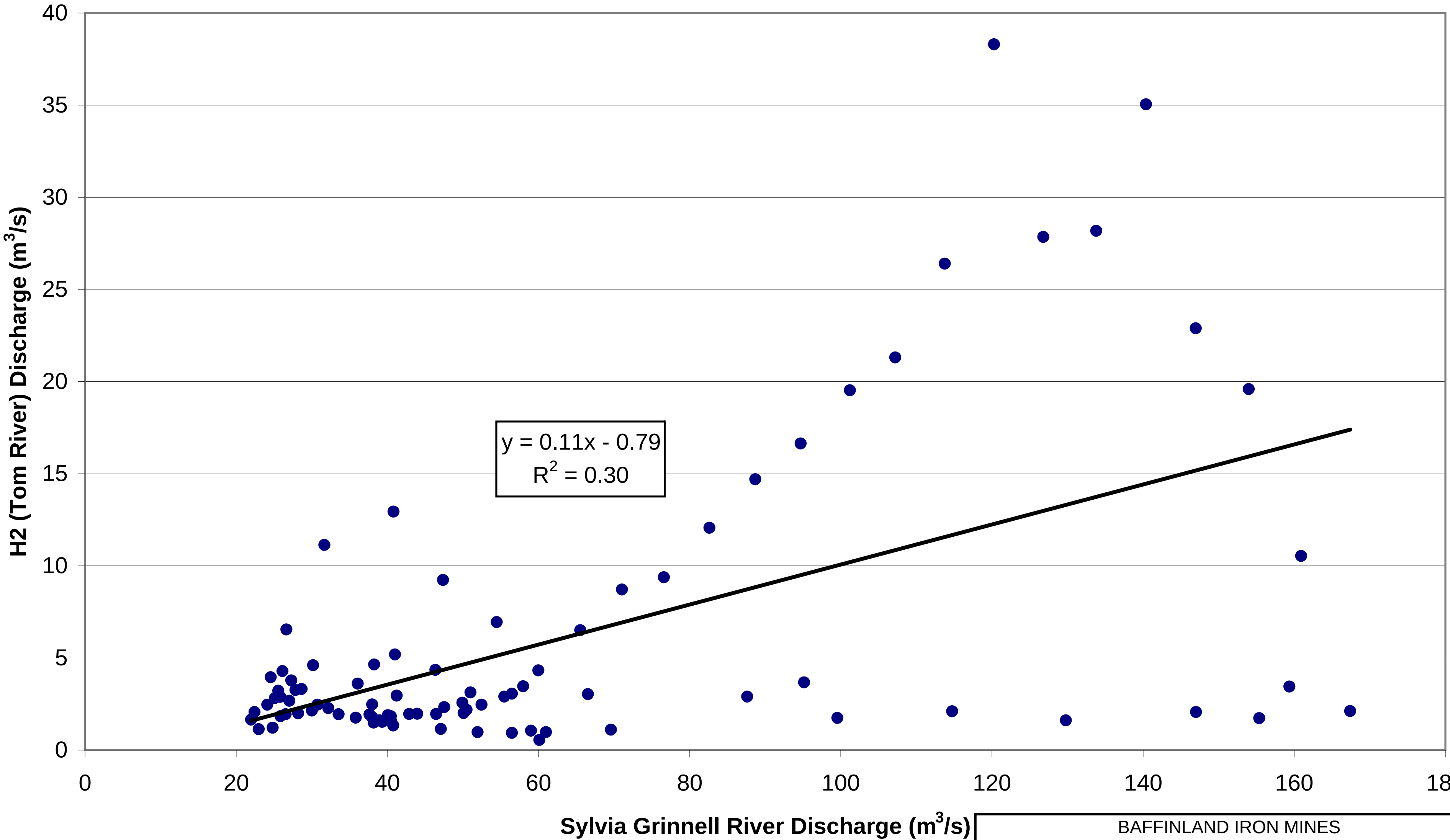

BAFFINLAND IRON MINES		
MARY RIVER PROJECT		
REGIONAL HYDROLOGIC ANALYSIS REGRESSION OF H2 AND SYLVIA GRINNELL RIVER DAILY DISCHARGE RECORDS (2007)		
Knight Piésold CONSULTING	PROJECT / ASSIGNMENT NO. NB102-00181/11	REF NO. VA08-01442
	FIGURE 2	REV. 0

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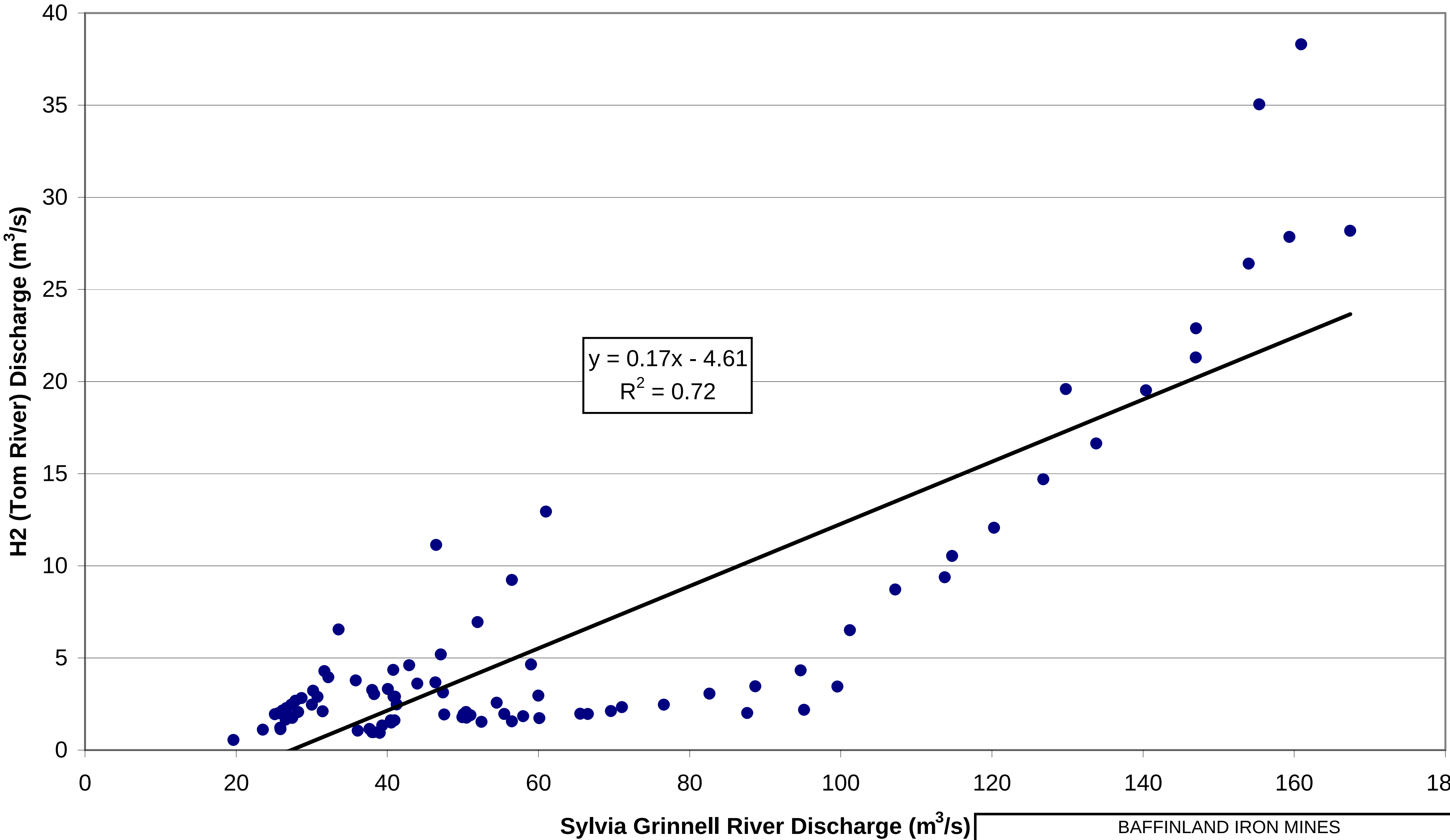

BAFFINLAND IRON MINES		
MARY RIVER PROJECT		
REGIONAL HYDROLOGIC ANALYSIS REGRESSION OF H2 AND SYLVIA GRINNELL RIVER SHIFTED DAILY DISCHARGE RECORDS (2007)		
Knight Piésold CONSULTING	PROJECT / ASSIGNMENT NO. NB102-00181/11	REF NO. VA08-01442
	FIGURE 3	REV. 0

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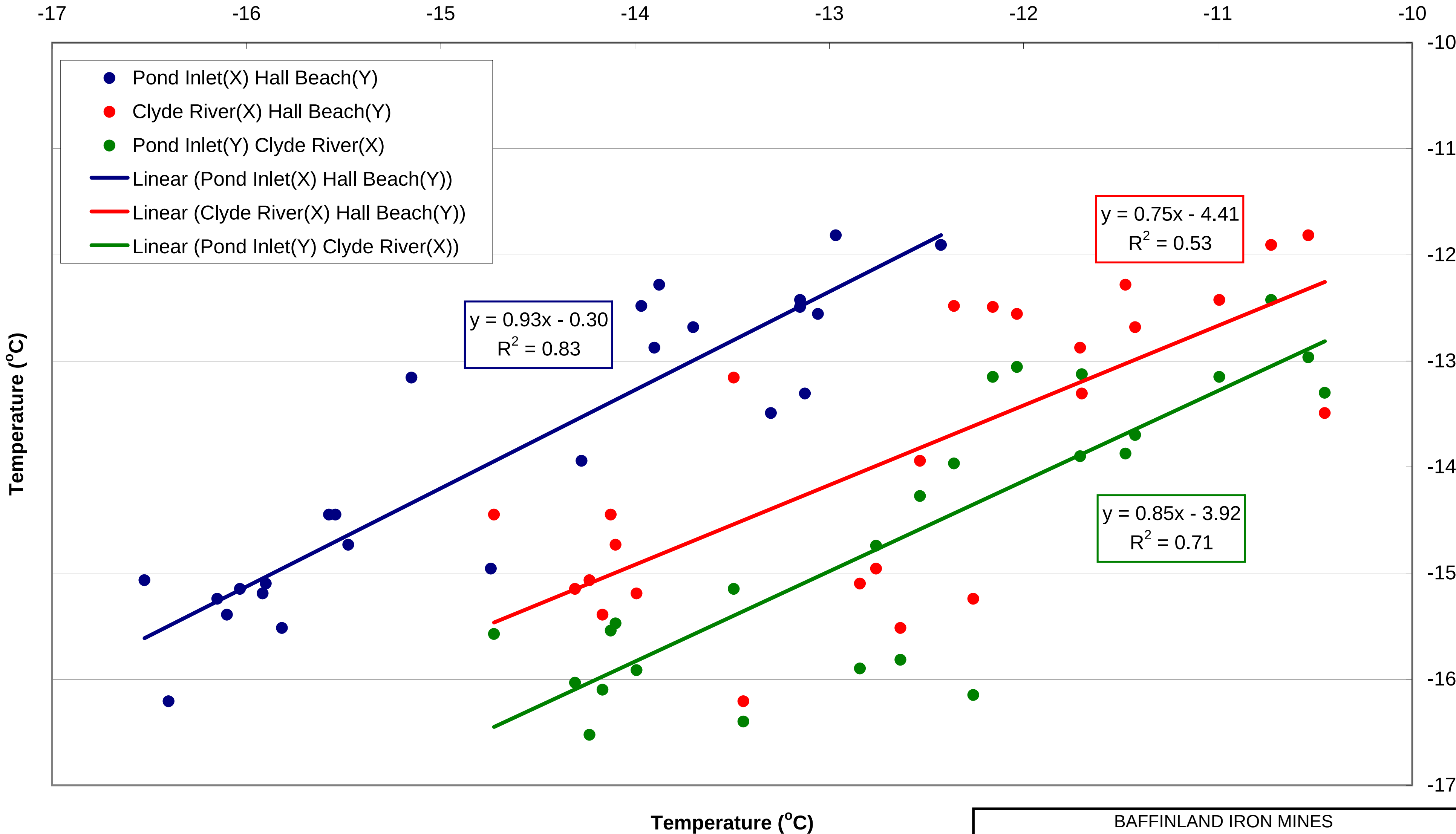

BAFFINLAND IRON MINES		
MARY RIVER PROJECT		
LINEAR REGRESSION OF REGIONAL ANNUAL AVERAGE TEMPERATURE RECORDS (1976-2006)		
Knight Piésold CONSULTING	PROJECT / ASSIGNMENT NO. NB102-00181/11	REF NO. VA08-01442
	FIGURE 4	REV. 0

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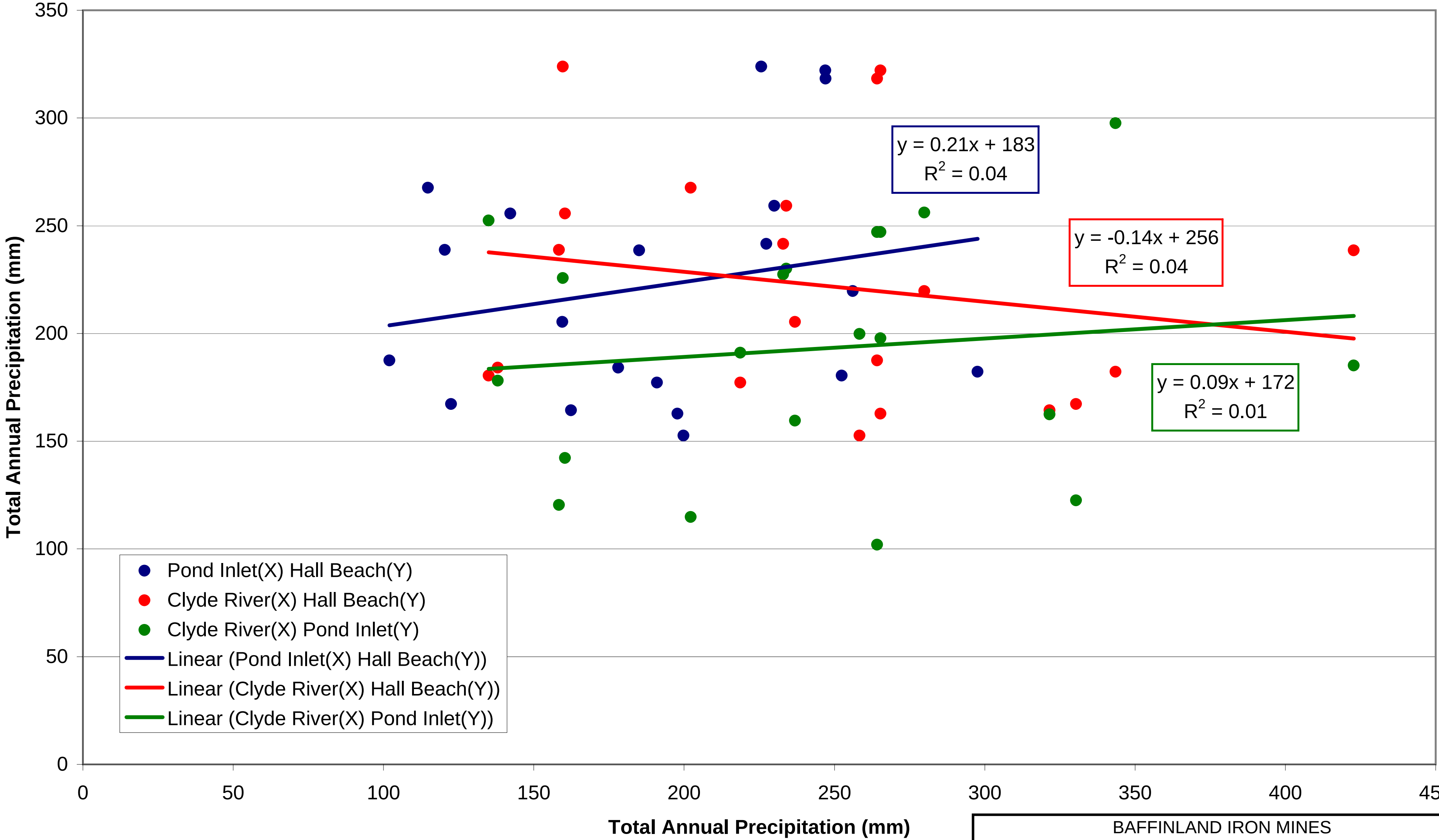

BAFFINLAND IRON MINES

MARY RIVER PROJECT

LINEAR REGRESSION OF REGIONAL TOTAL ANNUAL PRECIPITATION RECORDS (1976-2004)

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NB102-00181/11	VA08-01442

FIGURE 5 REV. 0

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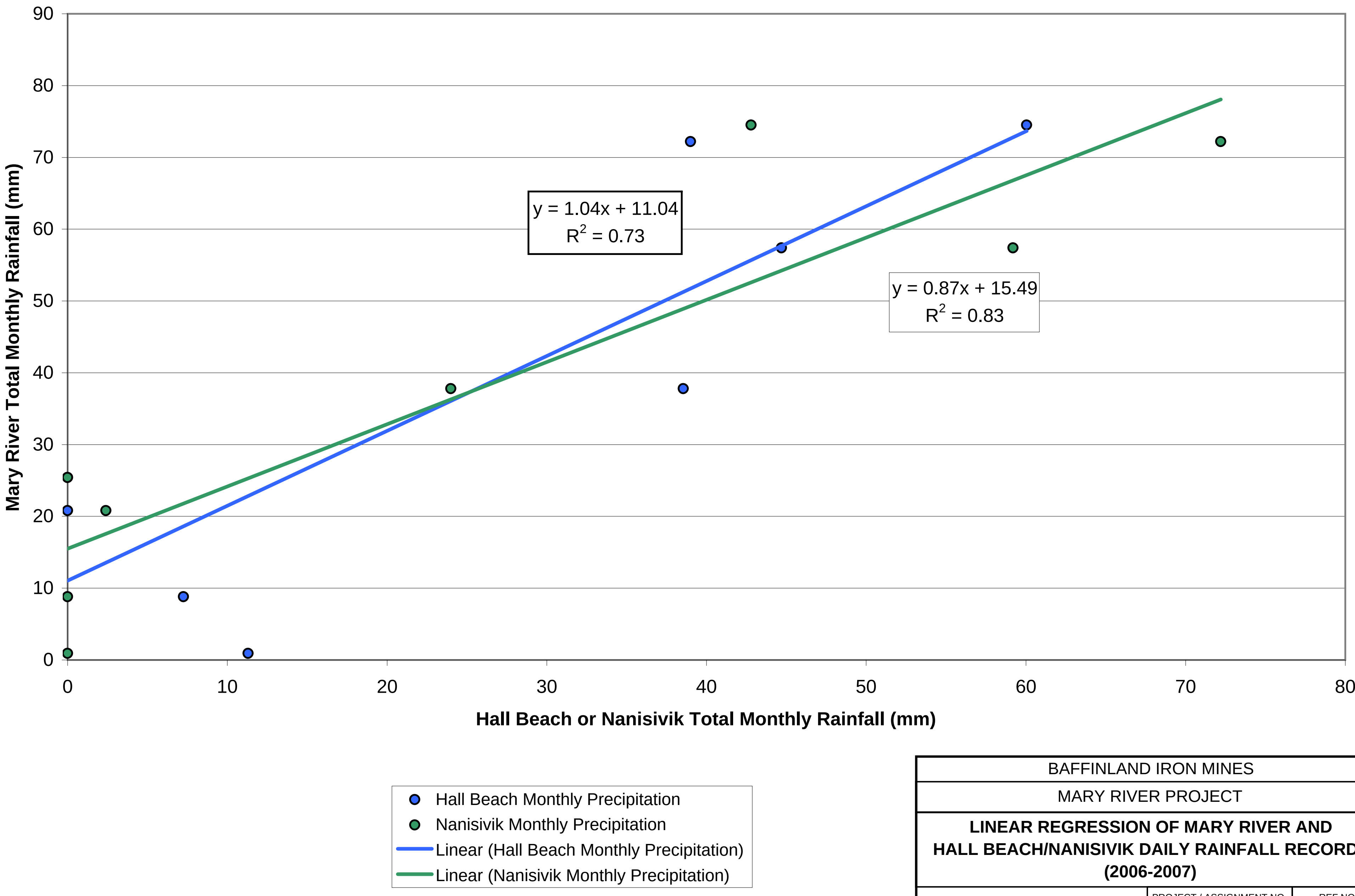

BAFFINLAND IRON MINES
MARY RIVER PROJECT
LINEAR REGRESSION OF MARY RIVER AND HALL BEACH/NANISIVIK DAILY RAINFALL RECORDS (2006-2007)

Knight Piésold CONSULTING	PROJECT / ASSIGNMENT NO. NB102-00181/11	REF NO. VA08-01442
	FIGURE 6	REV. 0

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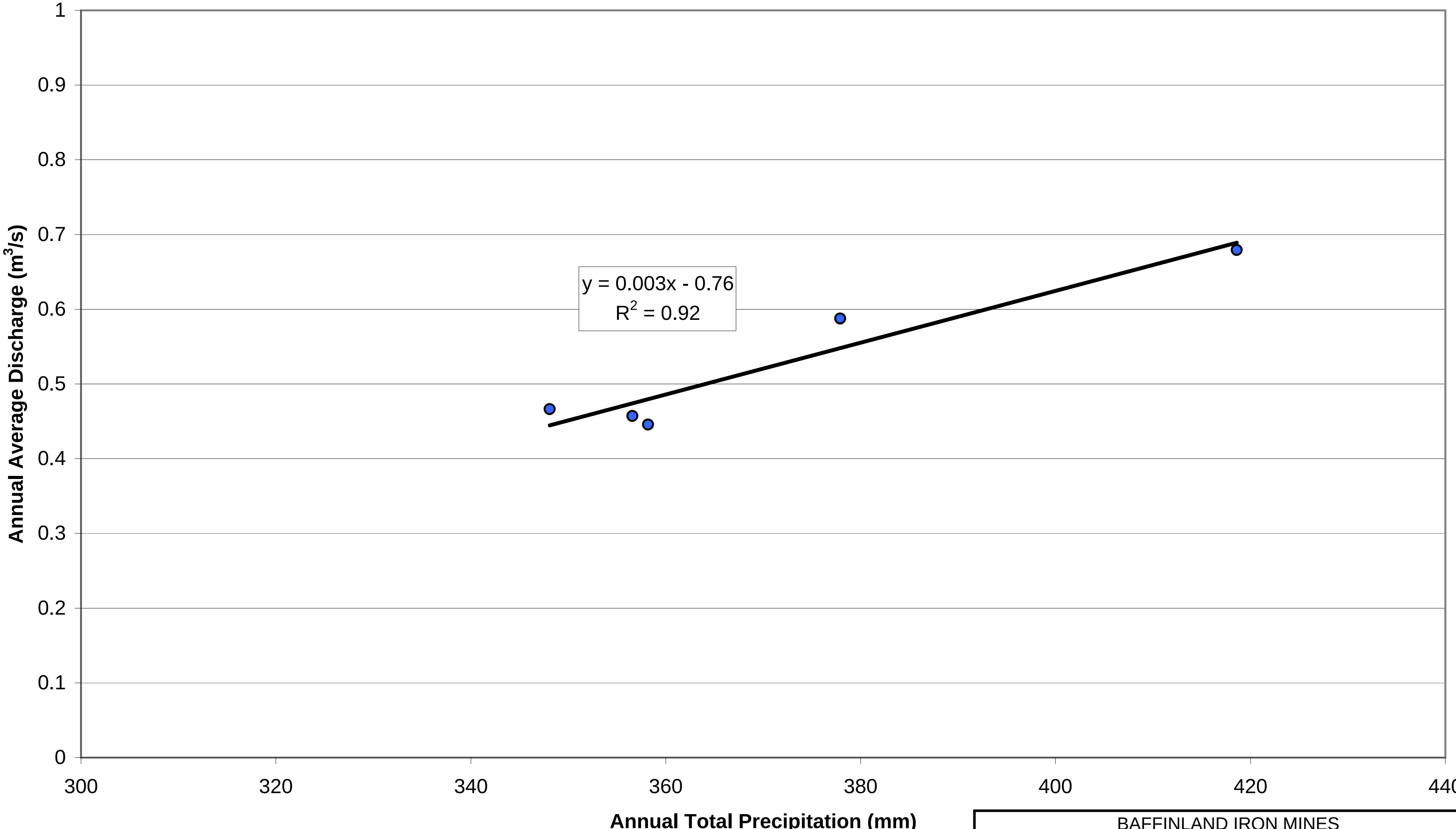

BAFFINLAND IRON MINES

MARY RIVER PROJECT

REGIONAL HYDROLOGIC ANALYSIS
CORRELATION OF APEX RIVER ANNUAL STREAMFLOW AND IQALUIT ANNUAL PRECIPITATION RECORDS

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NB102-00181/11	VA08-01442

FIGURE 7 REV. 0

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APPENDIX C

HYDROLOGY FOR HAUL ROAD DESIGN

(8 Pages)

Knight Piésold
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Memorandum

Date:	October 13, 2006	Our Ref:	NB102-181/6-A.01
To:	Kevin Hawton	Cont.#:	VA06-01475
From:	Jaime Cathcart		
Re:	Hydrology for haul road design		

Kevin,

This memorandum briefly summarizes the hydrologic characteristics of the haul road area and the procedure used to develop design flow estimates for the haul road crossing of streams and rivers.

Hydrology

Baffin Island is one of the northernmost and coldest parts of Canada, and the project area, which is situated towards the northern end of the Island, has a mean annual temperature of approximately -12 °C, and monthly average temperatures that are below -20 °C from December to March and above freezing only from June through August, with a high of 4.4 °C in July. These extremely cold temperatures, combined with permafrost ground conditions, result in a short period of runoff that typically occurs from June to September.

All rivers and creeks, with perhaps the exception of the very largest systems, freeze completely solid during the winter months. Even the Sylvia Grinnell River near Iqaluit, which is the largest system on the Island that is continuously gauged by WSC (basin area of ~4000 km^2), freezes solid by April every year, when the active groundwater reserves are completely depleted or frozen. Streams and rivers usually begin to flow in late May with the melting of snow and ice, then peak in June or July with rising temperatures and corresponding snowmelt, before dropping steadily through to November when flows essentially cease. The peak runoff period is quite short and the volume of the annual hydrograph is low, relative to the rest of Canada, due the region's very low average annual precipitation of approximately 200 mm. The annual runoff coefficient is very high, however, due to the low temperatures (low evaporation) and the ground conditions of permafrost (low infiltration) and minimal vegetative cover (low transpiration). Correspondingly, surface water is abundant, and the region is dotted with thousands of small lakes and streams. The mean annual runoff in the area is typically in the order of 10 $l/s/km^2$.

The ground conditions are conducive to a very rapid basin runoff response, and peak flows are correspondingly quite large relative to rates of snowmelt and rainfall. Annual peak flows are due to snowmelt, rainfall, or rain and snowmelt, and most commonly occur in July, but may occur at any time during the non-freeze period. Flood water levels in the streams and rivers typically rise and fall very quickly.

Peak Design Flows

For the purpose of designing river and creek crossings for the bulk sample haul road, it was necessary to develop a design flow model. The hydrologic data currently being collected in the project area are of very short duration and the rating curves for the various measurement sites are not yet fully developed, so the data are not appropriate for this application. Rather, long-term historical peak flow and extreme rainfall data collected by Environment Canada were used. These data were combined with an understanding of the hydrologic characteristics of the area, as described above, to develop a series of peak flow scaling equations. Each equation corresponds to a different return period (flood severity) and requires an input of drainage area to generate a design flow estimate. The equations for return periods of 2 years, 5 years, 10 years and 25 years are presented, as follows:

$$\mathbf{Q_2 = 1.1 \times A^{0.79}}$$

$$\mathbf{Q_5 = 1.7 \times A^{0.77}}$$

$$\mathbf{Q_{10} = 2.0 \times A^{0.76}}$$

$$\mathbf{Q_{25} = 2.6 \times A^{0.75}}$$

Where, Q = peak instantaneous flow in m^3/s
A = drainage area in km^2

These equations were developed according to a regional scaling model using linear moment (L-moment) statistics computed from the historical peak daily flow records for five WSC stations, as summarized in Table 1. The regional scaling plots for the mean and L-standard deviation are shown on Figure 1. The "least squares fit" equations for these plots are shown in red, and the upper envelope equations are shown in black. The upper envelope equations were selected for design purposes because of the need to incorporate a reasonable margin of error into a model based on such a limited dataset, and because the flood values produced with the envelope equations agree much more closely with those generated by rain-fall runoff modelling using the IDF values summarized in Table 2 and on Figure 2.

In addition to estimates of the mean and L-standard deviation, an estimate of the L-coefficient of skewness (L-Cs) is also required for generating flood quantile values. The values shown in Table 1 indicate a wide range, with two of the five values negative. However, research at the University of BC (Cathcart, 2001) has indicated that the L-Cs may follow a similar scaling pattern to the L-Cv (ratio of the mean to the L-Stdev), given a large enough sample size, and that L-Cs values at any specific scale are often similar to, but slightly less than, that of the L-Cv. Given this information, and the understanding that higher L-Cs values correspond to higher design flows, it was considered prudent, yet reasonable, to use relatively high L-Cs values, so L-Cs values were selected to be slightly less than their associated L-Cv values.

Statistical parameters for basin scales of 10 km^2 and 1000 km^2 were determined to be:

For 10 km^2,
$Q_{mean} = 3.3\ m^3/s$
L-Stdev = 0.84 m^3/s
L-Cv = 0.25
L-Cs = 0.20

For 1000 km^2,
$Q_{mean} = 192\ m^3/s$
L-Stdev = 35 m^3/s
L-Cv = 0.18
L-Cs = 0.16

These parameters where then used to develop synthetic distributions of flood values at the two basin scales, and for this purpose a generalized extreme value (GEV) distribution type was selected. The GEV is commonly used in Canada to model flood distributions and is found to consistently provide a reasonable, yet conservative, fit to measured data (Cathcart, 2001). The derived distributions provided peak daily flood estimates for different return periods at the two scales. These values were used to develop scaling equations for peak daily flows at different return periods.

For design purposes, peak instantaneous values, rather than peak daily values, are required. The preceding discussion dealt with the estimation of peak daily flows, as there is not sufficient peak instantaneous regional data to develop meaningful scaling relationships. However, a limited number of concurrent peak daily and instantaneous flow data sets are available for the region, as summarized in Table 1. These values permitted the development of a regional envelope curve relating drainage areas to ratios of instantaneous to daily peak flow values, according to the equation:

$$I/D = 2.8 \times A^{-0.10}$$

Where, I/D = ratio of instantaneous peak flow to daily flow
A = drainage area in km^2

Application of this equation to the peak daily flow estimates resulted in a series of design flood estimates at different scales, from which the design flow equations for return periods of 2 years, 5 years, 10 years and 25 years were derived. These equations are considered applicable for basin areas ranging from 0.5 km2 to 1000 km2.

For basins smaller than 0.5 km2, it is recommended that the simple Rational Equation be used, as follows:

$$Q = 0.28\ CIA$$

Where, Q = peak instantaneous flow in m^3/s
A = drainage area in km^2
C = runoff coefficient = 0.90
I = rainfall intensity corresponding to the time of concentration.

Time of Concentration should be computed with the modified Kirpich equation: $T_c = 0.13\left(\frac{L}{\sqrt{S}}\right)^{0.77}$

Where, T_c = time of concentration in hours.
L= main channel length in km.
S = main channel slope.

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Signed: ______________________
Jaime Cathcart, Ph.D., P.Eng. - Specialist Engineer

Approved by: ______________________
Jeremy Haile, P.Eng. - President

Reference: Cathcart, J., 2001. The Effects of Scale and Storm Severity on the Linearity of Watershed Response Revealed Through the Regional L-Moment Analysis of Annual Peak Flows. Ph.D. Thesis, Resource Management and Environmental Studies, University of British Columbia, Vancouver, BC, Canada.

Encl:
Table 1 – Regional Flood Statistics for Daily and Instantaneous Peak Flow Records
Table 2 – Estimated Site Rainfall IDF values
Figure 1 – Regional Peak Flow Scaling Plots
Figure 2 – IDF Curves for Mine Site and Transportation Corridor

/jc

TABLE 1

BAFFINLAND IRON MINES CORPERATION
MARY RIVER PROJECT

REGIONAL FLOOD STATISTICS FOR DAILY AND INSTANTANEOUS PEAK FLOW RECORDS

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M:\1\02\00181\04\A\Data\Hydrology\[Peak flows.xls]Table 1_r0
Rev'd Oct 4, 2006

Region	Station Name	WSC Data	Years of Record			Drainage Area	Peak Daily Flows								Peak Instantaneous Flows							Ratio I/D
		Sta. ID	Begin - End	Daily	Instantaneous	(km^2)	mean (m^3/s)	unit mean ($m^3/s/km^2$)	Stdev (m^3/s)	Cv	Cs	L-Stdev (m^3/s)	L-Cv	L-Cs	mean (m^3/s)	Stdev (m^3/s)	Cv	Cs	L-Stdev (m^3/s)	L-Cv	L-Cs	mean
Baffin Island	Duval River near Pangnirtung	10UF001	1977-1983	2	5	95.5									26.24	10.74	0.41	0.08	6.68	0.26	0.07	1.68
	Sylvia Grinnell River near Iqaluit	10UH001	1971-1999	17	9	3980	361.23	0.09	130.48	0.36	-0.26	70.11	0.19	-0.03	422.11	119.75	0.28	0.48	69.86	0.17	0.08	1.10
	Apex River at Apex	10UH002	1973-1992	13	7	58.5	7.85	0.13	3.41	0.43	0.76	1.94	0.25	0.23	10.85	6.02	0.56	0.86	3.55	0.33	0.28	1.37
	Marcil Creek near Arctic Bay	10UB001	1978-1983	3	2	143.9	10.2	0.07	6.80	0.67	0.12	3.74	0.37	0.04								1.56
	Mecham River near Resolute	10VC002	1971-1979	4	2	86.8	22.21	0.26	8.42	0.38	0.79	4.71	0.21	0.21								1.91
	Allen River near Mouth	10VC001	1970-1984	6	5	448.0	60.75	0.14	22.67	0.37	-0.09	12.69	0.21	-0.01	112.34	13.65	0.12	0.44	8.46	0.08	0.16	1.74
Regional Average													0.25	0.09						0.21	0.15	1.56
Northern Quebec	Hamelin River next to Arnaud Rive	03HA009	1963-1978		16	4120	283.13	0.07	79.85	0.28	0.21	46.63	0.17	0.03								
	Hamelin River d/s of Pelletier Lake	03HA012	1980-1993		14	3760	231.64	0.06	58.43	0.25	-0.59	33.45	0.14	-0.10								
	False River	03MB001	1973-1991		24	2140	182.46	0.09	96.53	0.53	-0.73	51.29	0.29	-0.19								
	Tunulic River next to the mouth	03MC001	1973-1993		20	3680	578.15	0.16	131.04	0.23	-0.01	74.66	0.13	-0.002								

Notes:
1) Ratio I/D is the average of the annual ratios of the peak instantaneous to peak daily flows.
2) Statistics were not computed for datasets with 2 or less years of record.
3) Northern Quebec values provided for comparison purposes. Only peak daily statistics were computed.

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TABLE 2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ESTIMATED SITE RAINFALL IDF VALUES

Duration	Mean	St. Dv.	C.V.
5 min	0.8	0.3	0.35
10 min	1.2	0.4	0.35
15 min	1.5	0.5	0.35
30 min	2.5	0.9	0.35
1 hr	4	1.6	0.40
2 hr	6	2.4	0.40
6 hr	12	6.0	0.50
12 hr	16	8.0	0.50
24 hr	25	12.5	0.50

Year	2	5	10	15	20	25	50	100	200
Freq. Factor	-0.0164	0.719	1.305	1.635	1.866	2.044	2.592	3.137	3.679

Return Period Rainfall Amounts (mm)

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Rev'd 13/Oct/06

Duration	2 yrs	5 yrs	10 yrs	15 yrs	20 yrs	25 yrs	50 yrs	100 yrs	200 yrs
5 min	0.8	1.0	1.2	1.3	1.3	1.4	1.5	1.7	1.8
10 min	1.2	1.5	1.7	1.9	2.0	2.1	2.3	2.5	2.7
15 min	1.5	1.9	2.2	2.4	2.5	2.6	2.9	3.1	3.4
30 min	2.5	3.1	3.6	3.9	4.1	4.3	4.8	5.2	5.7
1 hr	4.0	5.2	6.1	6.6	7.0	7.3	8.1	9.0	9.9
2 hr	6.0	7.7	9.1	9.9	10.5	10.9	12.2	13.5	14.8
6 hr	11.9	16.3	19.8	21.8	23.2	24.3	27.6	30.8	34.1
12 hr	15.9	21.8	26.4	29.1	30.9	32.4	36.7	41.1	45.4
24 hr	24.8	34.0	41.3	45.4	48.3	50.6	57.4	64.2	71.0

Rainfall Intensity (mm/hr)

Duration	2 yrs	5 yrs	10 yrs	15 yrs	20 yrs	25 yrs	50 yrs	100 yrs	200 yrs
5 min	9.5	12.0	14.0	15.1	15.9	16.5	18.3	20.1	22.0
10 min	7.2	9.0	10.5	11.3	11.9	12.4	13.7	15.1	16.5
15 min	6.0	7.5	8.7	9.4	9.9	10.3	11.4	12.6	13.7
30 min	5.0	6.3	7.3	7.9	8.3	8.6	9.5	10.5	11.4
1 hr	4.0	5.2	6.1	6.6	7.0	7.3	8.1	9.0	9.9
2 hr	3.0	3.9	4.6	5.0	5.2	5.5	6.1	6.8	7.4
6 hr	2.0	2.7	3.3	3.6	3.9	4.0	4.6	5.1	5.7
12 hr	1.3	1.8	2.2	2.4	2.6	2.7	3.1	3.4	3.8
24 hr	1.0	1.4	1.7	1.9	2.0	2.1	2.4	2.7	3.0

Notes:
1) Data derived from IDF information published for climate stations at Clyde Airport (#2400800) and Pond Inlet Airport (#2403201) by the Atmospheric Environment Branch of Environment Canada.

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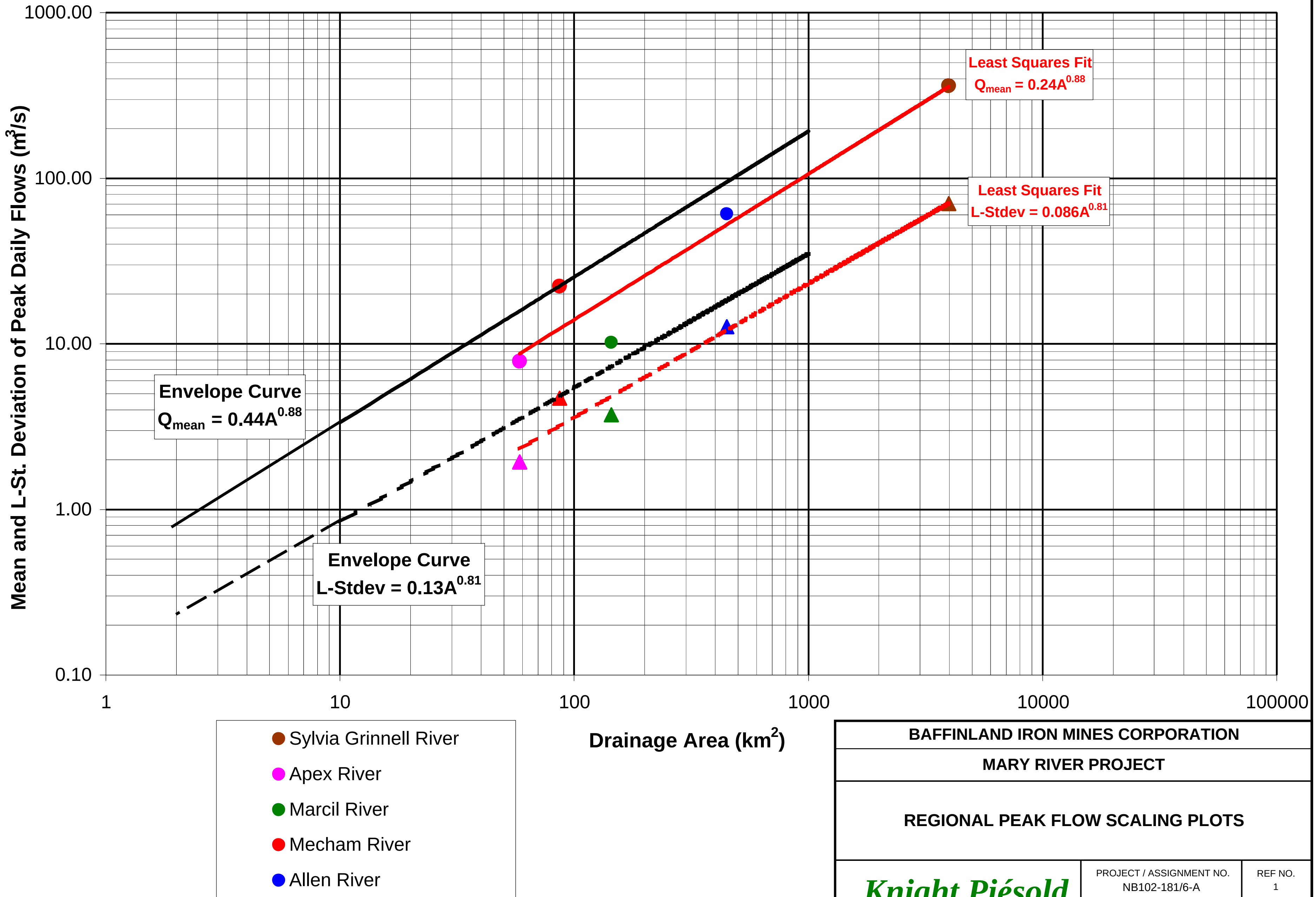

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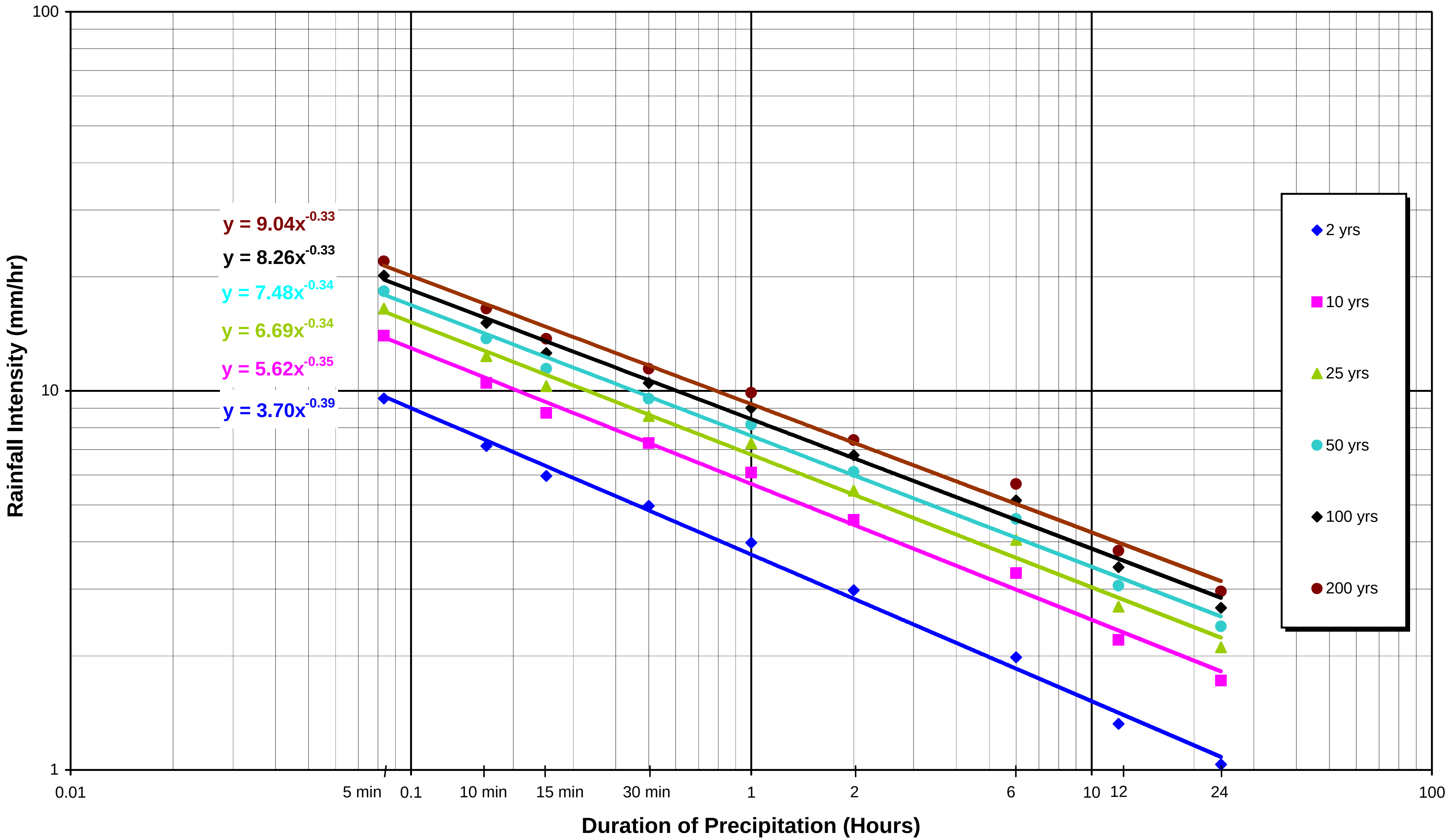
BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

REGIONAL PEAK FLOW SCALING PLOTS

Knight Piésold CONSULTING

PROJECT / ASSIGNMENT NO.	REF NO.
NB102-181/6-A	1
FIGURE 1	REV. 0



Notes:
1) IDF curves based on extreme precipitation data for Clyde Airport and Pond Inlet Airport, as published by Environment Canada.

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MARY RIVER PROJECT			
IDF CURVES FOR MINESITE AND TRANSPORATION CORRIDOR			
Knight Piésold CONSULTING	PROJECT NO. NB102-181/6	REF. NO. 1	REV. 0
	FIGURE 2		