Office Report

Probability Estimates for Historical Flood Events and Recorded Floods

Skagit River near Concrete

MBK ENGINEERS
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March 10, 2011

Prepared by:

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President, MBK Engineers

Certification of independent technical review

MBK Engineers completed *Probability Estimates for Historical Flood Events and Recorded Floods, Skagit River near Concrete*. I was not involved in the work.

I reviewed the following items associated with the work:

1. Office report titled *Probability Estimates for Historical Flood Events and Recorded Floods, Skagit River near Concrete*, dated March 2011.

My independent technical review was appropriate to the level of risk and complexity inherent in the project. I verified that the work performed complies with established policy, principles, and procedures, and reflects the use of justified and verified assumptions. I checked and confirmed computations made by MBK Engineers and included in the report.

I documented all concerns arising from my review; that documentation is on file with MBK Engineers. I corresponded with the MBK project team about my concerns, and I confirm that all issues resulting from my technical review of the project have been addressed in an appropriate manner.

March 10, 2011

David T. Ford, PE, PhD, D.WRE
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date

Office Report

Probability Estimates for Historical Flood Events and Recorded Floods

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Background - The U.S. Geological Survey (USGS) established a stream gage (USGS 12194000) on the Skagit River near Concrete, Washington in September 1924. The gage has been continuously operated and maintained until present. Data for water year 1925 through water year 2010, or 86 years of continuously recorded flow and stage data, are available for statistical analysis. The largest flood of record since the establishment of the gage is the October 2003 (2003) flood. The peak stage was 42.21 feet and the peak flow was 166,000 cfs. Because the flow in the river is regulated by dams, it is necessary to estimate what the unregulated flow would have been. The U.S. Army Corps of Engineers Seattle District (USACE) has adopted 205,000 cfs as the unregulated peak flow for the 2003 flood (Attachment A).

A large flood occurred in December 1921 (1921) prior to the establishment of the gage. High water marks were determined for this flood by the USGS (James Stewart) approximately 11 months after the flood event. High water elevation estimates were also available for the November 1897 (1897), Nov 1909 (1909), and Dec 1917 (1917) floods. All four of these floods occurred prior to the establishment of the gage near Concrete. These flood events are referred to as “historic” floods because they occurred prior to the establishment of the stream gage and are not as well documented as the systematically recorded data from September 1924 to present. Historic floods have considerably more uncertainty associated with estimating the maximum stages and flows than recorded or “systematic” record. For the remainder of this report, the floods that occurred prior to water year 1925 (September 1924) will be referred to as part of the historic record or as Historic floods and floods that occurred after September 1924will be referred to as the recorded floods or Systematic floods.

The USGS has estimated peak flows for each of the Historic floods (Mastin, 2007). The estimates rely heavily on the estimate of the 1921 flood; the 1921 flood is the only historic flood for which the USGS has directly calculated a peak flow estimate. The other three (3) Historic floods were estimated based on the magnitude of the 1921 flood estimate. In other words, if the estimate of the 1921 flood were to change, the estimates of all the historic floods would be subject to change. The USGS has estimated the peak flow for the 1921 flood several times (Mastin, 2007; Bodhaine 1954; Riggs & Robinson 1950; Stewart 1923) and each time a different flow estimate has been obtained. The current estimates of the Historic floods are shown in Table 1. The USGS estimates are primarily based on the use of the Slope-Area Method used to estimate the 1921 flood (Mastin, 2007).

Table 1 Estimate of Unregulated Flood Peaks

Flood	USGS cfs	PIE cfs
Nov 1897	265,000	181,200
Nov 1909	245,000	179,000
Dec 1917	210,000	158,700
Dec 1921	228,000	169,700
Oct 2003	205,000	205,000

Pacific International Engineers (PIE) has also estimated the Historic floods. The PIE estimate of the 1921 flood is primarily based upon the same high water elevation data used by the USGS, with the use of additional high water marks established by Stewart upstream from the gage (PIE, 2010). PIE used HEC-RAS and the existing stream gage to estimate the 1921 flood peak flow, and also used the Slope-Area method to support the 1921 flood estimate from HEC-RAS. The PIE estimates are also shown in Table 1. The PIE frequency calculations are contained in Attachment B. The USACE estimated the 2003 unregulated flow based on the measured regulated flow and the changes in upstream reservoir storage. The 2003 flood estimate is also shown in Table 1.

Flood Frequency Estimates – Based on the "Systematic" flow record and the use of the Historical floods, both the USACE (using USGS flow estimates for the historical floods) and PIE calculated unregulated peak flow frequency curves for the Skagit River near Concrete. The USACE calculations are documented in output from computer program HEC-FFA and can be found in Attachment A to this report. The PIE calculations utilized the PEAKFQ computer Program and are documented in Attachment B to this report. PIE and USACE calculated frequency curves for Skagit River near Concrete with and without the utilization of the Historic floods. See Bulletin 17B, Guide lines for Developing Flood Flow Frequency (Bulletin 17B) (IACWD, 1982). The Corps and FEMA are required to use the methods described in Bulletin 17B. Bulletin 17B requires the use of the Log Pearson type 3 probability distribution function (LP3pdf) to estimate the Annual Exceedance Probability (AEP) of floods. The LPpdf has three parameters; the Mean, Standard Deviation, and Skew. These parameters are used to fit the LPpdf to the available data. The Log Pearson parameters calculated by USACE and PIE are summarized in Table 2.

Table 2 Log Pearson Parameters

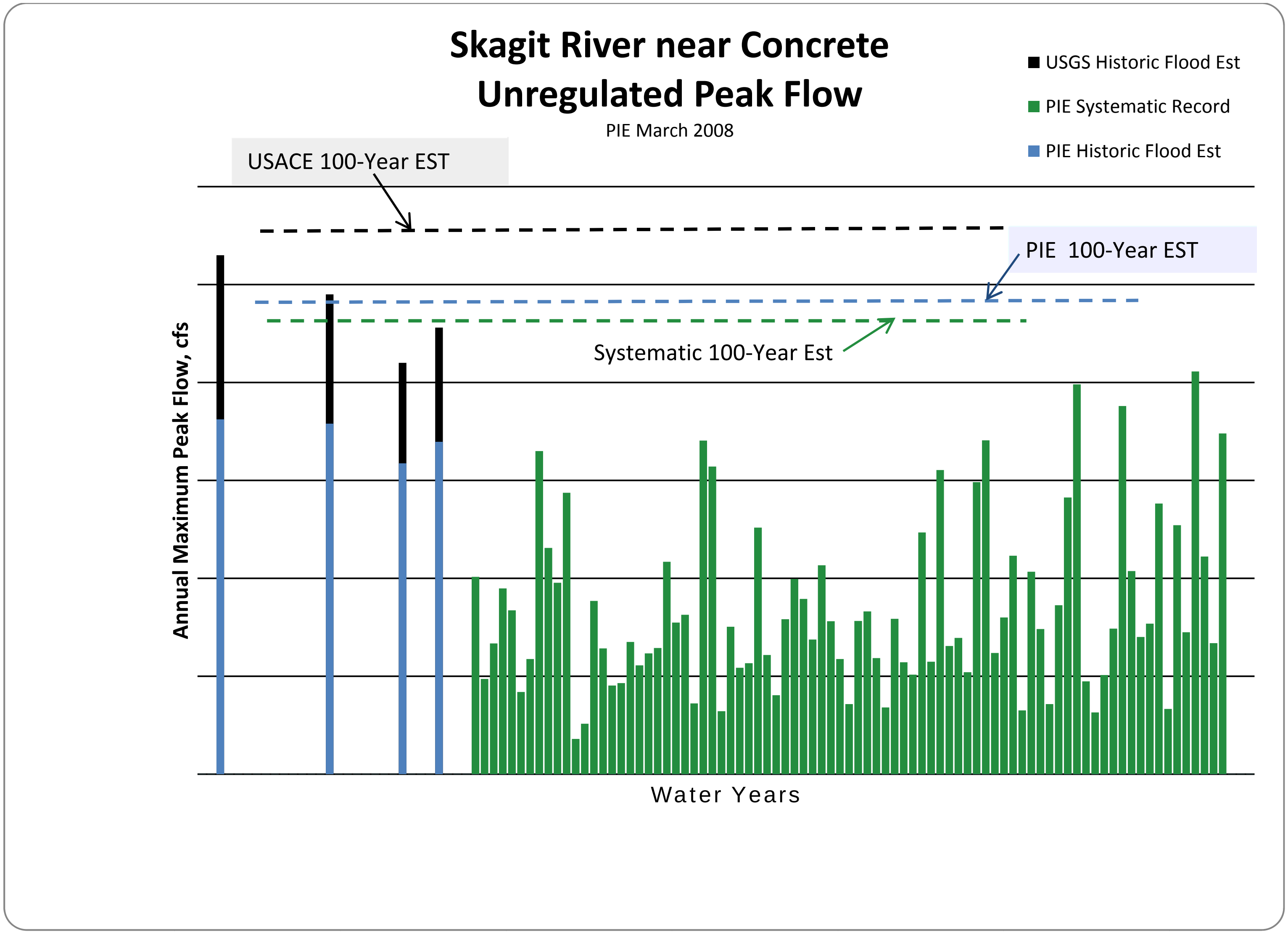
	USACE Systematic Record	USACE with Historical Floods	PIE Systematic Record	PIE with Historical Floods
Mean	4.8879	4.9056	4.8748	4.8821
Standard Dev	0.2171	0.2316	0.2222	0.2249
Skew	-0.10	0.00	-0.16	-0.14
10-year Flood	146,000 cfs	159,000 cfs	143,000 cfs	146,800 cfs
100-year Flood	238,000 cfs	278,000 cfs	232,100 cfs	240,800 cfs
500-Year Flood	307,000 cfs	373,000 cfs	296,400 cfs	309,500 cfs

Table 2 also shows the estimates of the 10-year, 100-year, and 500-year floods by the USACE and PIE. USACE and PIE 100-year (1 in 100 AEP) estimates based on only the systematic record (do not use historical floods) are within 2% of each other. The USACE 100-year estimate based on the use of USGS historical floods is 16% greater than the USACE Systematic flood estimate. Because the estimated historical floods are so much larger than the 1925 through 2010 recorded flows, they have the effect of dramatically changing the flood estimates. The PIE 100-year flood estimate based on the use of the PIE historical floods estimates is 3% greater than the PIE systematic estimate. Figure 1 on the next page presents the systematic record, historical record, and 100-year flood estimates graphically.

Reasonableness of Historic Flood Estimates – Historic data is less reliable than recorded data because it was not collected in a systematic method, and because of the significant uncertainty of establishing high water elevations months or years after the actual flood event. In addition, the flow calculations associated with historic high water marks is approximate (Slope-Area Calculations, for instance); and must therefore, be checked for reasonableness. A quote from Bulletin 17B (IACWD, 1982, pg. 19) explains the procedure to be used:

> "10. Historic Flood Data –Information which indicates that any flood peaks which occurred before, during or after the systematic record are maximums in an extended period of time should be used in frequency computations. Before such data are used, the reliability of the data, the peak discharge magnitude, changes in watershed conditions over the extended period of time, and the effects of these on the computed frequency curve must all be evaluated by the analyst. ... The underlying assumption to this adjustment is that the data for the systematic record is representative of the intervening period between the systematic and historic record lengths. Comparison of results from systematic and historically adjusted analyses should be made.
>
> The historic information should be used unless the comparison of the two analyses, the magnitude of the observed peaks, or other factors suggest that the historic data are not indicative of the extended record. All decisions should be thoroughly documented." (emphasis added)

Figure 1



Skagit River near Concrete
Unregulated Peak Flow
PIE March 2008
USGS Historic Flood Est
PIE Systematic Record
PIE Historic Flood Est
USACE 100-Year EST
PIE 100-Year EST
Systematic 100-Year Est
Annual Maximum Peak Flow, cfs
Water Years

The USACE Skagit River near Concrete frequency calculations that incorporate the historical floods estimated by USGS, result in much greater peak flow estimates for the 100-year flood than the PIE frequency calculations that incorporate historical floods estimated by PIE.

Although it cannot be determined absolutely, it is possible to estimate the likelihood that the historic data "are not indicative of the extended record" (Bulletin 17B). By using the binomial distribution described in Bulletin 17B (IACWD, 1982, Appendix 10), it is possible to calculate the probability of several floods exceeding a specified magnitude in a given time period. For the Skagit River, there were four historic events that occurred between 1897 and 1921, a period of 25 years. The smallest of these floods was the 1917 flood. In order to calculate the probability that four floods at or greater than the magnitude of the 1917 flood could occur in a 25 year time span, it is necessary to use the binomial distribution. The required information is the annual exceedance probability (AEP) of the smallest or most likely to occur flood (1917); the knowledge that the 1897, 1909, and 1921 floods were larger than the 1917 flood; and the period of time in which the floods occurred (25 years). Table 3 shows the probability that the 1917 flood could be equaled or exceeded four (4) times in the 25 years (1896 and 1921). The conditions assessed are: (1) USGS estimated historic flows and the USACE frequency estimates calculated with Historic flood adjustment and (2) without Historic flood adjustment (Systematic); (3) PIE estimated historic floods (PIE 2011) and PIE frequency estimates with Historic flood adjustment and (4) without Historic flood adjustment (Systematic). The details of the calculation supporting Table 3 can be found in Attachment C.

The calculated probability that floods with the magnitudes of the four historical floods (specifically, four at or exceeding the 1917 flood magnitude) calculated by USGS would occur in 25 years is less than 1% with the adopted USACE frequency curve (with historic floods), and less than 0.2% with the USACE Systematic Record frequency curve. Such a low probability of occurrence strongly suggests the USGS estimated historic flows are not "indicative of the extended record" as required by Bulletin 17B. The PIE estimated historical floods have a 0.0757 (7.57%) probability of occurring in a 25-year period with the PIE adopted frequency curve and 0.0587 (5.87%) probability with the PIE systematic record frequency curve.

Table 3 Skagit River near Concrete Probability of Four Historic Floods Occurring in 25 years

Condition	AEP of 1917 Flood	Probability 4 Historical Floods would Occur in 25 year period
USACE Systematic Record Frequency Curve based on USGS 1917 Peak Flow	0.0200 or 1 in 50	0.0013 or 1 in 769 chance
USACE with **USGS Historic** Frequency Curve based on USGS 1917 Peak Flow	0.0357 or 1 in 28	0.00958 or 1 in 104 chance
PIE Systematic Record Frequency Curve based on PIE 1917 Peak Flow	0.0667 or 1 in 15	0.0587 or 1 in 17 chance
PIE Historic Frequency Curve based on PIE Historic Peak Flows	0.0741 or 1 in 14	0.0757 or 1 in 13 Chance

Conclusion -The inclusion of the USGS historic flood estimates to the USACE frequency calculation causes the 100-year flood estimate to exceed all measured and estimated historic flood peaks. (See Figure 1.) The USACE 100-year flood estimate (278,000 cfs) exceeds the largest recorded flood by 35%. Considering the record length is nearly 90 years, the 100-year estimate appears to be very high. The USACE systematic 100-year estimate (238,000 cfs) is 16% larger than largest recorded flood peak and appears to be much more reasonable. The PIE estimated 100-year flood (240,000 cfs) is 17% larger than the largest recorded flood and is consistent with the systematic flood record estimate by USACE.

Bulletin 17B advises that when the use of historic data is included in the frequency calculation that the resultant frequency curve be compared with the calculated frequency curve based only on the systematic record (text printed above). If it is determined that the historic data is not "indicative of the extended record", then the historic data should not be used. Our review of the USACE frequency calculation shows that four historic floods of the magnitudes estimated by the USGS have a 0.0096 (0.96%) chance of occurring in a 25-year period (1897 through 1921). Significantly, if the USACE Systematic frequency curve is used to estimate the AEPs of the historic floods as estimated by USGS, there is a 0.0013 (0.13%) chance the four historical floods could occur in a 25-year period. It is my opinion that the USGS historic flood estimates should not be included in the USACE frequency analysis. The PIE frequency analysis with the PIE estimated historic flows is consistent with the systematic record. The estimated historic flood estimates have a 0,0757 (7.57%) chance of occurring in a 25-year period. The PIE utilization of the PIE estimated historic flood estimates appears reasonable and can be used in that frequency calculation.

References

Bodhaine, G.L. 1954, Skagit River Flood Peaks, Memorandum of Review, U.S. Geological Survey, May 13, 1954

Interagency Advisory Committee on Water Data, Hydrology Subcommittee (IACWD). (1982). “Guidelines for Determining Flood Flow Frequency, Bulletin 17B.” Washington, D.C.

Mastin, M.C., Re-evaluation of the 1921 peak discharge at Skagit River near Concrete, Washington: U.S. Geological Survey Scientific Investigation Report 2007-5159

Pacific International Engineering (PIE), 2011, Skagit River FEMA Appeal, March 2011

Riggs, H.C. and Robinson, W.H. 1950. Proposed Revision of Skagit river Flood Peaks. U.S. Geological Survey. November 11, 1950

Stewart, J.E. 1923. Stage and Volume of Past Floods in Skagit Valley and Advisable Protective Measures prior to the Construction of Permanent Flood Controlling Works, 1923. Unpublished report.

Attachment A

USACE Frequency Computations

Seattle District

March 7, 2008

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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       *
*        07 MAR 08    15:48:57      *       *          (916) 756-1104            *
*                                   *       *                                    *
*************************************       *************************************



 INPUT FILE NAME: WPKCONUR.DAT
OUTPUT FILE NAME: WPKCONUR.OUT
   DSS FILE NAME: WPKCONUR.DSS



   -----DSS---ZOPEN:  Existing File Opened,  File: WPKCONUR.DSS
                      Unit:  71;  DSS Version: 6-JB

**TITLE RECORD(S)**
TT    MAX ANNUAL PEAK FLOWS AT CONCRETE (Unregulated PEAK FLOWS)
TT    USGS GAGE #12194000, WINTER ONLY PEAKS
TT    HISTORIC PEAKS REVISED AUGUST 2007
TT    PERIOD OF RECORD PEAKS (WY 1944-2007) BASED ON REGRESSION OF OBSERVED
TT    PEAK TO 1-DAY MEANS FOR YEARS WITH MINIMAL REGULATION
TT    EXCEPT WY 1991, 1996, 2004, AND 2007 WHICH ARE DETERMINED FROM
TT    UNREGULATING HOURLY DATA THAT IS AVAILABLE AND ROUTING THROUGH
TT    CALIBRATED HEC-RAS MODEL
TT    RELATIONSHIP IS: Peak = 1.1794 * 1-DAY
TT       8      16      24      32      40      48      56      64      72      80

**JOB RECORD(S)**
     IPPC   ISKFX  IPROUT    IFMT    IWYR   IUNIT   ISMRY   IPNCH    IREG
J1     2       0       0       0       0       0       0       0       0

**FREQUENCY ARRAY**
FR    14    .200    .400    .500   1.000   1.333   2.000   4.000  10.000  20.000
FR50.000  80.000  90.000  95.000  99.000

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS   PEAK    .000     .00

**STATION IDENTIFICATION**
ID    UNREGULATED PKconcrete

**HP PLOT **
     HP PLOT FILE                  IHPCV  KLIMIT    IPER    BAREA
HP  concretP.PLT                       3       0       0       2737 SQ MI
```

```
     SELECTED CURVES ON HPPLOT
          EXPECTED PROBABILITY CURVE
          COMPUTED PROBABILITY CURVE
          CONFIDENCE LIMITS

HP    PEAK UNREGULATED DISCHARGE
HP     USGS GAGE #12194000

**HISTORIC EVENTS**
QH  11  19  1897   265000.

QH  11  30  1909   245000.
QH  12  30  1917   210000.
QH  12  13  1921   228000.

**SYSTEMATIC EVENTS**
     79 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++



DDDDDDDDDDDDDDDDDDDDDDPRELIMINARY RESULTS DDDDDDDDDDDDDDDDDDDDDD

-PLOTTING POSITIONS-  UNREGULATED PKconcrete
IMMMMMMMMMMMMMMMMMMMMMMMMMMQMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM;
:      EVENTS ANALYZED     3          ORDERED EVENTS          :
:                    FLOW   3        WATER      FLOW    MEDIAN  :
: MON DAY  YEAR      CFS    3   RANK  YEAR      CFS    PLOT POS :
GDDDDDDDDDDDDDDDDDDDDDDDDDDEDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD6
:  12   0  1924   100721.  3     1   2004    205651.      .88  :
:  12   0  1925    48591.  3     2   1991    199017.     2.14  :
:  10   0  1926    66754.  3     3   1996    187982.     3.40  :
:   1   0  1928    94812.  3     4   1932    182000.     4.66  :
:  10   0  1928    83631.  3     5   2007    173974.     5.92  :
:   1   0  1930    41937.  3     6   1981    170470.     7.18  :
:   2   0  1932   182000.  3     7   1950    170342.     8.44  :
:  11   0  1932   115519.  3     8   1951    157098.     9.70  :
:  12   0  1933    97733.  3     9   1976    155281.    10.96  :
:   1   0  1935   143702.  3    10   1980    149079.    12.22  :
:   3   0  1936    18000.  3    11   1935    143702.    13.48  :
:  10   0  1937    88484.  3    12   1990    141277.    14.74  :
:   1   0  1939    64203.  3    13   2000    138206.    15.99  :
:  12   0  1939    45280.  3    14   2002    127137.    17.25  :
:  10   0  1940    46471.  3    15   1956    125871.    18.51  :
:  12   0  1941    67515.  3    16   1974    123434.    19.77  :
:  11   0  1942    55529.  3    17   1933    115519.    21.03  :
:  12   3  1943    61643.  3    18   1984    111556.    22.29  :
:   2   8  1945    64412.  3    19   2005    111118.    23.55  :
:  10  25  1945   108451.  3    20   1946    108451.    24.81  :
:  10  25  1946    77377.  3    21   1963    106674.    26.07  :
:  10  19  1947    81409.  3    22   1997    103692.    27.33  :
:  10   7  1948    36127.  3    23   1986    103347.    28.59  :
:  11  27  1949   170342.  3    24   1925    100721.    29.85  :
```

:	2	10	1951	157098.	3	25	1960	99673.	31.11	:
:	10	20	1951	32094.	3	26	1934	97733.	32.37	:
:	1	12	1953	75243.	3	27	1928	94812.	33.63	:
:	11	1	1953	54313.	3	28	1961	89468.	34.89	:
:	11	19	1954	56676.	3	29	1938	88484.	36.15	:
:	11	4	1955	125871.	3	30	1989	86250.	37.41	:
:	10	20	1956	60813.	3	31	1929	83631.	38.66	:
:	1	17	1958	40293.	3	32	1968	83101.	39.92	:
:	12	3	1958	79089.	3	33	1948	81409.	41.18	:
:	11	23	1959	99673.	3	34	1983	79992.	42.44	:
:	1	15	1961	89468.	3	35	1971	79312.	43.70	:
:	1	3	1962	68720.	3	36	1959	79089.	44.96	:
:	11	20	1962	106674.	3	37	1967	78247.	46.22	:
:	10	22	1963	78105.	3	38	1964	78105.	47.48	:
:	12	1	1964	58788.	3	39	1947	77377.	48.74	:
:	10	6	1965	35738.	3	40	1999	76869.	50.00	:
:	12	16	1966	78247.	3	41	1953	75243.	51.26	:
:	10	28	1967	83101.	3	42	1995	74313.	52.52	:
:	1	5	1969	59240.	3	43	1987	74104.	53.78	:
:	1	23	1970	34032.	3	44	2003	72461.	55.04	:
:	1	31	1971	79312.	3	45	1998	70049.	56.30	:
:	3	13	1972	57099.	3	46	1978	69589.	57.56	:
:	12	26	1972	50781.	3	47	1962	68720.	58.82	:
:	1	16	1974	123434.	3	48	1942	67515.	60.08	:
:	12	21	1974	57427.	3	49	2006	66893.	61.34	:
:	12	3	1975	155281.	3	50	1927	66754.	62.59	:
:	1	18	1977	65441.	3	51	1977	65441.	63.85	:
:	12	2	1977	69589.	3	52	1945	64412.	65.11	:
:	11	8	1978	52015.	3	53	1939	64203.	66.37	:
:	12	18	1979	149079.	3	54	1982	61885.	67.63	:
:	12	26	1980	170470.	3	55	1944	61643.	68.89	:
:	2	15	1982	61885.	3	56	1957	60813.	70.15	:
:	12	4	1982	79992.	3	57	1969	59240.	71.41	:
:	1	4	1984	111556.	3	58	1965	58788.	72.67	:
:	11	3	1984	32515.	3	59	1975	57427.	73.93	:
:	1	19	1986	103347.	3	60	1972	57099.	75.19	:
:	11	24	1986	74104.	3	61	1955	56676.	76.45	:
:	12	10	1987	35801.	3	62	1943	55529.	77.71	:
:	10	16	1988	86250.	3	63	1954	54313.	78.97	:
:	11	10	1989	141277.	3	64	1979	52015.	80.23	:
:	11	10	1990	199017.	3	65	1973	50781.	81.49	:
:	3	2	1994	50609.	3	66	1994	50609.	82.75	:
:	12	20	1994	74313.	3	67	1926	48591.	84.01	:
:	11	29	1995	187982.	3	68	1941	46471.	85.26	:
:	3	19	1997	103692.	3	69	1940	45280.	86.52	:
:	10	5	1997	70049.	3	70	1930	41937.	87.78	:
:	12	13	1998	76869.	3	71	1958	40293.	89.04	:
:	11	12	1999	138206.	3	72	1949	36127.	90.30	:
:	10	20	2000	33277.	3	73	1988	35801.	91.56	:
:	1	8	2002	127137.	3	74	1966	35738.	92.82	:
:	1	26	2003	72461.	3	75	1970	34032.	94.08	:
:	10	21	2003	205651.	3	76	2001	33277.	95.34	:
:	12	11	2004	111118.	3	77	1985	32515.	96.60	:
:	12	25	2005	66893.	3	78	1952	32094.	97.86	:
:	11	7	2006	173974.	3	79	1936	18000.	99.12	:

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HMMMMMMMMMMMMMMMMMMMMMMMMMMMOMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM<




-SKEW WEIGHTING -
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
BASED ON  79 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =   .074
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =   .302
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD


 PRELIMINARY RESULTS

-FREQUENCY CURVE-  UNREGULATED PKconcrete
IMMMMMMMMMMMMMMMMMMMMMMMMMQMMMMMMMMMMMMQMMMMMMMMMMMMMMMMMMMMMMMM;
:  COMPUTED   EXPECTED   3   PERCENT   3    CONFIDENCE LIMITS  :
:   CURVE   PROBABILITY  3    CHANCE   3      .05         .95   :
:      FLOW IN CFS       3  EXCEEDANCE 3      FLOW IN CFS       :
GDDDDDDDDDDDDDDDDDDDDDDDDEDDDDDDDDDDDDDEDDDDDDDDDDDDDDDDDDDDDDDD6
:   307000.    322000.   3      .20    3   386000.    255000.  :
:   277000.    288000.   3      .40    3   344000.    233000.  :
:   267000.    277000.   3      .50    3   330000.    226000.  :
:   238000.    245000.   3     1.00    3   290000.    203000.  :
:   226000.    232000.   3     1.33    3   274000.    194000.  :
:   210000.    215000.   3     2.00    3   252000.    181000.  :
:   182000.    185000.   3     4.00    3   214000.    159000.  :
:   146000.    147000.   3    10.00    3   167000.    130000.  :
:   118000.    118000.   3    20.00    3   133000.    107000.  :
:    77900.     77900.   3    50.00    3    85500.     71000.  :

:    50900.     50600.   3    80.00    3    56300.     45300.  :
:    40500.     40100.   3    90.00    3    45500.     35300.  :
:    33500.     32900.   3    95.00    3    38200.     28500.  :
:    23300.     22500.   3    99.00    3    27400.     18900.  :
LMMMMMMMMMMMMMMMMMMMMMMMMOMMMMMMMMMMMMMOMMMMMMMMMMMMMMMMMMMMMMMM9
:                      SYSTEMATIC STATISTICS                    :
GDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDBDDDDDDDDDDDDDDDDDDDDDDDDDDDDD6
: LOG TRANSFORM: FLOW, CFS       3       NUMBER OF EVENTS       :
GDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDEDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD6
:  MEAN                   4.8879  3  HISTORIC EVENTS         0  :
:  STANDARD DEV            .2171  3  HIGH OUTLIERS       0      :
:  COMPUTED SKEW          -.1380  3  LOW OUTLIERS        0      :
:  REGIONAL SKEW           .0000  3  ZERO OR MISSING     0      :
:  ADOPTED SKEW           -.1000  3  SYSTEMATIC EVENTS      79  :
HMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMOMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM<



DDDDDDDDDDDDDDDDDDDDDD   FINAL RESULTS    DDDDDDDDDDDDDDDDDDDDDD

-PLOTTING POSITIONS-  UNREGULATED PKconcrete
IMMMMMMMMMMMMMMMMMMMMMMMMMMQMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM;
:      EVENTS ANALYZED     3           ORDERED EVENTS           :
:                    FLOW   3         WATER      FLOW    MEDIAN  :
: MON DAY  YEAR     CFS    3   RANK  YEAR      CFS    PLOT POS :
```

GDDDDDDDDDDDDDDDDDDDDDDDDDDDDEDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD6

11	19	1897	265000.	3	1	1897	265000.	.63	
11	30	1909	245000.	3	2	1909	245000.	1.54	
12	30	1917	210000.	3	3	1921	228000.	2.45	
12	13	1921	228000.	3	4	1917	210000.	3.35	
12	0	1924	100721.	3	5	2004	205651.	4.41	
12	0	1925	48591.	3	6	1991	199017.	5.63	
10	0	1926	66754.	3	7	1996	187982.	6.84	
1	0	1928	94812.	3	8	1932	182000.	8.06	
10	0	1928	83631.	3	9	2007	173974.	9.27	
1	0	1930	41937.	3	10	1981	170470.	10.49	
2	0	1932	182000.	3	11	1950	170342.	11.70	
11	0	1932	115519.	3	12	1951	157098.	12.92	
12	0	1933	97733.	3	13	1976	155281.	14.14	
1	0	1935	143702.	3	14	1980	149079.	15.35	
3	0	1936	18000.	3	15	1935	143702.	16.57	
10	0	1937	88484.	3	16	1990	141277.	17.78	
1	0	1939	64203.	3	17	2000	138206.	19.00	
12	0	1939	45280.	3	18	2002	127137.	20.21	
10	0	1940	46471.	3	19	1956	125871.	21.43	
12	0	1941	67515.	3	20	1974	123434.	22.64	
11	0	1942	55529.	3	21	1933	115519.	23.86	
12	3	1943	61643.	3	22	1984	111556.	25.07	
2	8	1945	64412.	3	23	2005	111118.	26.29	
10	25	1945	108451.	3	24	1946	108451.	27.50	
10	25	1946	77377.	3	25	1963	106674.	28.72	
10	19	1947	81409.	3	26	1997	103692.	29.93	
10	7	1948	36127.	3	27	1986	103347.	31.15	
11	27	1949	170342.	3	28	1925	100721.	32.37	
2	10	1951	157098.	3	29	1960	99673.	33.58	
10	20	1951	32094.	3	30	1934	97733.	34.80	
1	12	1953	75243.	3	31	1928	94812.	36.01	
11	1	1953	54313.	3	32	1961	89468.	37.23	
11	19	1954	56676.	3	33	1938	88484.	38.44	
11	4	1955	125871.	3	34	1989	86250.	39.66	
10	20	1956	60813.	3	35	1929	83631.	40.87	
1	17	1958	40293.	3	36	1968	83101.	42.09	
12	3	1958	79089.	3	37	1948	81409.	43.30	
11	23	1959	99673.	3	38	1983	79992.	44.52	
1	15	1961	89468.	3	39	1971	79312.	45.73	
1	3	1962	68720.	3	40	1959	79089.	46.95	
11	20	1962	106674.	3	41	1967	78247.	48.17	
10	22	1963	78105.	3	42	1964	78105.	49.38	
12	1	1964	58788.	3	43	1947	77377.	50.60	
10	6	1965	35738.	3	44	1999	76869.	51.81	
12	16	1966	78247.	3	45	1953	75243.	53.03	
10	28	1967	83101.	3	46	1995	74313.	54.24	
1	5	1969	59240.	3	47	1987	74104.	55.46	
1	23	1970	34032.	3	48	2003	72461.	56.67	
1	31	1971	79312.	3	49	1998	70049.	57.89	
3	13	1972	57099.	3	50	1978	69589.	59.10	
12	26	1972	50781.	3	51	1962	68720.	60.32	
1	16	1974	123434.	3	52	1942	67515.	61.53	
12	21	1974	57427.	3	53	2006	66893.	62.75	
12	3	1975	155281.	3	54	1927	66754.	63.97	

```
:   1  18  1977    65441.  3    55   1977     65441.    65.18  :
:  12   2  1977    69589.  3    56   1945     64412.    66.40  :
:  11   8  1978    52015.  3    57   1939     64203.    67.61  :
:  12  18  1979   149079.  3    58   1982     61885.    68.83  :
:  12  26  1980   170470.  3    59   1944     61643.    70.04  :
:   2  15  1982    61885.  3    60   1957     60813.    71.26  :
:  12   4  1982    79992.  3    61   1969     59240.    72.47  :
:   1   4  1984   111556.  3    62   1965     58788.    73.69  :
:  11   3  1984    32515.  3    63   1975     57427.    74.90  :
:   1  19  1986   103347.  3    64   1972     57099.    76.12  :
:  11  24  1986    74104.  3    65   1955     56676.    77.33  :
:  12  10  1987    35801.  3    66   1943     55529.    78.55  :
:  10  16  1988    86250.  3    67   1954     54313.    79.77  :
:  11  10  1989   141277.  3    68   1979     52015.    80.98  :
:  11  10  1990   199017.  3    69   1973     50781.    82.20  :
:   3   2  1994    50609.  3    70   1994     50609.    83.41  :
:  12  20  1994    74313.  3    71   1926     48591.    84.63  :
:  11  29  1995   187982.  3    72   1941     46471.    85.84  :
:   3  19  1997   103692.  3    73   1940     45280.    87.06  :
:  10   5  1997    70049.  3    74   1930     41937.    88.27  :
:  12  13  1998    76869.  3    75   1958     40293.    89.49  :
:  11  12  1999   138206.  3    76   1949     36127.    90.70  :
:  10  20  2000    33277.  3    77   1988     35801.    91.92  :
:   1   8  2002   127137.  3    78   1966     35738.    93.13  :
:   1  26  2003    72461.  3    79   1970     34032.    94.35  :
:  10  21  2003   205651.  3    80   2001     33277.    95.57  :
:  12  11  2004   111118.  3    81   1985     32515.    96.78  :
:  12  25  2005    66893.  3    82   1952     32094.    98.00  :
:  11   7  2006   173974.  3    83   1936     18000.    99.21  :
GDDDDDDDDDDDDDDDDDDDDDDDDDDDADDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD6
: NOTE- PLOTTING POSITIONS BASED ON-HISTORIC PERIOD (H) = 110  :
:       NUMBER OF HISTORIC EVENTS PLUS HIGH OUTLIERS(Z) =   4  :
:       WEIGHTING FACTOR FOR SYSTEMATIC EVENTS  (W) =  1.3418  :
HMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM<


-OUTLIER TESTS  -
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
LOW OUTLIER TEST
DDDDDDDDDDDDDDDDD


BASED ON  79 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.935

       0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF  17813.2


DDDDDDDDDDDDDDDDD
HIGH OUTLIER TEST
DDDDDDDDDDDDDDDDD


BASED ON  79 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.935

      0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF  335050.
```

```
STATISTICS AND FREQUENCY CURVE ADJUSTED FOR  0 HIGH OUTLIER(S)
                                        AND  4 HISTORIC EVENT(S)
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD


-SKEW WEIGHTING -
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
BASED ON 110 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =   .049
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =   .302
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD



FINAL RESULTS

-FREQUENCY CURVE-  UNREGULATED PKconcrete
IMMMMMMMMMMMMMMMMMMMMMMMMQMMMMMMMMMMMMMQMMMMMMMMMMMMMMMMMMMMMMMM;
:  COMPUTED   EXPECTED   3   PERCENT   3    CONFIDENCE LIMITS  :
:   CURVE   PROBABILITY  3    CHANCE   3      .05        .95   :
:      FLOW IN CFS       3  EXCEEDANCE 3      FLOW IN CFS      :
GDDDDDDDDDDDDDDDDDDDDDDDDEDDDDDDDDDDDDDEDDDDDDDDDDDDDDDDDDDDDDD6
:   373000.    395000.   3      .20    3   482000.    305000.  :
:   331000.    347000.   3      .40    3   420000.    274000.  :
:   318000.    332000.   3      .50    3   401000.    264000.  :
:   278000.    288000.   3     1.00    3   345000.    234000.  :
:   262000.    270000.   3     1.33    3   323000.    222000.  :
:   241000.    247000.   3     2.00    3   293000.    205000.  :
:   205000.    208000.   3     4.00    3   244000.    177000.  :
:   159000.    161000.   3    10.00    3   185000.    141000.  :
:   126000.    127000.   3    20.00    3   143000.    113000.  :
:    80500.     80500.   3    50.00    3    88900.     72800.  :
:    51400.     51100.   3    80.00    3    57200.     45400.  :
:    40600.     40200.   3    90.00    3    46000.     35100.  :
:    33500.     32900.   3    95.00    3    38400.     28300.  :
:    23300.     22500.   3    99.00    3    27600.     18800.  :
LMMMMMMMMMMMMMMMMMMMMMMMMOMMMMMMMMMMMMMOMMMMMMMMMMMMMMMMMMMMMMM9
:                        ADJUSTED STATISTICS                   :
GDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDBDDDDDDDDDDDDDDDDDDDDDDDDDDDDD6
: LOG TRANSFORM: FLOW, CFS       3       NUMBER OF EVENTS      :
GDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDEDDDDDDDDDDDDDDDDDDDDDDDDDDDDD6
:  MEAN                   4.9056  3  HISTORIC EVENTS         4  :
:  STANDARD DEV            .2316  3  HIGH OUTLIERS       0      :
:  COMPUTED SKEW           .0083  3  LOW OUTLIERS        0      :
:  REGIONAL SKEW           .0000  3  ZERO OR MISSING     0      :
:  ADOPTED SKEW            .0000  3  SYSTEMATIC EVENTS      79  :
:                                 3  HISTORIC PERIOD       110  :
HMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMOMMMMMMMMMMMMMMMMMMMMMMMMMMMMM<


HP PLOT WRITTEN TO THE FILE:    concretP.PLT



+++++++++++++++++++++++++
+ END OF RUN            +
+ NORMAL STOP IN FFA    +
```

Attachment B

PIE Frequency Calculations

September 4, 2008

OUTPUT OF PEAKFQ FOR UNREGULATED PEAK IN THE SKAGIT RIVER NEAR CONCRETE

```
1
  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.000.000
  Ver. 5.0 Beta 8     Annual peak flow frequency analysis      Run Date / Time
  05/06/2005          following Bulletin 17-B Guidelines       09/04/2008 14:37

                         --- 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

                      Input files used:
                         peaks (ascii)  -
C:\SKAGITPROJ\FREQANALYSES08\PEAKFQ\CONCRETE UNREG ANNUAL PEAK WY25-08(COE) W 08
                         specifications - PKFQWPSF.TMP
                      Output file(s):
                         main - C:\SKAGITPROJ\FREQANALYSES08\PEAKFQ\CONCRETE
UNREG ANNUAL PEAK WY25-08(COE) W 08

1


  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.001
  Ver. 5.0 Beta 8     Annual peak flow frequency analysis      Run Date / Time
  05/06/2005          following Bulletin 17-B Guidelines       09/04/2008 14:37

           Station - 12194000  Unregulated Peak WY25-08 & 4 Hist Est


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

                Number of peaks in record            =       88
                Peaks not used in analysis           =        0
                Systematic peaks in analysis         =       84
                Historic peaks in analysis           =        4
                Years of historic record             =      107
                Generalized skew                     =    0.000
                     Standard error                  =    0.550
                     Mean Square error               =    0.303
                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
    WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.            16535.8
```

WCF156I-17B HI-OUTLIER TEST SUPERSEDED BY MIN HIST PK 339795.8
WCF165I-HIGH OUTLIERS AND HISTORIC PEAKS ABOVE HHBASE. 7 4   158700.0
**WCF171W-NUMBER HI-OUT/HIST PKS EXCEEDS 10PCT OF SYS PKS.   11   84
WCF002J-CALCS COMPLETED. RETURN CODE = 2

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.002
Ver. 5.0 Beta 8 Annual peak flow frequency analysis Run Date / Time
05/06/2005 following Bulletin 17-B Guidelines 09/04/2008 14:37

Station - 12194000 Unregulated Peak WY25-08 & 4 Hist Est

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	4.8748	0.2220	-0.156
BULL.17B ESTIMATE	0.0	1.0000	4.8821	0.2249	-0.142

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	18750.0	18640.0	17930.0	14930.0	22480.0
0.9900	21660.0	21530.0	20920.0	17570.0	25610.0
0.9500	31870.0	31630.0	31360.0	27120.0	36390.0
0.9000	38970.0	38630.0	38580.0	33910.0	43800.0
0.8000	49500.0	48960.0	49250.0	44060.0	54810.0
0.6667	61610.0	60810.0	61490.0	55680.0	67700.0
0.5000	77170.0	75960.0	77170.0	70280.0	84770.0
0.4292	84590.0	83170.0	84650.0	77090.0	93160.0
0.2000	118200.0	115600.0	118800.0	106700.0	132900.0
0.1000	146800.0	143000.0	148100.0	130700.0	168400.0
0.0400	183900.0	178300.0	186800.0	161000.0	216300.0
0.0200	212100.0	205100.0	216700.0	183400.0	253900.0
0.0100	240800.0	232100.0	247600.0	205800.0	292700.0
0.0050	270000.0	259500.0	279500.0	228200.0	333000.0
0.0020	309500.0	296400.0	323700.0	258200.0	388700.0

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.003
Ver. 5.0 Beta 8 Annual peak flow frequency analysis Run Date / Time
05/06/2005 following Bulletin 17-B Guidelines 09/04/2008 14:37

Station - 12194000 Unregulated Peak WY25-08 & 4 Hist Est

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

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
-1898	181200.0	H	1965	58788.0	
-1910	179000.0	H	1966	35738.0	
-1918	158700.0	H	1967	78247.0	
-1922	169700.0	H	1968	83101.0	
1925	100721.0		1969	59240.0	
1926	48591.0		1970	34032.0	
1927	66754.0		1971	79312.0	
1928	94812.0		1972	57099.0	
1929	83631.0		1973	50781.0	
1930	41937.0		1974	123434.0	
1931	58770.0		1975	57427.0	
1932	165000.0		1976	155281.0	
1933	115519.0		1977	65441.0	
1934	97733.0		1978	69589.0	
1935	143702.0		1979	52015.0	
1936	18000.0		1980	149079.0	
1937	25767.0		1981	170470.0	
1938	88484.0		1982	61885.0	
1939	64203.0		1983	79992.0	
1940	45280.0		1984	111556.0	
1941	46471.0		1985	32515.0	
1942	67515.0		1986	103347.0	
1943	55529.0		1987	74104.0	
1944	61643.0		1988	35801.0	
1945	64412.0		1989	86250.0	
1946	108451.0		1990	141277.0	
1947	77377.0		1991	199017.0	
1948	81409.0		1992	47389.0	
1949	36127.0		1993	31490.0	
1950	170342.0		1994	50609.0	
1951	157098.0		1995	74313.0	
1952	32094.0		1996	187982.0	
1953	75243.0		1997	103692.0	
1954	54313.0		1998	70049.0	
1955	56676.0		1999	76869.0	
1956	125871.0		2000	138206.0	
1957	60813.0		2001	33277.0	
1958	40293.0		2002	127137.0	
1959	79089.0		2002	72461.0	
1960	99673.0		2004	205651.0	
1961	89468.0		2005	111118.0	
1962	68720.0		2006	66893.0	
1963	106674.0		2007	173974.0	
1964	78105.0		2008	106503.0	

Explanation of peak discharge qualification codes

PEAKFQ CODE	NWIS 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

- Minus-flagged discharge -- Not used in computation
  -8888.0 -- No discharge value given
- Minus-flagged water year -- Historic peak used in computation

1

Station - 12194000 Unregulated Peak WY25-08 & 4 Hist Est

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
2004	205651.0	0.0118	0.0093
1991	199017.0	0.0235	0.0185
1996	187982.0	0.0353	0.0278
-1898	181200.0	--	0.0370
-1910	179000.0	--	0.0463
2007	173974.0	0.0471	0.0556
1981	170470.0	0.0588	0.0648
1950	170342.0	0.0706	0.0741
-1922	169700.0	--	0.0833
1932	165000.0	0.0824	0.0926
-1918	158700.0	--	0.1019
1951	157098.0	0.0941	0.1123
1976	155281.0	0.1059	0.1238
1980	149079.0	0.1176	0.1353
1935	143702.0	0.1294	0.1469
1990	141277.0	0.1412	0.1584
2000	138206.0	0.1529	0.1700
2002	127137.0	0.1647	0.1815
1956	125871.0	0.1765	0.1931
1974	123434.0	0.1882	0.2046
1933	115519.0	0.2000	0.2161
1984	111556.0	0.2118	0.2277
2005	111118.0	0.2235	0.2392
1946	108451.0	0.2353	0.2508
1963	106674.0	0.2471	0.2623
2008	106503.0	0.2588	0.2739
1997	103692.0	0.2706	0.2854
1986	103347.0	0.2824	0.2970
1925	100721.0	0.2941	0.3085
1960	99673.0	0.3059	0.3200

1934	97733.0	0.3176	0.3316
1928	94812.0	0.3294	0.3431
1961	89468.0	0.3412	0.3547
1938	88484.0	0.3529	0.3662
1989	86250.0	0.3647	0.3778
1929	83631.0	0.3765	0.3893
1968	83101.0	0.3882	0.4009
1948	81409.0	0.4000	0.4124
1983	79992.0	0.4118	0.4239
1971	79312.0	0.4235	0.4355
1959	79089.0	0.4353	0.4470
1967	78247.0	0.4471	0.4586
1964	78105.0	0.4588	0.4701
1947	77377.0	0.4706	0.4817
1999	76869.0	0.4824	0.4932
1953	75243.0	0.4941	0.5047
1995	74313.0	0.5059	0.5163
1987	74104.0	0.5176	0.5278
2002	72461.0	0.5294	0.5394
1998	70049.0	0.5412	0.5509
1978	69589.0	0.5529	0.5625
1962	68720.0	0.5647	0.5740
1942	67515.0	0.5765	0.5856
2006	66893.0	0.5882	0.5971
1927	66754.0	0.6000	0.6086
1977	65441.0	0.6118	0.6202
1945	64412.0	0.6235	0.6317
1939	64203.0	0.6353	0.6433
1982	61885.0	0.6471	0.6548
1944	61643.0	0.6588	0.6664
1957	60813.0	0.6706	0.6779
1969	59240.0	0.6824	0.6895
1965	58788.0	0.6941	0.7010
1931	58770.0	0.7059	0.7125
1975	57427.0	0.7176	0.7241
1972	57099.0	0.7294	0.7356
1955	56676.0	0.7412	0.7472
1943	55529.0	0.7529	0.7587
1954	54313.0	0.7647	0.7703
1979	52015.0	0.7765	0.7818
1973	50781.0	0.7882	0.7934
1994	50609.0	0.8000	0.8049
1926	48591.0	0.8118	0.8164
1992	47389.0	0.8235	0.8280
1941	46471.0	0.8353	0.8395
1940	45280.0	0.8471	0.8511
1930	41937.0	0.8588	0.8626
1958	40293.0	0.8706	0.8742
1949	36127.0	0.8824	0.8857
1988	35801.0	0.8941	0.8972
1966	35738.0	0.9059	0.9088
1970	34032.0	0.9176	0.9203
2001	33277.0	0.9294	0.9319
1985	32515.0	0.9412	0.9434
1952	32094.0	0.9529	0.9550
1993	31490.0	0.9647	0.9665
1937	25767.0	0.9765	0.9781

```
       1936        18000.0         0.9882         0.9896
1



 End PEAKFQ analysis.
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      88


Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4,  or *.)
(2, 4, and * records are ignored.)

 For the station below, the following records were ignored:


 FINISHED PROCESSING STATION:  12194000       USGS Unregulated Peak WY25-08 & 4


 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:
```

Attachment C

Probability (Chance) Calculations

March 7, 2011

Risk

There are various approaches to calculating risk but the most understandable and straightforward method uses the binomial distribution. In general, the binomial distribution can be used to determine the chance of an event of known probability "P" occurring or not occurring in "N" tries. Flood frequencies are typically given as the probability of a certain discharge being equaled or exceeded in a given year. Therefore, the binomial distribution can be used to predict the probability that a flood of a certain size with probability "P" will be equaled or exceeded, or not exceeded, in a period of "N" years.

The binomial expression for estimating risk is:

$$R_I = \frac{N!}{I!(N-I)!} P^I (1-P)^{N-I}$$

where R_I is the risk of "I" number of floods occurring in "N" years that exceed a given flood with an annual exceedance probability of "P".

R or Risk as defined above is the probability or chance I floods with an exceedance Probability P of a given flood will be equaled or exceeded in a given number of years N.

Condition	Years (N)	Floods (I)	AEP of 1917 Flood (P)	Chance (P)
USACE Frequency Curve based on Systematic Record and USGS estimated 1917 Peak Flow	25	4	0.0200 or 1 in 50	0.0013 or 1 in 769 chance
USACE Frequency Curve based on using USGS Historic and estimating USGS 1917 Peak Flow AEP	25	4	0.0357 or 1 in 28	0.00958 or 1 in 104 chance
PIE Frequency Curve based on Systematic Record	25	4	0.0667 or 1 in 15	0.0587 or 1 in 17 chance
PIE Frequency Curve based on PIE Historic	25	4	0.0741 or 1 in 14	0.0757 or 1 in 13 chance