

## **18. Appendix 2**

**Derivation of peak flows for the summer events at Walhalla**

**(from Manitoba Conservation Water Stewardship)**



## Memorandum

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**DATE:** February 15, 2011

**TO:** R. W. Harrison, P. Eng.  
Manager Surface Water Management  
Water Science and Management Branch  
Manitoba Water Stewardship

**FROM:** Bin Luo, P. Eng.  
Hydrologist  
Surface Water Management Section  
Manitoba Water Stewardship

**PHONE NO.:**

**File No.:** 5.5.1

**SUBJECT:** Instantaneous Summer Design Discharges - Pembina River at Walhalla

This memo is in response to your request for instantaneous summertime design discharges for the Pembina River at Walhalla. The summertime period is defined from May 1<sup>st</sup> to September 30<sup>th</sup>.

Annual instantaneous summertime discharges for the Pembina River at Walhalla (05099600) were obtained from the USGS Bismarck Office for the years from 2000 to 2010. To extend the hydrologic period, a correlation between the annual maximum summertime instantaneous discharge and the corresponding day mean daily discharge for the Pembina River at Walhalla was developed, as shown in Figure 1. The correlation, with a correlation coefficient of 0.993, was used to extend the period back to 1940 using the annual maximum recorded summertime mean daily discharge for Walhalla. Missing records of daily discharge during the periods 1991 to 1993 and 1996 to 1999 were extended by correlation with daily peak flows for the Pembina River at Neche. Figure 2 shows this relationship.

Table 1 lists the summer time maximum instantaneous and corresponding daily discharge (recorded and re-constructed). A probability fitting was conducted on the summertime recorded and re-constructed instantaneous discharges using the HEC-FFA software. The fitted curve and relevant frequencies are attached in this memo as shown on Figure 3. The summertime instantaneous design discharges for various return periods are listed in Table 2.

*Original Signed By*

BIN LUO, P. Eng.

Attachment

cc: Duane Kelln, P. Eng.

**Table 1. Pembina River at Walhalla Peak Discharge in Summertime**

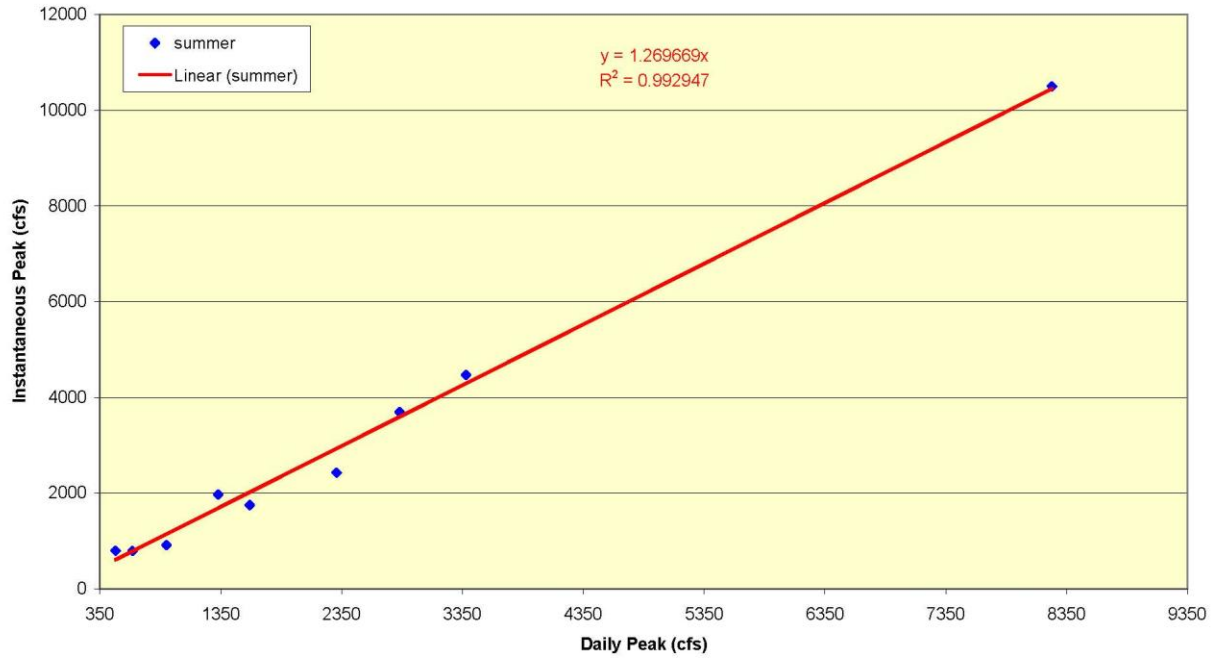
Date	Daily Peak Discharge (CFS)	Instantaneous Discharge (CFS)
1940-08-01	46	58
1941-09-04	931	1182
1942-08-01	447	568
1943-06-04	950	1206
1944-08-04	1190	1511
1945-07-20	375	476
1946-07-10	86	109
1947-08-17	958	1216
1948-07-03	504	640
1949-06-02	969	1230
1950-07-15	884	1122
1951-06-03	334	424
1952-06-26	188	239
1953-08-01	283	359
1954-07-06	996	1265
1955-06-04	1600	2031
1956-09-01	253	321
1957-09-03	259	329
1958-07-05	75	95
1959-06-10	354	449
1960-08-22	56	71
1961-06-01	119	151
1962-06-07	432	548
1963-07-26	1020	1295
1964-06-19	558	708
1965-06-06	588	747
1966-07-03	438	556
1967-09-28	10	13
1968-09-28	435	552
1969-06-01	1340	1701
1970-06-11	3340	4241
1971-06-11	755	959
1972-07-25	205	260
1973-08-09	238	302
1974-08-24	165	209
1975-06-22	563	715
1976-07-19	1310	1663
1977-09-25	84	107
1978-06-01	380	482
1979-07-03	785	997
1980-06-01	78	99
1981-08-06	18	23
1982-06-07	1490	1892
1983-06-22	242	307
1984-06-17	232	295
1985-07-01	436	554
1986-06-04	837	1063
1987-08-20	87	110
1988-06-15	10	13
1989-06-29	36	46
1990-06-13	478	607
1991-06-17	535	679
1992-06-18	202	256
1993-07-30	3592	4561
1994-09-13	340	432
1995-08-19	6800	8634
1996-06-02	1447	1837
1997-07-16	3675	4665
1998-06-12	652	828
1999-06-02	3787	4808
2000-06-16	119	136
2001-06-21	901	920
2002-06-11	2830	3700
2003-06-10	570	795
2004-06-08	2320	2946
2005-06-30	8230	10500
2006-08-12	110	1970
2007-06-26	2310	2430
2008-09-23	480	796
2009-06-27	3380	4470
2010-06-22	1050	1750

**Table 2. Summertime Instantaneous Design Discharge  
for Pembina River at Walhalla (05099600)**

<b>Frequency in %</b>	<b>Return Period Year</b>	<b>Design Discharge (CFS)</b>
0.2	500	21300
0.5	200	15600
1	100	12000
2	50	8970
3	33.3	7430
5	20	5740
10	10	3820
20	5	2310
30	3.33	1590
50	2	842

Pembina River at Walhalla Instantaneous VS. Daily Peak Flows (Summertime)

Figure 1



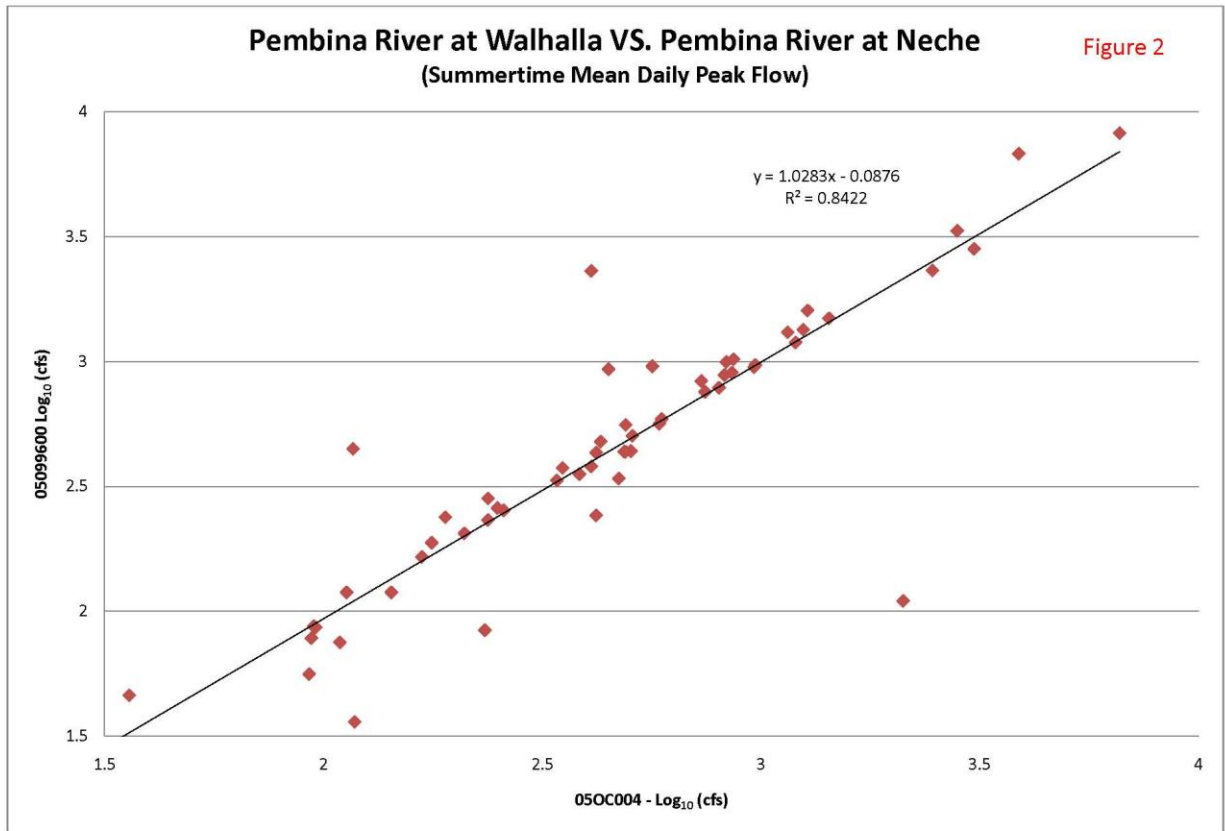
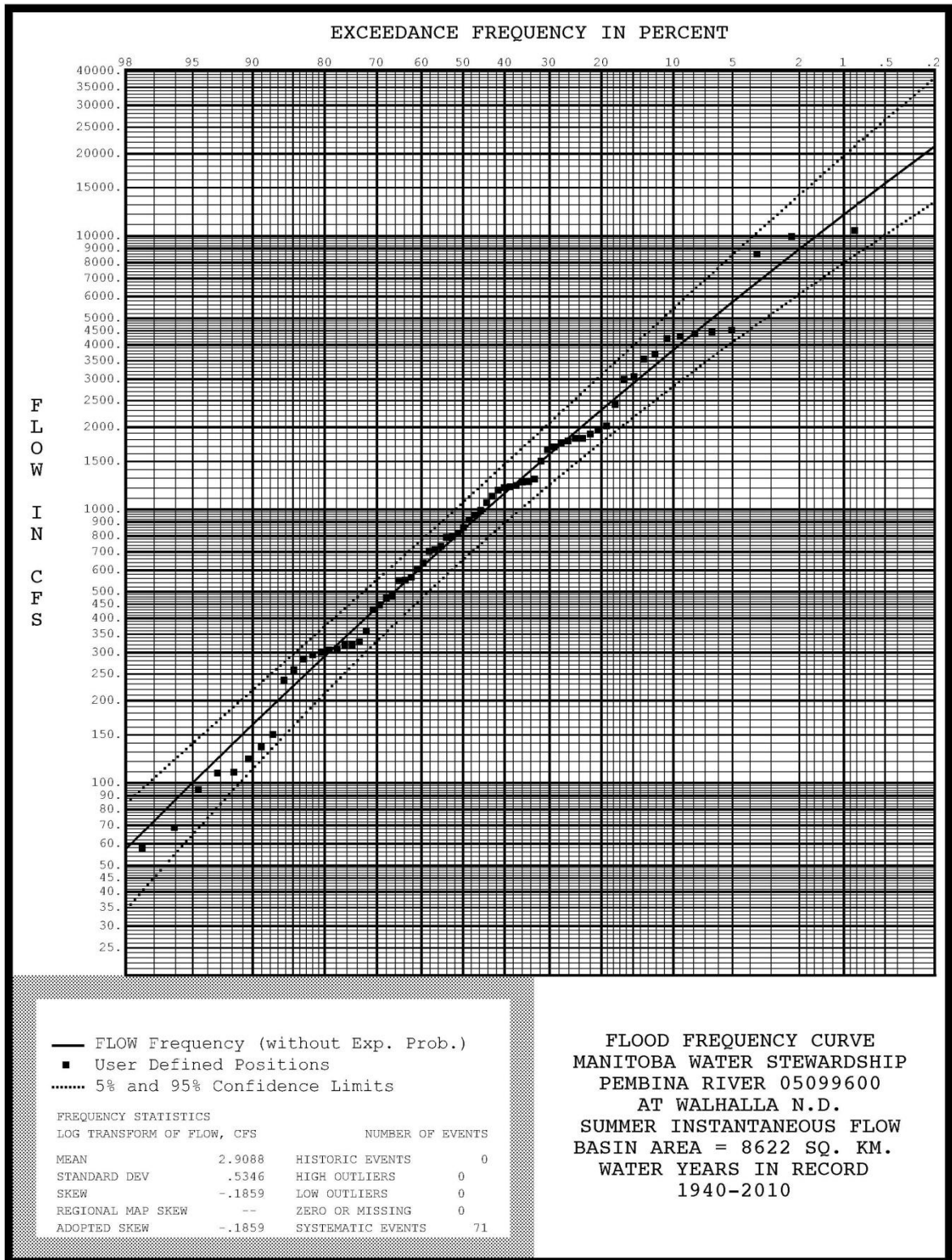


Figure 3



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*****
*****
*           FFA           *   *
*
*   FLOOD FREQUENCY ANALYSIS   *   *   U.S. ARMY CORPS OF ENGINEERS
*
*   PROGRAM DATE: FEB 1995     *   *   THE HYDROLOGIC ENGINEERING CENTER
*
*           VERSION: 3.1       *   *           609 SECOND STREET
*
*   RUN DATE AND TIME:        *   *           DAVIS, CALIFORNIA 95616
*
*       15 FEB 11    11:39:51 *   *           (916) 756-1104
*
*
*
*****
*****

```

INPUT FILE NAME: 99600IPQ.FFA  
OUTPUT FILE NAME: 99600IPQ.OUT

\*\*TITLE RECORD(S)\*\*

```

TT FLOOD FREQUENCY ANALYSIS
TT SUMMER INSTANTANEOUS FLOWS
TT SUMMER PEAKS ARE PICKED OFF AS INCREASES ON RECESSION LIMB WHICH CAN BE
TT UP TO 4 MONTHS IN LENGTH
TT 2000-2003, 2005-2010 PEMBINA R. AT WALHALLA DATA RECEIVED FROM U.S.G.S.
TT 1940-1999, 2004 RECORDS EXTENDED BY CORRELATION WITH DAILY MEAN PEAK
TT INSTANTANEOUS=1.269669*DAILY PEAK CFS R**2=0.99

```

\*\*JOB RECORD(S)\*\*

	IPPC	ISKFX	IPROUT	IFMT	IWYR	IUNIT	ISMRY	IPNCH	IREG
J1	4	2	7	0	0	1	3	0	0
	A	B	CLIMIT	NDSSCV	IEXT				
J2	.40	.20	.00	0	1				

\*\*FREQUENCY ARRAY\*\*

```

FR 14 .200 .500 1.000 2.000 3.000 5.000 10.000 20.000
30.000
FR50.000 80.000 90.000 95.000 99.000

```

\*\*STATION IDENTIFICATION\*\*

ID PEMBINA RIVER AT WALHALLA NORTH DAKOTA

\*\*SPECIAL STATION INFORMATION\*\*

	IYRA	IYRL	HITHRS	LOTHRS	LOGT	NDEC	NSIG
SI	0	0	0.	0.	0	2	3

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**HP PLOT **
  HP PLOT FILE                IHPCV  KLIMIT  IPER   BAREA
HP WALH-SIN.PCL                2      0      0    8622 SQ. KM.
    
```

SELECTED CURVES ON HP PLOT  
 COMPUTED PROBABILITY CURVE  
 CONFIDENCE LIMITS

HP FLOOD FREQUENCY CURVE  
 HP MANITOBA WATER STEWARDSHIP  
 HP PEMBINA RIVER 05099600  
 HP AT WALHALLA N.D.  
 HP SUMMER INSTANTANEOUS FLOW

\*\*SYSTEMATIC EVENTS\*\*  
 71 EVENTS TO BE ANALYZED

\*\*END OF INPUT DATA\*\*

ED ++++++

\*\*\*\*\*  
 CAUTION FROM SUBROUTINE WTSKEW  
 \*\*\*\*\* NO GENERALIZED SKEW PROVIDED  
 ADOPTED SKEW SET TO COMPUTED SKEW

\* \* \* \* \* FINAL RESULTS \* \* \* \* \*

-PLOTTING POSITIONS- PEMBINA RIVER AT WALHALLA NORTH DAKOTA

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*****
*.....EVENTS ANALYZED.....*.....ORDERED EVENTS.....*
*      FLOW *      WATER      FLOW  SPECIAL *
* MON DAY  YEAR  CFS * RANK  YEAR  CFS  PLOT POS *
*-----*-----*-----*-----*-----*-----*-----*
*  0  0  1940   58.00 *   1  2005 10500.00   .84 *
*  0  0  1941  1182.00 *   2  1974  9980.00   2.24 *
*  0  0  1942   568.00 *   3  1995  8634.00   3.64 *
*  0  0  1943  1206.00 *   4  1999  4531.00   5.04 *
*  0  0  1944  1511.00 *   5  2009  4470.00   6.44 *
*  0  0  1945   476.00 *   6  1997  4404.00   7.84 *
*  0  0  1946   109.00 *   7  1993  4311.00   9.24 *
*  0  0  1947  1216.00 *   8  1970  4241.00  10.64 *
*  0  0  1948   640.00 *   9  2002  3700.00  12.04 *
*  0  0  1949  1230.00 *  10  1967  3555.00  13.45 *
*  0  0  1950  1122.00 *  11  1966  3073.00  14.85 *
*  0  0  1951   824.00 *  12  2004  3009.00  16.25 *
*  0  0  1952   239.00 *  13  2007  2430.00  17.65 *
*  0  0  1953   359.00 *  14  1955  2031.00  19.05 *
*  0  0  1954  1265.00 *  15  2006  1970.00  20.45 *
*  0  0  1955  2031.00 *  16  1982  1892.00  21.85 *
*  0  0  1956   321.00 *  17  1975  1828.00  23.25 *
*  0  0  1957   329.00 *  18  1996  1828.00  24.65 *
*  0  0  1958    95.00 *  19  1965  1790.00  26.05 *
    
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*	0	0	1959	449.00	*	20	2010	1750.00	27.45	*
*	0	0	1960	1270.00	*	21	1969	1701.00	28.85	*
*	0	0	1961	151.00	*	22	1976	1663.00	30.25	*
*	0	0	1962	736.00	*	23	1944	1511.00	31.65	*
*	0	0	1963	1295.00	*	24	1963	1295.00	33.05	*
*	0	0	1964	708.00	*	25	1960	1270.00	34.45	*
*	0	0	1965	1790.00	*	26	1954	1265.00	35.85	*
*	0	0	1966	3073.00	*	27	1949	1230.00	37.25	*
*	0	0	1967	3555.00	*	28	1947	1216.00	38.66	*
*	0	0	1968	552.00	*	29	1943	1206.00	40.06	*
*	0	0	1969	1701.00	*	30	1941	1182.00	41.46	*
*	0	0	1970	4241.00	*	31	1950	1122.00	42.86	*
*	0	0	1971	959.00	*	32	1986	1063.00	44.26	*
*	0	0	1972	260.00	*	33	1979	997.00	45.66	*
*	0	0	1973	302.00	*	34	1971	959.00	47.06	*
*	0	0	1974	9980.00	*	35	2001	920.00	48.46	*
*	0	0	1975	1828.00	*	36	1998	862.00	49.86	*
*	0	0	1976	1663.00	*	37	1951	824.00	51.26	*
*	0	0	1977	321.00	*	38	2008	796.00	52.66	*
*	0	0	1978	482.00	*	39	2003	795.00	54.06	*
*	0	0	1979	997.00	*	40	1962	736.00	55.46	*
*	0	0	1980	123.00	*	41	1991	715.00	56.86	*
*	0	0	1981	310.00	*	42	1964	708.00	58.26	*
*	0	0	1982	1892.00	*	43	1948	640.00	59.66	*
*	0	0	1983	307.00	*	44	1990	607.00	61.06	*
*	0	0	1984	295.00	*	45	1942	568.00	62.46	*
*	0	0	1985	554.00	*	46	1985	554.00	63.87	*
*	0	0	1986	1063.00	*	47	1968	552.00	65.27	*
*	0	0	1987	110.00	*	48	1978	482.00	66.67	*
*	0	0	1988	69.00	*	49	1945	476.00	68.07	*
*	0	0	1989	46.00	*	50	1959	449.00	69.47	*
*	0	0	1990	607.00	*	51	1994	432.00	70.87	*
*	0	0	1991	715.00	*	52	1953	359.00	72.27	*
*	0	0	1992	285.00	*	53	1957	329.00	73.67	*
*	0	0	1993	4311.00	*	54	1956	321.00	75.07	*
*	0	0	1994	432.00	*	55	1977	321.00	76.47	*
*	0	0	1995	8634.00	*	56	1981	310.00	77.87	*
*	0	0	1996	1828.00	*	57	1983	307.00	79.27	*
*	0	0	1997	4404.00	*	58	1973	302.00	80.67	*
*	0	0	1998	862.00	*	59	1984	295.00	82.07	*
*	0	0	1999	4531.00	*	60	1992	285.00	83.47	*
*	0	0	2000	136.00	*	61	1972	260.00	84.87	*
*	0	0	2001	920.00	*	62	1952	239.00	86.27	*
*	0	0	2002	3700.00	*	63	1961	151.00	87.68	*
*	0	0	2003	795.00	*	64	2000	136.00	89.08	*
*	0	0	2004	3009.00	*	65	1980	123.00	90.48	*
*	0	0	2005	10500.00	*	66	1987	110.00	91.88	*
*	0	0	2006	1970.00	*	67	1946	109.00	93.28	*
*	0	0	2007	2430.00	*	68	1958	95.00	94.68	*
*	0	0	2008	796.00	*	69	1988	69.00	96.08	*
*	0	0	2009	4470.00	*	70	1940	58.00	97.48	*
*	0	0	2010	1750.00	*	71	1989	46.00	98.88	*

\*\*\*\*\*

-OUTLIER TESTS -

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-----  
 LOW OUTLIER TEST  
 -----

BASED ON 71 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.897  
 0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 22.9

-----  
 HIGH OUTLIER TEST  
 -----

BASED ON 71 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.897  
 0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 28677.

-----  
 -SKEW WEIGHTING -  
 -----

BASED ON 71 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = -99.000  
 DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = .302  
 -----

FINAL RESULTS

-FREQUENCY CURVE- PEMBINA RIVER AT WALHALLA NORTH DAKOTA

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*****
*.....FLOW IN CFS.....* PERCENT *...CONFIDENCE LIMITS...*
*          EXPECTED * CHANCE *
* COMPUTED PROBABILITY * EXCEEDANCE * .05 LIMIT .95 LIMIT *
*-----*-----*-----*-----*-----*
* 21300.00 24000.00 * .20 * 38200.00 13400.00 *
* 15600.00 17100.00 * .50 * 26800.00 10200.00 *
* 12000.00 12900.00 * 1.00 * 19900.00 8040.00 *
* 8970.00 9500.00 * 2.00 * 14300.00 6190.00 *
* 7430.00 7800.00 * 3.00 * 11600.00 5220.00 *
* 5740.00 5960.00 * 5.00 * 8630.00 4130.00 *
* 3820.00 3910.00 * 10.00 * 5470.00 2840.00 *
* 2310.00 2340.00 * 20.00 * 3130.00 1770.00 *
* 1590.00 1600.00 * 30.00 * 2090.00 1240.00 *
* 842.00 842.00 * 50.00 * 1070.00 661.00 *
* 291.00 287.00 * 80.00 * 379.00 215.00 *
* 164.00 159.00 * 90.00 * 221.00 114.00 *
* 101.00 96.00 * 95.00 * 141.00 65.80 *
* 39.10 35.40 * 99.00 * 60.40 22.50 *
*****
*          SYSTEMATIC STATISTICS *
* LOG TRANSFORM: FLOW, CFS * NUMBER OF EVENTS *
*-----*-----*-----*-----*
* MEAN 2.9088 * HISTORIC EVENTS 0 *
    
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* STANDARD DEV          .5346 * HIGH OUTLIERS          0      *
* COMPUTED SKEW        -.1859 * LOW OUTLIERS          0      *
* REGIONAL SKEW       -99.0000 * ZERO OR MISSING      0      *
* ADOPTED SKEW        -.1859 * SYSTEMATIC EVENTS    71     *
*****
    
```

HP PLOT WRITTEN TO THE FILE: WALH-SIN.PCL

TABLE 1. SUMMARY OF STATISTICS -- PRELIMINARY AND FINAL RESULTS

```

-----
STATION STATION NAME AND LOCATION AREA
....YEARS..... MEAN STD .....SKEW..... HIST OUTLIER ZERO/
NUMBER ..... SQ MI RECD SYST
HIST LOG DEV ADOPT COMP GENRL EVENT HI LO MSNG
-----
                PEMBINA RIVER AT WALHALLA NORTH DAKOTA          71  71  0
2.909 .535  -.19  -.186 -99.00  0  0  0  0  0 **
                PEMBINA RIVER AT WALHALLA NORTH DAKOTA          71  71  0
2.909 .535  -.19  -.186 -99.00  0  0  0  0
-----
    
```

\*\* PRELIMINARY STATISTICS

TABLE 2. SUMMARY OF FREQUENCY CURVE ORDINATES -- PRELIMINARY AND FINAL RESULTS

```

-----
STATION STATION NAME AND LOCATION AREA
....YEARS..... PERCENT CHANCE EXCEEDANCE.....
NUMBER ..... SQ MI RECD SYST
HIST 10. 5. 2. 1. .5 .2
-----
                PEMBINA RIVER AT WALHALLA NORTH DAKOTA          71  71
0 5740 7434 8968 11994 15577 21255
                PEMBINA RIVER AT WALHALLA NORTH DAKOTA          71  71
0 5740 7434 8968 11994 15577 21255
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