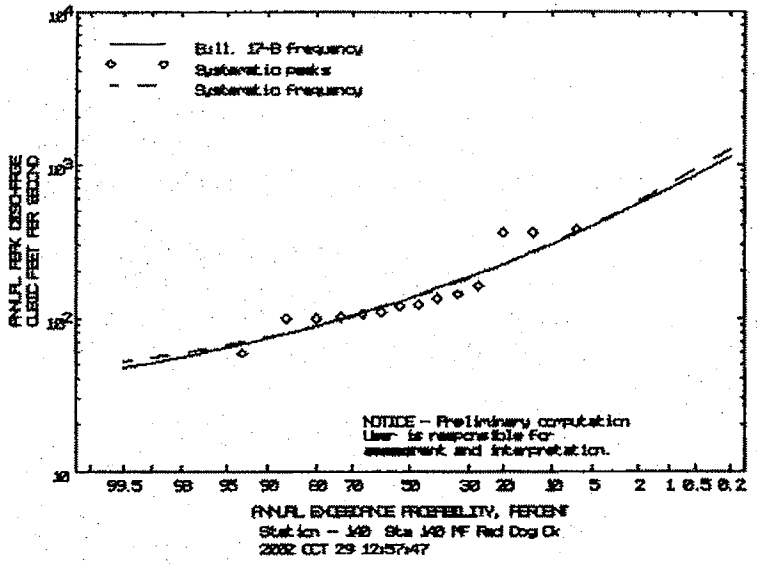
Red Dog Mine
Closure and Reclamation Plan

SD E2: Flood Frequency Update for Middle Fork Red Dog Creek (Peratrovich, Nottingham & Drage Inc., 2002)



Flood Frequency Update for Middle Fork Red Dog Creek

October 2002

Prepared for:
TeckCominco Alaska

Prepared by:
Peratrovich, Nottingham & Drage, Inc.
1506 West 36th Ave
Anchorage, Alaska, 99503

Peratrovich, Nottingham, & Drage, Inc.

The Teck Cominco - Red Dog zinc mine in the De Long Mountains of Alaska lies within the drainage basin of Middle Fork Red Dog Creek. A reach of the creek is being relocated to accommodate expansion of the open pit. The flood frequency curve for this reach was updated for input into the sizing of the creek diversion.

M.F. Red Dog Creek has been gaged for a total of 16 years (Table 1) at various locations. During this period, portions of the drainage area have been lost to mining and diversions. The changes in drainage area made in 1991 and 1996 were less than 5%, within the range of gaging and area measurement error and therefore no adjustments to the peak discharges were made.

Table 1. Annual peak flow data

Year	Date of Peak	Peak Discharge (cfs)	Location	Drainage Area (mi^2)	Comments
1982	breakup?	107/58	various	various	Not used due to the uncertainity of the peak flow occurring during the period of record
1988		564	unknown	unknown	Not used in analysis
1989	5-Aug	360	Sta 37	3.84	Above Sulphur Ck
1990	27-Aug	162	Sta 37	3.84	
1991	21-Jul	107	Sta 140	4.03	Gage moved below Sulphur Ck; pit opened (drainage area removed)
1992	5-Jun	100	Sta 140	4.03	Daily average discharge
1993	14-Sep	121	Sta 140	4.03	
1994	17-Sep	360	Sta 140	4.03	
1995	26-May	101	Sta 140	4.03	
1996	6-Sep	142	Sta 140	3.87	Hilltop extension of lined diversion (drainage area removed)
1997	27-May	59	Sta 140	3.87	
1998	16-May	120	Sta 140	3.87	
1999	18-May	99	Sta 140	3.87	
2000	5-Sep	109	Sta 140	3.87	
2001	12-Jul	133	Sta 140	3.87	
2002	26-May	380	Sta 140	3.87	

Changes from the 2000 flood frequency analysis include:

- Addition of three years of data.
- Dropped 1988 peak flow data.
- Six years of data were revised based on a review of gage data by Norman Paley of TeckCominco

In addition data from 1982 was considered but not used because the period of gaging did not include the breakup flows. High water marks indicated that the breakup flood, prior to gages being set up, was probably the peak flow for that year, but channel-ice conditions were not observed during that period.

The resulting flood frequency curve for Sta 140 on Middle Fork Red Dog Creek is shown in Table 2. The complete output from the U.S. Geological Survey's program "peakfq" annual peak flow frequency analysis program is attached at the end of this report. The "expected probability" estimate of the flood frequency curve was used. The expected probability is the

average of all estimated true probabilities and takes into account the confidence limits of the flood frequency estimate, which are mainly influenced by the length of record. See "Guidelines for Determining Flood Flow Frequency (Revised)", Bulletin #17-B, 1982 from the Interagency Advisory Committee on Water Data for further discussions.

Table 2. Station 140 Flood Frequency Curve (Expected Probability)

Return Interval	Discharge (cfs)
Q_2	135
Q_5	232
Q_{10}	328
Q_{25}	507
Q_{50}	705
Q_{100}	991
Q_{200}	1410

The Station 140 flood frequency curve was adjusted for the different segments of the diversion using the equations in Jones and Fahl, as outlined in the December 2000 report Flood Frequency on Middle Fork Red Dog Creek for Cominco Alaska. The drainage areas for the inlet and outlet points for the diversion are listed in Table 3. The 100 year return interval for these points are listed in Table 4.

Table 3. Drainage Areas for sub-basins above the Station 140 gage and the segments of the diversion.

Basin	Area (mi^2)	Comments
Sta 140	4.03	1991-1995
Sta 140	3.87	1996-present
Shelly Ck	0.98	
Connie Ck	1.11	
M.F. Red Dog Ck	1.50	
Diversion Segments		
Shelly Ck	0.94	
Connie Ck	1.10	
M.F. Red Dog Ck	1.35	Segment 1
Segment 2	2.45	Segment 1 + Connie Diversion
Segment 3	3.39	Outlet = Segment 2 +Shelly Diversion

Basin	Area (mi^2)	Q_{100} (cfs)	Comments
Sta 140	3.87	991	
Diversion Segments			
Shelly Ck	0.94	345	
Connie Ck	1.10	368	
M.F. Red Dog Ck	1.35	434	Segment 1
Segment 2	2.45	682	Segment 1 + Connie Diversion
Segment 3	3.39	887	Outlet = Segment 2 +Shelly Diversion

Table 4. 100 year return interval flood for the segments of the creek diversion.

An engineering factor of safety has not been applied to these values. The factor of safety should be chosen based on anticipated amount of damage if the diversion is overwhelmed, the consequences of the damage and the difficulty in making repairs.

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
Following Bulletin 17-B Guidelines
Program peakfq
(Version 4.0, December, 2000)

--- PROCESSING DATE/TIME ---

2002 OCT 29 13:03:52

--- PROCESSING OPTIONS ---

Plot option	= None
Basin char output	= None
Print option	= Yes
Debug print	= No
Input peaks listing	= Long
Input peaks format	= WATSTORE peak file

1

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Following Bulletin 17-B Guidelines
Program peakfq
(Version 4.0, December, 2000)

Station - 140 Sta 140 MF Red Dog Ck
2002 OCT 29 13:03:52

I N P U T D A T A S U M M A R Y

Number of peaks in record	=	14
Peaks not used in analysis	=	0
Systematic peaks in analysis	=	14
Historic peaks in analysis	=	0
Years of historic record	=	0
Generalized skew	=	0.130
Standard error of generalized skew	=	1.150
Skew option	=	WEIGHTED
Gage base discharge	=	0.0
User supplied high outlier threshold	=	--
User supplied low outlier criterion	=	--
Plotting position parameter	=	0.00

********* NOTICE -- Preliminary machine computations. *********
********* User responsible for assessment and interpretation. *********

WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE. 0.0
WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE. 493.2
WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION. 41.5

1

Station - 140 Sta 140 MF Red Dog Ck
2002 OCT 29 13:03:52

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	2.1555	0.2429	0.830
BULL.17B ESTIMATE	0.0	1.0000	2.1555	0.2429	0.659

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	47.7	52.0	41.7	26.2	67.4
0.9900	51.2	55.0	45.7	28.9	71.5
0.9500	64.0	66.2	59.9	39.5	86.1
0.9000	73.5	74.8	70.3	47.8	96.9
0.8000	88.6	88.7	86.4	61.3	114.5
0.5000	134.6	132.5	134.6	103.0	173.5
0.2000	223.0	220.9	232.2	173.1	318.6
0.1000	301.2	302.2	328.2	226.1	477.0
0.0400	427.0	438.0	506.5	302.5	777.2
0.0200	543.7	568.3	705.2	367.6	1097.0
0.0100	683.1	728.6	991.3	440.7	1523.0
0.0050	849.7	925.7	1410.0	523.1	2088.0
0.0020	1120.0	1257.0	2322.0	648.8	3121.0
0.6667	107.7	(1.50-year flood)			
0.4292	148.1	(2.33-year flood)			

1

Station - 140 Sta 140 MF Red Dog Ck
2002 OCT 29 13:03:52

I N P U T D A T A L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1989	360.0		1996	142.0	
1990	162.0		1997	59.0	
1991	107.0		1998	120.0	
1992	100.0		1999	99.0	
1993	121.0		2000	109.0	
1994	360.0		2001	133.0	
1995	101.0		2002	380.0	

Explanation of peak discharge qualification codes

PEAKFQ CODE	WATSTORE CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

1

Station - 140 Sta 140 MF Red Dog Ck
2002 OCT 29 13:03:52

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
2002	380.0	0.0667	0.0667
1989	360.0	0.1333	0.1333
1994	360.0	0.2000	0.2000
1990	162.0	0.2667	0.2667
1996	142.0	0.3333	0.3333
2001	133.0	0.4000	0.4000
1993	121.0	0.4667	0.4667
1998	120.0	0.5333	0.5333
2000	109.0	0.6000	0.6000
1991	107.0	0.6667	0.6667
1995	101.0	0.7333	0.7333
1992	100.0	0.8000	0.8000
1999	99.0	0.8667	0.8667
1997	59.0	0.9333	0.9333

1

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ANNUAL PEAK FLOW FREQUENCY ANALYSIS
Following Bulletin 17-B Guidelines
Program peakfq
(Version 4.0, December, 2000)

End PEAKFQ analysis.
Stations processed : 1
Number of errors : 0
Stations skipped : 0
Station years : 14

CARD types 4, 2, and * are ignored
2140 ENT
Unrecognized CARD type. Must be Y, Z, N, H, I, 2, 3, 4, or *.
(2, 4, and * records are ignored.)

Flood Frequency on Middle Fork Red Dog Creek

December 2000

Prepared for:
Cominco Alaska

Prepared by:
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1506 West 36th Ave
Anchorage, Alaska, 99503

Introduction

The Middle Fork Red Dog Creek runs on the west and north sides of the Red Dog Mine. Five tributaries join the creek in the vicinity of the mine; Hilltop drainage, Rachel Creek, Connie Creek, Shelly Creek, and Sulfur Creek (from upstream to downstream). To separate the clean water draining from undisturbed ground, Middle Fork Red Dog Creek has been channelized from the confluence with the Hilltop drainage to below Sulfur Creek. This channel excludes the Hilltop tributary and the pit area, which drain disturbed areas and has it's own drainage system.

Two separate calculations of the 100-year flow event were done in 1990 for the existing channel. One used the Lamke regional flood frequency equations and gave a value of 730 ft^3/s for the 100-year flow event. The other used the peak discharge resulting from an assumed 100-year precipitation event of 1 inch of rain over 1 hour. The peak discharge was calculated as 1700 ft^3/s (CESL 1991). The recommended design capacity for the channel was 1700 ft^3/s. As built, the capacity of the channel is 3000 ft^3/s, based on dimensions of 7.5 ft deep, 15 ft bottom width with 3:1 side slopes, a slope of 0.02 and a Manning's roughness coefficient of 0.05.

In order to expand the existing pit, the clean water channel that routes the Middle Fork Red Dog Creek around the east side of the pit upstream of the confluence with Shelly Creek will be moved farther east onto a terrace of the expanded pit wall. The channel size will affect the width of the terrace and therefore the amount of waste rock removal. This report summarizes 100-year flood discharge calculations for the basin above Shelly Creek based on regional flood frequency equations updated in 1994 and 12 years of flow data collected on Middle Fork Red Dog Creek at the mine site.

Methods and Results

The updated regional flood frequency equations (Jones and Fahl, 1994) use the basin characteristics of drainage area, annual precipitation, percent of area covered by ponds and lakes, and the average basin elevation. Using these equations, the 100-year flow is 389 ft^3/s at Station 140 and 267 ft^3/s above the confluence with Shelly Creek. See Appendix A for basin characteristics and flood frequency calculations for Station 140 (gage site below Sulfur creek) and the downstream end of the new channel.

The 12-years of flow data were collected from 1988 to 2000 using two gages, Station 37 and Station 140, on the Middle Fork Red Dog Creek. The gaging sites are 4500 ft apart with a tributary, Sulfur Creek, entering between them. The 1988 to 1990 data are from Station 37, the upstream site above Sulfur Creek, before mining began. The 1991 to 2000 data are Station 140, downstream site below Sulfur Creek. Two factors complicate combining the peak flow

data; 1) Station 140 has a larger drainage than Station 37, even with part of the drainage area diverted at the start of mining, and 2) two of the peak flow values from Station 37, the second and third highest yearly peaks, are time averaged discharges. Both these factors reduce the Station 37 peak flow values in relation to the Station 140 data. Using combined yearly peak flow data from these gages to calculate a flood frequency curve yields a 100-year flow event of 755 ft^3/s for (see Appendix A for flood frequency output).

The flood frequency calculations from 12 years of on site data are more accurate than the regional equations. Given the change in basin area and the difference in the type of data reported from the stations, the 755 ft^3/s 100-year flow event is probably low and it is recommended that a discharge of 943 ft^3/s, 25% higher, be used as the 100-year flow event at Station 140. The additional 25% reflects the short time period the basin has been monitored and the uncertainty of the measuring instruments accuracy.

The new channel will drain the basin above the confluence with Shelly Creek reducing the area compared to Station 140 by 37%. Given that peak flow is affected by basin characteristics in addition to drainage area, the percentage change between the 100-year flows calculated by the regional equation, 32%, was used to reduce the value at Station 140. This gives a 100-year discharge for the channel above Shelly Creek of 641 ft^3/s.

An engineering factor of safety of 1.3 was used in PN&D's discharge estimates for the port road stream crossings. Factors considered in applying the factor of safety include the physical damage from overflow, as well as the time to make repairs and the effect on operations. An engineering factor of safety of 2.0 is recommended in applying this data to the channel design. This higher factor is recommended based on anticipation that overtopping of the proposed channel will cause erosion of the channel bank and pit wall and diversion of the flow into the pit. It also reflects the more difficult access along the channel and the increased time and difficulty in making repairs.

Appendix A

Flood Frequency Results

Station 140

Magnitude and frequency of floods in Alaska and Conterminous basins of Canada
Jones and Fahl, USGS WRIR 93-4179

Equations for estimating magnitude and frequency of floods
Flood Frequency Area 3

A	(drainage area in square miles)	3.9	mi^2
P	(mean annual precipitation in inches)	20	in
ST	(area of lakes and ponds as percent of basin area)	0	%
E	(mean basin elevation in feet)	1200	ft

$Q_2=16.2\ A^{0.894}\ P^{0.949}\ (ST+1)^{-0.209}\ E^{-0.345}=$ **81** ft^3/s

$Q_5=43.9\ A^{0.843}\ P^{0.753}\ (ST+1)^{-0.206}\ E^{-0.305}=$ **152** ft^3/s

$Q_{10}=70.3\ A^{0.818}\ P^{0.667}\ (ST+1)^{-0.202}\ E^{-0.288}=$ **205** ft^3/s

$Q_{25}=112\ A^{0.793}\ P^{0.568}\ (ST+1)^{-0.194}\ E^{-0.272}=$ **279** ft^3/s

$Q_{50}=147\ A^{0.778}\ P^{0.544}\ (ST+1)^{-0.187}\ E^{-0.264}=$ **337** ft^3/s

$Q_{100}=185\ A^{0.765}\ P^{0.509}\ (ST+1)^{-0.179}\ E^{-0.257}=$ **389** ft^3/s

$Q_{200}=224\ A^{0.754}\ P^{0.480}\ (ST+1)^{-0.171}\ E^{-0.252}=$ **441** ft^3/s

$Q_{500}=275\ A^{0.742}\ P^{0.451}\ (ST+1)^{-0.160}\ E^{-0.245}=$ **513** ft^3/s

Middle Fork Red Dog above Shelly Creek
Downstream end of proposed channel

Magnitude and frequency of floods in Alaska and Conterminous basins of Canada
Jones and Fahl, USGS WRIR 93-4179

Equations for estimating magnitude and frequency of floods
Flood Frequency Area 3

A	(drainage area in square miles)	2.48	mi^2
P	(mean annual preciplation in inches)	20	in
ST	(area of lakes and ponds as percent of basin area)	0	%
E	(mean basin elevation in feet)	1350	ft

$Q_2=16.2\ A^{0.694}\ P^{0.949}\ (ST+1)^{-0.209}\ E^{-0.345}=$ **52** ft^3/s

$Q_5=43.9\ A^{0.643}\ P^{0.753}\ (ST+1)^{-0.206}\ E^{-0.305}=$ **100** ft^3/s

$Q_{10}=70.3\ A^{0.618}\ P^{0.667}\ (ST+1)^{-0.202}\ E^{-0.288}=$ **137** ft^3/s

$Q_{25}=112\ A^{0.793}\ P^{0.586}\ (ST+1)^{-0.194}\ E^{-0.272}=$ **189** ft^3/s

$Q_{50}=147\ A^{0.778}\ P^{0.544}\ (ST+1)^{-0.187}\ E^{-0.264}=$ **229** ft^3/s

$Q_{100}=185\ A^{0.765}\ P^{0.509}\ (ST+1)^{-0.179}\ E^{-0.257}=$ **267** ft^3/s

$Q_{200}=224\ A^{0.754}\ P^{0.480}\ (ST+1)^{-0.171}\ E^{-0.252}=$ **304** ft^3/s

$Q_{500}=275\ A^{0.742}\ P^{0.451}\ (ST+1)^{-0.160}\ E^{-0.245}=$ **356** ft^3/s

Station 140 and 37 combined

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ANNUAL PEAK FLOW FREQUENCY ANALYSIS
Following Bulletin 17-B Guidelines
Program peakfq
(Version 2.3, Jan, 1997)

--- PROCESSING DATE/TIME ---

1900 DEC 21 10:10:41

--- PROCESSING OPTIONS ---

Plot option	= None
Basin char output	= WDM
Print option	= Yes
Debug print	= No
Input peaks listing	= Long
Input peaks format	= WDM file

1

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
Following Bulletin 17-B Guidelines
Program peakfq
(Version 2.3, Jan, 1997)

Station - red dog Sta 140 and Sta 37
1900 DEC 21 10:10:41

I N P U T D A T A S U M M A R Y

Number of peaks in record	=	13
Peaks not used in analysis	=	1
Systematic peaks in analysis	=	12
Historic peaks in analysis	=	0
Years of historic record	=	0
Generalized skew	=	-0.150
Standard error of generalized skew	=	0.550
Skew option	=	WEIGHTED
Gage base discharge	=	0.0
User supplied high outlier threshold	=	--
User supplied low outlier criterion	=	--
Plotting position parameter	=	0.00

********* NOTICE -- Preliminary machine computations. *********
********* User responsible for assessment and interpretation. *********

```
  **WCF109W-PEAKS WITH MINUS-FLAGGED DISCHARGES WERE BYPASSED.        1
  **WCF113W-NUMBER OF SYSTEMATIC PEAKS HAS BEEN REDUCED TO NSYS =    12
    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                    0.0
    WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.        602.5
    WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.              39.0
  **WCF233W-EXPECTED PROB OUT OF RANGE AT TAB PROB.    0.00008    0.00200
    WCF002J-CALCS COMPLETED.  RETURN CODE =  2
1
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Station - red dog Sta 140 and Sta 37
1900 DEC 21 10:10:41

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	2.1856	0.2785	0.797
BULL.17B ESTIMATE	0.0	1.0000	2.1856	0.2785	0.219

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B LOWER	UPPER
0.9950	33.5	47.1	24.0	13.6	54.0
0.9900	38.3	50.4	29.4	16.5	59.9
0.9500	55.6	62.9	49.1	28.7	81.2
0.9000	68.5	72.6	63.3	38.7	96.7
0.8000	88.8	88.5	85.3	55.6	121.8
0.5000	149.8	140.9	149.8	107.8	206.7
0.2000	260.9	252.9	273.7	190.6	414.7
0.1000	353.5	361.2	389.9	249.3	633.7
0.0400	493.8	550.2	595.9	329.1	1029.0
0.0200	616.2	738.6	813.2	393.2	1427.0
0.0100	738.1	977.7	1110.0	461.6	1932.0
0.0050	912.3	1281.0	1525.0	534.9	2566.0
0.0020	1152.0	1806.0	--	640.6	3649.0

1

Station - red dog Sta 140 and Sta 37
1900 DEC 21 10:10:41

I N P U T D A T A L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1988	564.0		1995	111.0	
1989	353.0		1996	142.0	
1990	283.0		1997	59.0	
1991	-999.0		1998	120.0	
1992	105.5		1999	99.0	
1993	109.5		2000	109.0	
1994	215.0				

Explanation of peak discharge qualification codes

PEAKFQ CODE	WATSTORE CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

Station - red dog Sta 140 and Sta 37
1900 DEC 21 10:10:41

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
1988	564.0	0.0769	0.0769
1989	353.0	0.1538	0.1538
1990	283.0	0.2308	0.2308
1994	215.0	0.3077	0.3077
1996	142.0	0.3846	0.3846
1998	120.0	0.4615	0.4615
1995	111.0	0.5385	0.5385
1993	109.5	0.6154	0.6154
2000	109.0	0.6923	0.6923
1992	105.5	0.7692	0.7692
1999	99.0	0.8462	0.8462
1997	59.0	0.9231	0.9231
1991	-999.0	--	--

1

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ANNUAL PEAK FLOW FREQUENCY ANALYSIS
Following Bulletin 17-B Guidelines
Program peakfq
(Version 2.3, Jan, 1997)

End PEAKFQ analysis.
Stations processed : 1
Number of errors : 0
Stations skipped : 0
Station years : 13

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