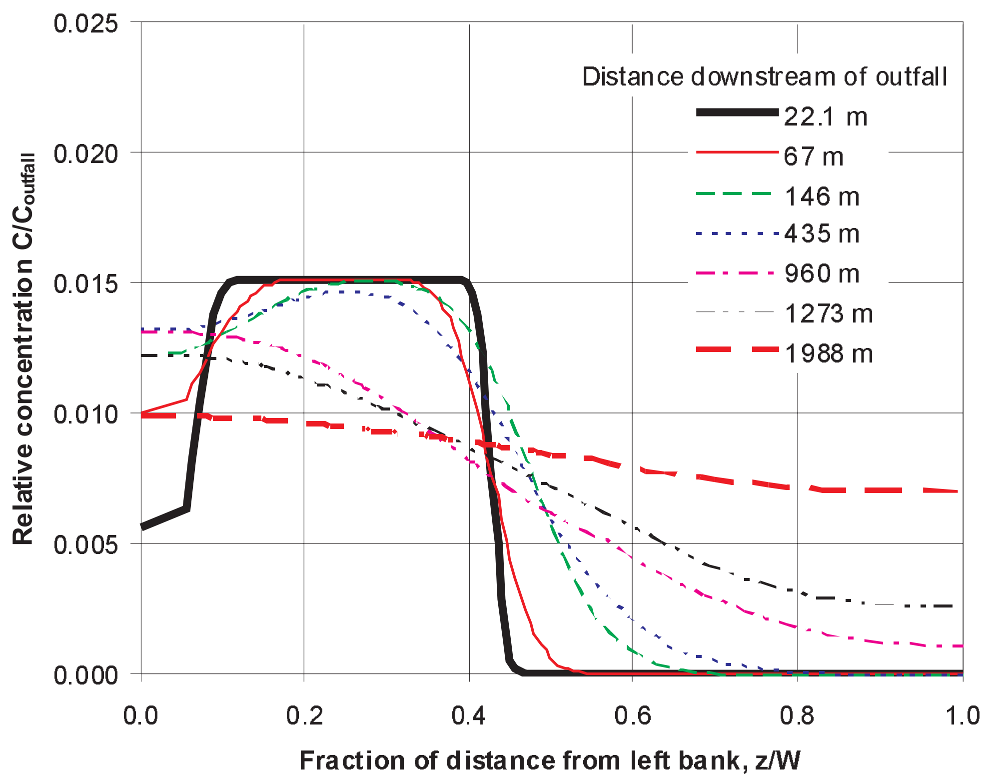
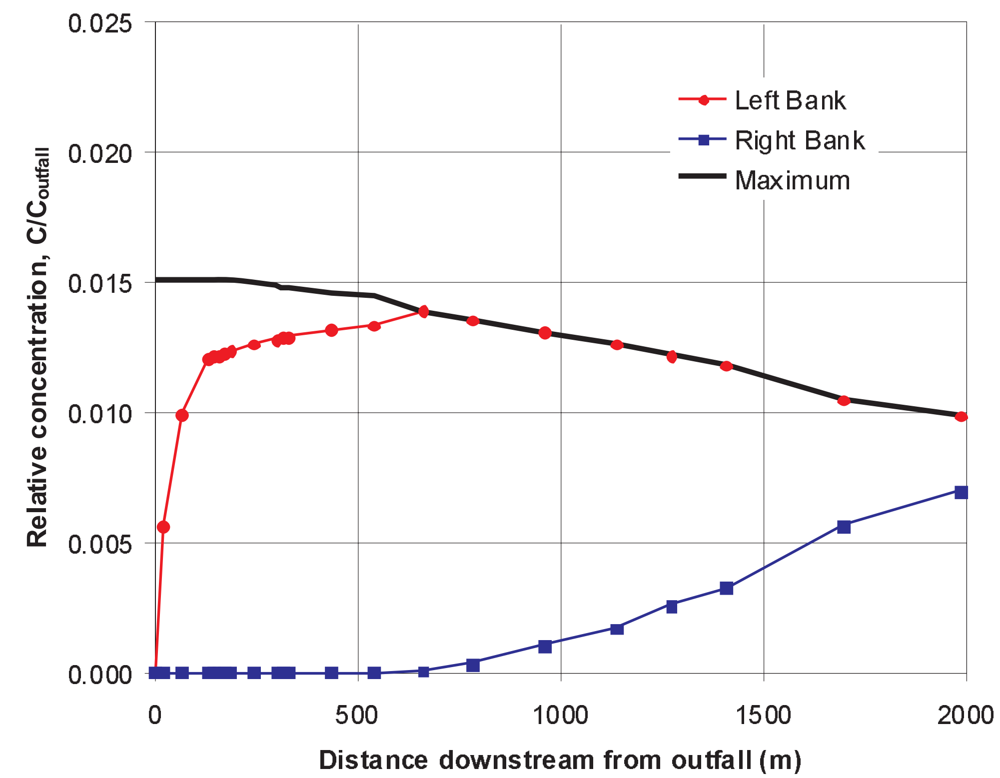


CHART C
LONGITUDINAL CONCENTRATION PROFILES



Prairie Creek Discharge	10.2 m^3/s
Outfall Discharge	0.0925 m^3/s
Vertical Mixing Length	22.1 m
Fully-mixed Dilution	111.3

CANADIAN ZINC CORPORATION

PRAIRIE CREEK MINE

EXFILTRATION TRENCH OUTFALL CONCENTRATION DISTRIBUTIONS FOR MEAN OPEN-WATER CONDITIONS

Project 16987	29 Apr 2011	**Figure 5**

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