ATTACHMENT 5

BFE Analyses

COWLITZ TIMBER TRAILS ASSOCIATION

BFE Estimate for Shoreline Permit

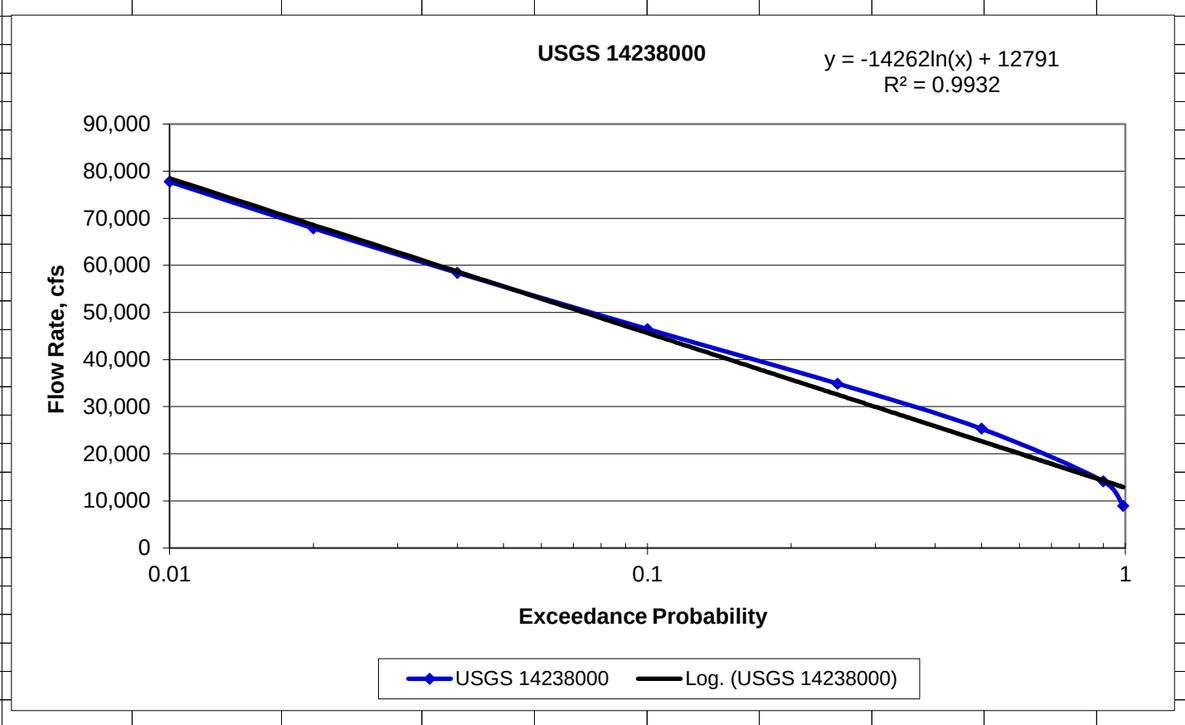
USGS Peak Yearly Flows and Stage

USGS 14238000 Cowlitz River Below Mayfield Dam

USGS Technical Bulletin 17B

Date	Q, cfs	Log(Q)	Log(Q)^2	Log(Q)^3
11/6/1934	36,900	4.567	20.858	95.258
6/8/1936	23,400	4.369	19.090	83.409
4/15/1937	29,900	4.476	20.032	89.655
12/30/1937	36,100	4.558	20.771	94.663
2/15/1939	19,400	4.288	18.385	78.832
12/17/1939	25,900	4.413	19.477	85.959
11/29/1940	17,700	4.248	18.045	76.656
12/20/1941	33,600	4.526	20.488	92.734
11/24/1942	47,500	4.677	21.871	102.286
12/4/1943	22,500	4.352	18.941	82.437
2/8/1945	29,200	4.465	19.940	89.038
12/29/1945	37,600	4.575	20.932	95.769
12/13/1946	67,000	4.826	23.291	112.404
10/20/1947	27,100	4.433	19.651	87.113
5/13/1949	25,400	4.405	19.403	85.465
11/28/1949	36,300	4.560	20.793	94.813
2/11/1951	51,200	4.709	22.177	104.439
2/4/1952	22,500	4.352	18.941	82.437
2/1/1953	37,100	4.569	20.879	95.405
12/10/1953	47,600	4.678	21.880	102.346
6/11/1955	28,600	4.456	19.859	88.500
12/12/1955	49,900	4.698	22.072	103.697
12/11/1956	30,700	4.487	20.134	90.346
4/21/1958	26,500	4.423	19.565	86.541
11/12/1958	37,400	4.573	20.911	95.624
11/24/1959	60,800	4.784	22.886	109.483
2/22/1961	36,400	4.561	20.804	94.888
12/25/1961	29,200	4.465	19.940	89.038
11/21/1962	49,500	4.695	22.039	103.466
1/26/1964	27,500	4.439	19.708	87.489
1/31/1965	64,700	4.811	23.145	111.347
5/7/1966	24,500	4.389	19.265	84.556
12/13/1966	40,400	4.606	21.219	97.742
2/20/1968	35,200	4.547	20.671	93.982
1/5/1969	22,400	4.350	18.925	82.327
1/27/1970	13,100	4.117	16.952	69.796
1/26/1971	24,200	4.384	19.218	84.247
3/19/1972	33,800	4.529	20.511	92.893
12/27/1972	25,700	4.410	19.448	85.762
6/19/1974	27,200	4.435	19.665	87.208
1/18/1975	26,800	4.428	19.608	86.829
12/4/1975	64,700	4.811	23.145	111.347
1/9/1977	10,600	4.025	16.203	65.222
12/4/1977	55,200	4.742	22.486	106.627
2/7/1979	14,700	4.167	17.367	72.372
12/18/1979	28,600	4.456	19.859	88.500
12/31/1980	28,700	4.458	19.873	88.590
1/24/1982	28,900	4.461	19.900	88.770
1/8/1983	25,200	4.401	19.372	85.265
11/16/1983	31,200	4.494	20.197	90.770
6/13/1985	13,300	4.124	17.006	70.131
2/23/1986	26,200	4.418	19.521	86.251
11/24/1986	24,200	4.384	19.218	84.247
12/9/1987	14,100	4.149	17.216	71.433
11/28/1988	17,700	4.248	18.045	76.656
2/10/1990	24,900	4.396	19.327	84.963
11/24/1990	32,700	4.515	20.381	92.012
12/8/1991	19,500	4.290	18.404	78.955
5/21/1993	10,300	4.013	16.103	64.618
1/17/1994	13,000	4.114	16.925	69.627
2/19/1995	27,000	4.431	19.637	87.019
11/28/1995	68,400	4.835	23.378	113.033
1/4/1997	25,000	4.398	19.342	85.064
11/7/1997	15,600	4.193	17.582	73.725
12/29/1998	17,800	4.250	18.066	76.788
12/18/1999	19,200	4.283	18.347	78.584
12/12/2000	10,200	4.009	16.069	64.414
1/31/2003	20,300	4.307	18.555	79.924
1/5/2004	13,900	4.143	17.165	71.113
1/18/2005	13,900	4.143	17.165	71.113
1/16/2006	21,200	4.326	18.717	80.977
11/9/2006	29,300	4.467	19.953	89.127
12/3/2007	14,300	4.155	17.267	71.749
1/7/2009	34,800	4.542	20.626	93.674
12/11/2009	14,000	4.146	17.190	71.274
1/20/2011	19,400	4.288	18.385	78.832
6/22/2012	14,000	4.146	17.190	71.274
11/22/2012	15,100	4.179	17.464	72.981
3/16/2014	15,500	4.190	17.559	73.578
11/25/2014	14,300	4.155	17.267	71.749
12/10/2015	19,800	4.297	18.461	79.322
3/27/2017	14,700	4.167	17.367	72.372
N		82		
Sums		361.353	1595.689	7060.923
Mean X = Sum[log(Q)] / N		4.407		
S = SQRT[((Sum(X^2) - (Sum(x)^2/N)) / (N-1)]				0.202
G = [N^2*Sum(X^3) - 3*N*Sum(X)*(SumX^2) + 2*(Sum(X)^3] / N*(N-1)*(N-2)*S^3				0.134
MSEG-bar (from tech bulletin description)				0.302
G-bar (from map)				0
A = -0.33 + 0.08*ABS(G)				-0.319
B = 0.94 - 0.26*ABS(G)				0.905
MSEG = 10^[A - B*(log(N/10)]				0.071
GW = [MSEG-bar*G + MSEG*G-bar] / [MSEG-bar + MSEG]				0.1

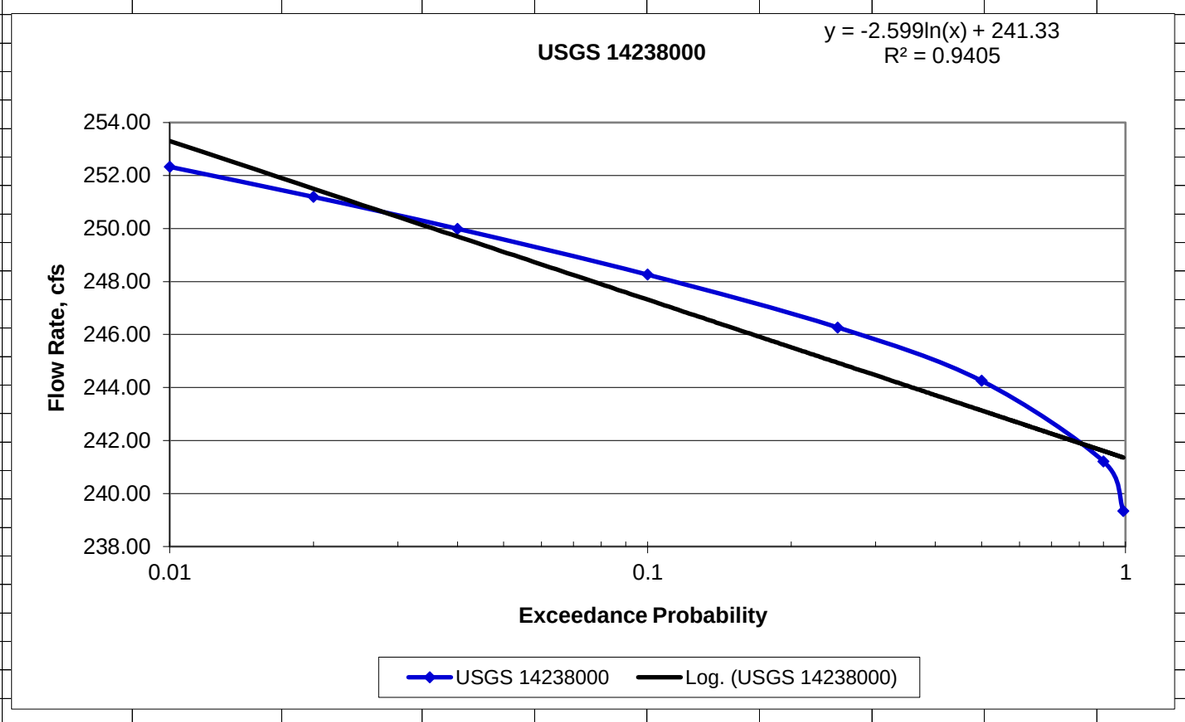
P	K for GW	Log(Q) MeanX + KS	Q, cfs	Design Event	P	-14262Ln(x) + 12791	% Difference
0.99	-2.252580	3.952	8,963	1.01-year	0.99	12,944	44%
0.9	-1.270370	4.151	14,143	1.11-year	0.9	14,399	2%
0.5	-0.016620	4.403	25,316	2-year	0.5	23,370	-8%
0.25	0.674230	4.543	34,892	4-year	0.25	33,949	-3%
0.1	1.291780	4.667	46,480	10-year	0.1	47,933	3%
0.04	1.784620	4.767	58,434	25-year	0.04	61,917	6%
0.02	2.106970	4.832	67,869	50-year	0.02	72,496	7%
0.01	2.399610	4.891	77,748	100-year	0.01	83,075	7%
				32-year	0.031	65,808	



Date near calculated 100-year event flow rate

COWLITZ TIMBER TRAILS ASSOCIATION			Gage datum, NGVD29:		226.6
BFE Estimate for Shoreline Permit			NAVD88 Conversion:		3.484
USGS Peak Yearly Flows and Stage			100-year WSEL NAVD88:		255.81
USGS 14238000 Cowlitz River Below Mayfield Dam					
USGS Technical Bulletin 17B					
Date	**Stage, ft**	**Elevation, NGVD29**	**Log(Q)**	**Log(Q)^2**	**Log(Q)^3**
11/6/1934	20.1	246.7	2.392	5.722	13.689
6/8/1936	16.57	243.17	2.386	5.693	13.582
4/15/1937	18.32	244.92	2.389	5.707	13.635
12/30/1937	19.91	246.51	2.392	5.721	13.683
2/15/1939	15.45	242.05	2.384	5.683	13.548
12/17/1939	17.26	243.86	2.387	5.698	13.603
11/29/1940	14.96	241.56	2.383	5.679	13.533
12/20/1941	19.26	245.86	2.391	5.715	13.664
11/24/1942	21.5	248.1	2.395	5.734	13.731
12/4/1943	16.42	243.02	2.386	5.691	13.577
2/8/1945	18.22	244.82	2.389	5.707	13.632
12/29/1945	20.33	246.93	2.393	5.724	13.696
12/13/1946	24.75	251.35	2.400	5.761	13.829
10/20/1947	17.7	244.3	2.388	5.702	13.616
5/13/1949	16.97	243.57	2.387	5.696	13.594
11/28/1949	19.52	246.12	2.391	5.718	13.672
2/11/1951	22.5	249.1	2.396	5.743	13.761
2/4/1952	16.39	242.99	2.386	5.691	13.576
2/1/1953	19.14	245.74	2.390	5.714	13.660
12/10/1953	21.09	247.69	2.394	5.731	13.719
6/11/1955	17.47	244.07	2.388	5.700	13.609
12/12/1955	22.05	248.65	2.396	5.739	13.748
12/11/1956	18.28	244.88	2.389	5.707	13.634
4/21/1958	17.36	243.96	2.387	5.699	13.606
11/12/1958	19.69	246.29	2.391	5.719	13.677
11/24/1959	23.71	250.31	2.398	5.753	13.798
2/22/1961	19.29	245.89	2.391	5.716	13.665
12/25/1961	17.93	244.53	2.388	5.704	13.623
11/21/1962	21.83	248.43	2.395	5.737	13.741
1/26/1964	17.49	244.09	2.388	5.700	13.610
1/31/1965	24.36	250.96	2.400	5.758	13.817
5/7/1966	16.76	243.36	2.386	5.694	13.588
12/13/1966	20.09	246.69	2.392	5.722	13.689
2/20/1968	19.03	245.63	2.390	5.713	13.657
1/5/1969	16.65	243.25	2.386	5.693	13.584
1/27/1970	14.11	240.71	2.381	5.672	13.507
1/26/1971	17.11	243.71	2.387	5.697	13.598
3/19/1972	19.27	245.87	2.391	5.715	13.664
12/27/1972	17.47	244.07	2.388	5.700	13.609
6/19/1974	17.85	244.45	2.388	5.703	13.621
1/18/1975	17.76	244.36	2.388	5.703	13.618
12/4/1975	25.26	251.86	2.401	5.766	13.844
1/9/1977	13.38	239.98	2.380	5.665	13.484
12/4/1977	23.69	250.29	2.398	5.753	13.797
2/7/1979	14.73	241.33	2.383	5.677	13.526
12/18/1979	18.4	245	2.389	5.708	13.638
12/31/1980	18.42	245.02	2.389	5.708	13.638
1/24/1982	18.45	245.05	2.389	5.709	13.639
1/8/1983	17.56	244.16	2.388	5.701	13.612
11/16/1983	18.97	245.57	2.390	5.713	13.655
6/13/1985	14.29	240.89	2.382	5.673	13.512
2/23/1986	17.82	244.42	2.388	5.703	13.620
11/24/1986	17.32	243.92	2.387	5.699	13.605
12/9/1987	14.69	241.29	2.383	5.676	13.524
11/28/1988	15.83	242.43	2.385	5.686	13.559
2/10/1990	17.78	244.38	2.388	5.703	13.619
11/24/1990	19.62	246.22	2.391	5.718	13.675
12/8/1991	16.35	242.95	2.386	5.691	13.575
5/21/1993	13.39	239.99	2.380	5.665	13.485
1/17/1994	14.32	240.92	2.382	5.673	13.513
2/19/1995	18.31	244.91	2.389	5.707	13.635
11/28/1995	26.19	252.79	2.403	5.773	13.872
1/4/1997	17.83	244.43	2.388	5.703	13.620
11/7/1997	15.7	242.3	2.384	5.685	13.555
12/29/1998	16.37	242.97	2.386	5.691	13.576
12/18/1999	16.78	243.38	2.386	5.694	13.588
12/12/2000	13.86	240.46	2.381	5.669	13.499
1/31/2003	17.08	243.68	2.387	5.697	13.597
1/5/2004	15.17	241.77	2.383	5.681	13.539
1/18/2005	15.15	241.75	2.383	5.680	13.539
1/16/2006	17.33	243.93	2.387	5.699	13.605
11/9/2006	19.34	245.94	2.391	5.716	13.666
12/3/2007	15.11	241.71	2.383	5.680	13.537
1/7/2009	20.59	247.19	2.393	5.727	13.704
12/11/2009	15.03	241.63	2.383	5.679	13.535
1/20/2011	16.75	243.35	2.386	5.694	13.587
6/22/2012	15.1	241.7	2.383	5.680	13.537
11/22/2012	15.23	241.83	2.384	5.681	13.541
3/16/2014	15.39	241.99	2.384	5.682	13.546
11/25/2014	15.21	241.81	2.383	5.681	13.540
12/10/2015	16.64	243.24	2.386	5.693	13.584
3/27/2017	15.16	241.76	2.383	5.681	13.539
N			82		
Sums			195.843	467.740	1117.128
Mean X = Sum[log(Q)] / N			2.388		
S = SQRT[((Sum(X^2) - (Sum(x)^2/N)) / (N-1)]					0.005
G = [N^2*Sum(X^3) - 3*N*Sum(X)*(SumX^2) + 2*(Sum(X)^3] / N*(N-1)*(N-2)*S^3					0.852
MSEG-bar (from tech bulletin description)					0.302
G-bar (from map)					0
A = -0.33 + 0.08*ABS(G)					-0.262
B = 0.94 - 0.26*ABS(G)					0.718
MSEG = 10^[A - B*(log(N/10)]					0.121
GW = [MSEG-bar*G + MSEG*G-bar] / [MSEG-bar + MSEG]					0.6

		K	**Log(Q)**					
P		**for GW**	**MeanX + KS**	**Elevation, ft**	**Design Event**	**P**	**-2.599Ln(x) + 241.33**	**Difference, ft**
0.99		-1.880290	2.379	239.35	1.01-year	0.99	241.36	2.01
0.9		-1.200280	2.382	241.21	1.11-year	0.9	241.60	0.40
0.5		-0.099450	2.388	244.25	2-year	0.5	243.13	-1.12
0.25		0.621510	2.391	246.27	4-year	0.25	244.93	-1.33
0.1		1.328500	2.395	248.26	10-year	0.1	247.31	-0.95
0.04		1.938960	2.398	249.99	25-year	0.04	249.70	-0.30
0.02		2.359310	2.400	251.19	50-year	0.02	251.50	0.30
0.01		2.755140	2.402	252.33	100-year	0.01	253.30	0.97
					32-year	0.031	250.36	



Date near calculated 100-year event elevation

CTTA Shoreline Permitting Support

Bulletin 17 Editor - CTTA Sample Peak Flow Analysi

Frequency Curve for: USGS14238000_Q-USGS 14238000-F

Percent Chance Exceedance	Computed Curve Flow in cfs	Variance Log (EMA)	Confidence Limits Flow in cfs	
			0.05	0.95
0.2	104281.7	0.00750	167499.9	80926.0
0.5	89194.2	0.00518	131390.6	72020.6
1.0	78491.5	0.00377	108536.6	65206.4
2.0	68336.6	0.00264	88922.7	58295.4
5.0	55646.6	0.00156	67260.3	48931.0
10.0	46467.4	0.00103	53616.1	41603.9
20.0	37461.9	0.00073	41857.8	33960.8
50.0	25025.3	0.00059	27461.4	22809.3
80.0	16907.7	0.00065	18580.4	15250.5
90.0	13835.9	0.00086	15336.2	12169.1
95.0	11751.5	0.00125	13212.9	9957.9
99.0	8699.3	0.00296	10303.6	6646.5

Events

Event	Number
Historic Events	0
High Outliers	
Low Outliers and Zero Flows	0
Missing Flows	1
Systematic Events	82
Historic Period	83
Equivalent Record Length (years)	82.000

Similar to TB17B results

* Low outlier plotting positions are computed using Median parameters.
<< Frequency Curve >>
USGS14238000_Q-USGS 14238000-F

Computed Curve FLOW, CFS	Variance Log(EMA)	Percent Chance Exceedance	Confidence Limits 0.05 FLOW, CFS	0.95
104,281.7	0.00750	0.200	167,499.9	80,926.0
89,194.2	0.00518	0.500	131,390.6	72,020.6
78,491.5	0.00377	1.000	108,536.6	65,206.4
68,339.6	0.00264	2.000	88,922.7	58,295.4
55,646.6	0.00156	5.000	67,260.3	48,931.0
46,467.4	0.00103	10.000	53,616.1	41,603.9
37,461.9	0.00073	20.000	41,857.8	33,960.8
25,025.3	0.00059	50.000	27,461.4	22,809.3
16,907.7	0.00065	80.000	18,580.4	15,250.5
13,835.9	0.00086	90.000	15,336.2	12,169.1
11,751.5	0.00125	95.000	13,212.9	9,957.9
8,699.3	0.00296	99.000	10,303.6	6,646.5

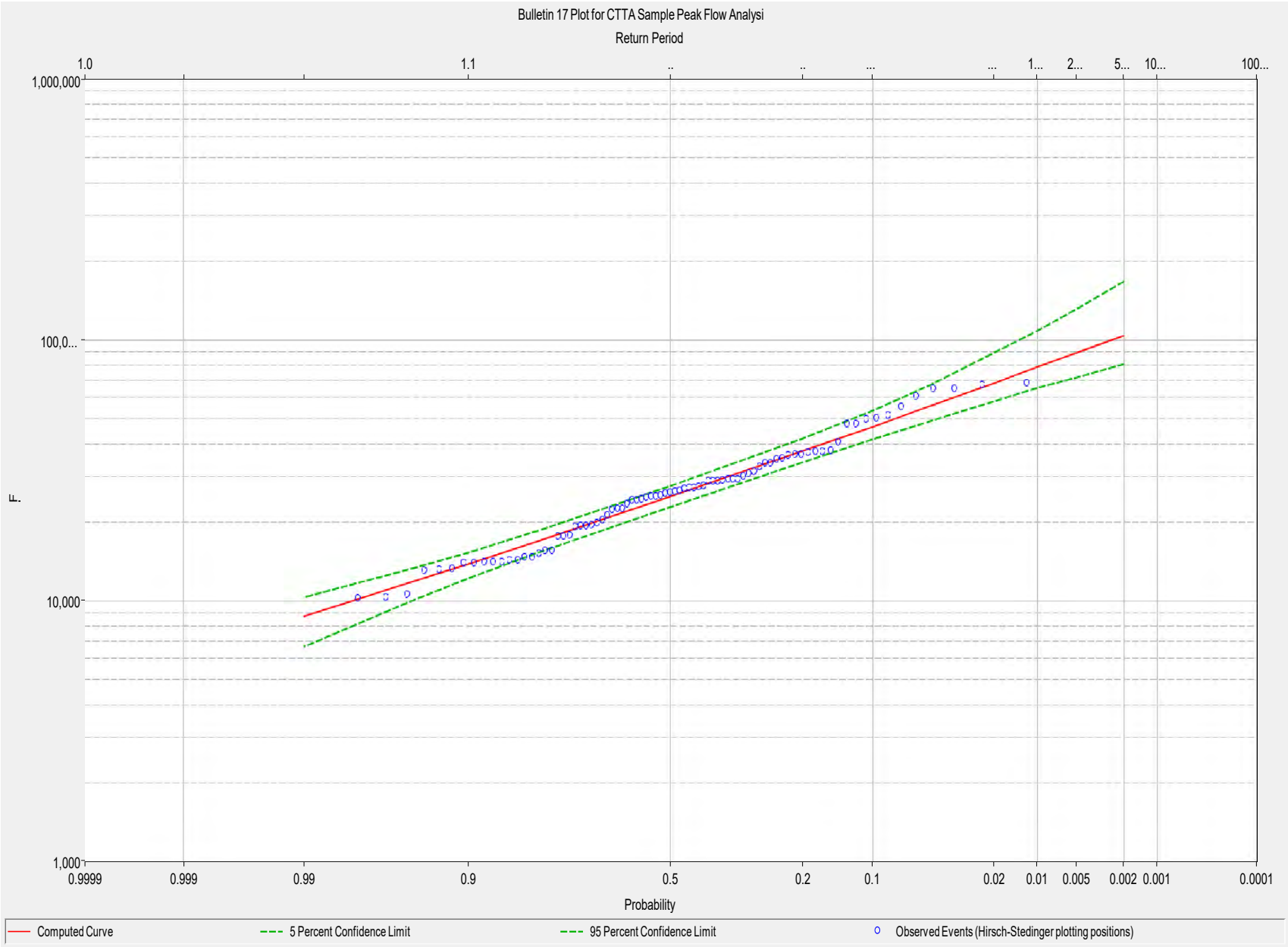
<< Multiple Grubbs-Beck Test P-Values >>
USGS14238000_Q-USGS 14238000-F

Number Of Low Outliers	P-Values
1	9.170E-1
2	7.038E-1
3	5.060E-1
4	9.571E-1
5	9.010E-1
6	8.386E-1
7	8.766E-1
8	7.562E-1
9	6.349E-1
10	4.564E-1
11	3.240E-1
12	2.430E-1
13	1.262E-1
14	1.180E-1
15	5.179E-2
16	4.666E-2
17	4.240E-2
18	1.969E-2
19	3.581E-1
20	2.280E-1
21	1.518E-1
22	5.277E-1
23	4.726E-1
24	3.349E-1
25	2.464E-1
26	2.279E-1
27	2.737E-1
28	4.908E-1
29	8.284E-1
30	7.703E-1
31	6.614E-1
32	8.574E-1
33	9.508E-1
34	9.122E-1
35	9.162E-1
36	9.350E-1
37	9.069E-1
38	8.905E-1
39	8.709E-1
40	8.705E-1
41	8.463E-1

* = p-value corresponds to a zero flow value.

<< Systematic Statistics >>
USGS14238000_Q-USGS 14238000-F

Log Transform: FLOW, CFS			
Mean	4.402	Historic Events	0
Standard Dev	0.205	High Outliers	0
Station Skew	0.101	Low Outliers	0


Bulletin 17 Plot for CTTA Sample Peak Flow Analysi
Return Period
1.0
1.1
..
..
...
...
1...
2...
5...
10...
100...
1,000,000
100,0...
10,000
1,000
F..
0.9999
0.999
0.99
0.9
0.5
0.2
0.1
0.02
0.01
0.005
0.002
0.001
0.0001
Probability
Computed Curve
5 Percent Confidence Limit
95 Percent Confidence Limit
Observed Events (Hirsch-Stedinger plotting positions)

HEC-SSP
Peak Stage Duration Analysis

Duration Analysis
16 Aug 2019 07:50 AM

--- Input Data ---

Analysis Name: Peak Stage Duration
Description: Peak Stage as Peak Stage Duration Analysis

Data Set Name: ANNUALPEAKSTAGE
DSS File Name: C:\Program Files\HEC\HEC-SSP\2.2\CTTA_Cowlitz_River_Peak_Stage\CTTA_Cowlitz_River_Peak_Stage.dss
DSS Pathname: /STAGE/USGS 14238000/STAGE//1YEAR/1/

Project Path: C:\Program Files\HEC\HEC-SSP\2.2\CTTA_Cowlitz_River_Peak_Stage
Report File Name: C:\Program Files\HEC\HEC-SSP\2.2\CTTA_Cowlitz_River_Peak_Stage\DurationAnalysisResults\Peak_Stage_Duration\Peak_Stage_Duration.rpt
Result File Name: C:\Program Files\HEC\HEC-SSP\2.2\CTTA_Cowlitz_River_Peak_Stage\DurationAnalysisResults\Peak_Stage_Duration\Peak_Stage_Duration.xml

Duration Analysis Method: Standard

Duration Plot Position Method: Rank/(N+1)

X-Axis Scale: Normal Probability

Y-Axis Scale: Logarithmic

Duration Period: Annual

Use User-Specified Percent Exceedance
Percent Exceedance: 99.0
Percent Exceedance: 95.0
Percent Exceedance: 90.0
Percent Exceedance: 80.0
Percent Exceedance: 50.0
Percent Exceedance: 20.0
Percent Exceedance: 10.0
Percent Exceedance: 5.0

Percent Exceedance: 2.0
Percent Exceedance: 1.0
Percent Exceedance: 0.5
Percent Exceedance: 0.2

Display ordinate values using 2 digits in fraction part of value

--- End of Input Data ---

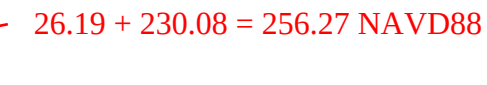
Annual Duration Analysis
ANNUALPEAKSTAGE

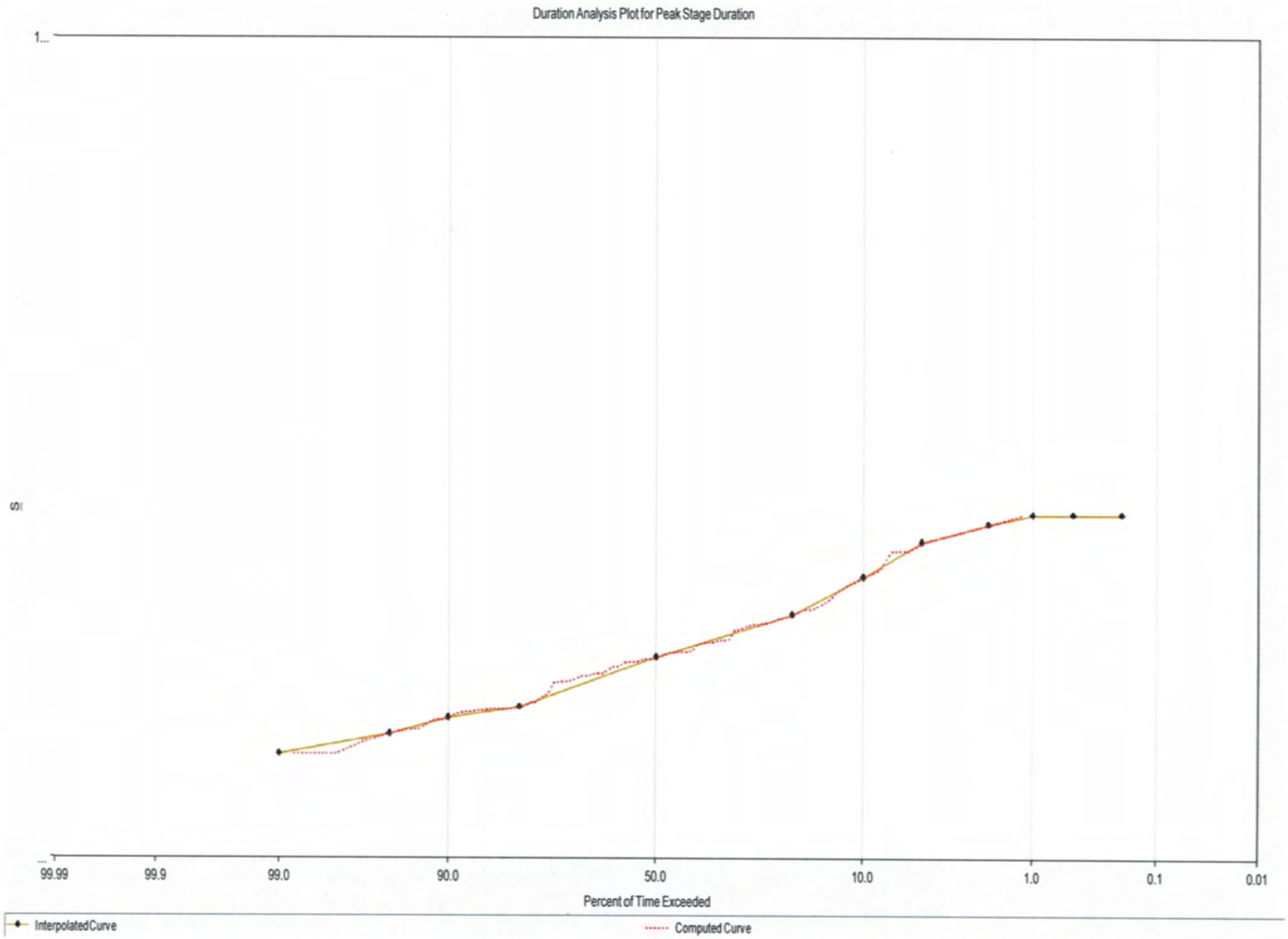
Time Period: 01Jan - 31Dec

Number Valid Values: 82
Number Missing Values: 0

Minimum Value: 13.38
Maximum Value: 26.19

Percent of Time Exceeded	STAGE FEET
99.0	13.38
95.0	14.14
90.0	14.80
80.0	15.22
50.0	17.52
20.0	19.78
10.0	21.98
5.0	24.25
2.0	25.52
1.0	26.19
0.5	26.19
0.2	26.19




Duration Analysis Plot for Peak Stage Duration
1...
99.99
99.9
99.0
90.0
50.0
10.0
1.0
0.1
0.01
Percent of Time Exceeded
Interpolated Curve
Computed Curve

HEC-SSP
Peak Stage as Flow Rate Analysis

CTTA Shoreline Permitting Support

Bulletin 17 Editor - PEAK STAGE AS FLOW

Frequency Curve for: PEAK STAGE AS FLOW-USGS 14238000-FLOW-PEAK

Percent Chance Exceedance	Computed Curve Flow in cfs	Variance Log (EMA)	Confidence Limits Flow in cfs	
			0.05	0.95
0.2	29.9	0.00131	37.7	27.0
0.5	27.9	0.00089	33.6	25.7
1.0	26.5	0.00063	30.7	24.7
2.0	25	0.00043	28.1	23.6
5.0	23.1	0.00023	25.0	22.0
10.0	21.6	0.00014	22.8	20.8
20.0	20.0	0.00009	20.8	19.3
50.0	17.5	0.00006	18.0	17.0
80.0	15.5	0.00005	16.0	15.1
90.0	14.7	0.00006	15.1	14.2
95.0	14.1	0.00009	14.6	13.5
99.0	13.1	0.00023	13.8	12.3

Events

Event	Number
Historic Events	0
High Outliers	
Low Outliers and Zero Flows	0
Missing Flows	1
Systematic Events	82
Historic Period	83
Equivalent Record Length (years)	82.000

26.5 + 230.08 = 256.58 NAVD88

* Low outlier plotting positions are computed using Median parameters.
<< Frequency Curve >>
PEAK STAGE AS FLOW-USGS 14238000-FLOW-PEAK

Computed Curve FLOW, CFS	Variance Log(EMA)	Percent Chance Exceedance	Confidence Limits 0.05 FLOW, CFS	0.95
29.9	0.00131	0.200	37.7	27.0
27.9	0.00089	0.500	33.6	25.7
26.5	0.00063	1.000	30.7	24.7
25.1	0.00043	2.000	28.1	23.6
23.1	0.00023	5.000	25.0	22.0
21.6	0.00014	10.000	22.8	20.8
20.0	0.00009	20.000	20.8	19.3
17.5	0.00006	50.000	18.0	17.0
15.5	0.00005	80.000	16.0	15.1
14.7	0.00006	90.000	15.1	14.2
14.1	0.00009	95.000	14.6	13.5
13.1	0.00023	99.000	13.8	12.3

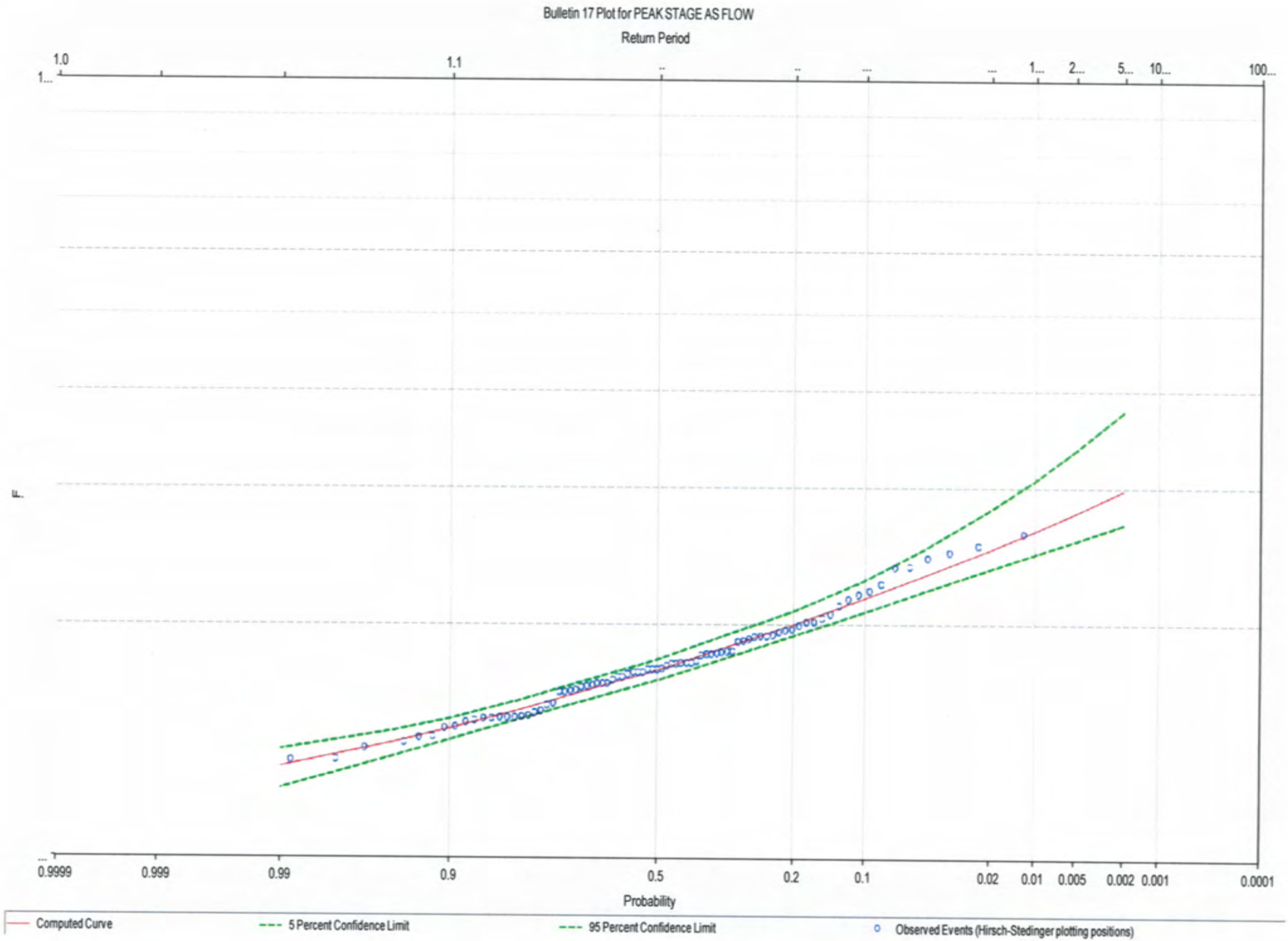
<< Multiple Grubbs-Beck Test P-Values >>
PEAK STAGE AS FLOW-USGS 14238000-FLOW-PEAK

Number Of Low Outliers	P-Values
1	9.614E-1
2	8.155E-1
3	9.042E-1
4	9.172E-1
5	9.151E-1
6	8.296E-1
7	9.521E-1
8	9.129E-1
9	9.592E-1
10	9.444E-1
11	9.272E-1
12	8.649E-1
13	8.050E-1
14	6.944E-1
15	5.614E-1
16	4.616E-1
17	3.376E-1
18	3.993E-1
19	3.345E-1
20	5.379E-1
21	5.876E-1
22	9.773E-1
23	9.625E-1
24	9.401E-1
25	9.146E-1
26	9.553E-1
27	9.552E-1
28	9.245E-1
29	9.402E-1
30	9.023E-1
31	8.574E-1
32	9.404E-1
33	9.584E-1
34	9.413E-1
35	9.722E-1
36	9.703E-1
37	9.494E-1
38	9.290E-1
39	9.483E-1
40	9.085E-1
41	8.659E-1

* = p-value corresponds to a zero flow value.

<< Systematic Statistics >>
PEAK STAGE AS FLOW-USGS 14238000-FLOW-PEAK

Log Transform: FLOW, CFS		Number of Events	
Mean	1.248	Historic Events	0
Standard Dev	0.066	High Outliers	0
Station Skew	0.475	Low Outliers	0


Bulletin 17 Plot for PEAK STAGE AS FLOW
Return Period
1.0
1.1
100...
0.9999
0.999
0.99
0.9
0.5
0.2
0.1
0.02
0.01
0.005
0.002
0.001
0.0001
Probability
Computed Curve
5 Percent Confidence Limit
95 Percent Confidence Limit
Observed Events (Hirsch-Stedinger plotting positions)