Leaders in
water resource
technology

nhc

northwest hydraulic consultants

4823 - 99th street
edmonton, alberta
canada T6E 4Y1
tel (780) 436-5868
fax (780) 436-1645
nhc@nhc-edm.com

6217/4096

December 11, 2001

BGC Engineering Inc.
Suite 1605, 840 - 7th Avenue SW
Calgary, Alberta
T2P 3G2

Attention: J W Cassie, P.Eng.

Dear Sir:

Re: Hydrotechnical Assessment for Faro Mine Site

1 INTRODUCTION

1.1 Background

This report provides a preliminary hydrotechnical assessment for the fresh water supply dam (FWSD) and down valley facilities at the Faro Mine site.

The Faro mine is located approximately 20 km northwest of the town of Faro in Yukon. Faro town lies in the Tintina Trench about 150 km northwest of Whitehorse (see Figure 1).

1.2 Overview of Faro Mine Site

The map of Figure 2 provides an overview of the Faro mine site. Significant hydraulic features include:

- The flow-through rock drain that conveys the North Fork Rose Creek flow through the 60 m high haul road causeway. The rock drain acts to retard North Fork flood peaks.
- The 16 m high fresh water supply dam (FWSD) and reservoir on the South Fork Rose Creek, with a 30 m wide concrete overflow weir spillway. The reservoir capacity at the spillway crest is 5.7 million m^3.
- The Rose Creek diversion channel that conveys the combined flows of North and South Fork Rose Creek around the tailings ponds.

1.3 Objectives

The objectives of the assessment are to provide hydrotechnical information to assist the planning and execution of the mine abandonment plan. Specifics include:

- Site runoff characteristics: average monthly flows; start dates of spring runoff; characteristics of annual flood peaks up to the 500-year event, plus the probable maximum flood (PMF).
- Characteristics of the FWSD reservoir: time to fill in spring; routing effect on ordinary and extreme floods.
- Hydraulic capacity of the Rose Creek diversion channel downstream of the FWSD.

2 HYDROLOGY

2.1 Overview of Mine Site

The mine site is located between 1100 and 1400 m elevation (see Figure 2). The highest source elevation of the streams that drain though the site is a little over 1800 m.

Table 1 summarizes meteorological data collected at the mine site (Anvil, Stn. 2100120, Elev. 1158 m) and at Faro town (Faro, Stn. 2100517 ZFA, Elev. 717 m). Annual precipitation at the mine site is around 390 mm, of which 210 mm falls as rain and the remainder as snow. July is the wettest month with about 66 mm of rain on average. Mean monthly temperatures vary from –19°C in December/January to 12°C in July. Comparison of the Anvil and Faro data show that the annual snowfall at the higher elevations of the mine site is significantly greater (180 vs 110 mm) than at the lower elevation of Faro town.

Rose Creek, the main stream that passes through the site, has two principal tributaries, North and South Forks, which join upstream of the tailings impoundments (Figure 2).

Two local streamflow gauging stations have been operated by site staff since 1997: Stn. R7 (drainage area of 95 km^2), on North Fork Rose Creek upstream of the mine site; and Stn. X14 (drainage area of 230 km^2), on Rose Creek downstream of the mine site. Figure 2 shows the locations of these gauging stations and also the abandoned Water Survey of Canada gauge (Stn. 09BC003) that operated prior to the mine start-up from 1967-69. Figures 3 and 4 are plots of the daily discharge hydrographs of Stns, R7 and X14 for the period of record. .

Tables 2 and 3 list monthly flows at both mine site stations. There are significant gaps in the Stn. X14 data record.

Table 4 lists the estimated monthly runoff into the FWSD reservoir (drainage area of 67 km^2). The runoff values were estimated by multiplying the average monthly flow data of Stn. R7 (Table 2) by the ratio of the respective drainage areas (67/95).

Table 5 lists the FWSD reservoir elevation-capacity relationship. The reservoir volume of 5.7 million m^3 is only slightly greater than the average June inflow (see Table 4). The relatively small reservoir capacity indicates that attenuation of summer flood peaks by the reservoir is likely insignificant.

Figure 5 presents the 1996 spring hydrograph on Rose Creek at Stn. X14 downstream of the mine site. It shows that spring runoff proper started on about May 12 as rising temperatures started to melt the snowpack. Table 6 lists the limited start date of spring runoff as indicated by the streamflow records of Stns. 9BC003, R7 and X14.

The following summarizes significant information from Table 6:

- Date of spring runoff at Stn. X14: May 2
- Date of spring runoff at Stn. R7: April 21
- Date of spring runoff at Stn. X14 compared to Stn. R7: a few days later

It is concluded from the limited information available, that spring runoff at Stn. X14 could start as early as the second to last week of April. It is suggested that April 14 be used as the possible earliest date of spring runoff for the mine site.

Figure 5 shows that on Rose Creek at Stn. X14 the 1996 flood peak of 7.57 m^3/s occurred on June 3, primarily, as a result of snowmelt.

2.2 Snowmelt/Rainfall Floods

2.2.1 Regional Analysis

A regional analysis approach was used to estimate annual flood discharges for return periods up to 500 years. Annual flood peak series of streamflow gauging stations in the region of Faro were used for the analysis. The length of record of the stations ranged from 14 to 37 years with a mean of 21 years. Because of the short data record length, the analysis was limited to estimation of flood discharges up to the 500-year event. Flood estimates with a greater return period would have an extremely low level of confidence.

A homogeneity test was first performed on the annual flood peak series of eight gauging stations within about 150 km of Faro, including Vangorda Creek (Stn. 29BC003) adjacent to the mine site, to determine the conforming station records. The homogeneity test used is based on the assumption of a 3LN (3-parameter lognormal) distribution and is described in the Hydrology of Floods in Canada (Watt et al. 1989). On the basis of the test, the records of seven of the eight gauging stations were accepted as homogeneous.

For each gauging station, frequency analyses were conducted of annual maximum (daily) discharges. The 3LN distribution was mainly used to derive 2-and 100-year flood estimates. Table 7 lists the seven gauging stations and the flood estimates.

Log-log plots of the 2-and 100-year flood estimates versus gross drainage area are shown in Figure 6. The log-log regression fitting lines for the plots are:

For 2-year floods

$$Q_2 = 0.0973 \times (DA)^{0.90} \qquad (1)$$

$(R^2 = 0.84)$

For 100-year floods

$$Q_{100} = 1.060 \times (DA)^{0.72} \qquad (2)$$

$(R^2 = 0.92)$

Where Q_2 = 2-year flood (daily) in m^3/s
Q_{100} = 100-year flood (daily) in m^3/s
DA = gross drainage area in km^2
R^2 = logarithmic coefficient of determination

Equations 1 and 2 were used to compute 2-and 100-year flood (daily) estimates for six sub-basins in the vicinity of the mine site. The sites (see Figure 2) are:

Sub-Basin	Drainage Area (km^2)
North Fork Rose Cr. above Faro Creek Diversion Channel (Stn. R7)	95
Faro Creek & Diversion above North Fork Rose Creek (Loc.1)	16
North Fork Rose Creek at Flow-through Rock Drain (Loc.3)	118
Fresh Water Supply Dam (FWSD) catchment (Loc.4)	67
Rose Creek above Tailings Diversion Channel (Loc.5)	203
Rose Creek downstream of Tailings Diversion Channel (Stn. X 14)	230

Instantaneous to daily ratios of 1.3 and 1.8 were used to convert the 2-year and 100-year daily flood estimates to instantaneous equivalents, and flood frequency plots were synthesized for the sites (see Figures 7a through 7f). Values for the 2-to 500-year instantaneous flood discharges were read from Figures 7a through 7f and are listed in Table 8.

The flow-through rock drain at Loc. 3 (see Figure 2) retards the North Fork Rose Creek flow and so downstream Rose Creek peak flows at Loc. 5 and Stn. X14 will be reduced somewhat. The retarding affect of the rock drain on peak flows will be addressed in detail at the next stage of this study .

Referring to the flood discharge estimates of Table 8, it is noted that the discharges down the system are not additive. For example, the 100-year flood estimate at North Fork Rose Creek at Flow-through Rock Drain (Loc. 3) of 59 m^3/s is less than the sum of the flood estimates at the two upstream locations (Stn. R7 & Loc. 1) of 65 m^3/s (51+14). This is because the discharge per square kilometer – the unit discharge (discharge divided by drainage area) decreases with increasing drainage area, and is primarily due to the time taken by the water to flow down the catchment streams and, in the case of rainfall events, to the lower average rainfall intensity as the storm area increases. The 100-year unit discharges for Loc. 1 and at Loc. 3 are:

	Unit Discharge ($m^3/s/km^2$)	100-year Flood (m^3/s)	Drainage Area (km^2)
Loc. 1	0.88	14	16
Loc. 3	0.50	59	118

Table 9 compares the 100-year flood estimates of this report (Table 8) with early estimates by Acres (1985), DIAND (1986) and Hydrocon (1980) as reported by Curragh Resources (1988). In summary, the 100-year flood estimates of this report are:

- Larger than the estimates of Acres by up to 18%
- Significantly larger than estimates of DIAND by up to 170%
- Smaller than the estimates of Hydrocon by up to 30%

The earlier flood studies were made in the early-to mid-1980s when the flood records of streams in the region were significantly smaller than the present time. Greater confidence can therefore be placed on the present study.

2.2.2 *Flood Hydrographs*

Figure 8 is the 20-day non-dimensional snowmelt flood hydrograph adopted for the mine site. The non-dimensional hydrograph was developed, primarily, from the May 1993 flood of record on Vangorda Creek, the gauged stream immediately east of the mine site. The non-dimensional hydrograph values are listed in Table 10. Figure 9 plots the generated May 1993 flood hydrograph using the non-dimensional data of Table 10 and the recorded instantaneous peak discharge.

northwest
hydraulic
consultants

Table11 list the generated inflow hydrographs to the FWSD reservoir for 100, 200 and 500-year floods. The hydrographs are plotted in Figure 10. Flood volumes are:

Flood Volume in 10^6 m^3 for:		
100-year flood	200-year flood	500-year flood
13	16	21

The 100-year flood volumes exceed the FWSD reservoir dead storage capacity of 5.8 million m^3 by a factor of two (see Table 5).

2.3 Probable Maximum Flood (PMF)

The PMF was computed for four locations on Rose Creek: : Locs. 3, 4, 5 and Stn. X14 (see Figure 2). The procedure followed was:

- A 24-hour probable maximum precipitation (PMP) of 250 mm, extrapolated from U.S. Weather Bureau (1963) map of Alaska, was used to estimate the PMF. The adopted PMP is essentially identical to that used by Klohn Leonoff (1981).
- An effective precipitation, that is the proportion of the precipitation that runs off, of 200 mm was adopted.
- The duration of effective precipitation was reduced to account for the relatively small catchments of the sites. Runoff reaches a peak, or equilibrium, when the entire catchment is contributing to flow at the downstream location. For the site, a time to equilibrium of about 2 hours was computed using the procedures of Kirpich, and Watt and Chow (Watt et al. 1989).
- An effective 2-hour point PMP of 88 mm was adopted by multiplying the 24-hour precipitation by 44%; where the multiplier was determined from the 2-to 24-hour rainfall ratio (22/50 = 44%) for the site area computed from the Rainfall Frequency Atlas of Canada (Hogg and Carr, 1985).
- The average PMP over each catchment was computed from the point PMP of 80 mm using the World Meteorological Organization area-reduction curves (see Figure 11).
- The average PMP runoff for each catchment were distributed over an 8-hour hydrograph with a peak discharge of 3 times the average discharge.

The estimated PMF peak discharges are listed in Table 12. Values range from 550 m^3/s for the FWSD catchment (Loc. 4) to 1680 m^3/s at the downstream end of the Rose Creek diversion channel (Stn. X14).

3. HYDRAULICS

3.1 Fresh Water Supply Dam (FWSD) Reservoir

3.1.1 Spillway Capacity

The spillway consists of a 30 m wide broad-crested weir. The height of the embankment dam and the top of the clay core above the spillway crest are:

Top of clay core above the spillway crest	1.5 m
Top of embankment above the spillway crest	3.2 m

The computed maximum discharges that can be passed over the spillway before the clay core and the embankment dam are overtopped were computed as:

Spillway Crest Overflow Condition	Spillway Discharge (m^3/s)
To top of clay core	94
To top of dam embankment	290

3.1.2 Reservoir Routing of Extreme Floods

The 100-to 500-year FWSD reservoir inflow hydrographs (see Figure 10 and Table 11) and the PMF hydrograph (see Figure 12; Loc. 4) were routed through the reservoir using the elevation-capacity relationship of Table 5. The effect on flood peaks are summarized below:

Flood Event	Peak Reservoir Inflow (m^3/s)	Peak Reservoir Outflow (m^3/s)
100-yr snowmelt	39	36
200-yr snowmelt	49	46
500-yr snowmelt	63	60
PMF	550	330

Note: Reservoir outflow was restricted to the 30 m wide spillway crest for the PMF even though the embankment dam would be overtopped.

The reservoir routing results show that:

- Minor attenuation of the 100-to 500-year snowmelt flood peaks occur.
- Reservoir attenuation reduces the PMF peak by 40% (550 down to 330 m^3/s).

The reason that snowmelt flood peaks are not significantly reduced, compared to the PMF, is because snowmelt produces a multi-day hydrograph with a large total runoff. The PMF, by comparison, is a short duration event resulting from a 2-hour rainfall.

Referring to the spillway capacities of the existing 30 m wide spillway given in the previous section, the following is concluded:

- The spillway crest water levels **will not** reach the top of the clay core during the 500-year flood event.
- The dam embankment **will be** overtopped during the PMF.

3.2 Rose Creek Diversion Channel

The flow capacity of the diversion channel was computed to be 160 m^3/s at the bankfull depth of 3.4 m and exceeds the estimated 500-year flood peak of 145m^3/s for the downstream end of the channel (see Table 8). The bankfull discharge computed herein is identical to the channel design discharge.

The channel capacity analysis used the following information:

- Channel geometry as designed: bed width 12.2 m; depth 3.4 m; side slopes 1:2 (Vertical to Horizontal); channel slope 0.0019 m/m. (Information from Golder Associates: Drgs. No. 7922025, set of 12, dated August 1980; and Drgs. No. 9122402, set of 8, dated July 1991)
- Channel roughness, Manning,s "n": 0.0030

Before it is assumed that the diversion channel can convey flows up to the 500-year peak of 145 m^3/s, the present-day condition of the channel should be checked. Flow velocities would be high at this discharge and it is possible that the right bank could erode through into the tailings area during a single flood event. This means that condition of the Diversion Channel should be assessed. The assessment should include the following:

- Channel geometry: channel cross-sections at selected intervals, and channel slope.
- Condition and size rock riprap and underlying filters that protect the channel bed and banks.

northwest

hydraulic

consultants

4. REFERENCES

Acres Consulting Services Ltd. 1985. Cyprus Anvil Mine, Rose Creek Reservoir hydrology study.

Curragh Resources Inc. 1988. Review of peak flow estimates for Rose and Vangorda Creeks.

DIAND (Janowics, R.J.) 1986. A methodology for estimating design peak flows for Yukon Territory. Cold Regions Hydrology Symposium: American Water Resources Association.

Hydrocon Engineering (Continental) 1980. Hydrologic and hydraulic design of Down Valley tailings disposal project, Cyprus Anvil Mining Corporation, Faro, Y.T. Prepared for Golder Associates.

Klohn Leonoff 1981. Faro Mine tailings abandonment plan. Prepared for Cyprus Anvil Mining Corporation, Faro, Y.T.

Hogg, W.D. and D.A. Carr 1985. Rainfall frequency atlas for Canada. Canadian Government Publishing Centre, Ottawa.

Watt, W.E. et al. (editors) 1989. Hydrology of floods in Canada: A guide to planning and design. Associate Committee on Hydrology, National Research Council Canada, Ottawa.

WMO 1974 Guide to hydrological practices. WMO-No. 168, WMO, Geneva.

Yours sincerely,

northwest hydraulic consultants ltd.

B. J. Evans, P. Eng.
Senior Engineer

PROFESSIONAL
YUKON
EUGENE K. YAREMKO
TERRITORY
ENGINEER

E.K. Yaremko, P. Eng.
Principal

northwest
hydraulic
consultants

Table 1
Summary of meteorological data for Faro Airport and Anvil mine site

Parameter	Faro Airport (Elev. 717 m)	Anvil – Mine Site (Elev. 1158 mm)
Annual precipitation	320 mm	390 mm
Annual rainfall	210 mm	210 mm
Annual snowfall	110 mm	180 mm
Rainfall in wettest month	61 mm (July)	66 mm (July)
Range of mean monthly temperatures	-21°C (Dec/Jan) to 15°C (July)	-19°C (Dec) to 12°C (July)

Note:
Summarized from Environment Canada Climate data of:

- Faro Airport, Stn. 2100517 ZFA, Elev. 717 m, 1977-96
- Anvil, Stn. 2100120, Elev. 1158 m, 1968-75, 77-80, 86-89

Table 2
North Fork Rose Creek Stn. R7 monthly discharges
for 1997 - 2000

Month	Monthly Discharge in m^3/s for				Average Discharge
	1997	1998	1999	2000	(m^3/s)
Jan	0.23	0.42	0.30	0.34	0.32
Feb	0.21	0.40	0.26	0.32	0.29
Mar	0.21	0.36	0.28	0.29	0.29
Apr	0.37	0.36	0.96	0.30	0.50
May	2.28	2.24	2.85	1.37	2.19
Jun	3.76	1.36	3.40	2.97	2.87
Jul	3.46	0.96	1.18	1.66	1.82
Aug	1.36	0.95	0.79	2.16	1.32
Sep	0.82	0.85	0.78	1.05	0.87
Oct	0.87	0.87	0.68	0.54	0.74
Nov	0.49	2.44	1.35	1.54	1.46
Dec	0.41	0.93	0.51	0.75	0.65

Month	Monthly Discharge in 10^6 m^3				Average Volume
	1997	1998	1999	2000	(10^6 m^3)
Jan	0.62	1.12	0.80	0.90	0.86
Feb	0.50	0.96	0.63	0.76	0.71
Mar	0.56	0.97	0.75	0.78	0.76
Apr	0.95	0.94	2.49	0.79	1.29
May	6.10	6.00	7.63	3.68	5.85
Jun	9.75	3.52	8.80	7.69	7.44
Jul	9.27	2.57	3.17	4.45	4.86
Aug	3.65	2.55	2.11	5.78	3.52
Sep	2.12	2.21	2.02	2.72	2.27
Oct	2.34	2.33	1.81	1.46	1.98
Nov	1.28	6.33	3.49	4.00	3.78
Dec	1.10	2.50	1.37	2.00	1.74
Total	38.2	32.0	35.1	35.0	35.1

Notes:
1. Data from Gartner Lee Ltd. Whitehorse
2. Drainage area at gauge 95 km^2

Table 3
Rose Creek Stn. X14 monthly discharges for 1994, 96, 97, 99, 2000

Month	Monthly Discharge in m^3/s for					Average Discharge
	1994	1996	1997	1999	2000	(m^3/s)
Jan		0.13	1.77		0.39	0.77
Feb		0.29	0.51		0.14	0.31
Mar		0.27	0.37		0.13	0.26
Apr		0.33	1.03		0.12	0.50
May	4.23	2.79	4.47		1.85	3.33
Jun	5.32	3.55	4.95		6.45	5.07
Jul	2.92	3.47	3.95	2.89	3.82	3.41
Aug	1.80	2.58	3.98	2.06	5.56	3.20
Sep	1.82	3.15	3.03	1.98		2.50
Oct	2.13	1.56	2.19			1.96
Nov	0.98	1.11	1.23			1.11
Dec	0.66		1.09			0.88

Month	Monthly Discharge in 10^6 m^3					Average Volume
	1994	1996	1997	1999	2000	(10^6 m^3)
Jan		0.4	4.8		1.0	2.05
Feb		0.7	1.2		0.3	0.77
Mar		0.7	1.0		0.4	0.69
Apr		0.9	2.7		0.3	1.29
May	11.3	7.5	12.0		4.9	8.93
Jun	13.8	9.2	12.8		16.7	13.14
Jul	7.8	9.3	10.6	7.8	10.2	9.14
Aug	4.8	6.9	10.7	5.5	14.9	8.56
Sep	4.7	8.2	7.8	5.1		6.47
Oct	5.7	4.2	5.9			5.25
Nov	2.5	2.9	3.2			2.87
Dec	1.8		2.9			2.35
Total			75.6			61.5

Notes:
1. Data from Gartner Lee Ltd. Whitehorse
2. Drainage area at gauge 230 km^2

Table 4
Estimated monthly runoff into the FWSD reservoir for 1997 - 2000

Month	Monthly volume in 10^6 m^3 for				Average Volume (10^6 m^3)
	1997	1998	1999	2000	
Jan	0.44	0.79	0.56	0.63	0.61
Feb	0.35	0.68	0.44	0.54	0.50
Mar	0.40	0.68	0.53	0.55	0.54
Apr	0.67	0.67	1.76	0.55	0.91
May	4.30	4.23	5.38	2.59	4.13
Jun	6.88	2.48	6.21	5.42	5.25
Jul	6.54	1.81	2.24	3.14	3.43
Aug	2.57	1.80	1.49	4.08	2.48
Sep	1.49	1.56	1.42	1.92	1.60
Oct	1.65	1.64	1.28	1.03	1.40
Nov	0.90	4.47	2.46	2.82	2.66
Dec	0.77	1.77	0.97	1.41	1.23
Total	27.0	22.6	24.7	24.7	24.7

Table 5
Preliminary FWSD reservoir elevation-capacity relationship

	Elevation (m)	Capacity (10^6 m^3)
Spillway crest	1096.09	5.70
	1094.49	5.00
	1092.49	4.00
	1090.49	3.15
	1088.49	2.25
	1086.49	1.50
	1084.49	0.75
	1082.49	0.25

Note:

Data from Gartner Lee Ltd. 2001

Table 6
Start of spring runoff at mine site

Year	Rose Creek Below Faro Creek WSC Stn. 9BC003	North Fork Rose Creek Stn. R7	Rose Creek downstream of Tailings Stn. X14
1968	May 19		
1969	May20		
1996			May 12
1997		April 26	May 2
1998		May 1	
1999		April 21	
2000		May 2	May 8

Table 7
Hydrologic data for stream gauging stations used in the regional analysis

Station	No.	Record Length (years)	Drainage Area (km^2)	Estimated Flood Discharge (Daily) 2-year (m^3/s)	Estimated Flood Discharge (Daily) 100-year (m^3/s)
Vangorda Creek	29BC003	14	91	3.4	21.2
South Big Salmon River below Livingstone Creek	09AG003	22	515	29.2	108
South MacMillan River at km 407 Canol Rd.	09BB001	14	997	118	235
Big Creek near the mouth	09AH003	22	1750	91.7	267
Nordenskiold River below Rowlinson Creek	09AH004	17	6370	81	315
Big Salmon River near Carmacks	09AG001	22	6760	310	700
Ross River at Ross River	09BA001	37	7250	384	776

Table 8
Estimated 2-to 500-year floods for the Faro Mine site

Mine Site Sub-basins	Drainage Area (km^2)	Flood Discharge (Instantaneous) 2-year (m^3/s)	50-year (m^3/s)	100-year (m^3/s)	200-year (m^3/s)	500-year (m^3/s)
North Fork Rose Cr. above Faro Creek Diversion Channel (Stn. R7)	95	7.6	41	51	62	79
Faro Creek & Diversion above North Fork Rose Creek (Loc.1)	16	1.5	11	14	18	24
North Fork Rose Creek at Flow-through Rock Drain (Loc.3)	118	9.3	48	59	72	92
Fresh Water Supply Dam (FWSD) catchment (Loc.4)	67	5.6	31	39	49	63
Rose Creek above Tailings Diversion Channel (Loc.5)	203	15	71	88	105	135
Rose Creek downstream of Tailings Diversion Channel (Stn. X 14)	230	17	78	96	115	145

Table 9
Comparison of 100-year flood estimates

Mine Site Sub-basins	Drainage Area (km^2)	100-year Flood Peak in m^3/s estimated by: NHC, 2001 (This study)	Acres, 1985	DIAND, 1986 (No storage factor)	DIAND, 1986 (Using storage factor)	Hydrocon, 1980
North Fork Rose Creek at Flow-through Rock Drain (Loc.3)	118	**59**	52	34	25	87
Fresh Water Supply Dam (FWSD) catchment (Loc.4)	67	**39**	33	22	12	58
Rose Creek above Tailings Diversion Channel (Loc.5)	203	**88**	82	54	40	127

Note: Flood estimates by the various groups were only estimated for the above three locations.

Table 10
Non-dimensional hydrograph for snowmelt floods

Day	Q_n/Q_{peak}
1	0.054
2	0.059
3	0.065
4	0.075
5	0.086
6	0.124
7	0.172
8	0.226
9	0.349
9.5	0.457
9.75	0.538
10	1.000
10.25	0.699
10.5	0.484
11	0.349
12	0.242
13	0.188
14	0.177
15	0.172
16	0.167
17	0.161
18	0.156
19	0.151
20	0.145

Where:

Q_n = Discharge at time "n"

Q_{peak} = Instantaneous peak discharge

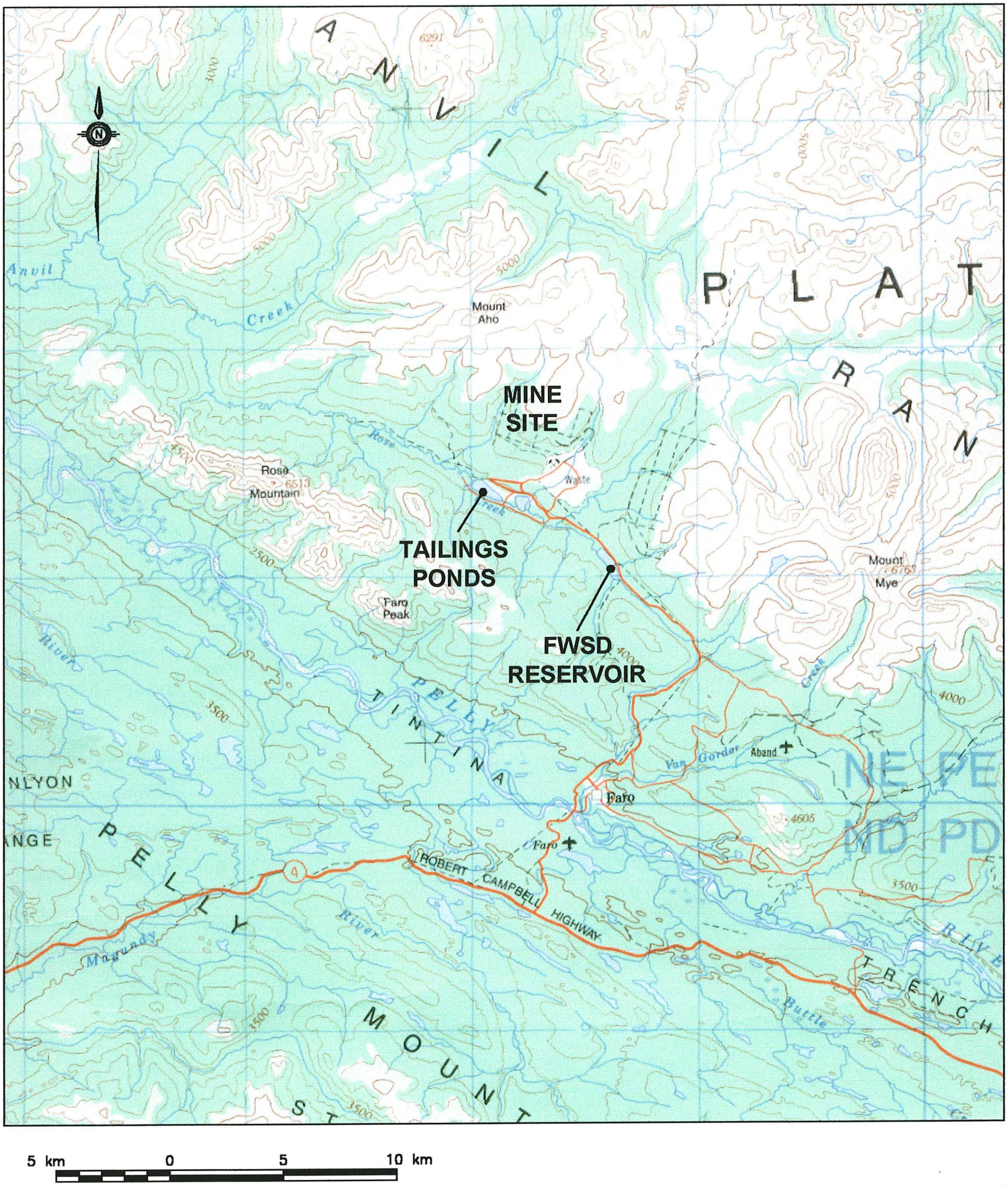
Table 11
Inflow hydrographs to FWSD reservoir for snowmelt floods

Day	Discharge for Flood Return Period of		
	100-yr m^3/s	200-yr m^3/s	500-yr m^3/s
1	2.1	2.6	3.4
2	2.3	2.9	3.7
3	2.5	3.2	4.1
4	2.9	3.7	4.7
5	3.4	4.2	5.4
6	4.8	6.1	7.8
7	6.7	8.4	10.8
8	8.8	11.1	14.2
9	13.6	17.1	22.0
9.5	17.8	22.4	28.8
9.75	21.0	26.3	33.9
10	**39.0**	**49.0**	**63.0**
10.25	27.3	34.2	44.0
10.5	18.9	23.7	30.5
11	13.6	17.1	22.0
12	9.4	11.9	15.2
13	7.3	9.2	11.9
14	6.9	8.7	11.2
15	6.7	8.4	10.8
16	6.5	8.2	10.5
17	6.3	7.9	10.2
18	6.1	7.6	9.8
19	5.9	7.4	9.5
20	5.7	7.1	9.1
Flood volumes (10^6 m^3)	**13**	**16**	**21**

Peak discharges (day 10)

Table 12
Estimated Probable Maximum Flood (PMF) for the Faro Mine site

Mine Site Sub-basins	Drainage Area (km^2)	PMF Peak Discharge (m^3/s)
North Fork Rose Creek at Flow-through Rock Drain (Loc.3)	118	920
Fresh Water Supply Dam (FWSD) catchment (Loc.4)	67	550
Rose Creek above Tailings Diversion Channel (Loc.5)	203	1480
Rose Creek downstream of Tailings Diversion Channel (Stn. X 14)	230	1680



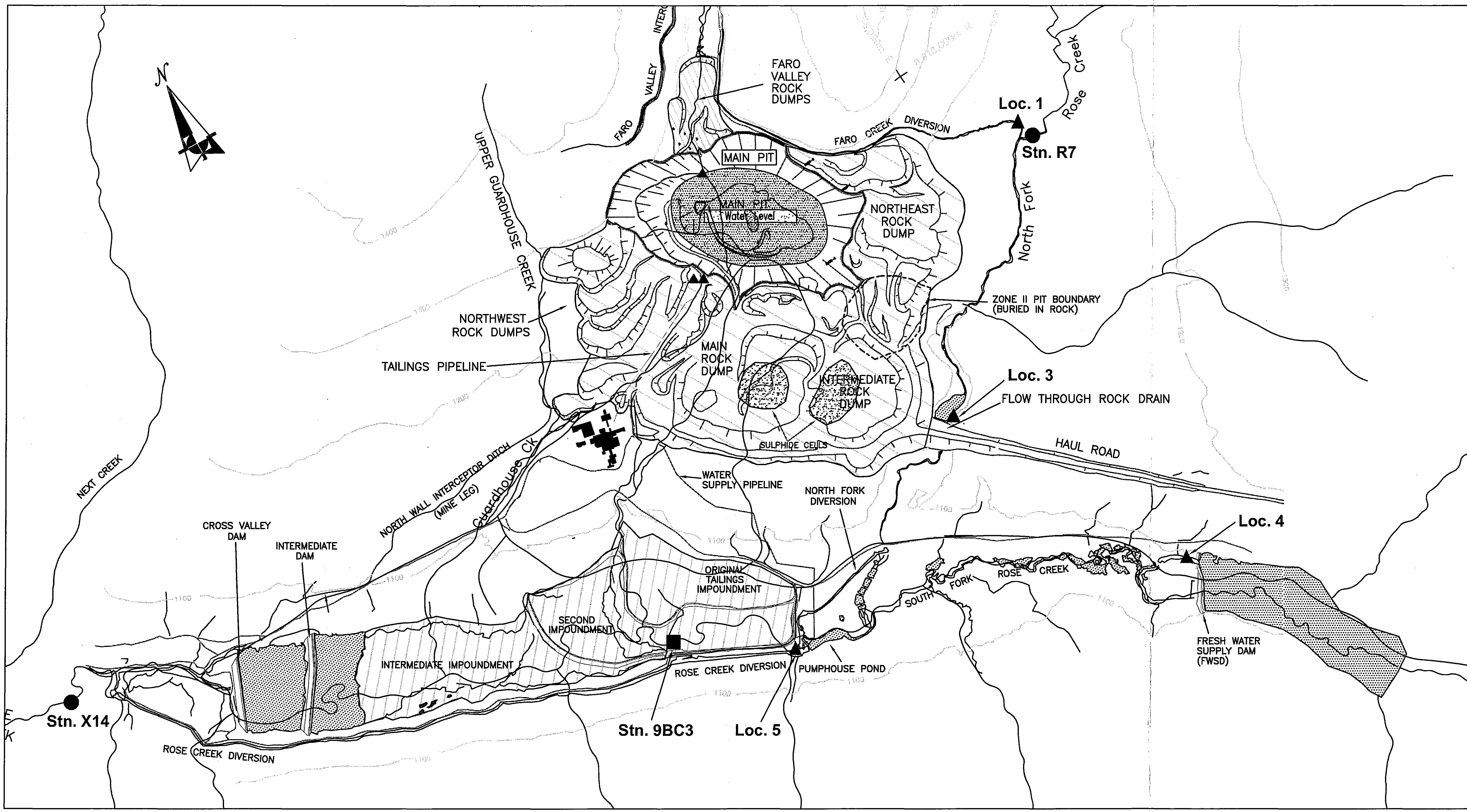
BGC ENGINEERING INC.

FARO MINE HYDROLOGY

LOCATION PLAN

Dwg. 6217–005	12 NOV 2001	**Figure 1**

northwest hydraulic consultants ltd.



Legend:

● **Stn. R7** Streamflow gauging station.

▲ **Loc. 1** Stream catchment location.

■ **Stn. 9BC3** Discontinued Water Survey of Canada streamflow gauging station 09BC003

Data Source: Robertson Geoconsultants Inc.

Notes:

Base Map supplied by the Orthoshop, January 1991
North American Datum 1927
Contour interval 100 m
Universal Transverse Mercator Projection
Map is a composite of 9 basemaps,
it was redigitized to simplify planimetric features.

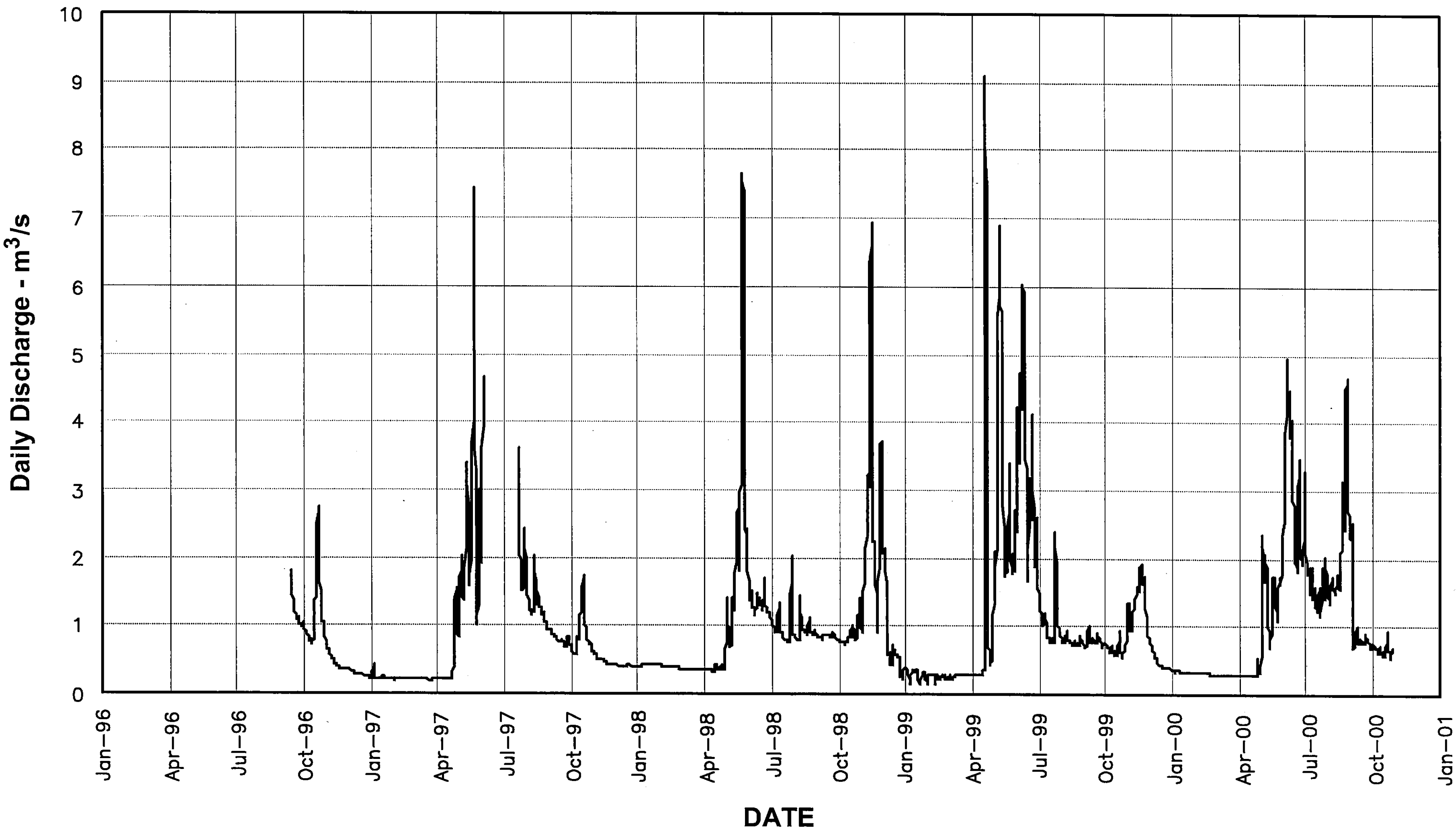
BGC ENGINEERING INC.

FARO MINE HYDROLOGY

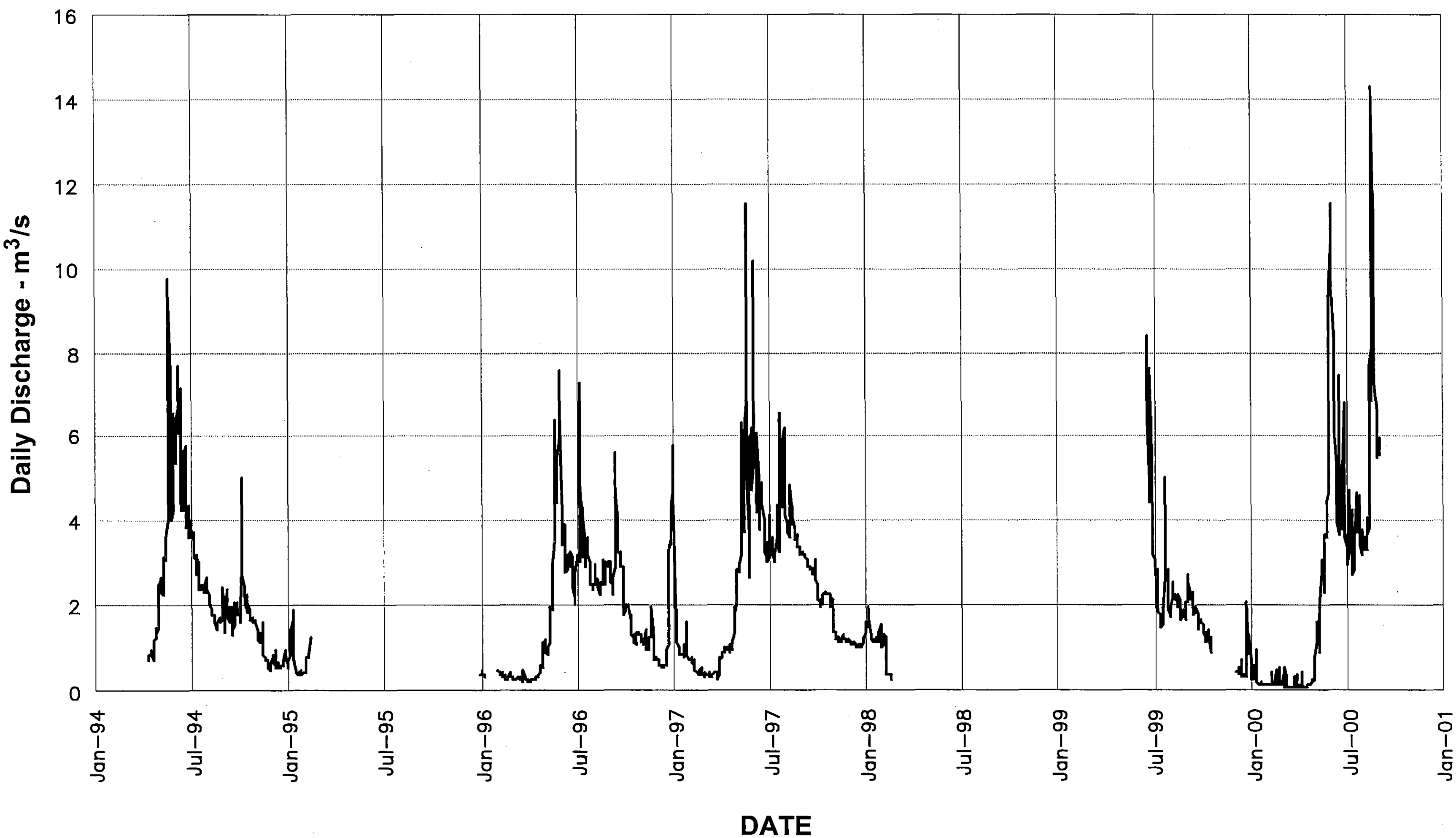
OVERVIEW OF FARO MINE SITE

Dwg. 6217-004 | 12 NOV 2001 | **Figure 2**

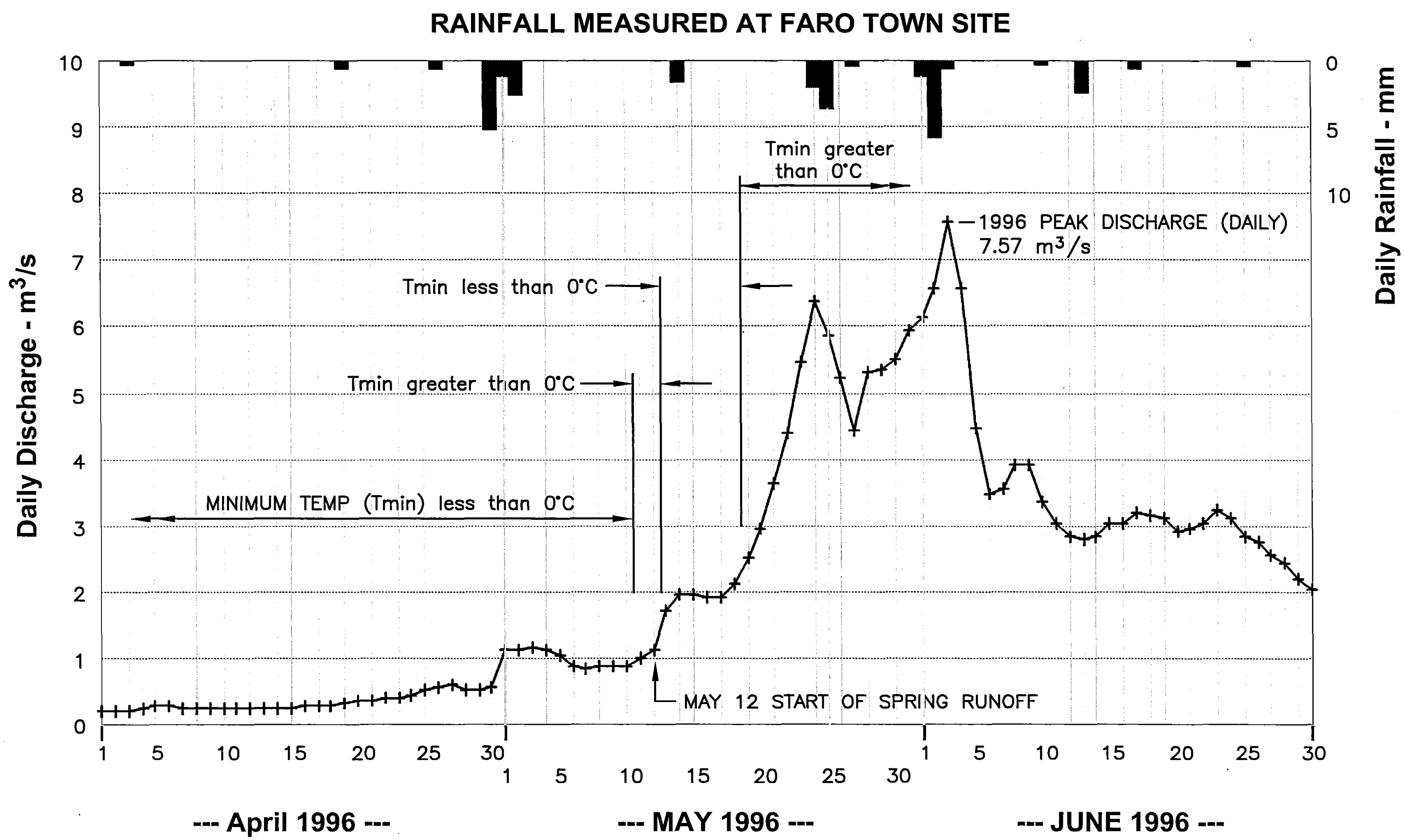
northwest hydraulic consultants ltd.



BGC ENGINEERING INC.		
FARO MINE HYDROLOGY **NORTH FORK ROSE CREEK HYDROGRAPH, STN. R7 1996 - 2000**		
Dwg. 6217-011	21 NOV 2001	**Figure 3**
northwest hydraulic consultants ltd.		

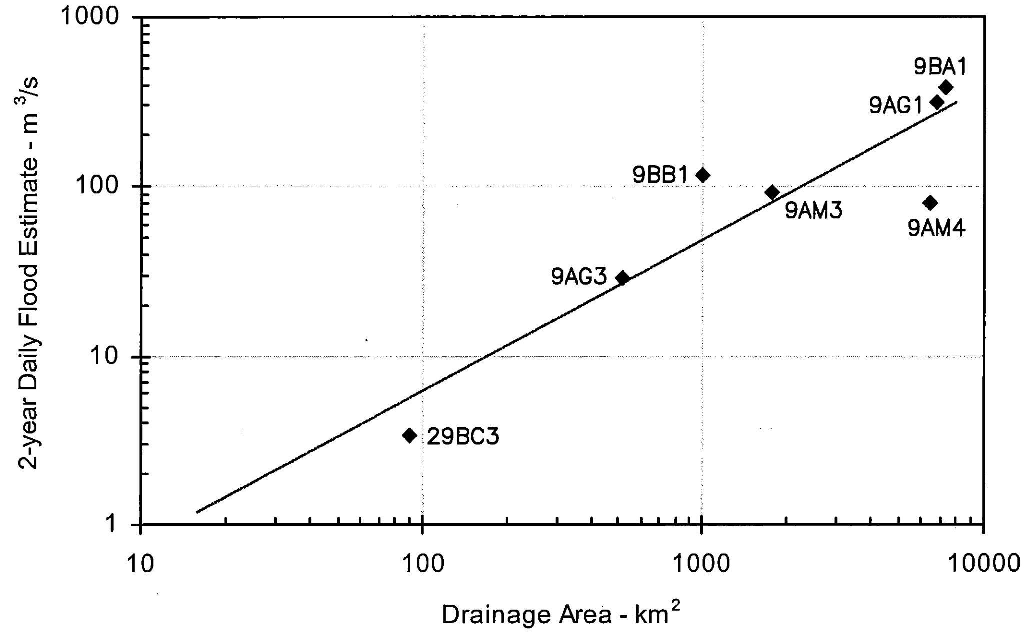


BGC ENGINEERING INC.		
FARO MINE HYDROLOGY **ROSE CREEK HYDROGRAPH, STN. X14** **1994 - 2000**		
Dwg. 6217-012	21 NOV 2001	**Figure 4**
northwest hydraulic consultants ltd.		

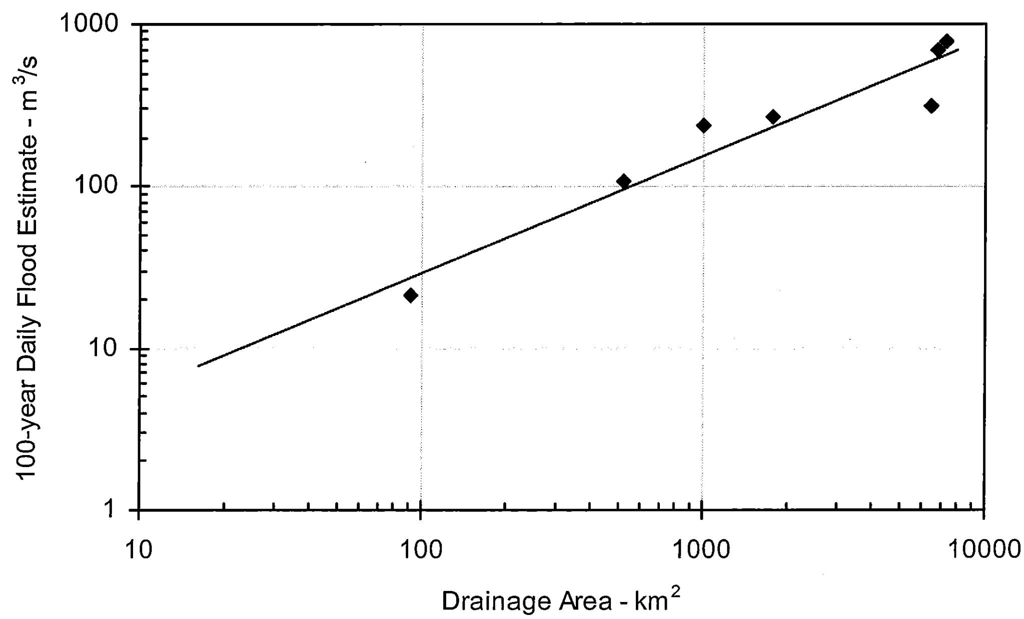


BGC ENGINEERING INC.		
FARO MINE HYDROLOGY **ROSE CREEK STN. X14** **1996 SPRING HYDROGRAPH**		
Dwg. 6217-007	16 NOV 2001	**Figure 5**
northwest hydraulic consultants ltd.		

Faro Mine Hydrology: 2-year Flood versus Drainage Area



Faro Mine Hydrology: 100-year Flood versus Drainage Area



BGC ENGINEERING INC.		
FARO MINE HYDROLOGY **2-AND 100-YEAR FLOOD ESTIMATES VS DRAINAGE AREA FOR FARO REGION**		
Dwg. 6217–006	16 NOV 2001	**Figure 6**
northwest hydraulic consultants ltd.		

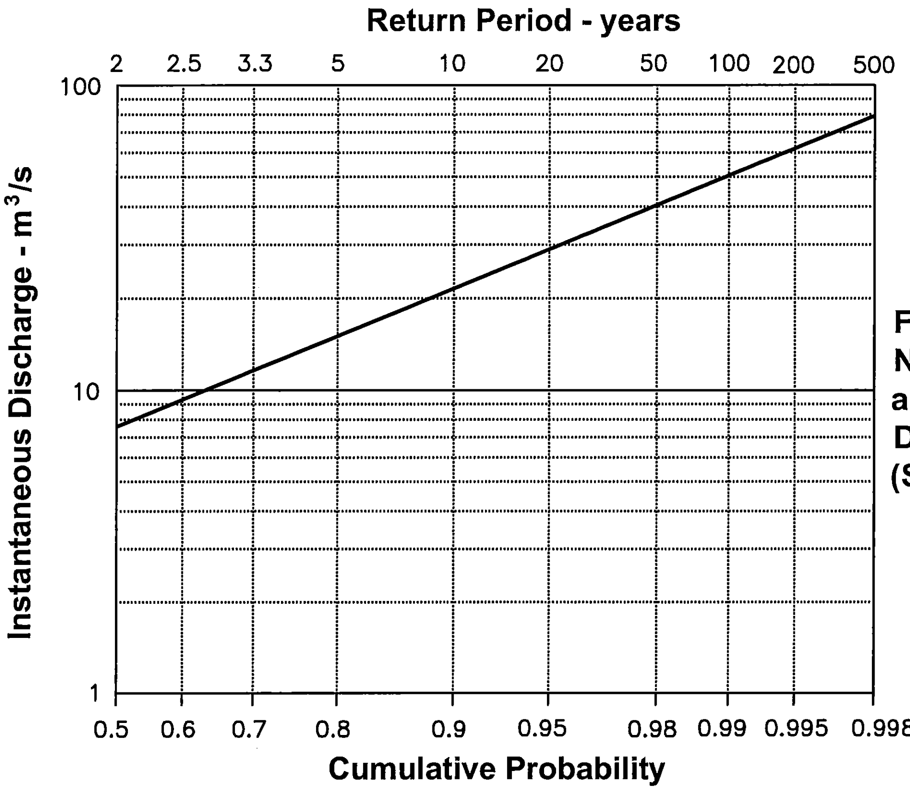


Fig. 7(a)
North Fork Rose Creek above Faro Creek Diversion Channel (Stn. R7)

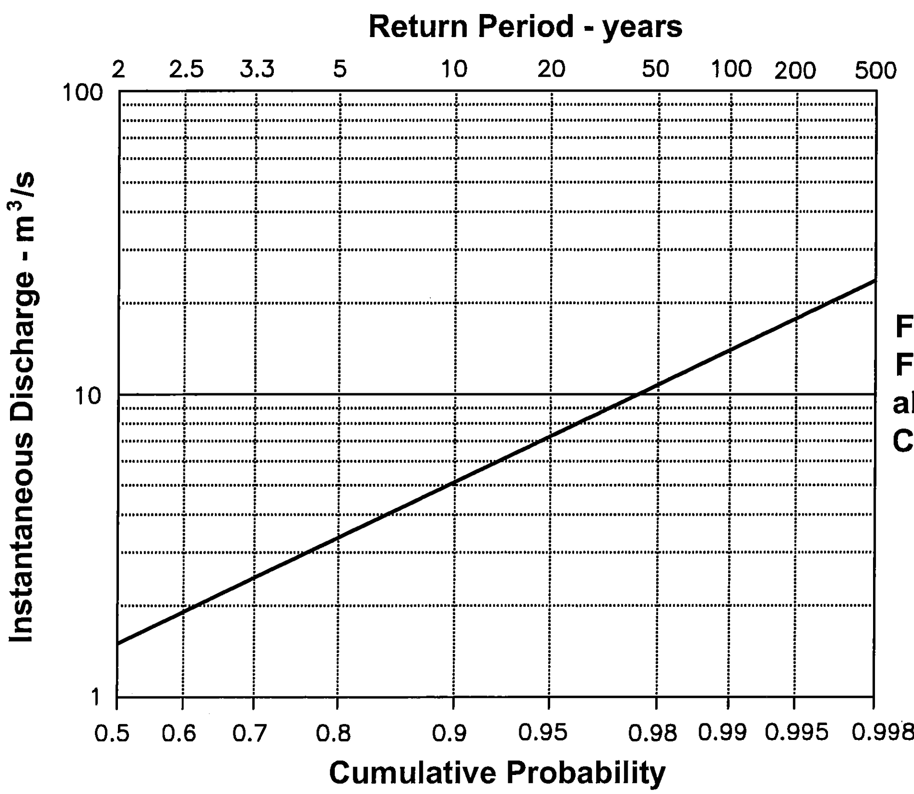


Fig. 7(b)
Faro Creek & Diversion above North Fork Rose Creek (Loc. 1)

BGC ENGINEERING INC.		
FARO MINE HYDROLOGY **SYNTHESIZED FLOOD FREQUENCY PLOTS FOR MINE SITE**		
Dwg. 6217–001	12 NOV 2001	**Figure 7a, b**
northwest hydraulic consultants ltd.		

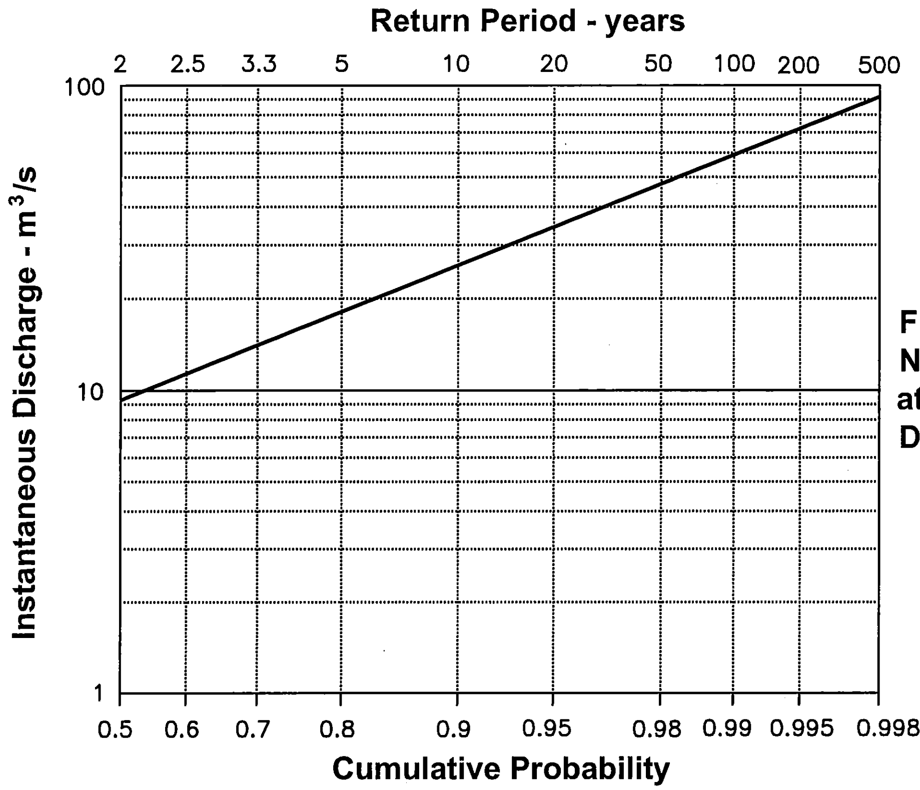


Fig. 7(c)
North Fork Rose Creek at Flow-through Rock Drain (Loc. 3)

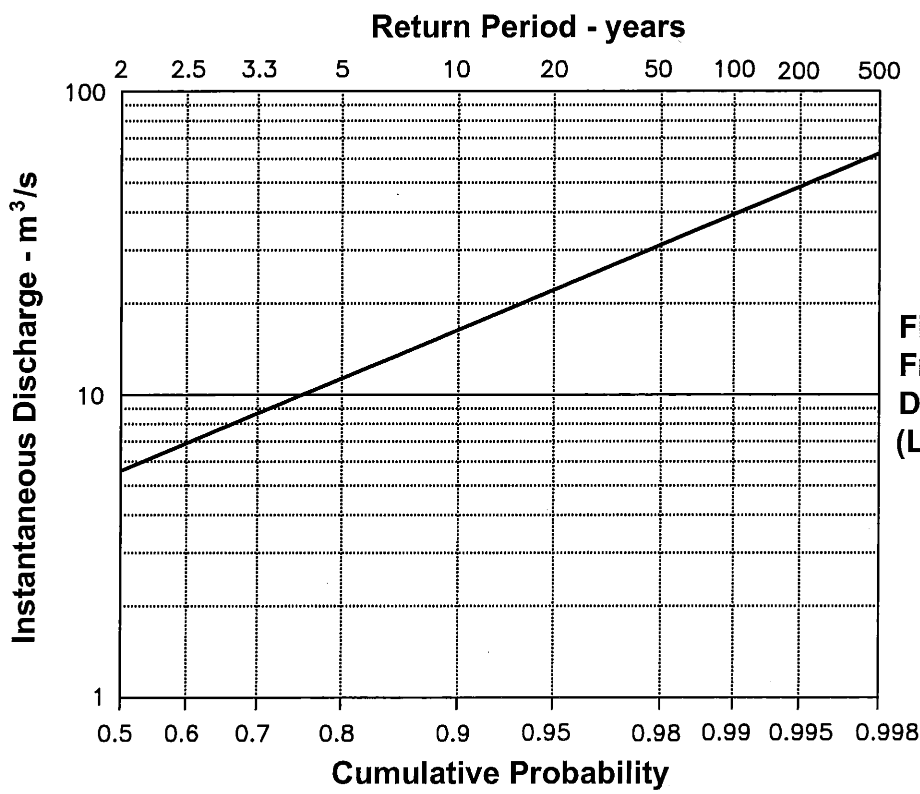


Fig. 7(d)
Fresh Water Supply Dam (FWSD) Catchment (Loc. 4)

BGC ENGINEERING INC.		
FARO MINE HYDROLOGY **SYNTHESIZED FLOOD FREQUENCY PLOTS FOR MINE SITE**		
Dwg. 6217–002	12 NOV 2001	**Figure 7c, d**
northwest hydraulic consultants ltd.		

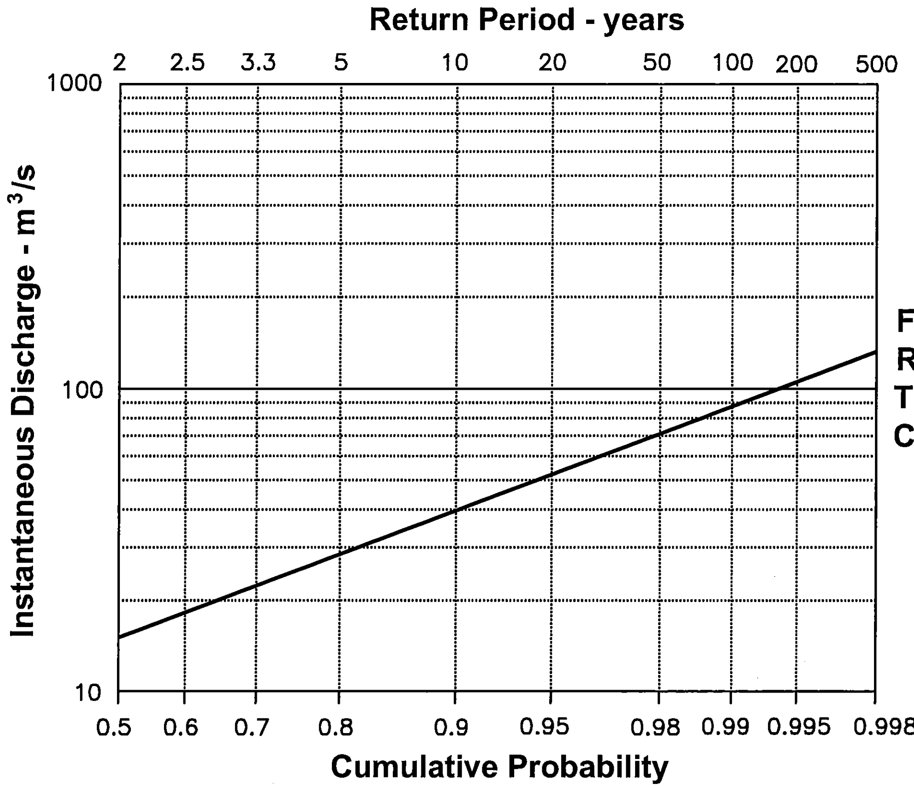


Fig. 7(e)
Rose Creek above Tailings Diversion Channel (Loc. 5)

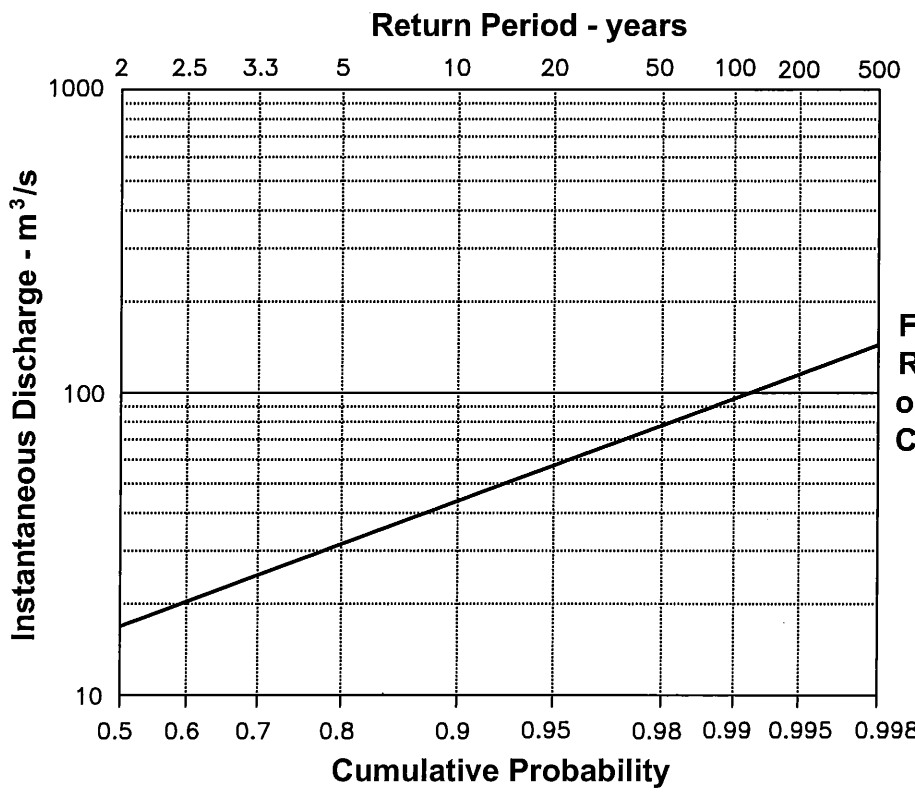
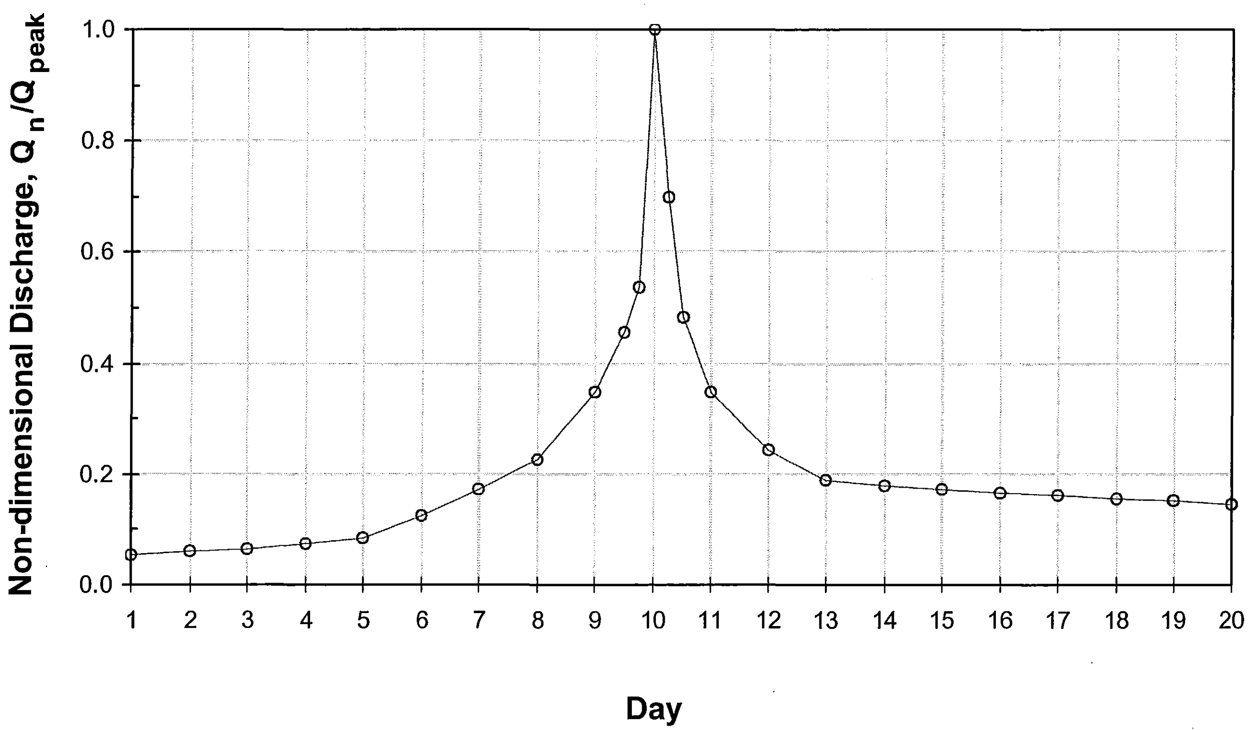


Fig. 7(f)
Rose Creek downstream of Tailings Diversion Channel (Stn. X 14)

BGC ENGINEERING INC.		
FARO MINE HYDROLOGY **SYNTHESIZED FLOOD FREQUENCY PLOTS FOR MINE SITE**		
Dwg. 6217–003	12 NOV 2001	**Figure 7e, f**
northwest hydraulic consultants ltd.		



BGC ENGINEERING INC.

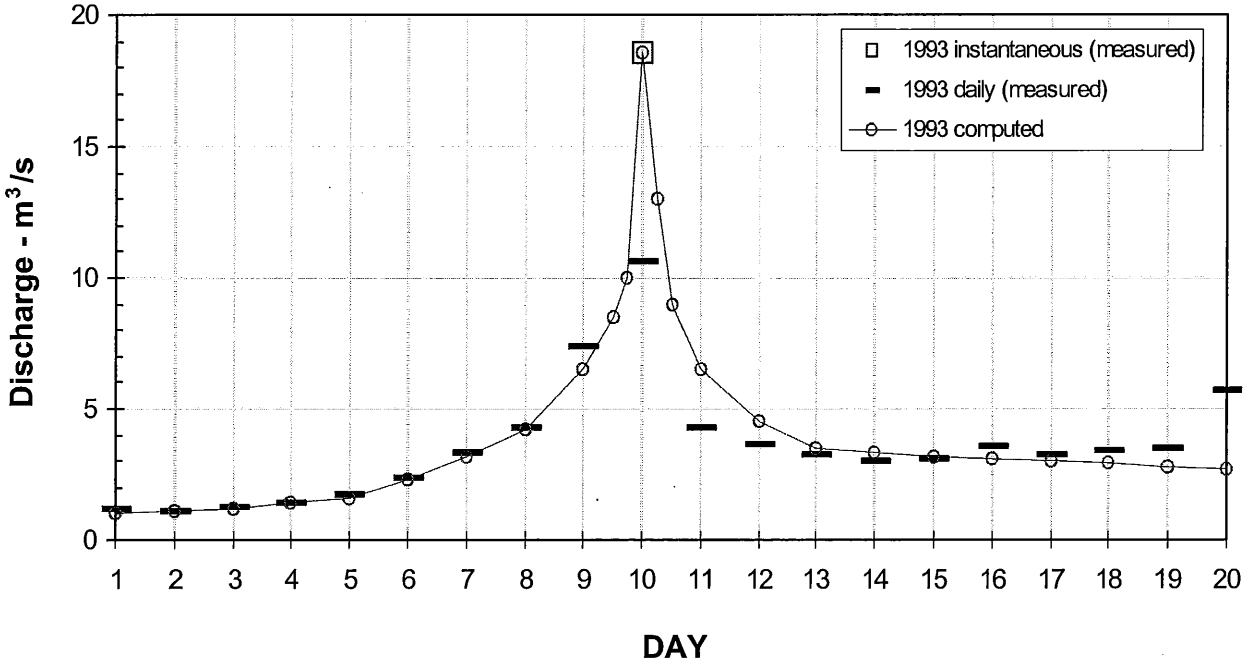
FARO MINE HYDROLOGY

ADOPTED NON-DIMENSIONAL HYDROGRAPH FOR SNOWMELT FLOODS

Dwg. 6217–014	21 NOV 2001	**Figure 8**

northwest hydraulic consultants ltd.

Vangorda Creek May 1993 hydrograph - Measured and computed from adopted non-dimensional snowmelt hydrograph



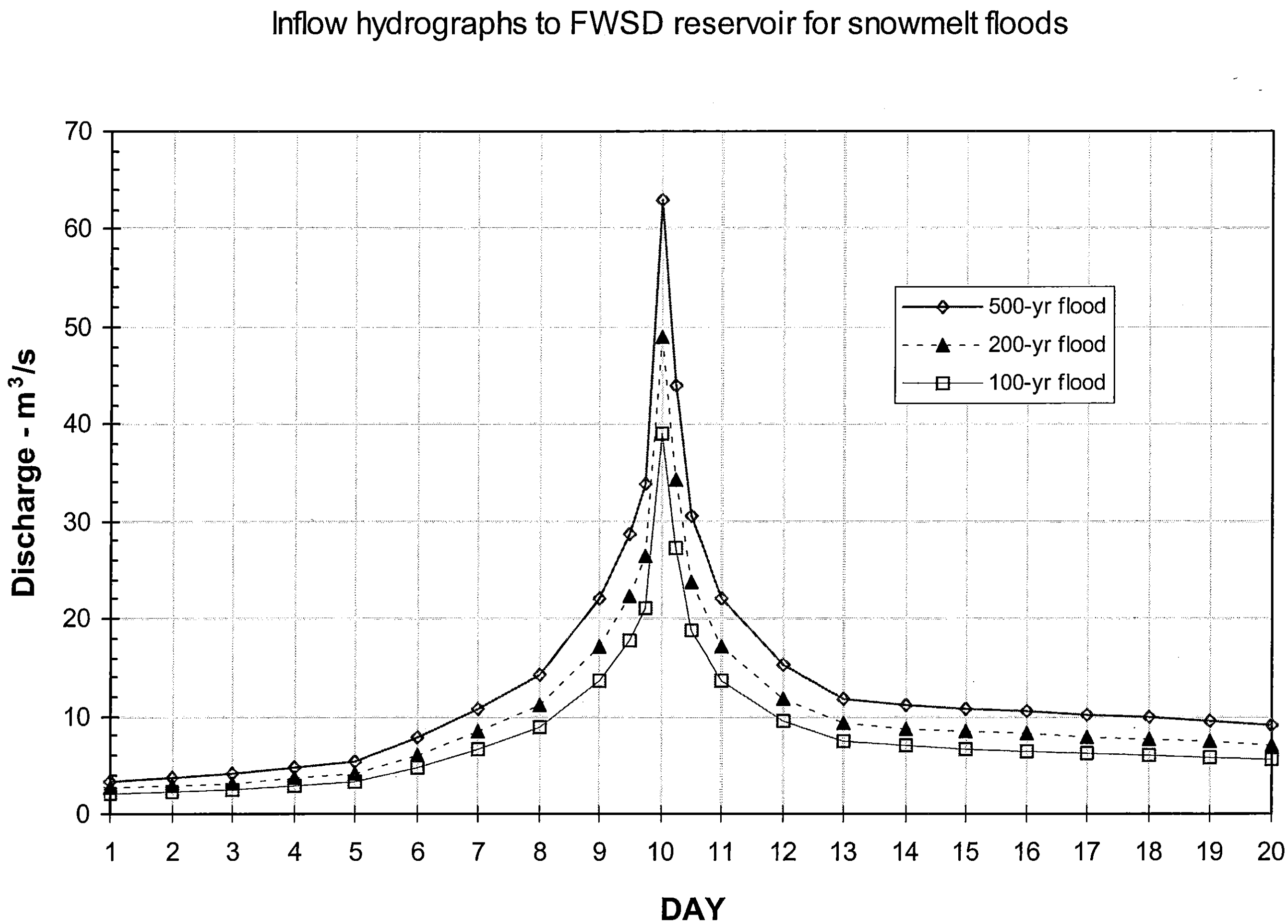
BGC ENGINEERING INC.

FARO MINE HYDROLOGY

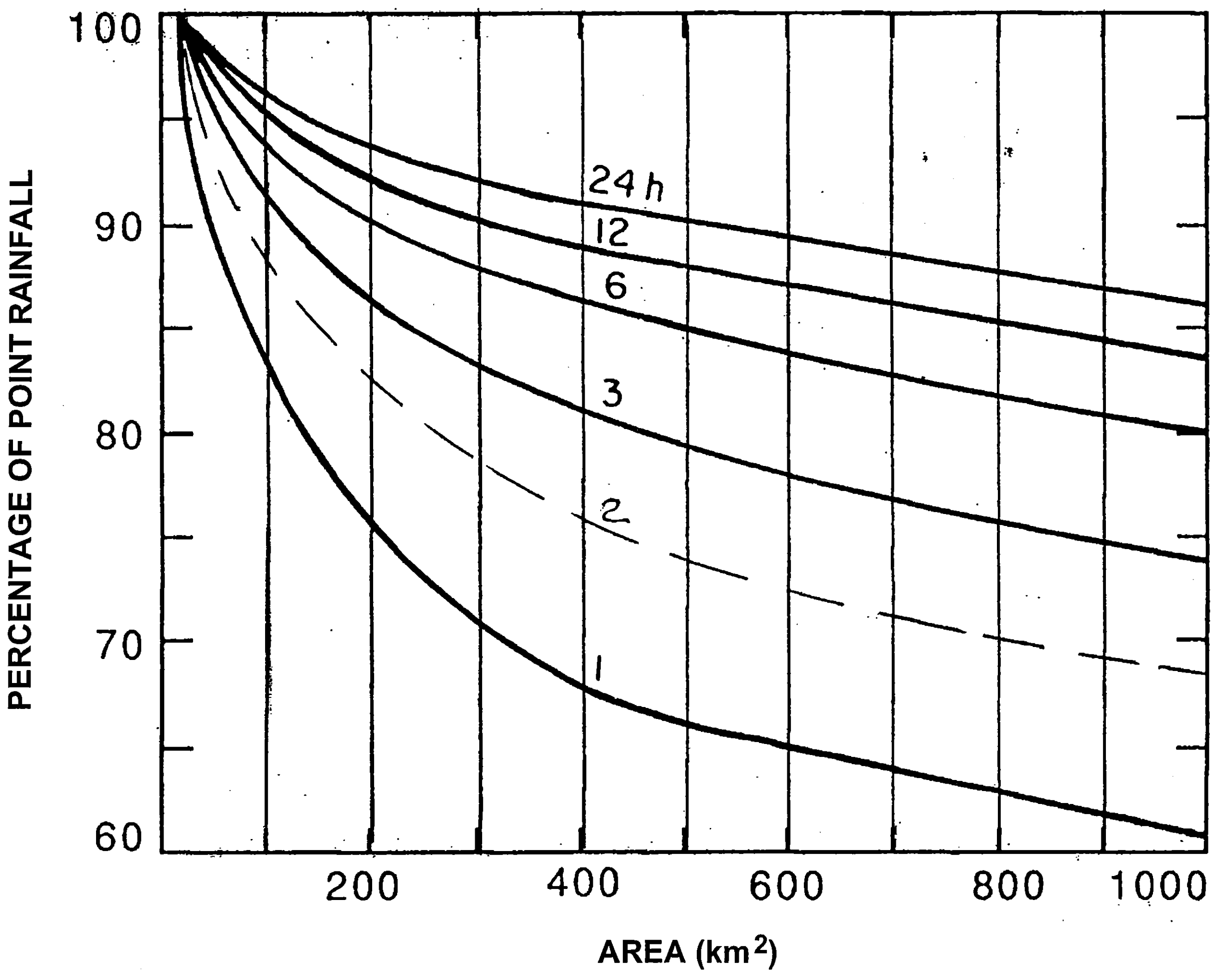
CALIBRATION OF NON-DIMENSIONAL SNOWMELT HYDROGRAPH

Dwg. 6217–009	20 NOV 2001	**Figure 9**

northwest hydraulic consultants ltd.



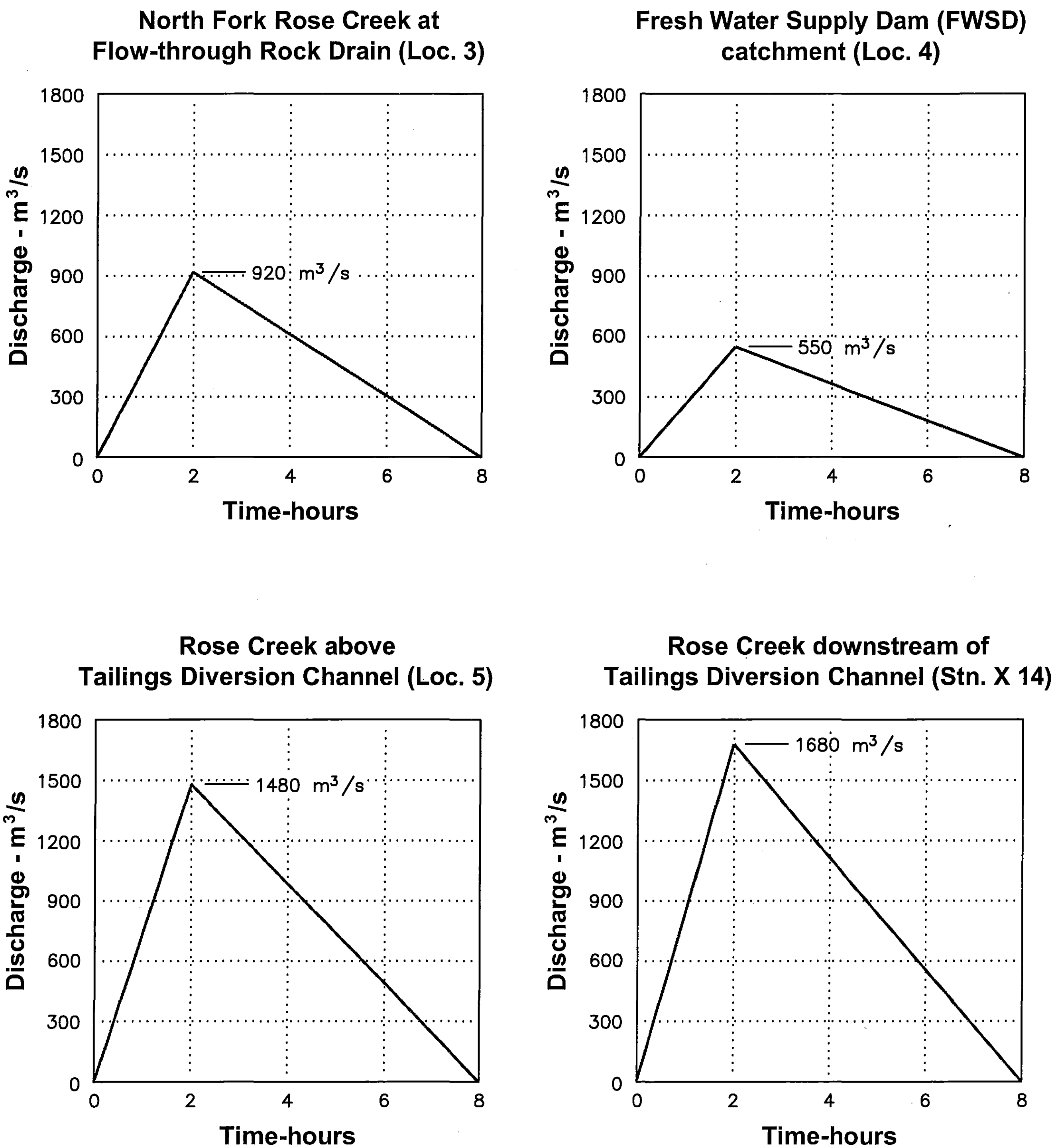
BGC ENGINEERING INC.		
FARO MINE HYDROLOGY **INFLOW SNOWMELT HYDROGRAPHS TO FWSD RESERVOIR 100, 200 & 500-year FLOODS**		
Dwg. 6217–010	20 NOV 2001	**Figure 10**
northwest hydraulic consultants ltd.		



NOTE:

– FROM WORLD METEOROLOGICAL ORGANIZATION, 1974

BGC ENGINEERING INC.		
FARO MINE HYDROLOGY		
AREA-REDUCTION CURVES FOR RAINFALL		
Dwg. 6217–016	21 NOV 2001	**Figure 11**
northwest hydraulic consultants ltd.		



BGC ENGINEERING INC.

FARO MINE HYDROLOGY

PMF HYDROGRAPHS FOR MINE SITE

Dwg. 6217–013	21 NOV 2001	**Figure 12**

northwest hydraulic consultants ltd.