US Army Corps
of Engineers ®
Omaha District

Lower Platte River
Flood Frequency Update

USACE Omaha District
Hydrologic Engineering Branch
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1 Executive Summary

A flood frequency analysis was completed for the Lower Platte River in Nebraska at Duncan, North Bend, Ashland, and Louisville. Flood frequency was computed for a single population (annual peak flow) and mixed population (rainfall and snowmelt season peak flows) to reproduce techniques used in previous studies and represent the runoff characteristics of the watershed. The analysis was completed according to Bulletin 17C (USGS, 2018). Streamflow gage data was obtained from USGS for the period after the construction of Kingsley Dam (1942-2016) because regulation likely had an impact on observed peak flows downstream. The data was separated into rainfall and snowmelt seasons. The rainfall and snowmelt seasons were assumed to be 01-April to 14-December and 15-December to 31-March, respectively. An analysis of Accumulated Freezing Degree Days (AFDD) showed that the separation of seasons by date was appropriate. The datasets contained varying periods of missing data.

Longer record lengths improve flood frequency confidence and using equivalent record lengths improves consistency amongst gages. Two methods were used to supplement observed annual and seasonal peak flows: the ratio method and the Maintenance of Variance Extension (MOVE) technique. The ratio method applied a ratio of annual peak flow to maximum daily average flow to years when the peak flow was observed in the opposite season in order to fill in gaps within the seasonal instantaneous peak flow record. The MOVE technique was applied according to Appendix 8 in Bulletin 17C to estimate missing observations based on a hydrologically-relevant longer-record length site (USGS, 2018). Final datasets included seasonal peak flow observations and estimates from 1942-2016.

Flood frequency analysis was completed using HEC-SSP v2.2. Single population analysis was performed on the annual maximum series for each gage according to Bulletin 17C (USGS, 2018). Station skew was utilized as is recommended in WRIR 99-4032 (USGS, 1999). Mixed population analysis computed Bulletin 17C flood frequency for each seasonal peak flow dataset, and combined them using the Union Probability Theorem, according to EM 1110-2-1415 (USACE, 1993). Some previous studies computed an adopted skew by weighting station skew with regional skew. However, station skew in conjunction with consistent record length amongst stations was considered superior. In general, the mixed population flow frequency curves were higher than the single population frequency curves, especially at the upper and lower ends of the curves. Because a mixed population analysis better represents the two flood-causing mechanisms of the watershed, it is recommended to adopt the mixed population flood flow frequency combined curves for the Lower Platte River, shown in Table 1 and Figure 1.

Table 1. Recommended adopted annual peak flood flow frequency.

Return Interval (yrs)	Flood Flow Frequency (cfs)			
	Duncan	**North Bend**	**Ashland**	**Louisville**
500	43,400	203,900	266,400	306,300
200	36,400	144,800	210,400	243,000
100+	41,200	172,500	246,800	283,200
100	31,600	113,900	176,100	202,900
50	27,000	91,000	146,600	168,100
25	22,800	73,300	120,700	137,600
10	17,500	54,500	90,600	102,400
5	13,700	42,400	70,000	78,600
2	8,700	27,300	43,700	49,000

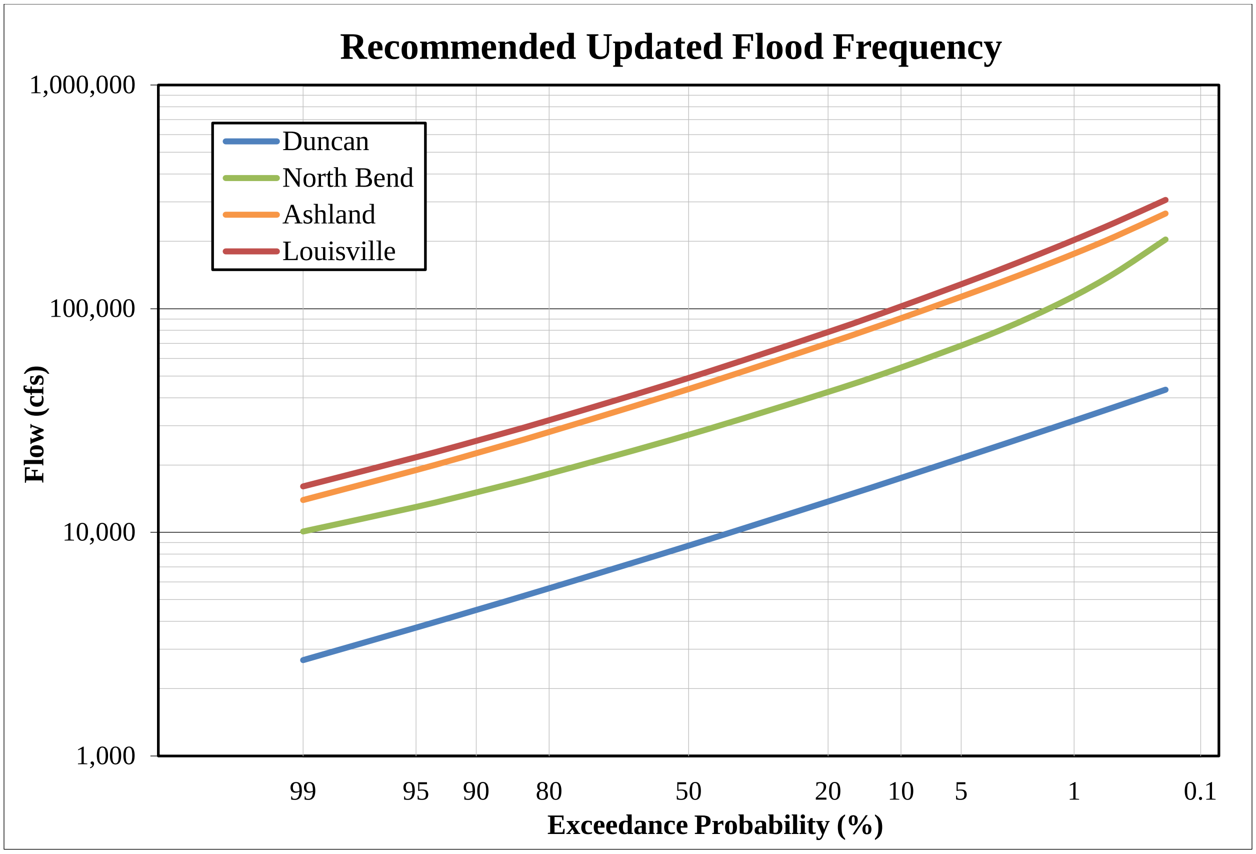


Figure 1. Recommended adopted annual peak flood flow frequency.

2 Purpose

The purpose of this study is to update flood frequency for four stations on the Lower Platte River in Nebraska: Duncan, North Bend, Ashland, and Louisville. The Platte River begins at the confluence of the North and South Platte Rivers in western Nebraska and flows into the Missouri River as a right-bank tributary in eastern Nebraska (USGS, 1999). Figure 2 shows the location of each U.S. Geological Survey (USGS) streamgage used in the analysis and Table 2 provides a description of each. Grand Island is outside the study reach, but data from this gage was used for record extension. Methods described in Bulletin 17C will be used to compute flood flow frequency as a single population (annual peaks) and a mixed population (rainfall and snowmelt flood seasons). A recommended flood frequency for return periods of 2, 5, 10, 25, 50, 100, 100+, 200, and 500 years will be provided. Several previous studies exist which computed flood frequency from Duncan to Louisville, and a comparison to those analyses will also be provided.

Table 2. Study gages.

Station	USGS Station ID	Platte River Mile	Contributing Drainage Area (mi^2)
Grand Island	06770500	169.0	52,940
Duncan	06774000	113.0	54,630
North Bend	06796000	72.3	57,800
Ashland	06801000	27.4	69,300
Louisville	06805500	16.1	71,000

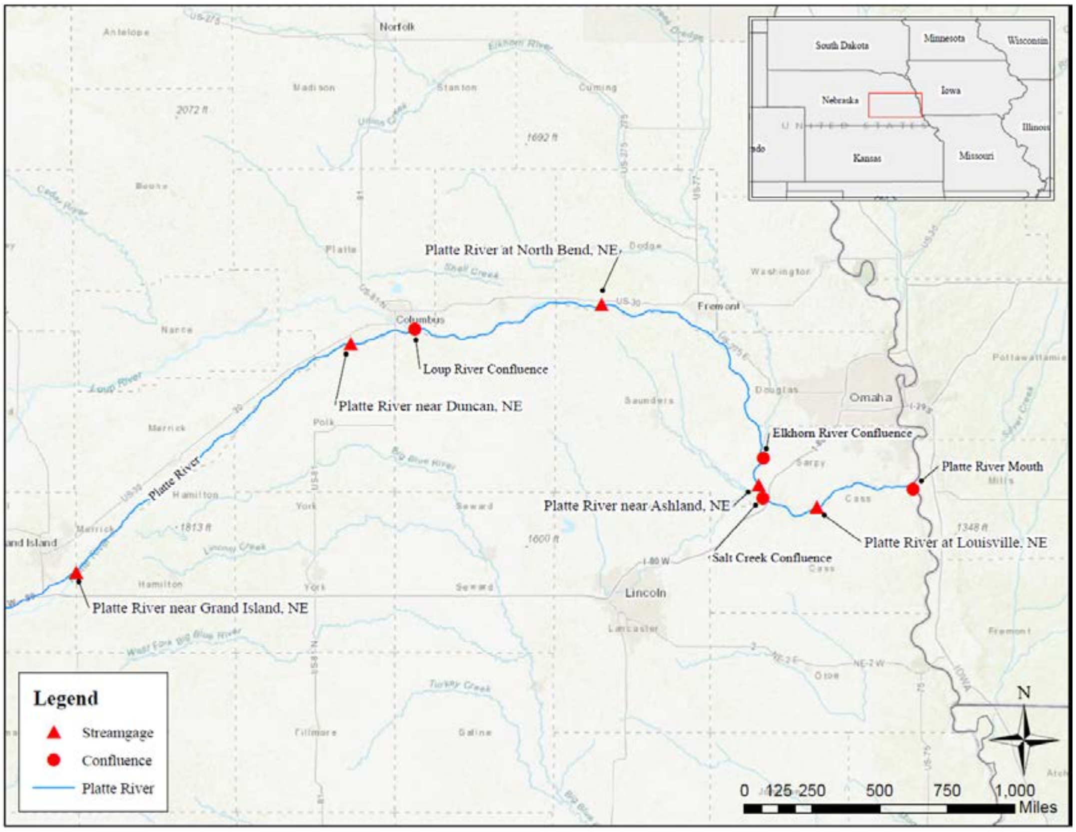


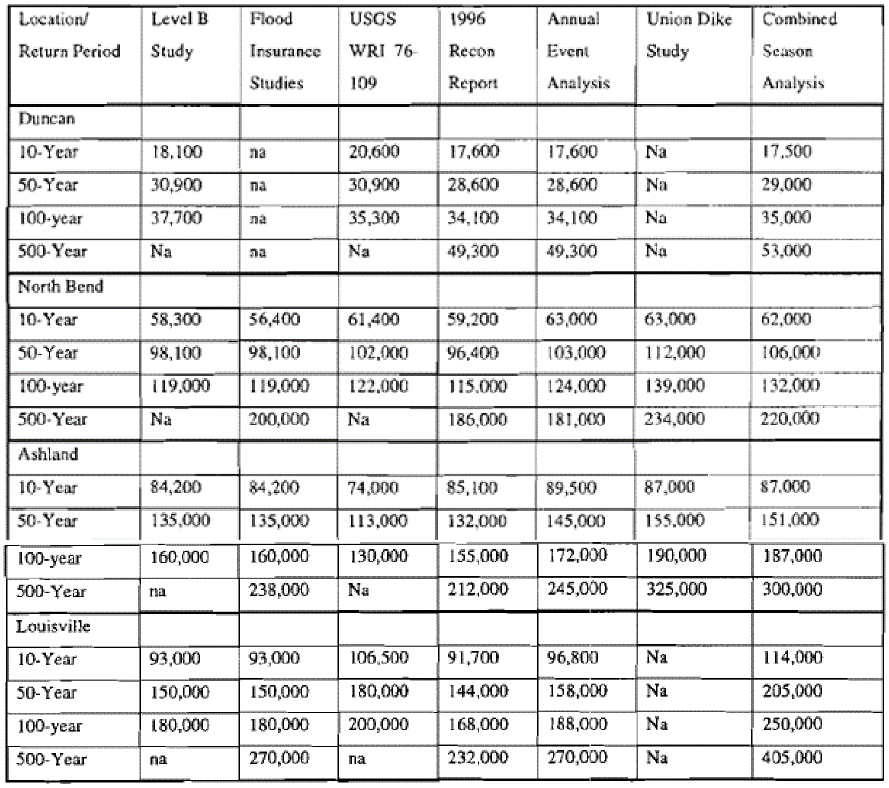
Figure 2. Analysis location and gages of interest.

3 Summary of Existing Studies

The updated study reproduces techniques used in previous Lower Platte River flood frequency studies. Previous studies that computed flood frequency are the Platte River Basin Level B Study (Missouri River Basin Commission, 1975), Flood Insurance Studies (FIS) for Sarpy County (FEMA, 1980), Douglas County (FEMA, 1980), and Dodge County (FEMA, 1988), the USGS Water Resources Investigations (WRI) 76-109 (1976), the Lower Platte River and Tributaries Reconnaissance Report (USACE, 1996), the Union Dike Study (USACE, 1997), Water Resources Investigation Report (WRIR) 99-4032 (USGS, 1999), and the Western Sarpy/Clear Creek Flood Reduction Study (FRS). Many of these studies computed flood frequency using the annual maximum series, or as a single population, including the USGS regional studies. However, floods on the Platte River can result from rainfall or snowmelt and there is a possibility that both could occur in the same year. For this reason, it may be appropriate to perform a flood frequency analysis using seasonal maximum series, or as a mixed population. The Union Dike Study computed flood frequency for the open-water and ice-affected seasons as part of a mixed population flood frequency analysis.

The Western Sarpy/Clear Creek FRS, also recommended a mixed population flood frequency curve at each gage station. For that study, as well as the Union Dike Study, the snowmelt flood season was 15-December through 31-March and the rainfall flood season was 1-April through 14-December. Seasons were selected based on historic experience. Periods of record for each gage included observed annual peaks in each season and were supplemented by applying a seasonal ratio of observed annual peaks to observed seasonal maximum daily average flow at each gage. The study weighted a regional skew estimate with station skew to compute an adopted skew. A comparison of available flood frequency data from previous studies is provided in Figure 3.

Figure 3. Comparison of computed flood frequency for various past studies as reported in the Western Sarpy/Clear Creek FRS (USACE, 2000). The "Combined Season Analysis" was recommended for adoption.



Location/ Return Period	Level B Study	Flood Insurance Studies	USGS WRI 76-109	1996 Recon Report	Annual Event Analysis	Union Dike Study	Combined Season Analysis
Duncan							
10-Year	18,100	na	20,600	17,600	17,600	Na	17,500
50-Year	30,900	na	30,900	28,600	28,600	Na	29,000
100-year	37,700	na	35,300	34,100	34,100	Na	35,000
500-Year	Na	na	Na	49,300	49,300	Na	53,000
North Bend							
10-Year	58,300	56,400	61,400	59,200	63,000	63,000	62,000
50-Year	98,100	98,100	102,000	96,400	103,000	112,000	106,000
100-year	119,000	119,000	122,000	115,000	124,000	139,000	132,000
500-Year	Na	200,000	Na	186,000	181,000	234,000	220,000
Ashland							
10-Year	84,200	84,200	74,000	85,100	89,500	87,000	87,000
50-Year	135,000	135,000	113,000	132,000	145,000	155,000	151,000
100-year	160,000	160,000	130,000	155,000	172,000	190,000	187,000
500-Year	na	238,000	Na	212,000	245,000	325,000	300,000
Louisville							
10-Year	93,000	93,000	106,500	91,700	96,800	Na	114,000
50-Year	150,000	150,000	180,000	144,000	158,000	Na	205,000
100-year	180,000	180,000	200,000	168,000	188,000	Na	250,000
500-Year	na	270,000	na	232,000	270,000	Na	405,000

4 Flood Frequency Analysis

Flood frequency will be computed for four Lower Platte River gage stations from Duncan to Louisville. Continuous annual peak flow datasets will be developed for each of the stations representing annual peaks as well as rainfall and snowmelt flood season peaks. A climate change assessment will be used to determine if any nonstationarities exist in the datasets. Flood frequency analysis will be performed for each streamgage location for a single population and mixed population according to Bulletin 17C (USGS, 2018) and EM 1110-2-1415 (USACE, 1993) using the Hydrologic Engineering Center Statistical Software Package (HEC-SSP) version 2.2. The two methods will be compared to determine a recommended discharge-frequency curve at each of the four Lower Platte River stations.

4.1 Streamflow Data Development

The objective of streamflow data development is to develop continuous datasets for each of the four Lower Platte River stations, shown in Figure 2, representing the annual peak flows as well as the rainfall and snowmelt flood season peak flows. Kingsley Dam (and upstream Lake McConaughy) was constructed on the North Platte River in 1941. Peak flow frequencies computed in WRIR 99-4032 are fairly uniform downstream of the Wyoming-Nebraska state line, with a noticeable reduction in peak flows downstream of Kingsley Dam (USGS, 1999). Therefore, the data was limited to the period following the construction of the dam (1942-2016).

Annual peak and daily average streamflow measurements for the four Lower Platte River study gages, as well as Grand Island, from 1942-2016 were downloaded in HEC-SSP v2.2 using the USGS data import tool. All datasets were separated into rainfall and snowmelt flood seasons by date. The rainfall flood season was assumed to be 1-April through 14-December, and the snowmelt flood season was assumed to be 15-December through 31-March, the same as the Western Sarpy/Clear Creek FRS which was determined based on historical flood experience (USACE, 2000). The assumption of seasonal separation by date is analyzed further in section 4.1.2. Annual and seasonal maximum daily average flows were extracted from the daily average flow datasets. A summary of missing years of data after 1942 is shown in Table 3, and annual peak flow data is shown in Figure 4.

Table 3. Summary of missing observations at each station.

Station	**Missing Years of Data (1942-2016)**	
	Annual Peak Streamflow	**Daily Average Streamflow**
Grand Island	-	-
Duncan	-	1969-1973
North Bend	1942-1948	1942-1948
Ashland	1954-1988	1961-1988
Louisville	1942-1952	1942-1952

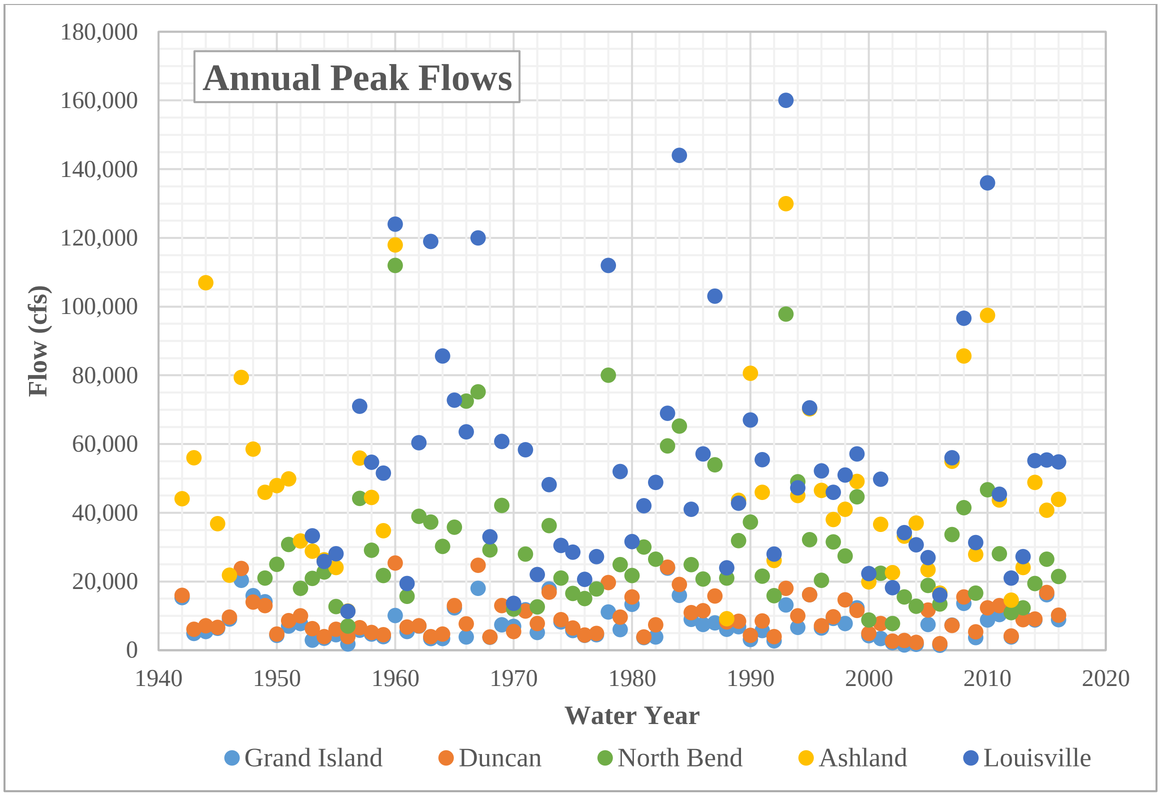


Figure 4. Annual peak flow data downloaded from USGS (2018).

4.1.1 Record Extension

Utilizing long, complete records improves flood frequency computations and consistency amongst gages. Two methods were utilized to supplement observed discharges in the period of record from 1942-2016: the ratio method and the Maintenance of Variance Extension (MOVE) technique. The ratio method applies a ratio of peak streamflow to maximum daily average streamflow to years and seasons when the peak flow was observed in the opposite season. The MOVE technique is a method to estimate missing observations based on a nearby station with a relatively longer record length (USGS, 2018).

4.1.1.1 Ratio Method

For each season, when available, a ratio of the observed annual peak flow to maximum daily average flow (Q_p/Q_d) was computed. The computed Q_p/Q_d ratios were averaged for each season and gage and are shown in Table 4, including a comparison to the Union Dike Study (USACE, 1997), Western Sarpy/Clear Creek FRS (USACE, 2000). Data used to compute the seasonal ratios at North Bend and Ashland for the Union Dike and Western Sarpy studies were available for comparison. At North Bend, the difference in ratios can be attributed to an observed peak in 1983 misclassified as a snowmelt season peak, as that peak flow was observed on June 15, 1983 (USGS, 2018). At Ashland, the difference can be attributed to the classification of the annual peak in 1946 as a snowmelt peak, which was reclassified as a rainfall season peak after further investigation for this analysis. The use of peak flow data from 1929-1941, prior to the construction of Kingsley Dam in 1942, also contributed to the difference in computed ratios.

The average seasonal ratio was applied to the maximum daily average flow for years when the annual peak was not observed during the season. The resulting datasets for the annual, rainfall season, and snowmelt season peak flows contained varying missing years of data, summarized in Table 5.

Table 4. Ratio of annual peak to maximum daily average flow for various studies and the current study

Gaging Station	Flood Season	1942-1994[1]			1942-2016
		Union Dike Study (USACE, 1997)	Western Sarpy/ Clear Creek FRS (USACE, 2000)	Update	Update
Grand Island	Rainfall	-	1.09	1.09	1.08
	Snowmelt	-	1.11	1.12	1.13
Duncan	Rainfall	-	1.07	1.12	1.10
	Snowmelt	-	1.12	1.13	1.12
North Bend	Rainfall	1.34	1.34	1.33	1.29
	Snowmelt	1.33	1.33	1.25	1.24
Ashland	Rainfall	1.25	1.25	1.34	1.27
	Snowmelt	1.29	1.29	1.22	1.22
Louisville	Rainfall	1.24	1.24	1.25	1.23
	Snowmelt	1.29	1.29	1.19	1.19

[1]Computed Union Dike and Western Sarpy/Clear Creek FRS ratios at Ashland include data from 1929-1941.

Table 5. Missing data after applying the seasonal ratio.

Station	Flood Season	Missing Years of Data	Number of Missing Observations
Duncan	Annual	-	-
	Rainfall	1969, 1972	2
	Snowmelt	1970-1971,1973	3
North Bend	Annual	1942-1948	7
	Rainfall	1942-1948	7
	Snowmelt	1942-1949	8
Ashland	Annual	1961-1987	27
	Rainfall	1961-1987	27
	Snowmelt	1961-1988	28
Louisville	Annual	1942-1952	11
	Rainfall	1942-1952	11
	Snowmelt	1942-1953	12

4.1.1.2 MOVE Technique

To complete the full period of record after the construction of Kingsley Dam (1942-2016) for each station, the Maintenance of Variance Extension (MOVE) technique was applied according to Bulletin 17C. The length of the short record is denoted as n_1, and n_2 represents the additional observations at the long-record site. The following general steps summarize the MOVE technique for record extension as described in Appendix 8 of Bulletin 17C (USGS, 2018):

1. Select a hydrologically-relevant longer record site nearby to extend the short-record site of interest.
2. Investigate the statistical properties and regression relationship between the short and long record sites using base-10 logarithms of the flood flows. If the correlation coefficient exceeds a critical value ($\hat{\rho} > 0.8$) record extension may be suitable.

3. Estimate the sample statistics for the concurrent n_1 records and the mean and variance for the complete record available at the long-record site (n_1+n_2).
4. Estimate the total effective record length n_1+n_e; n_e is the number of observations that need to be added to the *y*-series.
5. Estimate the extension parameters. Use the model to generate the additional n_e flow values to extend the record for the short site.
6. A frequency analysis can then be performed using the extended record flow series n_1+n_e.

Correlation of each site is shown in Table 6 and plotted in Figure 5. The hydrologically-relevant site selected to extend the record at each site was chosen as the closest site upstream or downstream with the highest correlation. Table 7 shows the computed record extension parameters using base-10 logarithm flood flows as recommended in Bulletin 17C (USGS, 2018).

Table 6. Correlation values used to determine the applicability of record extension.

Correlation of Annual Peak Datasets ($\hat{\rho}$)					
Station	**Grand Island**	**Duncan**	**North Bend**	**Ashland**	**Louisville**
Grand Island	-	0.924[1]	0.552	0.489	0.530
Duncan	0.924[1]	-	0.637	0.519	0.612
North Bend	0.552	0.637	-	0.827[1]	0.880
Ashland	0.489	0.519	0.827[1]	-	0.938[1]
Louisville	0.530	0.612	0.880	0.938[1]	-

[1] Correlation of sites selected to extend records

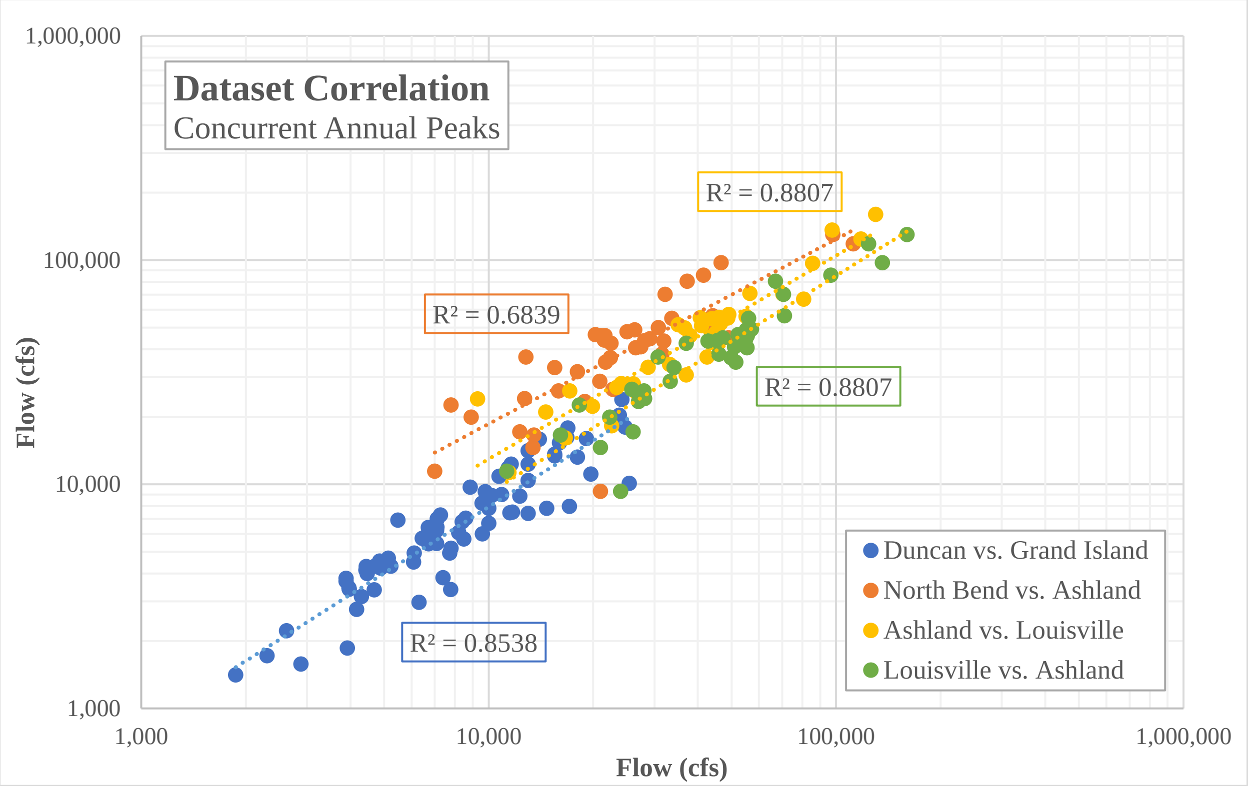


Figure 5. Annual peak dataset correlation. R is equivalent to the correlation coefficient.

Table 7. Statistics computed for MOVE technique. Parameters were computed using log-10 flood flows.

Station	Hydrologically-Relevant Station	Annual/Flood Season	Record Length			Extended Record Statistics		Regression Model Parameters	
			n_1	n_2	n_e	μ	σ^2	a	b
Duncan	Grand Island	Annual	75	0	0	-	-	-	-
		Rainfall	73	2	2	3.83	0.086	3.83	1.73
		Snowmelt	72	3	2	3.74	0.065	3.77	1.65
North Bend	Ashland	Annual	68	7	3	4.39	0.063	4.49	1.07
		Rainfall	68	7	4	4.33	0.050	4.41	0.89
		Snowmelt	67	8	6	4.20	0.071	4.27	1.05
Ashland	Louisville	Annual	48	27	18	4.60	0.072	4.64	1.03
		Rainfall	48	27	19	4.56	0.074	4.58	1.04
		Snowmelt	47	28	25	4.38	0.083	4.41	0.98
Louisville	Ashland	Annual	64	11	8	4.66	0.059	4.73	1.04
		Rainfall	64	11	8	4.62	0.065	4.70	1.01
		Snowmelt	63	12	11	4.40	0.074	4.47	1.04

The extended record length, n_1+n_e, for each station and season is shown in Table 7. Bulletin 17C recommends using the regression parameters to estimate only the most recent n_e observations in the extended record (USGS, 2018). For example, the annual maximum streamflows at North Bend should only be estimated for the most recent 3 years (n_e) in the record, but there were 7 total missing streamflows (n_2) from the record. A sensitivity of flood frequency analysis at Ashland using the full extended record (75 years) versus the computed extended record (66 years) shows that using the full 75 year record results in slightly higher (approximately 5%) computed flood frequency. This is primarily because the 4th and 5th highest peaks on record were estimated using the MOVE technique. In absence of local station skew data of basins with similar characteristics and drainage area there was limited ability to determine an appropriate regional skew. Therefore, consistency amongst streamgage record lengths was determined critical to this analysis, and the full extended record from 1942-2016 will be utilized for each of the four gages.

4.1.2 Seasonal Applicability

An integral assumption of flood frequency analyses is that the data are independent and identically-distributed. Peak flows resulting from snowmelt and rainfall typically occur several months apart and are therefore considered independent events, which suggests analyzing peak flows as a mixed population. The most accurate way to separate the data by season is to analyze each flood event separately to determine the source of flooding at each gage. However, this process is time-consuming and the necessary data may not have been available. Therefore, the peak data was initially separated by date based on historical experience and past studies and then checked with a technique using temperature data. In this analysis, the snowmelt flood season was assumed to be 15-December to 31-March.

Typically, peak flows on the Platte River representing the snowmelt season occur 2-9 days after the peak Accumulated Freezing Degree Days (AFDD). Therefore, the date of observed snowmelt season peak flows was compared to the date of peak AFDD. Freezing degree days were computed as the daily average degrees below freezing and AFDD were computed from the start of the assumed snowmelt season of each year, 15-December. Changing the start date of the AFDD computation only alters the value of the peak AFDD and not the date. A comparison of AFDD and observed peak flows was undertaken for the Duncan gage and assumed to be representative of the study area. Daily average temperature data at Columbus, NE was downloaded from the National Climate Data Center (NCDC) for the period of record following construction of Kingsley Dam (NCEI, 2018). The Columbus station is approximately 11 miles NNE of the Duncan streamgage, but the values were considered representative of those at Duncan. Over the period of record, 34 annual peaks were observed during the assumed snowmelt season.

A comparison of the timing of peak AFDD and peak flow is shown in Table 8. Figure 6 shows the 1978 snowmelt season peak of record observed at the Duncan gage with a typical time between peak AFDD and observed peak flow. The comparison of peak flow and AFDD revealed that 4 events were more likely the result of rainfall runoff rather than snowmelt: 1946, 1959, 1987 (shown in Figure 7), and 1992. The period between peaks in a few years was longer than expected to be representative of a snowmelt season flood, however snow depth records show that there was some snow accumulation that melted prior to the observed annual peak. In 1993 and 2002, the peak AFDD occurred after the observed peak flow, but again, snow depth records show that there was snowmelt prior to both events.

To account for the four years when the assumption of separating seasons by date was not appropriate, observed peaks in the snowmelt season were changed to observed peaks in the rainfall season. In 1987, the annual peak at each of the four Lower Platte stations was also observed on 24-March, so all were assumed to be rainfall season peaks. In 1946, 1959, and 1992, Duncan was the only station that observed an annual peak during the assumed snowmelt season. During years when the seasonal assumption was altered, the maximum daily average flow used to compute the seasonal ratios was changed to the maximum observed daily average flow 2-9 days after the peak AFDD. The computed ratios shown in Table 4 reflect this change. The analysis shows that the separation of seasons by date is generally appropriate given that only 4 of the 34 annual peaks observed in the snowmelt season were not the result of snowmelt.

Table 8. Comparison of peak AFDD to observed snowmelt season annual peak flows at the Duncan gage.

Date of Peak AFDD	Peak AFDD	Date of Observed Peak Flow	Peak Flow (cfs)	Days Between Peaks
3/20/1943	278	3/23/1943	6,100	3
2/1/1946	306	3/18/1946	4,430	45[1]
3/11/1948	535	3/20/1948	14,000	9
1/11/1950	59	3/18/1950	4,700	66[2]
3/6/1952	288	3/10/1952	10,000	4
3/1/1953	117	3/6/1953	6,300	5
1/21/1954	250	2/8/1954	3,960	18[2]
2/24/1955	192	3/11/1955	6,080	15[2]
2/5/1956	353	3/18/1956	3,920	42[2]
2/11/1959	406	3/28/1959	4,470	45[1]
2/23/1960	657	3/28/1960	25,400	34[2]
3/21/1962	543	3/24/1962	7000	3
2/25/1966	983	3/4/1966	7720	7
3/14/1969	1292	3/22/1969	13000	8
2/23/1972	929	2/29/1972	7800	6
2/9/1974	668	2/13/1974	8,400	4
2/7/1976	429	2/14/1976	4,440	7
3/11/1978	1,355	3/20/1978	19,700	9
3/5/1979	1,421	3/14/1979	9,600	9
2/15/1985	797	3/1/1985	10,900	14[2]
2/22/1986	306	2/27/1986	11,500	5
1/26/1987	100	3/24/1987	15,800	57[1]
2/15/1988	715	2/24/1988	8,200	9
3/7/1989	537	3/12/1989	8,400	5
2/21/1990	298	2/23/1990	4,300	2
2/12/1992	189	3/10/1992	3,950	27[1]
3/19/1993	1,004	3/11/1993	18,000	-8[2]
3/1/1994	907	3/6/1994	10,000	5
2/20/2000	189	2/25/2000	4,890	5
3/12/2001	1,031	3/17/2001	7,770	5
3/26/2002	507	3/15/2002	2,620	-11[2]
2/17/2004	664	3/1/2004	2,300	13[2]
2/18/2007	674	2/25/2007	7,140	7

[1] Observed peaks that are likely the result of rainfall rather than snowmelt.

[2] Observed AFDD did not occur 2-9 days after peak AFDD, but snow depth records indicate that flow is the result of snowmelt.

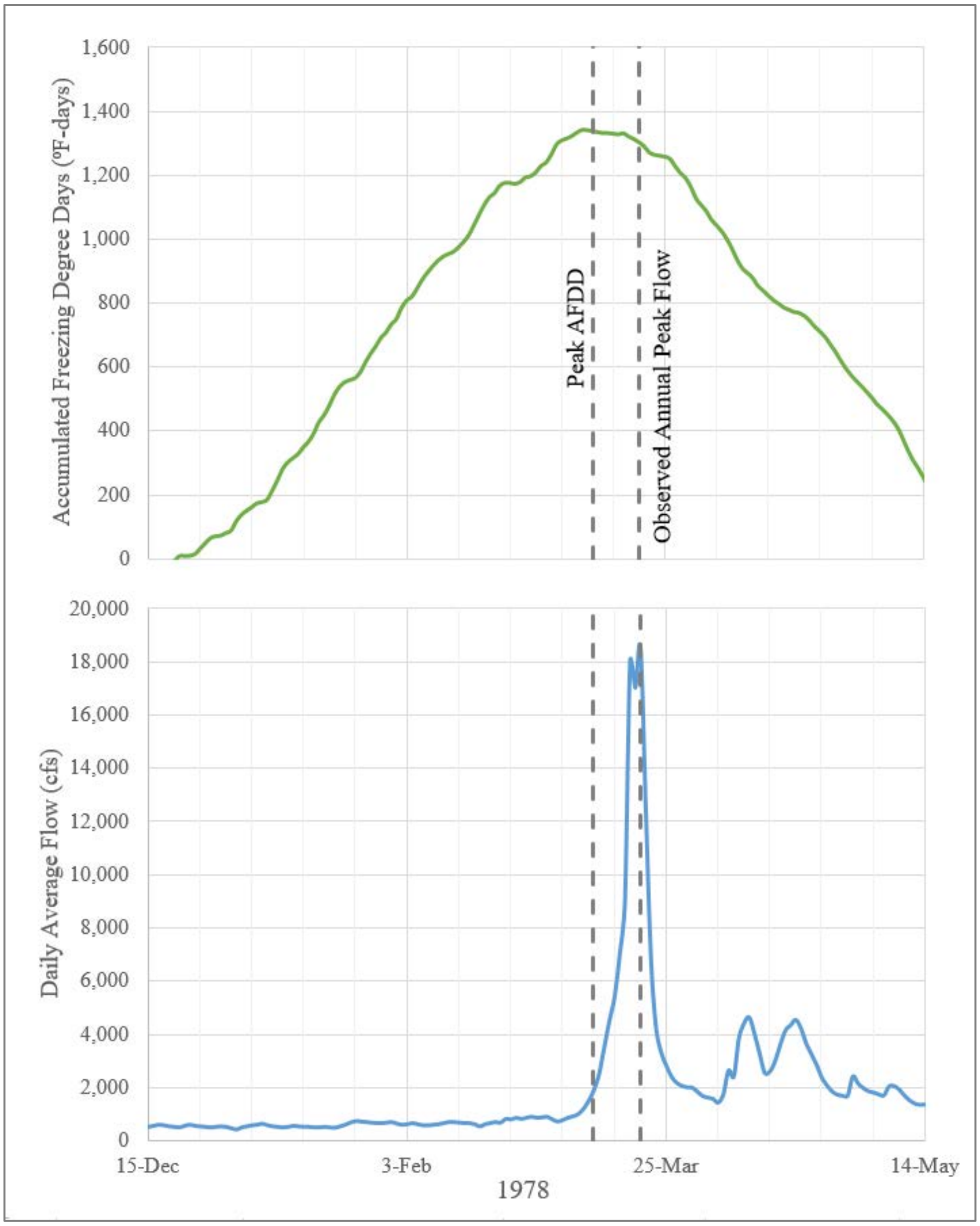


Figure 6. Comparison of AFDD at Columbus Airport and streamflow at Duncan in 1978 showing that the observed peak flow is part of the assumed snowmelt season.

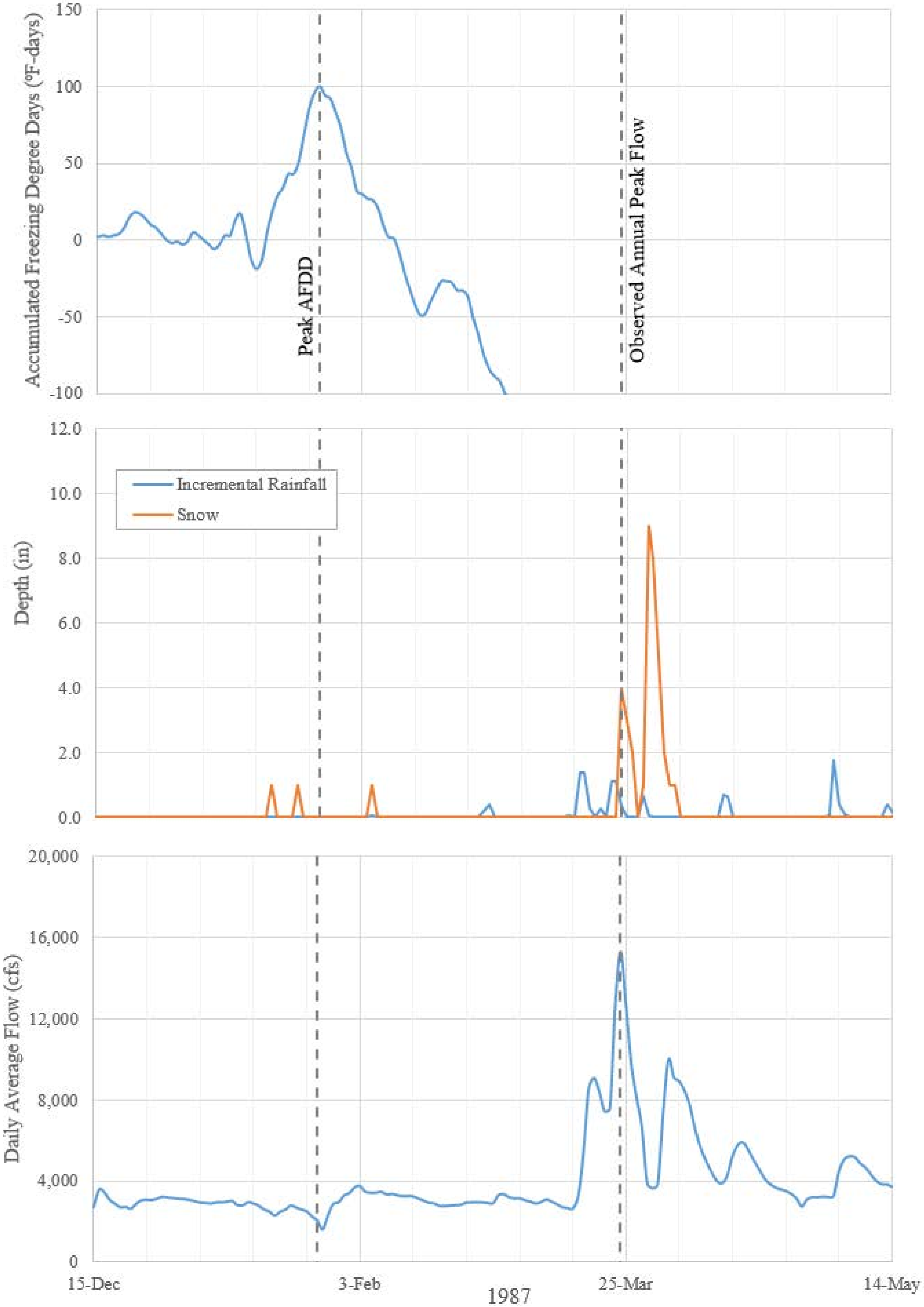


Figure 7. Comparison of AFDD at Columbus Airport to observed Duncan streamflows showing that the 1987 observed peak flow was actually caused by rainfall and not snowmelt.

4.1.3 Complete Datasets

Annual maximum streamflow datasets developed for each of the four study gages are shown in Figure 8. Rainfall and snowmelt flood season annual maximums are shown in Figure 9 and Figure 10. Complete datasets from 1942-2016, following the construction of Kingsley Dam, will be used for flood frequency analysis. Complete datasets are also shown in tabular form in Appendix A.

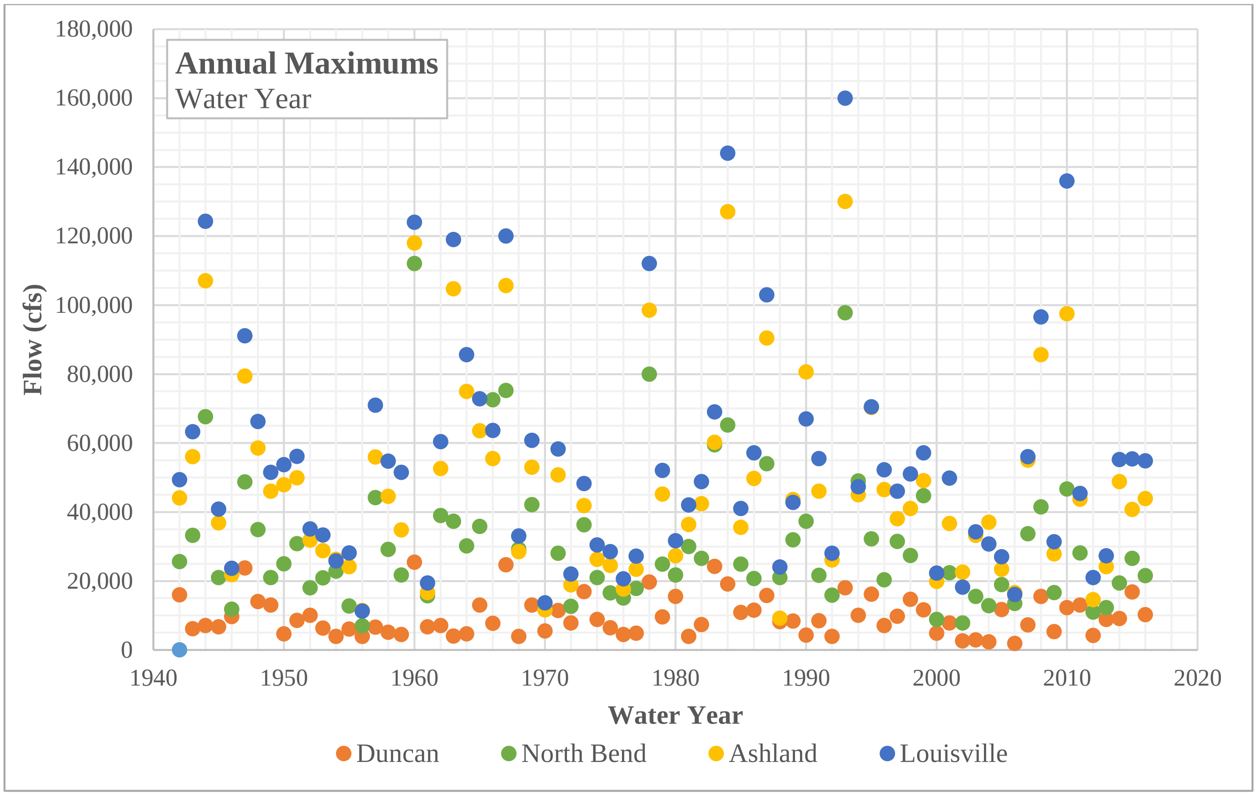


Figure 8. Annual peak flows on the Lower Platte River.

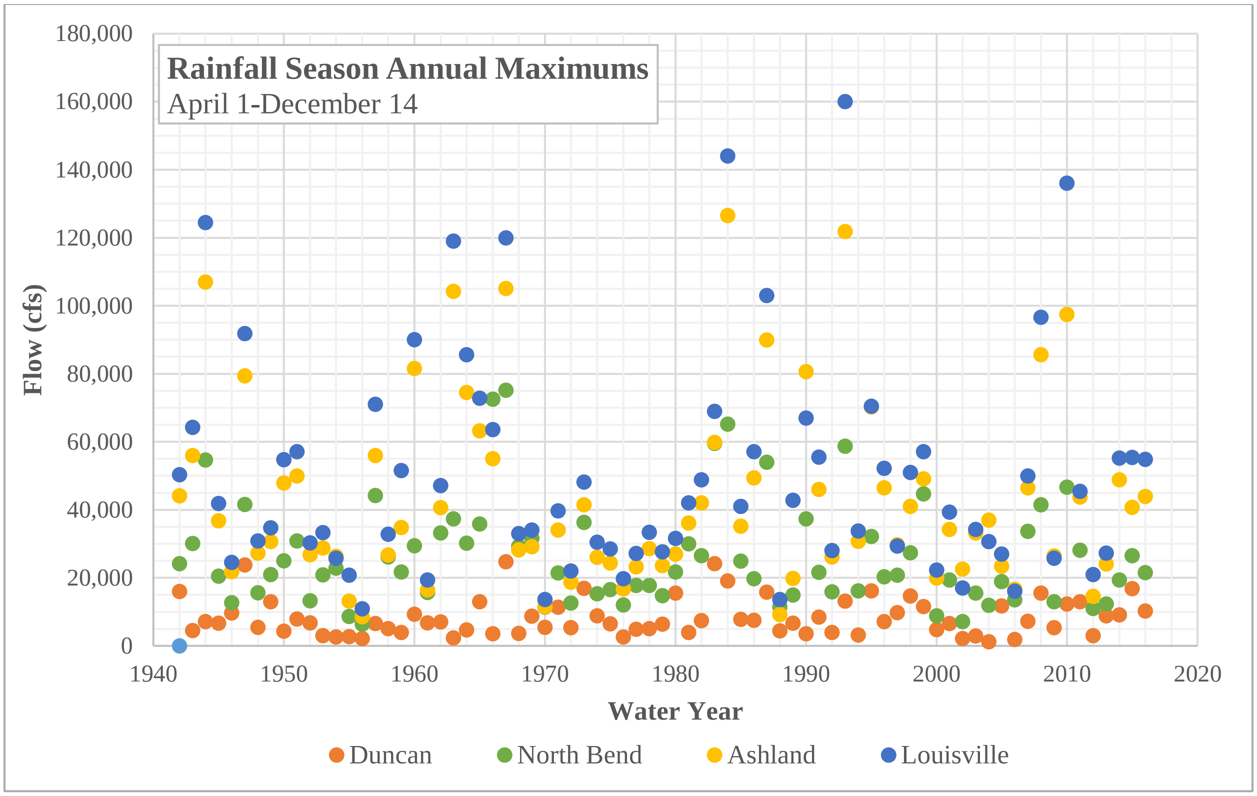


Figure 9. Rainfall season annual peak flows for the Lower Platte River.

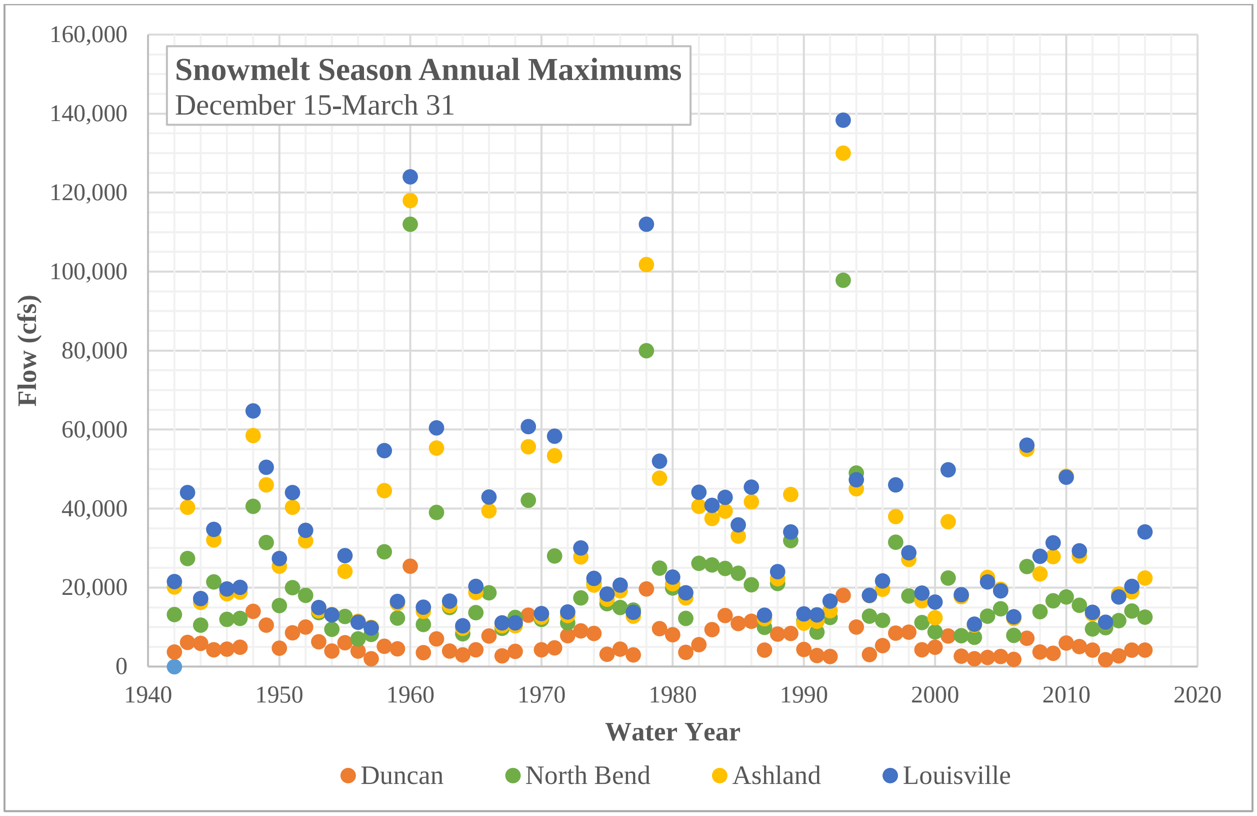


Figure 10. Snowmelt season annual peak flows for the Lower Platte River.

4.2 Nonstationarity Assessment

A climate change assessment was performed in accordance with Engineering-Construction Bulletin (ECB) No. 2016-25 (USACE, 2016). The full climate change assessment is provided in Appendix E. One of the primary assumptions of flood frequency analysis is that hydrologic processes are relatively unchanging in time. However, recent scientific evidence shows that climate change and human modifications to some watersheds are undermining this assumption. A test of nonstationarity of the available time-series peak flows was used to check if this assumption is reasonable. If any nonstationarities are detected in the time-series, Bulletin 17C recommends employing time-varying parameters or other appropriate techniques to address the nonstationarity (USGS, 2018).

Nonstationarity detection was performed according to ETL1110-2-3 (USACE, 2017). The USACE Nonstationarity Detection (NSD) tool analyzed 3 types of nonstationarities (mean, variance, and distribution) using 11 tests. With assistance from the Cold Regions Research and Engineering Laboratory (CRREL), the complete records (1942-2016) were tested for nonstationarities. A streamflow gage can hold the assumption of nonstationarity if a detected change point demonstrates consensus among multiple change point detection methods, robustness between changes in statistical properties, and for which an operationally significant change in magnitude is determined. When two or more detected tests target the same statistical property for a change point, detection methods demonstrate consensus while tests targeting changes in two or more different statistical properties indicate robustness between changes in statistical properties (USACE, 2017). Table 9 summarizes the results for the four streamgages. While there was one NSD test triggered at the Duncan gage and one at the North Bend gage, it is not recommended to assume a strong nonstationarity without consensus of multiple tests. Therefore, flood frequency analysis can be performed assuming stationarity.

Table 9. NSD results. No consensus nonstationarities were detected in the datasets.

Streamgage	USGS Station ID	Nonstationarity Tests Triggered	Type of Triggered Test	Year of Nonstationarity
Duncan	06774000	1	Distribution-based	2001
North Bend	06796000	1	Mean-based	1998
Ashland	06801000	0	N/A	N/A
Louisville	06805500	0	N/A	N/A

4.3 Flood Frequency for Single Population

Flood frequency analysis for the Lower Platte River was completed using HEC-SSP v2.2 to perform Bulletin 17C procedures for the extended peak flood records for a single population. Bulletin 17C uses an Expected Moments Algorithm (EMA) which allows systematic records, historical flood information, and paleoflood information to be used in the analysis. No historic or paleoflood information was included in the analysis due to the impact of regulation and to keep consistency in record length amongst the gages. The multiple Grubbs-Beck test did not identify any low outliers in any of the records. WRIR 99-4032 recommends the use of station skew for regulated streamflow because the flow characteristics are based on imposed criteria, not on the characteristics of the drainage basin (USGS, 1999). A comparison of all-season station skews from the Western Sarpy/Clear Creek FRS and the updated study is shown in Table 10.

Table 10. Comparison of all-season station skews.

Station	**All-Season Station Skew**	
	Western Sarpy/ Clear Creek FRS	**Updated Study**
Duncan	0.364	-0.146
North Bend	0.299	0.157
Ashland	-0.155	-0.042
Louisville	-0.091	-0.071
Mean Value	0.104	-0.026

Results of the updated single population frequency analysis using data from 1942-2016 are shown in Figure 11. The upper limit of the 68% confidence interval of the 100-year flood flow represents the 1%+ (100+ year return interval) flood flow. Computed all-season flood flow frequency is shown in Table 11. Complete single population flood flow frequency results for each of the four study locations are shown in Appendix B.

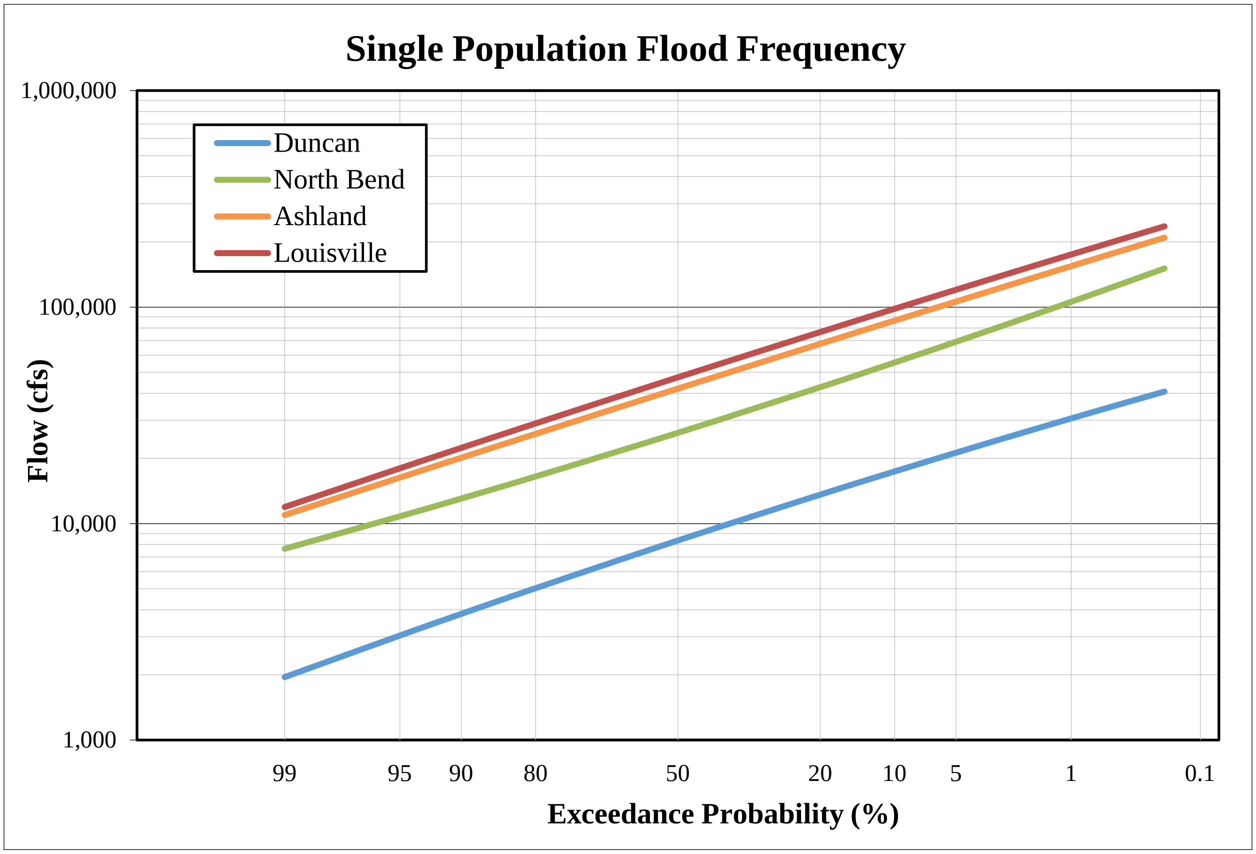


Figure 11. Single population flood flow frequency.

Table 11. Single population flood flow frequency results at study locations.

Return Interval (yrs)	Computed Flow (cfs)			
	Duncan	**North Bend**	**Ashland**	**Louisville**
500	40,700	150,800	209,200	236,000
200	34,800	124,000	177,300	200,400
100+	36,800	132,300	187,600	211,900
100	30,600	105,700	154,600	175,000
50	26,500	89,100	133,000	150,700
25	22,500	73,800	112,400	127,500
10	17,400	55,400	86,600	98,200
5	13,600	42,600	67,700	76,700
2	8,400	26,200	42,000	47,400

4.4 Flood Frequency for Mixed Population

Flooding in the Platte River watershed is caused primarily by two meteorological events: rainfall and snowmelt. When there are two or more types of distinct and generally independent causes of floods, it may be advisable to segregate the flood data by cause, analyzing and computing separate curves for each type of event and then combining the curves into an overall analysis of the flood frequency at the site (USGS, 2018). Previous studies, including the Western Sarpy/Clear Creek FRS (USACE, 2000) and the Union Dike study (USACE, 1997), have utilized a mixed population analysis to compute flood frequency on the Lower Platte River.

To compute the mixed population discharge-frequency, two separate flood frequency analyses must be performed on the rainfall and snowmelt driven flood peak datasets for each gage location according to Bulletin 17C (USGS, 2018). The curves are combined using the union probability theorem, as described in Chapter 10 of EM 1110-2-1415 (USACE, 1993), and applied to this study using the below equation.

$$P_{mixed} = P_{rainfall} + P_{snowmelt} - (P_{rainfall} * P_{snowmelt})$$

Where P_{mixed} is the combined probability of a given discharge being exceeded, $P_{rainfall}$ is the probability of a given discharge being exceeded in the rainfall season, and $P_{snowmelt}$ is the probability of a given discharge being exceeded in the snowmelt season. Computations were performed in HEC-SSP v2.2 and verified in Excel using peak discharge frequency curves for the rainfall and snowmelt flood seasons. Mixed population confidence limits were computed by applying the above equation to the confidence limits of the rainfall and snowmelt flood season frequency analyses.

No historic or paleoflood information was included in the analysis due to the impact of regulation and to keep consistency in record length amongst gages. The Multiple Grubbs-Beck Test identified one low outlier in the Duncan station rainfall season peak flow record. The Western Sarpy/Clear Creek FRS and the Union Dike study both utilized station skew weighted with regional skew to compute an adopted skew. For this study, station skew was considered sufficient because of the consistent record lengths for each season at each gage. The station skews for each season do not vary greatly between gages and between studies. Therefore, the use of station skew is sufficient for mixed population frequency analysis. A comparison of skews between the two previous USACE studies and the updated computations are shown in Table 12 and Table 13. While the snowmelt season station skew is higher at North Bend than the other stations, it is consistent with previous studies.

Table 12. Comparison of snowmelt flood season station skews computed for previous and current studies.

Station	**Snowmelt Season Station Skew**		
	Union Dike	**Western Sarpy/ Clear Creek FRS**	**Update**
Duncan	0.433	0.433	0.157
North Bend	0.858	0.919	1.095
Ashland	0.675	0.675	0.615
Louisville	0.570	0.570	0.548
Mean Value	0.634	0.649	0.604

Table 13. Comparison of rainfall flood season station skews computed for previous and current studies.

Station	**Rainfall Season Station Skew**		
	Union Dike	**Western Sarpy/ Clear Creek FRS**	**Update**
Duncan	0.407	0.408	-0.136
North Bend	0.237	0.189	0.042
Ashland	0.276	0.063	-0.015
Louisville	0.002	0.002	0.13
Mean Value	0.230	0.165	0.005

Results of the mixed population flood frequency analysis are shown in Figure 12. The upper limit of the 68% confidence interval of the 100-year flood flow represents the 1%+ (100+ year return interval) flood flow. Computed mixed population flood flow frequency at each of the study locations are shown in Table 14. Full mixed population flood flow frequency results for each gage are shown in Appendix C.

Table 14. Mixed population flood flow frequency results at study locations.

Return Interval (yrs)	**Computed Flow (cfs)**			
	Duncan	**North Bend**	**Ashland**	**Louisville**
500	43,400	203,900	266,400	306,300
200	36,400	144,800	210,400	243,000
100+	41,200	172,500	246,800	283,200
100	31,600	113,900	176,100	202,900
50	27,000	91,000	146,600	168,100
25	22,800	73,300	120,700	137,600
10	17,500	54,500	90,600	102,400
5	13,700	42,400	70,000	78,600
2	8,700	27,300	43,700	49,000

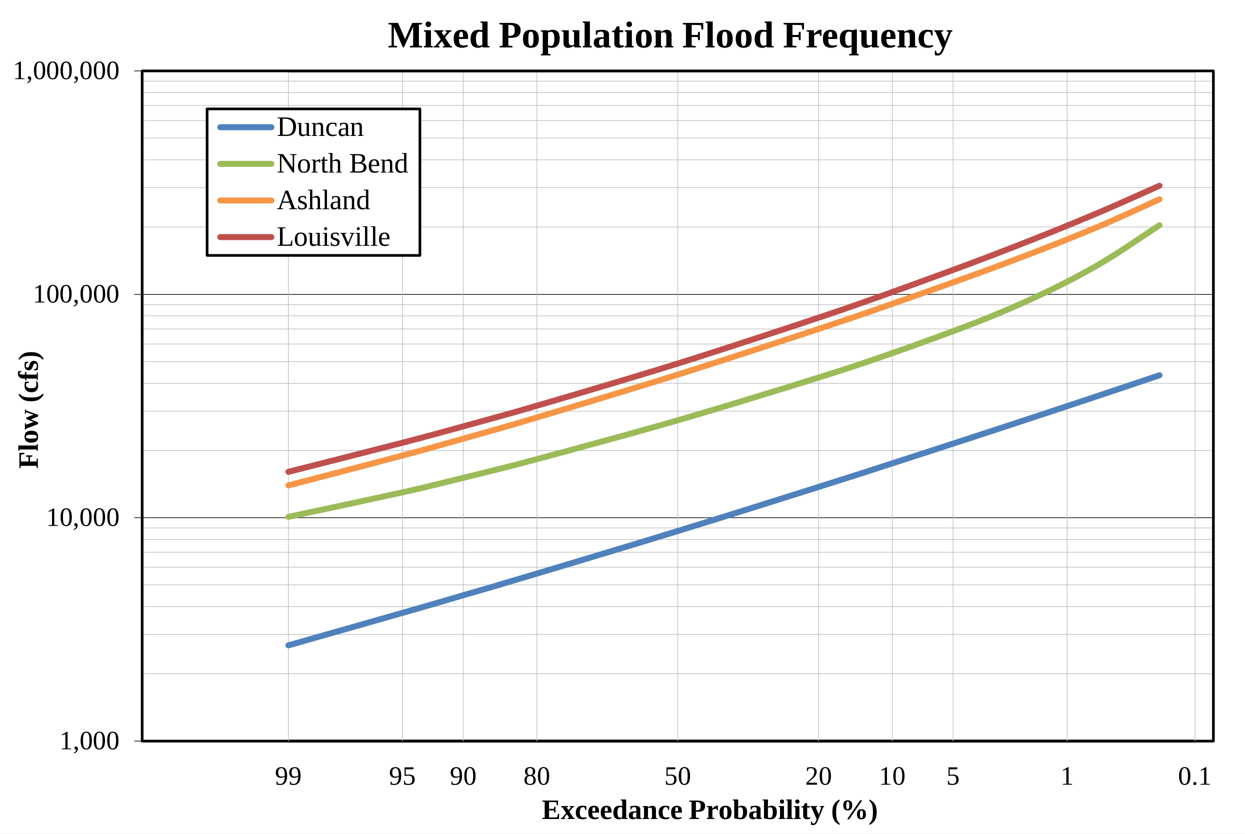


Figure 12. Mixed population flood flow frequency.

5 Single and Mixed Population Flood Frequency Comparison

Flood flow frequency was computed at the four Lower Platte River study stations using single and mixed population analyses. A comparison of flood flow frequency resulting from each computation is shown in Figure 13 and Table 15. In general, computed flood flow frequency is higher for the mixed population analyses. As is predicted in EM 1110-2-1415, the mixed population curve fits the single population curve only in the middle parts of the curve and has a more positive skew. At the lower end of the curve, the mixed population frequency analysis results in higher flow values than those of the single population analysis due to the inclusion of many smaller events. The upper end of the mixed population frequency curve has a higher slope than that of the single population again due to the inclusion of many more events in the seasonal annual maximum series (USACE, 1993). The higher slope at the upper end of the curve can also be attributed to the high skew computed for the snowmelt season, as shown in Table 12 and Table 13. Full results of the single population analysis are shown in Appendix B, and mixed population results are shown in Appendix C.

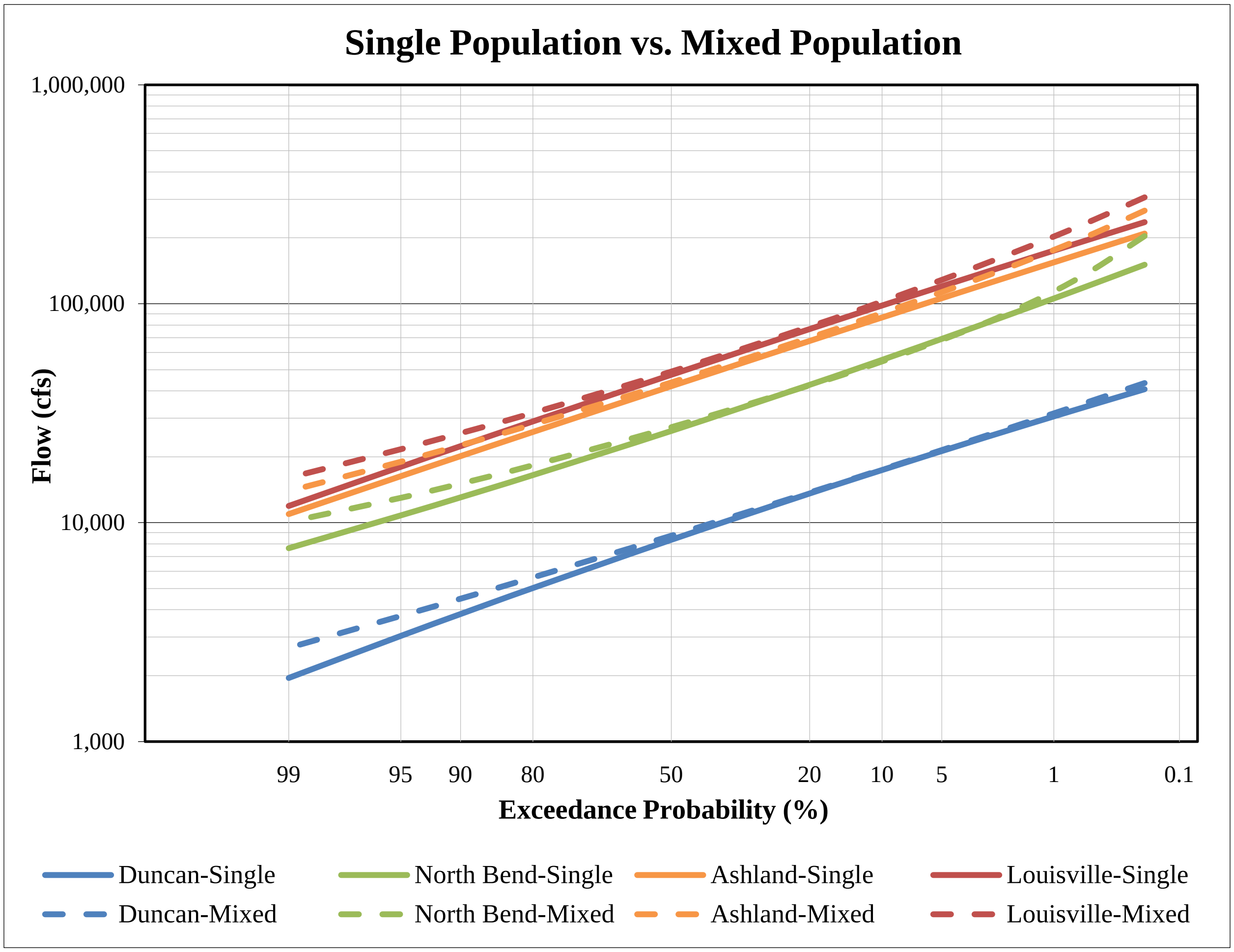


Figure 13. Comparison of single and mixed population flood flow frequency.

Table 15. Comparison of single and mixed population flood flow frequency

Return Interval (yrs)	**Flow (cfs)**							
	Duncan		**North Bend**		**Ashland**		**Louisville**	
	Single	**Mixed**	**Single**	**Mixed**	**Single**	**Mixed**	**Single**	**Mixed**
500	40,700	43,400	150,800	203,900	209,200	266,400	236,000	306,300
200	34,800	36,400	124,000	144,800	177,300	210,400	200,400	243,000
100+	36,800	41,200	132,300	172,500	187,600	246,800	211,900	283,200
100	30,600	31,600	105,700	113,900	154,600	176,100	175,000	202,900
50	26,500	27,000	89,100	91,000	133,000	146,600	150,700	168,100
25	22,500	22,800	73,800	73,300	112,400	120,700	127,500	137,600
10	17,400	17,500	55,400	54,500	86,600	90,600	98,200	102,400
5	13,600	13,700	42,600	42,400	67,700	70,000	76,700	78,600
2	8,400	8,700	26,200	27,300	42,000	43,700	47,400	49,000

6 Recommendation

Flood flow frequency was computed using two different methods: single and mixed population. Single population utilizes annual maximums at the streamgage to compute flood flow frequency according to Bulletin 17C methods (USGS, 2018). Mixed population utilizes annual rainfall and snowmelt season peak flows to compute flood flow frequency for each season according to Bulletin 17C (USGS, 2018) and combines the two frequency curves using the Union Probability Theorem as described in EM 1110-2-1415 (USACE, 1993). A comparison of flood flow frequency resulting from both methods is shown in Figure 13 and Table 15.

In general, the mixed population analysis results in higher flows at the specific return intervals defined in Table 15, which is considered a more conservative result. A primary assumption of flood frequency analysis is that the sample population is identically distributed, or caused by the same flood mechanism. The single population analysis does not account for this assumption, as floods in the Platte River watershed are caused by both rainfall and snowmelt. Therefore, results of the mixed population frequency analysis are recommended for adoption as the flood flow frequency at the four Lower Platte River study stations. Recommended adopted flood flow frequency for the Lower Platte River is shown in Table 16.

Table 16. Recommended adopted flood flow frequency on the Lower Platte River.

Return Interval (yrs)	Flood Flow Frequency (cfs)			
	Duncan	**North Bend**	**Ashland**	**Louisville**
500	43,400	203,900	266,400	306,300
200	36,400	144,800	210,400	243,000
100+	41,200	172,500	246,800	283,200
100	31,600	113,900	176,100	202,900
50	27,000	91,000	146,600	168,100
25	22,800	73,300	120,700	137,600
10	17,500	54,500	90,600	102,400
5	13,700	42,400	70,000	78,600
2	8,700	27,300	43,700	49,000

A qualitative climate change assessment was conducted to analyze the impacts of climate change on the watershed. The purpose of the qualitative climate change assessment is to enhance climate preparedness and resilience by incorporating relevant information about observed and expected climate change impacts in hydrologic analyses. The climate change assessment, included in Appendix E, concluded that the Platte River watershed is at risk of increased flood frequency in the future. A key assumption of flood frequency analysis is that the data are stationary through time, and results of the nonstationarity detection test support this assumption.

7 Comparison with Previous Studies

Previous studies have utilized both techniques, single and mixed population, to compute flood flow frequency. WRIR 99-4032 computed flood frequency as a single population (USGS, 1999). The Western Sarpy/Clear Creek FRS employed a mixed population approach to determine flood frequency (USACE, 2000). A comparison of flood frequency computed in all previous studies and the recommended update is shown in Table 18. In general, the recommended flood frequency curves are lower than the combined season frequency curves computed for the Western Sarpy/Clear Creek FRS, as shown in Figure 14. A key contributor to the lower flood frequencies is the addition of 22 years of data from 1995-2016 that, on average, observed lower peak flows than the previous 53 years, as shown in Table 17.

Table 17. Average flows over periods used in various studies.

Years of Data	Average Annual Peak Flow (cfs)			
	Duncan	**North Bend**	**Ashland**	**Louisville**
1942-1994	9,970	34,427	50,296	57,928
1995-2016	9,106	24,018	42,004	48,120
1942-2016	9,717	31,060	46,495	54,556

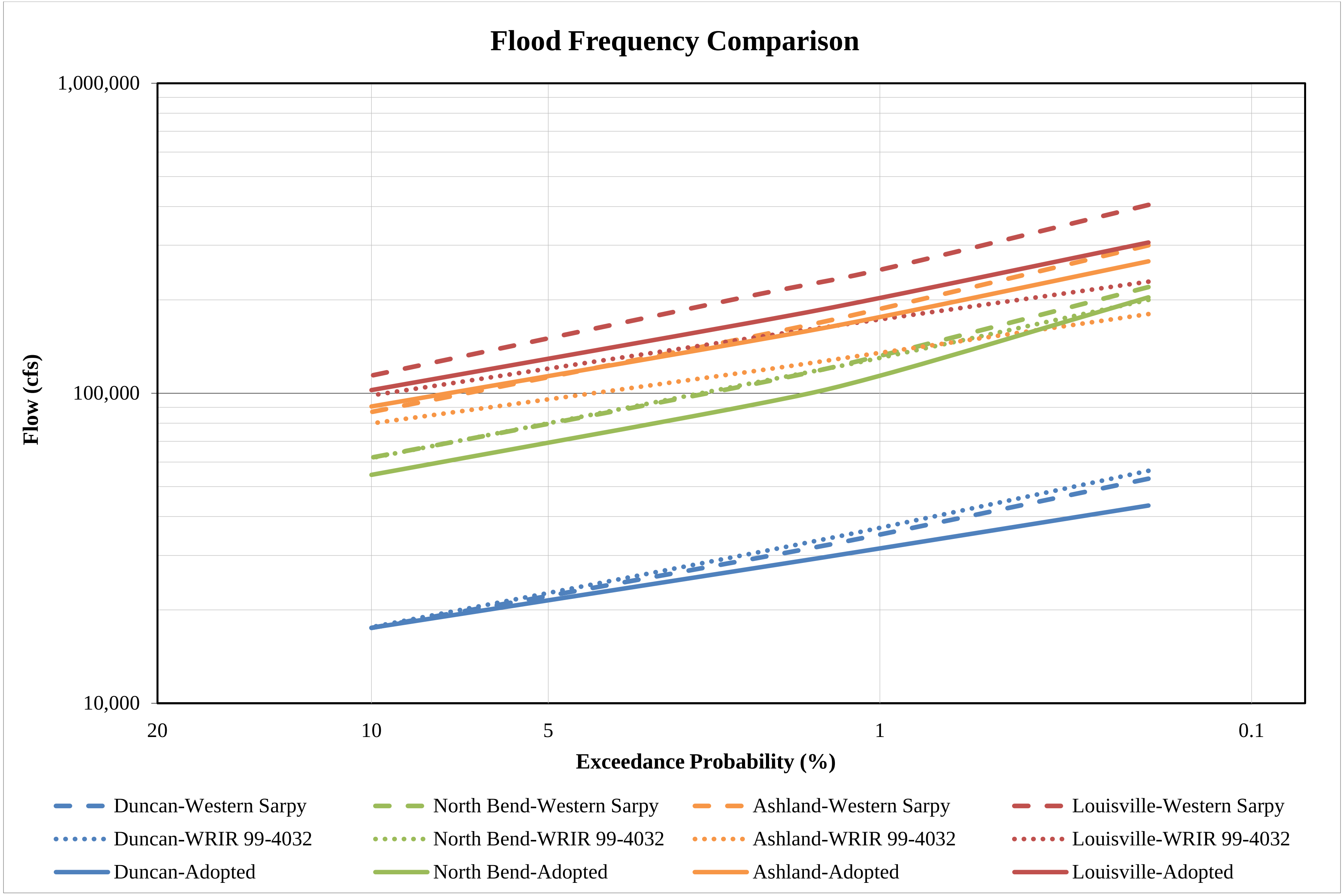


Figure 14. Comparison of previous flood frequency studies and the recommended update. The Western Sarpy and adopted flood frequency utilized a mixed population approach (USACE, 2000). WRIR 99-4032 utilized a single population (USGS, 2018).

Table 18. Comparison of computed flood frequency at Lower Platte River study gages.

Location/ Return Period	**Single Population Analysis**							**Mixed Population Analysis**		
	Level B Study[1]	**Flood Insurance Studies[2]**	**WRI 76-109[3]**	**1996 Recon Report[4]**	**Western Sarpy/ Clear Creek FRS[5]**	**WRIR 99-4032[6]**	**Updated Study**	**Union Dike Study[7]**	**Western Sarpy/ Clear Creek FRS[5]**	**Updated Study[8]**
Duncan										
10-year	18,100	-	20,600	17,600	17,600	17,600	17,400	-	17,500	17,500
50-year	30,900	-	30,900	28,600	28,600	30,200	26,500	-	29,000	27,000
100-year	37,700	-	35,300	34,100	34,100	36,800	30,600	-	35,000	31,600
500-year	-	-	-	49,300	49,300	56,200	40,700	-	53,000	43,400
North Bend										
10-year	58,300	56,400	61,400	59,200	63,000	61,800	55,400	63,000	62,000	54,500
50-year	98,100	98,100	102,000	96,400	103,000	107,000	89,100	112,000	106,000	91,000
100-year	119,000	119,000	122,000	115,000	124,000	130,000	105,700	139,000	132,000	113,900
500-year	-	200,000	-	186,000	181,000	200,000	150,800	234,000	220,000	203,900
Ashland										
10-year	84,200	84,200	74,000	85,100	89,500	79,900	86,600	87,000	87,000	90,600
50-year	135,000	135,000	113,000	132,000	145,000	117,000	133,000	155,000	151,000	146,600
100-year	160,000	160,000	130,000	155,000	172,000	135,000	154,600	190,000	187,000	176,100
500-year	-	238,000	-	212,000	245,000	180,000	209,200	325,000	300,000	266,400
Louisville										
10-year	93,000	93,000	106,500	91,700	96,800	98,400	98,200	-	114,000	102,400
50-year	150,000	150,000	180,000	144,000	158,000	150,000	150,700	-	205,000	168,100
100-year	180,000	180,000	200,000	168,000	188,000	173,000	175,000	-	250,000	202,900
500-year	-	270,000	-	232,000	270,000	229,000	236,000	-	405,000	306,300

[1] Missouri River Basin Commission, 1975

[2] FEMA, 1980

[3] USGS, 1976

[4] USACE, 1996

[5] USACE, 2000

[6] USGS, 1999

[7] USACE, 1997

[8] Recommended updated flood frequency

8 Annual Flood Frequency between Gages

WRIR 99-4032 computed peak flow frequency for the Platte River using streamgage data, shown in Figure 15. Flow frequency values for the Loup River at Columbus (USGS 06794500) were larger than those estimated graphically, resulting in a discontinuity in the plot at that point. Peak flow frequency values at the Elkhorn River were extrapolated from the values for the Platte River at North Bend based on estimated drainage areas resulting in a discontinuity in the plot at the point. Platte River flows at Ashland were not used to inform the computation because only 18 years of peak flow data existed. Peak flow frequency for the Salt Creek at Ashland (USGS 06805000) was computed based on only 21 years of peak flow data, and therefore, was not considered a reliable way to estimate peak flow frequency on the Platte River at the Salt Creek confluence (USGS, 1999).

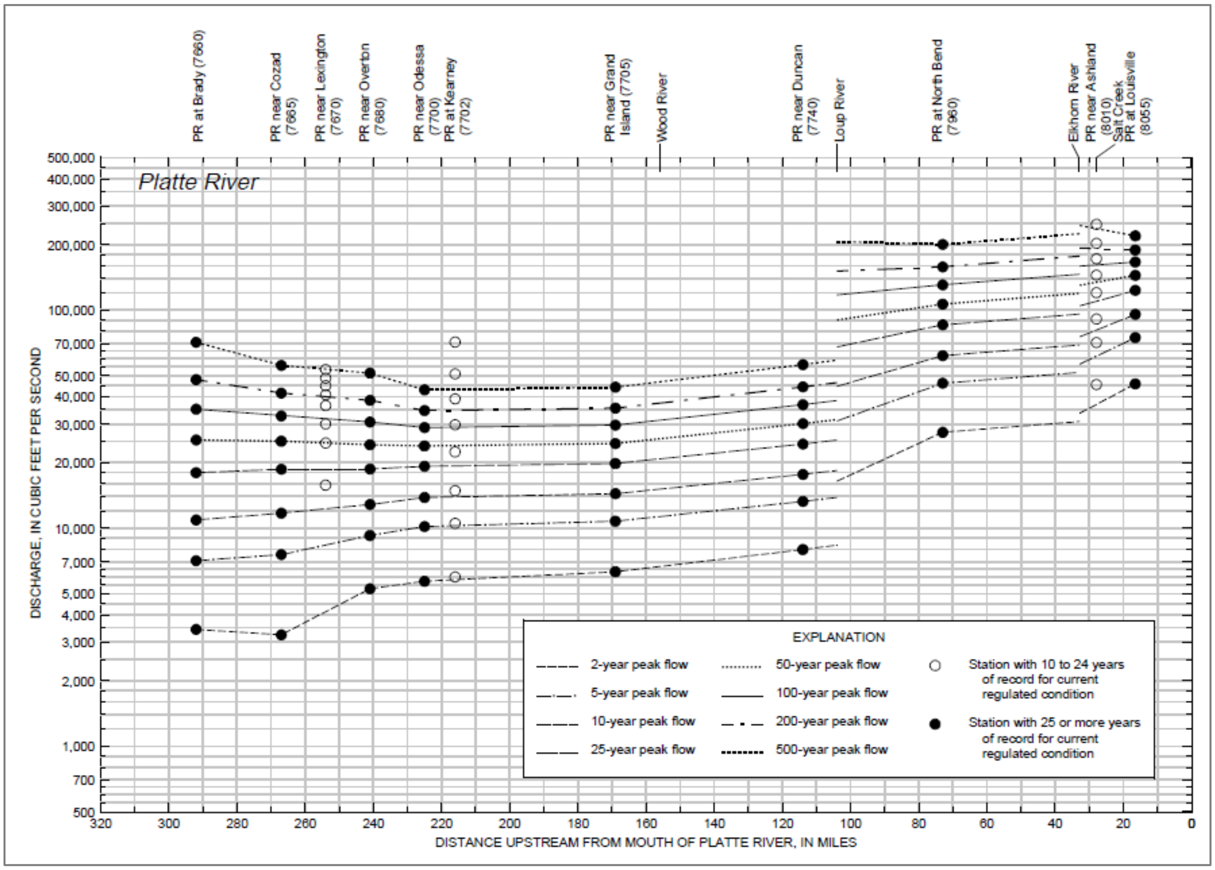


Figure 15. Peak flow frequency for the Platte River in Nebraska (USGS, 1999).

Detailed assessment of peak flood frequency between gages such as at tributary confluences was outside the scope of this study; however, a simplified approach was applied leveraging results from WRIR 99-4032 to aid in determination of updated flood frequency by river mile between gages based on the updated recommended flood flow frequency on the Lower Platte River. Upstream of the confluence with the Loup River, flow was determined by computing the percent difference between the flood frequencies at Duncan and the Loup River confluence and applying that percent difference to the recommended updated flood frequency at Duncan. WRIR 99-4032 reported flow frequency on the Loup River at Columbus computed using data up to 1978 when the gage was discontinued (USGS, 1999). In the absence of more recent peak flow data or a detailed flow frequency study at the gage, the flow frequency reported in WRIR 99-4032 for the Loup River at Columbus was again adopted as the flow downstream of the Loup River confluence with the Platte River. The 100-, 200-, and 500-year frequency flows were reduced slightly so as not to decrease frequency flows travelling downstream to the North Bend streamgage.

Frequency flows upstream of the Elkhorn River confluence were estimated using the same techniques as the Loup River confluence, utilizing the upstream percent difference from North Bend. WRIR 99-4032 did not utilize flow frequency at Ashland to inform flow frequency bat the Elkhorn River confluence due to the lack of peak flow data at the site. However, the updated study utilized 75 years of data to compute flood flow frequency, and the Ashland streamflow gage is less than 4 miles downstream of the Elkhorn River confluence. Therefore, flow frequency at Ashland was adopted as the flow frequency downstream of the Elkhorn River confluence. To be consistent with WRIR 99-4032, flows on the Salt Creek at Ashland were not used to inform Platte River flows given the lack of peak flow data at that site (21 years).

Backwater impacts at the Loup and Elkhorn Rivers' confluences with the Platte River were not assessed as part of this study. Flow frequency for several miles upstream of these confluences are likely impacted and should be assessed in greater detail prior to any application of reported numbers.

A comparison of values at the Loup River and Elkhorn River confluences from WRIR 99-4032 to recommended updates are shown in Table 19. Recommended updated flow frequency on the Platte River from Duncan to Louisville is shown in Figure 16. Flow frequency at each 0.5 mile interval along the Lower Platte study area is summarized in Table 39 in Appendix D.

Table 19. Comparison of confluence flows computed in WRIR 99-4032 and the recommended update.

Return Period (yrs)	**Loup River Confluence Flow (cfs) River Mile 102.5**				**Elkhorn River Confluence Flow (cfs) River Mile 32.3**			
	Upstream		**Downstream**		**Upstream**		**Downstream**	
	WRIR 99-4032	**Update**	**WRIR 99-4032[1]**	**Update[1]**	**WRIR 99-4032**	**Update**	**WRIR 99-4032**	**Update[2]**
2	8,100	8,900	16,400	16,400	30,700	30,500	45,400	43,700
5	13,500	13,900	31,000	31,000	51,800	47,600	70,900	70,000
10	18,000	17,900	44,700	44,700	69,600	61,400	91,000	90,600
25	25,100	23,500	67,800	67,800	96,100	82,300	120,100	120,700
50	31,400	28,100	90,000	90,000	119,500	101,700	145,300	146,600
100	38,700	33,300	117,000	113,900	146,600	128,500	171,900	176,100
200	46,500	38,000	151,000	144,800	177,500	162,600	202,500	210,400
500	58,800	45,400	206,000	203,900	223,700	228,100	248,400	266,400

[1] Adopted Loup River at Columbus flood flow frequency (USGS, 1999)

[2] Adopted updated Platte River at Ashland annual flood flow frequency

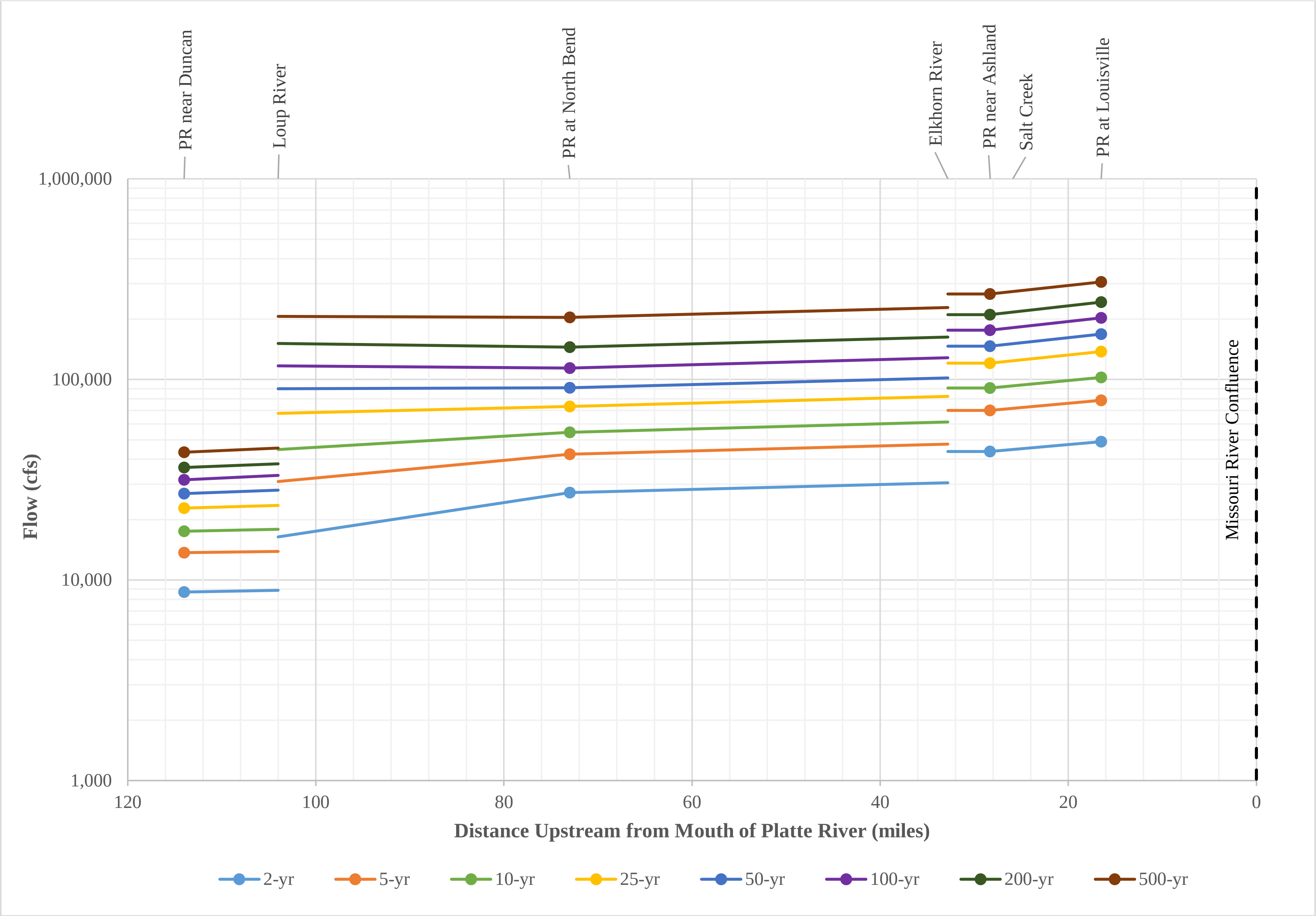


Figure 16. Peak flow frequency on the Lower Platte River estimated from streamflow gaging data.

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Appendix A: Annual Maximum Streamflow Data

Table 20. Combined extended record annual peak flows on the Lower Platte River.

Year	**Annual Maximum Flow (cfs)**			
	Duncan	**North Bend**	**Ashland**	**Louisville**
1942	16,000	24,640	44,100	49,873
1943	6,100	30,507	56,000	63,591
1944	7,090	54,425	107,000	122,861
1945	6,700	21,471	36,800	41,489
1946	4,430	13,124	21,800	24,358
1947	23,800	41,684	79,400	90,704
1948	14,000	40,417	58,500	64,968
1949	13,000	31,400	46,000	50,587
1950	4,700	25,000	47,900	54,248
1951	8,600	30,800	49,900	56,552
1952	10,000	18,000	32,060	36,059
1953	6,300	20,900	28,800	33,300
1954	3,960	22,800	27,110	25,800
1955	6,080	12,700	24,090	28,100
1956	3,920	7,000	11,440	11,270
1957	6,580	44,200	57,650	71,000
1958	5,140	29,100	44,510	54,700
1959	4,470	21,700	35,860	51,500
1960	25,400	112,000	117,990	124,000
1961	6,720	15,700	16,329	19,400
1962	7,120	39,000	54,982	60,400
1963	3,970	37,300	106,685	119,000
1964	4,680	30,200	75,867	85,600
1965	13,000	35,800	64,160	72,800
1966	7,720	72,500	55,789	63,600
1967	24,700	75,200	107,612	120,000
1968	3,890	29,200	28,294	33,000
1969	13,000	42,100	55,339	60,800
1970	5,480	12,000	12,567	13,650
1971	11,400	28,000	53,107	58,300
1972	7,800	12,600	18,598	22,000
1973	16,900	36,300	41,874	48,200
1974	9,580	21,000	42,873	49,310
1975	6,440	16,500	24,311	28,500
1976	4,440	15,000	19,183	20,630
1977	4,860	17,800	23,165	27,200
1978	19,700	80,000	100,715	112,000
1979	9,600	24,900	47,476	52,000
1980	15,500	21,700	27,053	31,600

Year	Annual Maximum Flow (cfs)			
	Duncan	North Bend	Ashland	Louisville
1981	3,890	30,000	36,314	42,000
1982	7,390	26,500	42,414	48,800
1983	24,200	59,500	60,697	69,000
1984	19,100	65,200	129,956	144,000
1985	10,900	24,900	35,420	41,000
1986	11,500	20,700	41,991	48,330
1987	17,110	54,350	105,623	117,570
1988	8,200	21,000	22,250	24,000
1989	8,400	31,900	43,600	42,800
1990	4,300	37,300	80,600	67,000
1991	8,480	21,600	46,000	55,500
1992	4,170	15,900	26,100	28,000
1993	18,000	97,800	130,000	160,000
1994	10,000	49,000	45,000	47,300
1995	16,200	32,200	70,300	70,500
1996	7,100	20,300	46,500	52,200
1997	9,770	31,500	38,000	46,000
1998	14,700	27,400	41,000	51,000
1999	11,600	44,700	49,100	57,100
2000	4,890	8,900	19,900	22,300
2001	7,770	22,390	36,680	49,800
2002	2,620	7,800	22,600	18,240
2003	2,880	15,500	33,200	34,200
2004	2,300	12,810	37,000	30,700
2005	11,700	18,900	23,400	27,000
2006	1,870	13,500	16,600	16,100
2007	7,260	33,700	55,020	56,040
2008	15,500	41,500	85,600	96,600
2009	5,230	22,500	42,500	37,000
2010	12,300	46,700	97,500	136,000
2011	13,000	28,100	43,700	45,400
2012	7,090	13,400	14,600	21,000
2013	8,850	12,300	17,480	26,070
2014	10,700	26,300	48,800	55,200
2015	16,800	26,500	40,700	55,400
2016	10,200	21,500	43,900	54,800

Table 21. Combined extended record rainfall season peak flows on the Lower Platte River.

Year	Rainfall Season Annual Maximum Flow (cfs)			
	Duncan	**North Bend**	**Ashland**	**Louisville**
1942	16,000	24,640	44,100	49,873
1943	4,960	30,507	56,000	63,591
1944	7,090	54,425	107,000	122,861
1945	6,700	20,959	36,800	41,489
1946	4,430	13,124	21,800	24,358
1947	23,800	41,684	79,400	90,704
1948	5,420	16,484	28,130	31,568
1949	13,000	21,000	31,550	35,476
1950	4,360	25,000	47,900	54,248
1951	7,840	30,800	49,900	56,552
1952	7,230	14,710	32,060	36,059
1953	3,000	20,900	28,800	33,300
1954	2,610	22,800	27,110	25,800
1955	4,260	8,750	13,560	20,780
1956	2,160	6,440	8,760	10,900
1957	6,580	44,200	57,650	71,000
1958	5,090	26,460	27,490	32,830
1959	4,470	21,700	35,860	51,500
1960	9,330	38,460	102,630	107,230
1961	6,720	15,700	16,329	19,400
1962	7,120	33,550	40,994	47,220
1963	2,330	37,300	106,685	119,000
1964	4,680	30,200	75,867	85,600
1965	13,000	35,800	64,160	72,800
1966	6,170	72,500	55,789	63,600
1967	24,700	75,200	107,612	120,000
1968	3,640	29,200	28,294	33,000
1969	8,845	32,010	29,235	34,060
1970	5,480	11,470	11,350	13,650
1971	11,400	21,680	34,276	39,720
1972	5,144	12,600	18,598	22,000
1973	16,900	36,300	41,874	48,200
1974	9,580	18,710	42,873	49,310
1975	6,440	16,500	24,311	28,500
1976	2,600	12,210	16,590	19,700
1977	4,860	17,800	23,165	27,200
1978	5,080	17,940	28,693	33,450
1979	6,400	14,970	23,579	27,670
1980	15,500	21,700	27,053	31,600

Year	Rainfall Season Annual Maximum Flow (cfs)			
	Duncan	North Bend	Ashland	Louisville
1981	3,890	30,000	36,314	42,000
1982	7,390	26,500	42,414	48,800
1983	24,200	59,500	60,697	69,000
1984	19,100	65,200	129,956	144,000
1985	7,830	24,900	35,420	41,000
1986	7,540	20,000	41,991	48,330
1987	15,800	54,000	91,878	103,000
1988	4,390	11,640	9,490	13,650
1989	6,650	15,100	20,400	42,800
1990	3,610	37,300	80,600	67,000
1991	8,480	21,600	46,000	55,500
1992	3,950	15,900	26,100	28,000
1993	13,180	59,360	125,560	160,000
1994	3,840	16,390	31,680	33,820
1995	16,200	32,200	70,300	70,500
1996	7,100	20,300	46,500	52,200
1997	9,770	21,040	30,660	29,390
1998	14,700	27,400	41,000	51,000
1999	11,600	44,700	49,100	57,100
2000	4,180	8,900	19,900	22,300
2001	6,610	19,400	34,200	39,350
2002	2,150	7,360	22,600	17,000
2003	2,880	15,500	33,200	34,200
2004	720	11,900	37,000	30,700
2005	11,700	18,900	23,400	27,000
2006	1,870	13,500	16,600	16,100
2007	7,260	33,700	46,500	49,900
2008	15,500	41,500	85,600	96,600
2009	5,230	22,500	42,500	37,000
2010	12,300	46,700	97,500	136,000
2011	13,000	28,100	43,700	45,400
2012	7,090	13,400	14,600	21,000
2013	8,850	12,300	17,480	26,070
2014	10,700	26,300	48,800	55,200
2015	16,800	26,500	40,700	55,400
2016	10,200	21,500	43,900	54,800

Table 22. Combined extended record snowmelt season peak flows on the Lower Platte River.

Year	**Snowmelt Season Annual Maximum Flow (cfs)**			
	Duncan	**North Bend**	**Ashland**	**Louisville**
1942	3,730	13,211	20,170	21,447
1943	6,100	27,363	40,350	44,137
1944	5,890	10,536	16,260	17,138
1945	4,250	21,471	32,030	34,707
1946	1,210	12,038	18,460	19,558
1947	4,920	12,291	18,830	19,966
1948	14,000	40,417	58,500	64,968
1949	10,510	31,400	46,000	50,587
1950	4,700	15,420	25,430	27,297
1951	8,600	20,020	40,350	44,137
1952	10,000	18,000	31,800	34,448
1953	6,300	13,680	14,180	14,863
1954	3,960	9,450	13,200	13,120
1955	6,080	12,700	24,090	28,100
1956	3,920	7,000	11,440	11,270
1957	2,020	8,120	9,930	9,810
1958	5,140	29,100	44,510	54,700
1959	1,680	12,260	16,020	16,460
1960	25,400	112,000	117,990	124,000
1961	3,570	10,680	14,054	15,020
1962	7,000	39,000	54,982	60,400
1963	3,970	14,920	15,474	16,570
1964	2,960	8,330	9,775	10,370
1965	4,250	13,060	18,855	20,270
1966	7,720	18,650	39,344	42,930
1967	2,730	9,700	10,439	11,090
1968	3,890	12,440	10,402	11,050
1969	13,000	42,100	55,339	60,800
1970	4,042	12,000	12,567	13,400
1971	4,552	28,000	53,107	58,300
1972	7,800	11,070	12,962	13,830
1973	9,902	17,410	27,735	30,050
1974	8,400	21,000	20,704	22,300
1975	3,130	15,920	17,111	18,360
1976	4,440	15,000	19,183	20,630
1977	2,960	14,300	12,852	13,710
1978	19,700	80,000	100,715	112,000
1979	9,600	24,900	47,476	52,000
1980	8,050	19,900	21,031	22,660

Year	**Snowmelt Season Annual Maximum Flow (cfs)**			
	Duncan	**North Bend**	**Ashland**	**Louisville**
1981	3,580	12,210	17,440	18,720
1982	5,590	26,120	40,413	44,120
1983	9,360	25,740	37,411	40,780
1984	12,970	24,870	39,236	42,810
1985	10,900	23,630	33,009	35,890
1986	11,500	20,700	41,561	45,400
1987	17,110	54,350	105,623	117,570
1988	8,200	21,000	22,250	24,000
1989	8,400	31,900	43,600	34,100
1990	4,300	11,550	11,000	13,350
1991	2,800	8,710	11,480	13,120
1992	4,170	12,440	14,180	16,570
1993	18,000	97,800	130,000	138,320
1994	10,000	49,000	45,000	47,300
1995	3,020	12,810	17,970	18,010
1996	5,310	11,700	19,560	21,700
1997	8,500	31,500	38,000	46,000
1998	8,730	17,910	27,140	28,860
1999	4,250	11,160	16,630	18,600
2000	4,890	8,830	12,350	16,340
2001	7,770	22,390	36,680	49,800
2002	2,620	7,800	17,730	18,240
2003	1,960	7,460	10,520	10,730
2004	2,300	12,810	22,620	21,460
2005	2,570	14,670	19,560	19,200
2006	1,790	7,550	9,480	9,000
2007	7,140	25,370	55,020	56,040
2008	3,730	13,930	23,480	27,900
2009	3,350	16,660	27,880	31,360
2010	5,960	17,660	48,170	47,930
2011	4,980	15,550	28,000	29,330
2012	4,180	9,540	13,330	13,710
2013	1,780	9,870	11,180	11,230
2014	2,680	11,670	18,340	17,650
2015	4,160	14,050	18,950	20,270
2016	4,160	12,560	22,380	34,100

Appendix B: Single Population Flood Flow Frequency Results

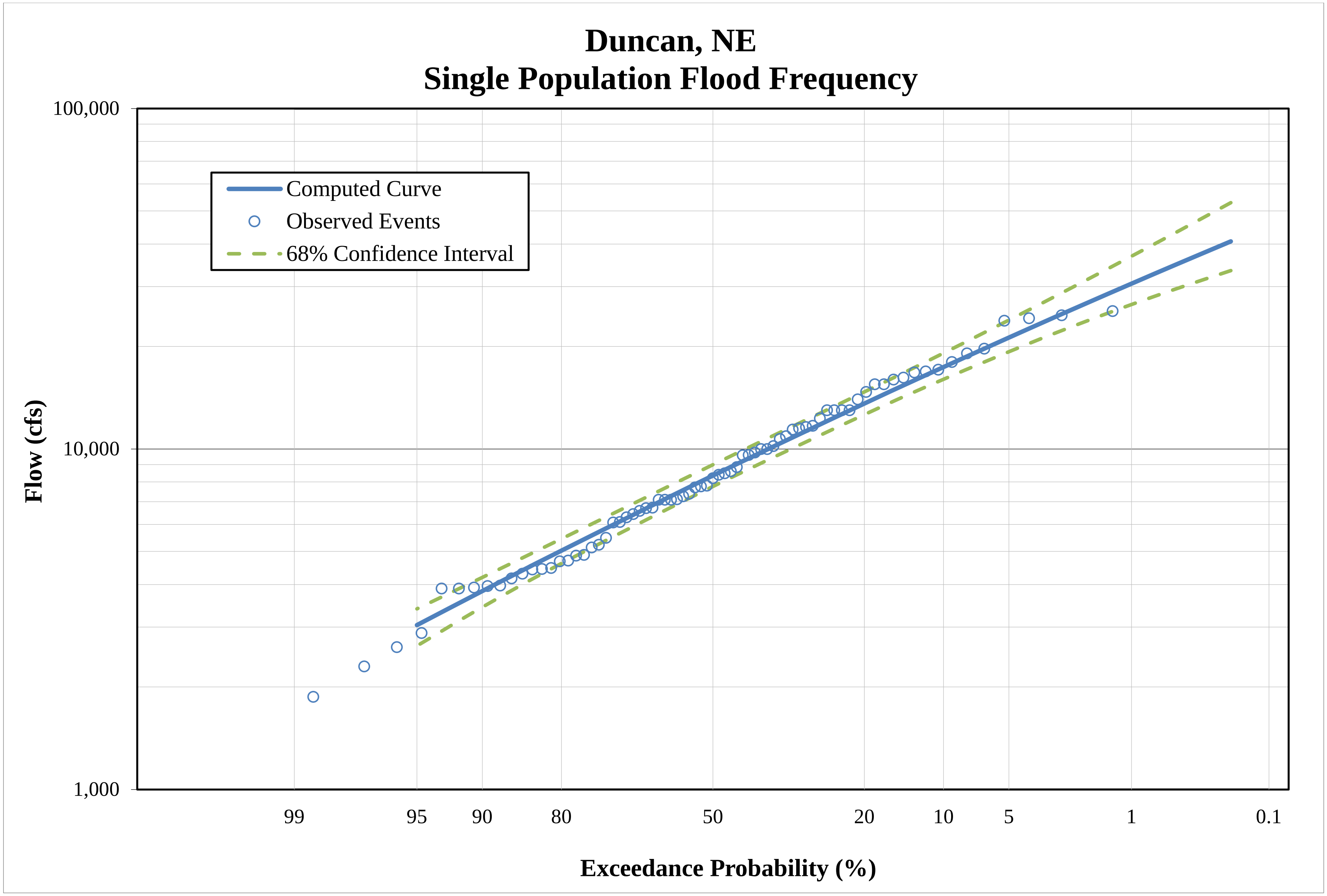


Figure 17. Single population flood flow frequency at Duncan.

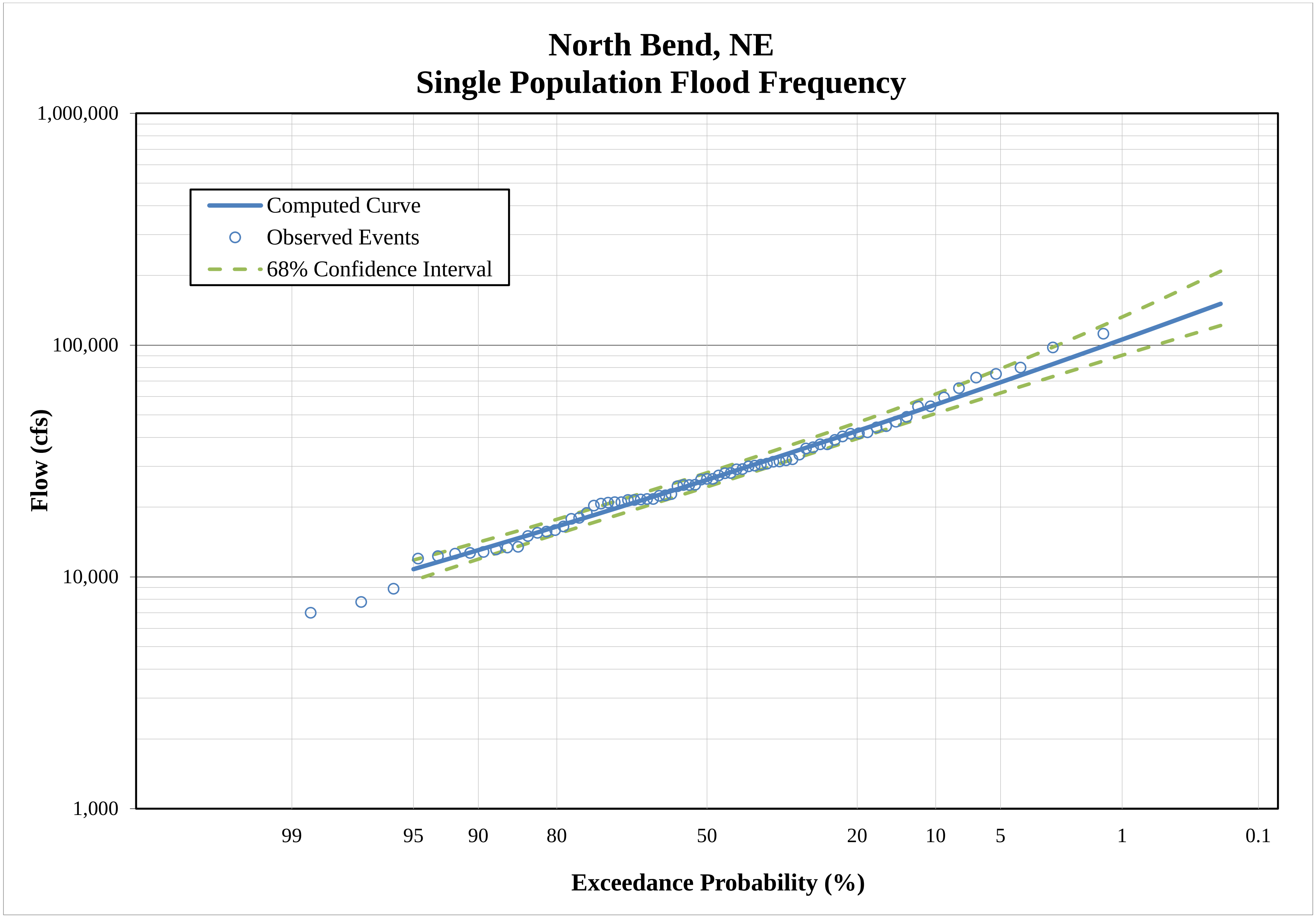


Figure 18. Single population flood flow frequency at North Bend.

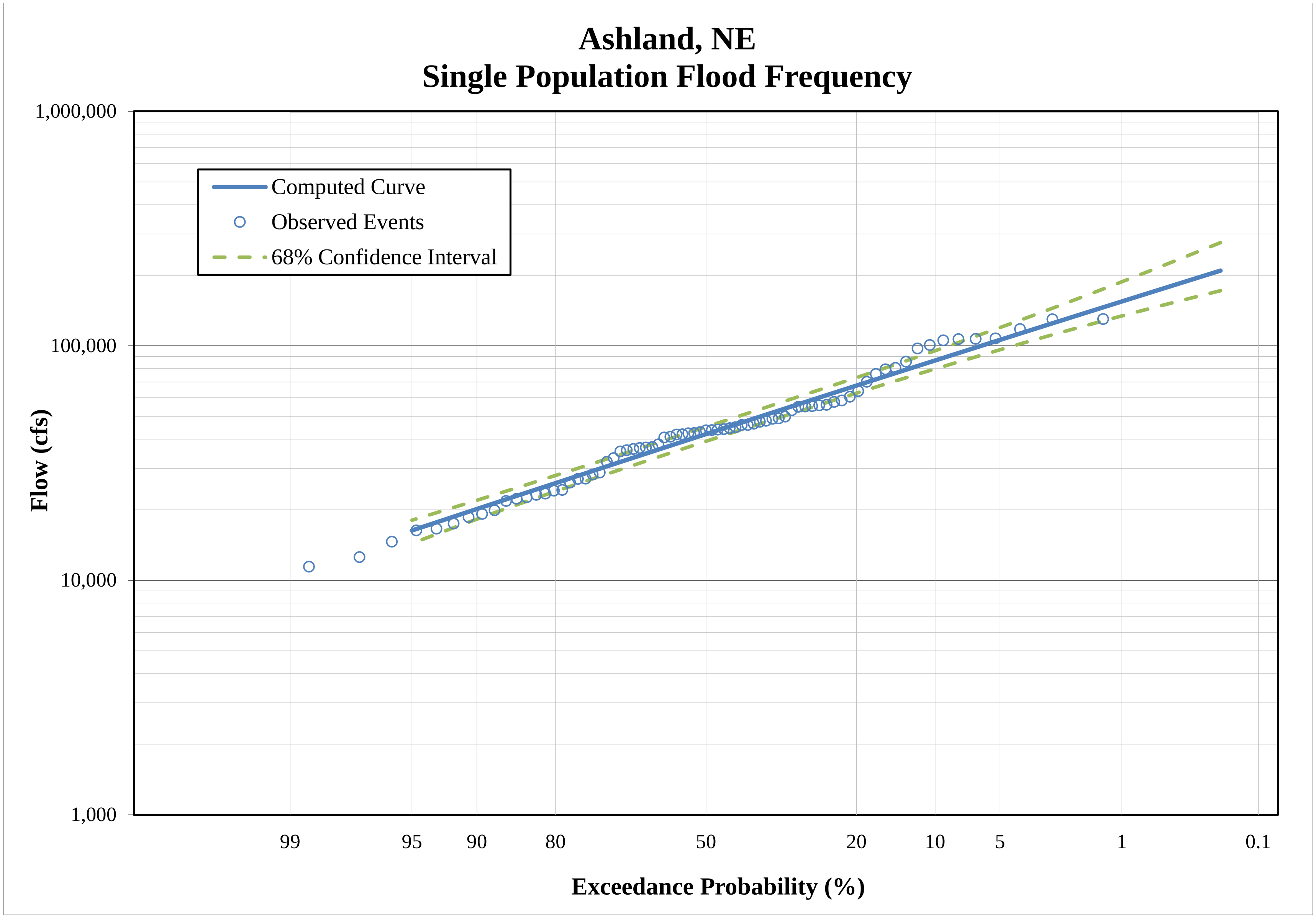


Figure 19. Single population flood flow frequency at Ashland.

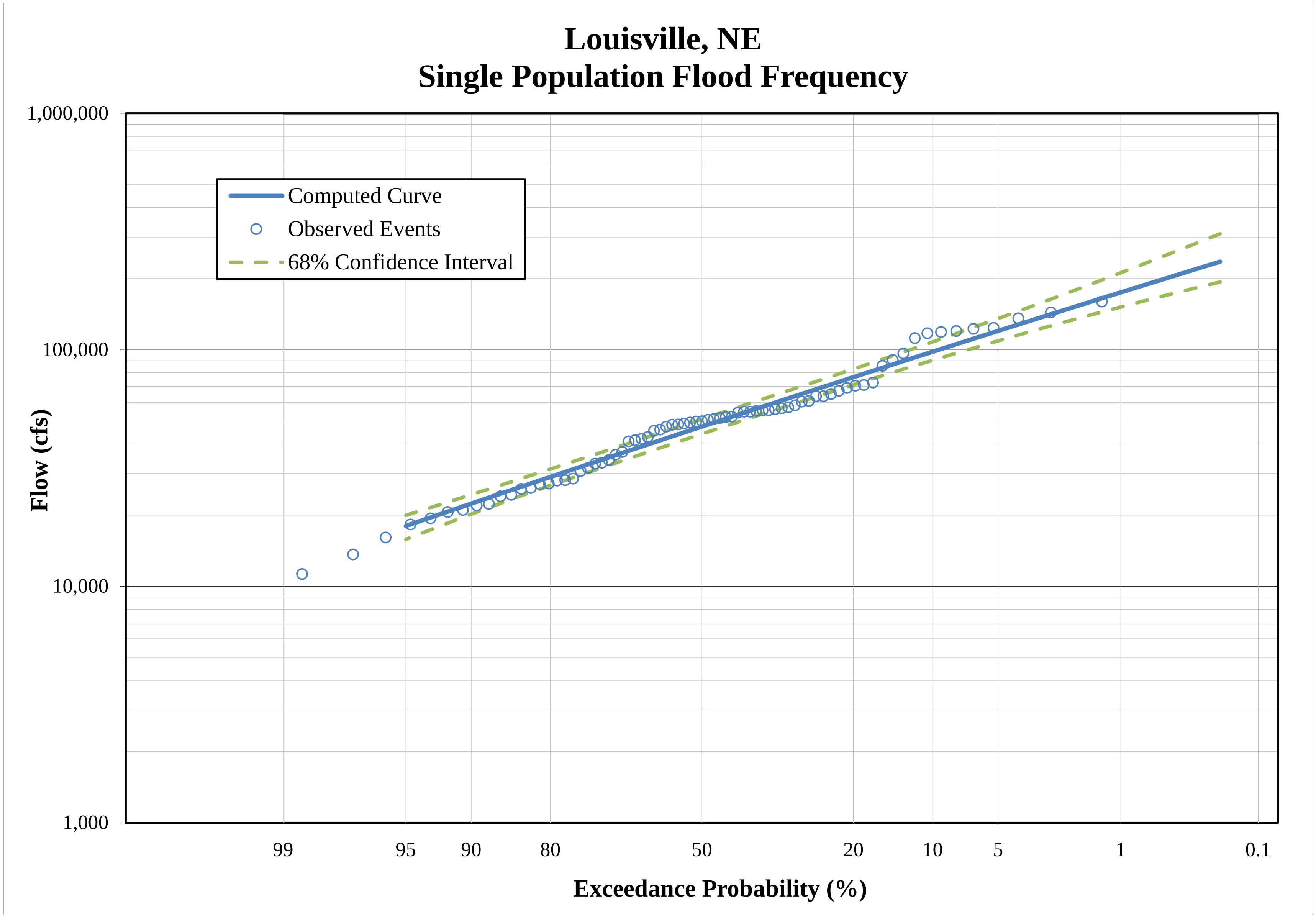


Figure 20. Single population flood flow frequency at Louisville.

Table 23. Single Population flood flow frequency at Duncan.

Duncan-Single Population			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	40,711	52,890	33,413
0.5	34,846	43,320	29,557
1	30,590	36,829	26,567
2	26,480	30,918	23,501
4	22,502	25,532	20,348
10	17,401	19,124	16,022
20	13,598	14,714	12,616
50	8,354	8,991	7,761
80	5,029	5,448	4,612
90	3,826	4,196	3,431
95	3,040	3,392	2,641
99	1,953	2,298	1,549
Mean	3.916	**Historic Events**	0
Standard Deviation	0.257	**High Outliers**	
Station Skew	-0.146	**Low Outliers**	0
Regional Skew		**Zero or Missing**	0
Weighted Skew		**Systematic Events**	75
Adopted Skew	-0.146	**Equivalent Record Length**	75

Table 24. Single population flood flow frequency at North Bend.

North Bend-Single Population			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	150,784	208,435	121,528
0.5	124,000	161,782	103,446
1	105,700	132,266	90,442
2	89,100	106,996	77,969
4	73,800	85,385	65,972
10	55,400	61,534	50,725
20	42,600	46,336	39,501
50	26,200	28,159	24,469
80	16,500	17,719	15,306
90	13,100	14,116	11,932
95	10,800	11,823	9,657
99	7,600	8,743	6,414
Mean	4.426	**Historic Events**	0
Standard Deviation	0.245	**High Outliers**	
Station Skew	0.157	**Low Outliers**	0
Regional Skew		**Zero or Missing**	0
Weighted Skew		**Systematic Events**	75
Adopted Skew	0.157	**Equivalent Record Length**	75

Table 25. Single population flood flow frequency at Ashland.

Ashland-Single Population			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	209,241	275,532	171,847
0.5	177,313	222,698	150,349
1	154,587	187,575	134,117
2	132,998	156,155	117,864
4	112,439	128,034	101,530
10	86,580	95,267	79,695
20	67,655	73,182	62,840
50	42,028	45,103	39,162
80	25,963	27,990	23,950
90	20,139	21,937	18,229
95	16,309	18,037	14,366
99	10,949	12,699	8,915
Mean	4.622	**Historic Events**	0
Standard Deviation	0.247	**High Outliers**	
Station Skew	-0.042	**Low Outliers**	0
Regional Skew		**Zero or Missing**	0
Weighted Skew		**Systematic Events**	75
Adopted Skew	-0.042	**Equivalent Record Length**	75

Table 26. Single population flood flow frequency at Louisville.

Louisville-Single Population			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	235,969	309,464	193,647
0.5	200,393	250,973	169,859
1	174,952	211,866	151,770
2	150,688	176,703	133,551
4	127,494	145,089	115,132
10	98,190	108,048	90,361
20	76,654	82,952	71,160
50	47,387	50,905	44,108
80	29,013	31,327	26,711
90	22,364	24,413	20,183
95	18,002	19,965	15,791
99	11,924	13,889	9,632
Mean	4.673	**Historic Events**	0
Standard Deviation	0.251	**High Outliers**	
Station Skew	-0.071	**Low Outliers**	0
Regional Skew		**Zero or Missing**	0
Weighted Skew		**Systematic Events**	75
Adopted Skew	-0.071	**Equivalent Record Length**	75

Appendix C: Mixed Population Flood Flow Frequency Results

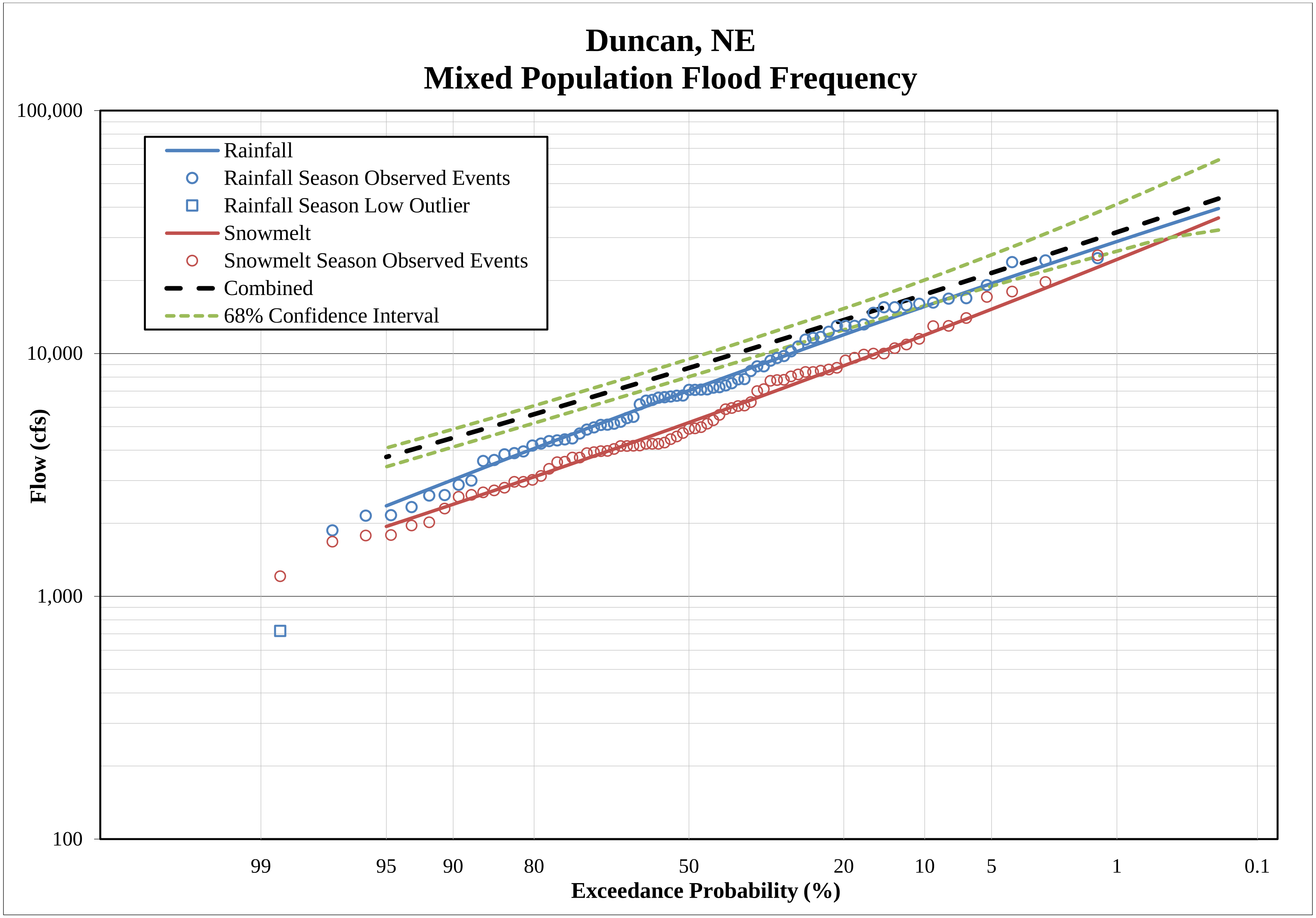


Figure 21. Mixed population flood flow frequency at Duncan.

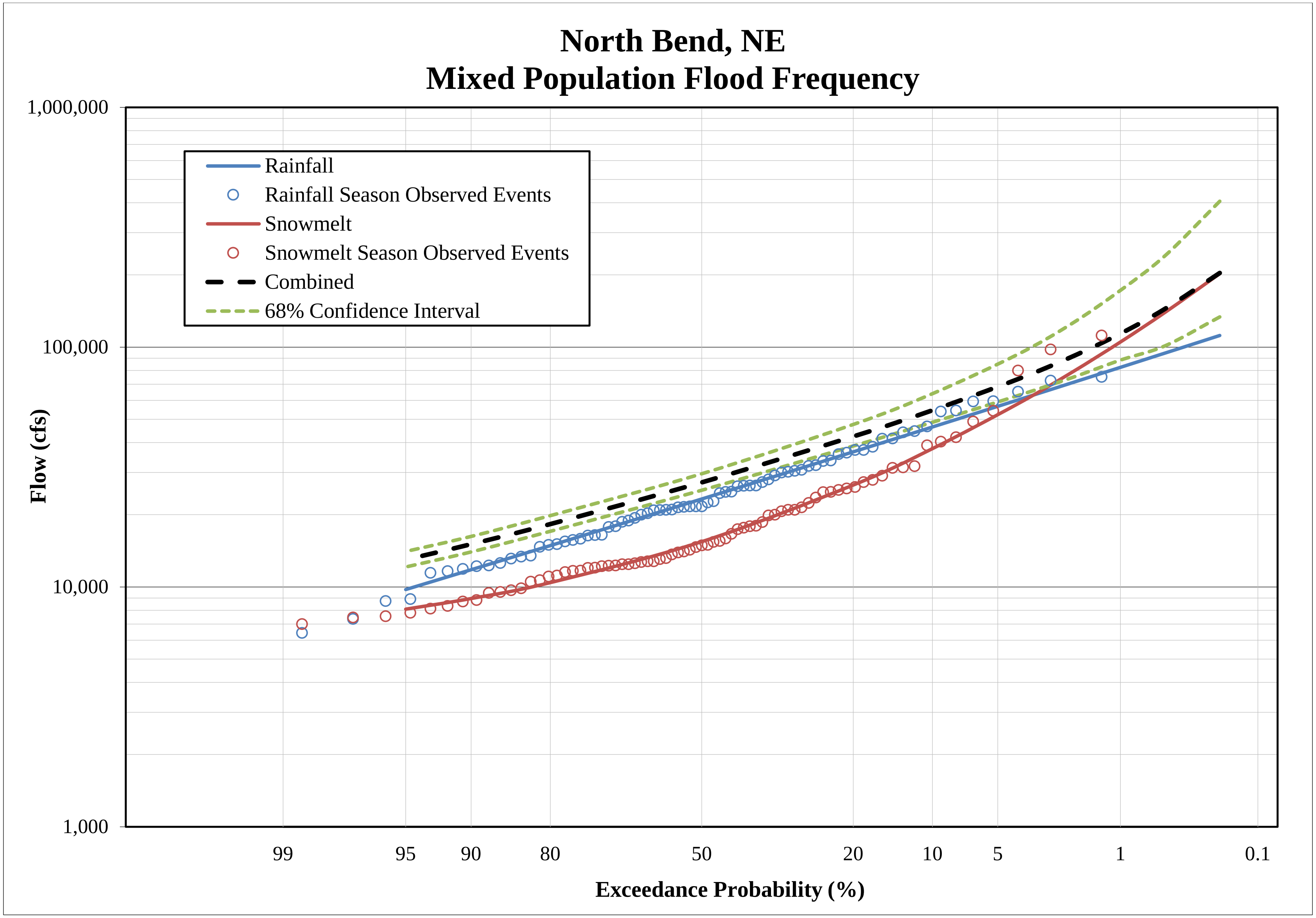


Figure 22. Mixed population flood flow frequency at North Bend.

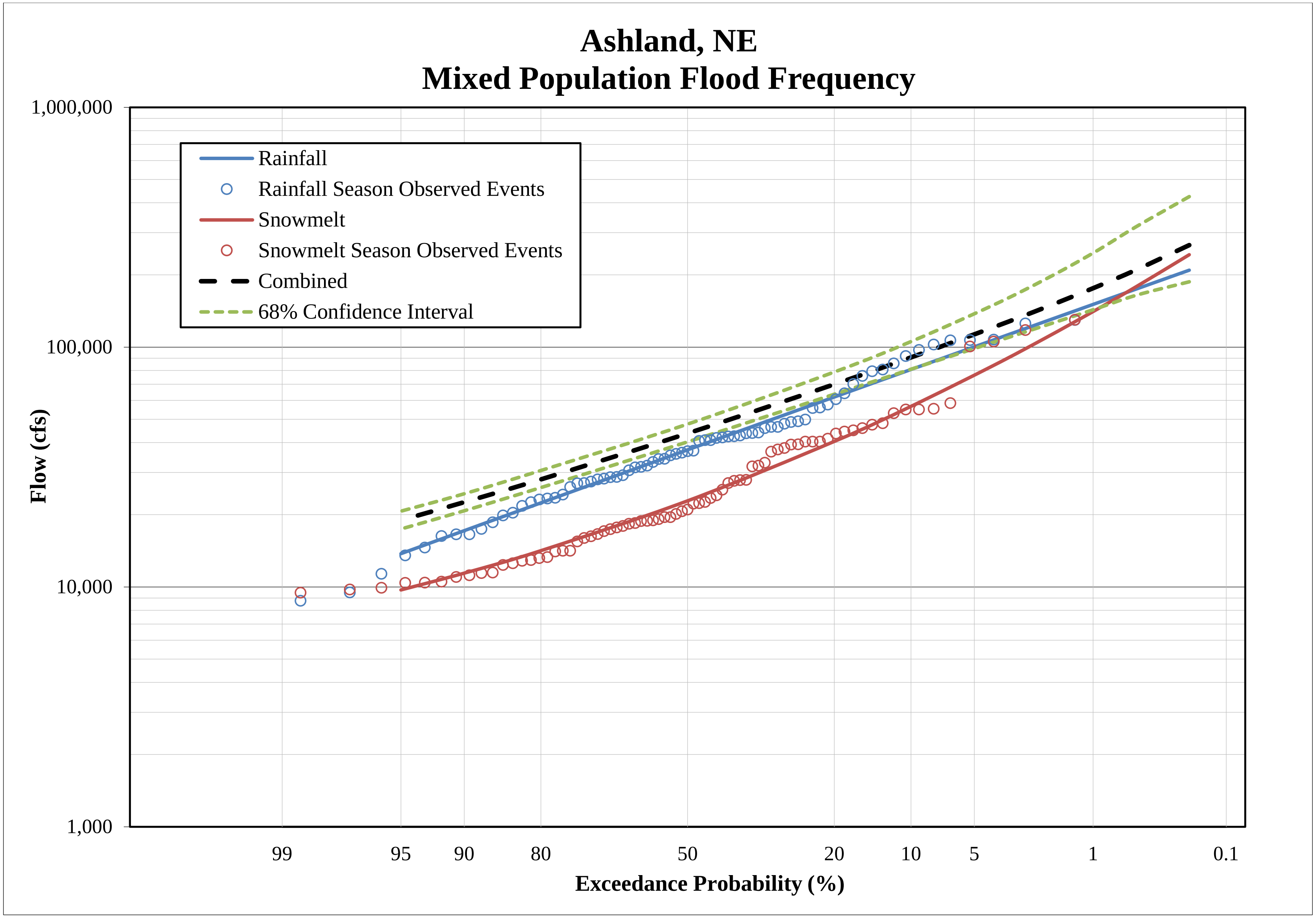


Figure 23. Mixed population flood flow frequency at Ashland.

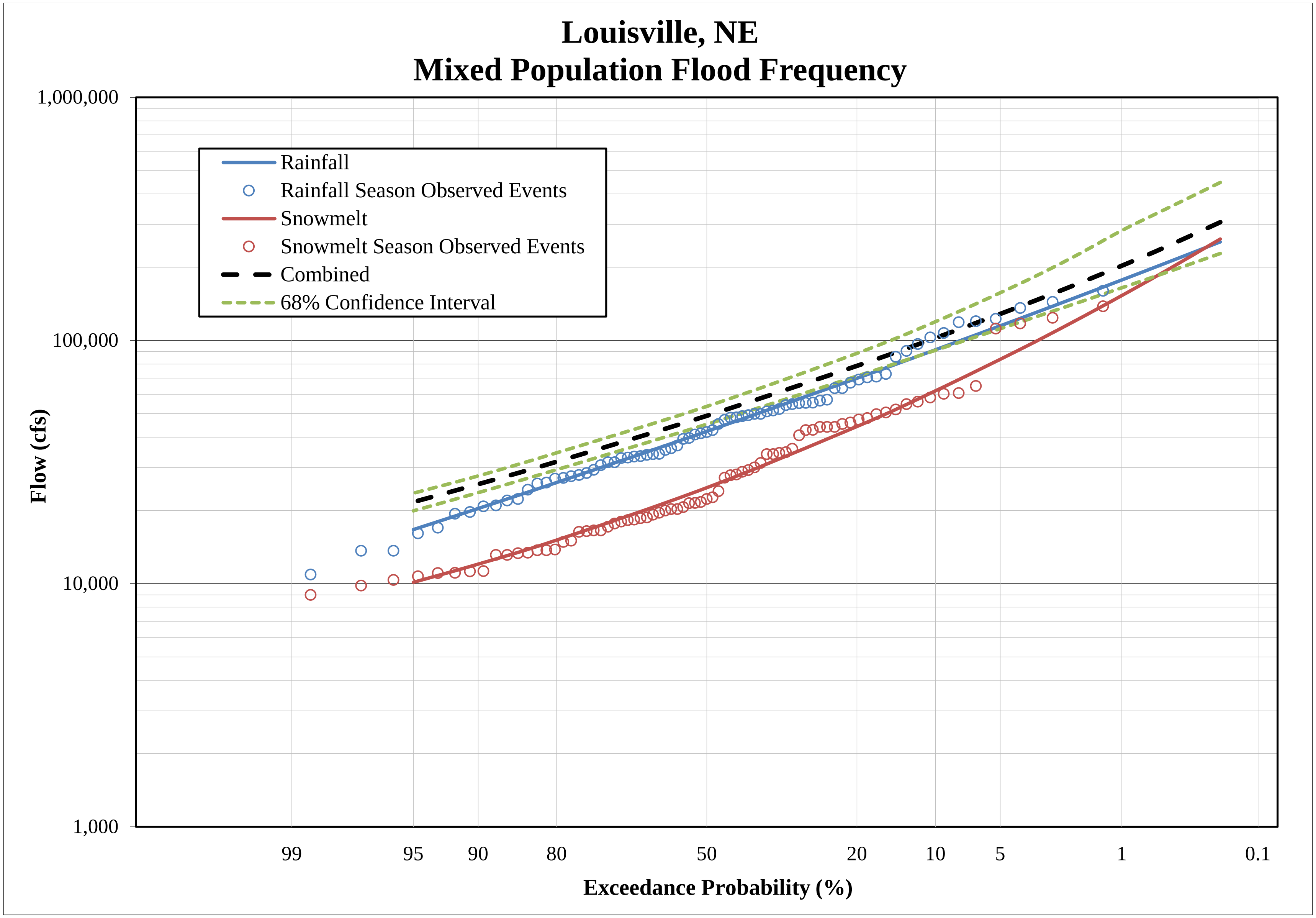


Figure 24. Mixed population flood flow frequency at Louisville.

Table 27. Rainfall season flood flow frequency at Duncan.

Duncan-Rainfall Season			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	39,532	53,412	31,912
0.5	33,340	42,725	27,894
1	28,912	35,655	24,814
2	24,695	29,363	21,695
4	20,674	23,767	18,530
10	15,622	17,314	14,276
20	11,944	13,019	11,005
50	7,038	7,623	6,496
80	4,063	4,430	3,691
90	3,023	3,342	2,665
95	2,358	2,661	1,994
99	1,464	1,759	1,106
Mean	3.841	**Historic Events**	0
Standard Deviation	0.278	**High Outliers**	
Station Skew	-0.136	**Low Outliers**	1
Regional Skew		**Zero or Missing**	0
Weighted Skew		**Systematic Events**	75
Adopted Skew	-0.136	**Equivalent Record Length**	74

Table 28. Snowmelt season flood flow frequency at Duncan.

Duncan-Snowmelt Season			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	36,148	51,772	28,455
0.5	29,098	39,085	23,798
1	24,385	31,257	20,502
2	20,154	24,705	17,390
4	16,354	19,235	14,448
10	11,908	13,373	10,794
20	8,903	9,763	8,178
50	5,197	5,618	4,807
80	3,105	3,360	2,857
90	2,394	2,611	2,167
95	1,940	2,145	1,714
99	1,323	1,535	1,088
Mean	3.723	**Historic Events**	0
Standard Deviation	0.272	**High Outliers**	
Station Skew	0.157	**Low Outliers**	0
Regional Skew		**Zero or Missing**	0
Weighted Skew		**Systematic Events**	75
Adopted Skew	0.157	**Equivalent Record Length**	75

Table 29. Rainfall Season flood flow frequency at North Bend.

North Bend-Rainfall Season			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	111,844	147,623	92,298
0.5	94,565	118,911	80,478
1	82,379	99,991	71,678
2	70,889	83,193	62,969
4	60,026	68,269	54,316
10	46,463	51,024	42,874
20	36,597	39,479	34,100
50	23,274	24,872	21,780
80	14,880	15,949	13,821
90	11,802	12,757	10,788
95	9,757	10,685	8,712
99	6,846	7,825	5,712
Mean	4.368	**Historic Events**	0
Standard Deviation	0.232	**High Outliers**	
Station Skew	0.042	**Low Outliers**	0
Regional Skew		**Zero or Missing**	0
Weighted Skew		**Systematic Events**	75
Adopted Skew	0.042	**Equivalent Record Length**	75

Table 30. Snowmelt season flood flow frequency at North Bend.

North Bend-Snowmelt Season			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	202,493	405,824	133,654
0.5	139,926	241,149	99,888
1	105,067	162,595	79,390
2	78,285	109,623	62,432
4	57,738	73,962	48,391
10	37,738	44,075	33,387
20	26,605	29,726	24,110
50	15,451	16,735	14,250
80	10,427	11,031	9,880
90	8,950	9,490	8,421
95	8,082	8,815	7,449
99	7,021	8,209	6,052
Mean	4.235	**Historic Events**	0
Standard Deviation	0.255	**High Outliers**	
Station Skew	1.095	**Low Outliers**	0
Regional Skew		**Zero or Missing**	0
Weighted Skew		**Systematic Events**	75
Adopted Skew	1.095	**Equivalent Record Length**	75

Table 31. Rainfall Season flood flow frequency at Ashland.

Ashland-Rainfall Season			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	209,389	282,526	169,554
0.5	174,900	224,035	146,520
1	150,729	185,908	129,394
2	128,093	152,393	112,489
4	106,867	122,949	95,760
10	80,686	89,418	73,827
20	61,956	67,385	57,261
50	37,318	40,222	34,624
80	22,429	24,281	20,604
90	17,173	18,788	15,472
95	13,769	15,301	12,062
99	9,087	10,616	7,341
Mean	4.571	**Historic Events**	0
Standard Deviation	0.262	**High Outliers**	
Station Skew	-0.015	**Low Outliers**	0
Regional Skew		**Zero or Missing**	0
Weighted Skew		**Systematic Events**	75
Adopted Skew	-0.015	**Equivalent Record Length**	75

Table 32. Snowmelt season flood flow frequency at Ashland.

Ashland-Snowmelt Season			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	242,922	424,299	176,514
0.5	179,102	279,491	137,331
1	140,730	202,451	112,220
2	109,290	145,679	90,456
4	83,575	103,951	71,609
10	56,639	65,394	50,466
20	40,453	44,994	36,795
50	22,871	24,801	21,076
80	14,172	15,227	13,202
90	11,422	12,270	10,546
95	9,720	10,580	8,817
99	7,465	8,653	6,401
Mean	4.387	**Historic Events**	0
Standard Deviation	0.275	**High Outliers**	
Station Skew	0.615	**Low Outliers**	0
Regional Skew		**Zero or Missing**	0
Weighted Skew		**Systematic Events**	75
Adopted Skew	0.615	**Equivalent Record Length**	75

Table 33. Rainfall Season flood flow frequency at Louisville.

<table>
<tr><th colspan="4">Louisville-Rainfall Season</th></tr>
<tr><th rowspan="2">Percent Annual Chance Exceedance</th><th rowspan="2">Computed Flow (cfs)</th><th colspan="2">Confidence Limits Flow (cfs)</th></tr>
<tr><th>16%</th><th>84%</th></tr>
<tr><td>0.2</td><td>254,311</td><td>353,030</td><td>203,941</td></tr>
<tr><td>0.5</td><td>208,507</td><td>273,091</td><td>173,216</td></tr>
<tr><td>1</td><td>177,313</td><td>222,583</td><td>151,100</td></tr>
<tr><td>2</td><td>148,816</td><td>179,395</td><td>129,881</td></tr>
<tr><td>4</td><td>122,758</td><td>142,524</td><td>109,478</td></tr>
<tr><td>10</td><td>91,555</td><td>101,924</td><td>83,587</td></tr>
<tr><td>20</td><td>69,902</td><td>76,147</td><td>64,592</td></tr>
<tr><td>50</td><td>42,295</td><td>45,497</td><td>39,324</td></tr>
<tr><td>80</td><td>26,055</td><td>28,073</td><td>24,084</td></tr>
<tr><td>90</td><td>20,369</td><td>22,120</td><td>18,535</td></tr>
<tr><td>95</td><td>16,683</td><td>18,353</td><td>14,826</td></tr>
<tr><td>99</td><td>11,572</td><td>13,321</td><td>9,605</td></tr>
<tr><td>Mean</td><td>4.632</td><td>Historic Events</td><td>0</td></tr>
<tr><td>Standard Deviation</td><td>0.255</td><td>High Outliers</td><td></td></tr>
<tr><td>Station Skew</td><td>0.130</td><td>Low Outliers</td><td>0</td></tr>
<tr><td>Regional Skew</td><td></td><td>Zero or Missing</td><td>0</td></tr>
<tr><td>Weighted Skew</td><td></td><td>Systematic Events</td><td>75</td></tr>
<tr><td>Adopted Skew</td><td>0.130</td><td>Equivalent Record Length</td><td>75</td></tr>
</table>

Table 34. Snowmelt season flood flow frequency at Louisville.

<table>
<tr><th colspan="4">Louisville -Snowmelt Season</th></tr>
<tr><th rowspan="2">Percent Annual Chance Exceedance</th><th rowspan="2">Computed Flow (cfs)</th><th colspan="2">Confidence Limits Flow (cfs)</th></tr>
<tr><th>16%</th><th>84%</th></tr>
<tr><td>0.2</td><td>261,265</td><td>446,279</td><td>191,031</td></tr>
<tr><td>0.5</td><td>193,873</td><td>297,784</td><td>149,342</td></tr>
<tr><td>1</td><td>152,989</td><td>217,617</td><td>122,408</td></tr>
<tr><td>2</td><td>119,240</td><td>157,780</td><td>98,912</td></tr>
<tr><td>4</td><td>91,434</td><td>113,272</td><td>78,432</td></tr>
<tr><td>10</td><td>62,067</td><td>71,600</td><td>55,296</td></tr>
<tr><td>20</td><td>44,278</td><td>49,266</td><td>40,248</td></tr>
<tr><td>50</td><td>24,805</td><td>26,934</td><td>22,834</td></tr>
<tr><td>80</td><td>15,107</td><td>16,277</td><td>14,024</td></tr>
<tr><td>90</td><td>12,031</td><td>12,976</td><td>11,059</td></tr>
<tr><td>95</td><td>10,126</td><td>11,055</td><td>9,136</td></tr>
<tr><td>99</td><td>7,597</td><td>8,809</td><td>6,469</td></tr>
<tr><td>Mean</td><td>4.420</td><td>Historic Events</td><td>0</td></tr>
<tr><td>Standard Deviation</td><td>0.281</td><td>High Outliers</td><td></td></tr>
<tr><td>Station Skew</td><td>0.548</td><td>Low Outliers</td><td>0</td></tr>
<tr><td>Regional Skew</td><td></td><td>Zero or Missing</td><td>0</td></tr>
<tr><td>Weighted Skew</td><td></td><td>Systematic Events</td><td>75</td></tr>
<tr><td>Adopted Skew</td><td>0.548</td><td>Equivalent Record Length</td><td>75</td></tr>
</table>

Table 35. Mixed population flood flow frequency at Duncan.

Duncan-Mixed Population			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	43,424	62,634	32,218
0.5	36,440	49,709	29,580
1	31,578	41,185	26,364
2	27,035	33,791	23,162
4	22,776	27,357	19,967
10	17,511	20,080	15,728
20	13,731	15,315	12,510
50	8,718	9,490	8,022
80	5,622	6,093	5,167
90	4,496	4,880	4,121
95	3,749	4,083	3,417
99	2,683	2,955	2,382

Table 36. Mixed population flood flow frequency at North Bend.

North Bend-Mixed Population			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	203,857	405,832	133,656
0.5	144,782	241,149	101,403
1	113,872	172,519	88,299
2	90,998	125,020	74,483
4	73,273	92,878	62,614
10	54,538	63,961	48,608
20	42,414	47,601	38,712
50	27,295	29,658	25,318
80	18,290	19,838	17,068
90	15,082	16,248	14,000
95	12,986	14,061	12,114
99	10,087	10,856	9,325

Table 37. Mixed population flood flow frequency at Ashland.

Ashland-Mixed Population			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	266,355	424,307	187,307
0.5	210,436	318,567	164,746
1	176,093	246,805	143,194
2	146,606	192,130	123,285
4	120,742	149,400	104,538
10	90,629	105,499	80,915
20	69,998	78,777	63,632
50	43,701	47,767	40,282
80	28,094	30,602	25,975
90	22,577	24,474	20,787
95	18,978	20,704	17,446
99	13,946	15,271	12,604

Table 38. Mixed population flood flow frequency at Louisville.

Louisville-Mixed Population			
Percent Annual Chance Exceedance	**Computed Flow (cfs)**	**Confidence Limits Flow (cfs)**	
		16%	**84%**
0.2	306,324	446,288	227,822
0.5	242,958	347,862	190,331
1	202,894	283,174	164,650
2	168,108	220,279	140,837
4	137,576	170,657	118,606
10	102,354	119,423	91,110
20	78,620	88,527	71,349
50	48,997	53,556	45,227
80	31,724	34,507	29,422
90	25,638	27,731	23,666
95	21,657	23,540	19,919
99	16,045	17,629	14,483

Appendix D: Annual Flood Frequency between Gages

Table 39. Flood frequency at each 0.5 mile interval. The data is also summarized in the attached KMZ files. Flow frequency is likely impacted several miles upstream of the Loup River and Elkhorn River confluences due to backwater and should be assessed in greater detail prior to any application of reported numbers.

River Mile	**Station/ Location**	**Flow Frequency (cfs)**							
		2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
16.1	Platte River at Louisville, NE	49,000	78,600	102,400	137,600	168,100	202,900	243,000	306,300
16.5		48,800	78,300	102,000	137,000	167,300	202,000	241,800	304,900
17		48,600	77,900	101,500	136,300	166,400	200,800	240,400	303,100
17.5		48,300	77,500	100,900	135,500	165,400	199,600	239,000	301,400
18		48,100	77,200	100,400	134,800	164,500	198,400	237,500	299,600
18.5		47,900	76,800	99,900	134,000	163,500	197,200	236,100	297,800
19		47,600	76,400	99,400	133,300	162,600	196,000	234,600	296,100
19.5		47,400	76,000	98,800	132,500	161,600	194,800	233,200	294,300
20		47,200	75,600	98,300	131,800	160,700	193,700	231,700	292,500
20.5		46,900	75,300	97,800	131,000	159,700	192,500	230,300	290,800
21		46,700	74,900	97,300	130,300	158,800	191,300	228,900	289,000
21.5		46,500	74,500	96,800	129,500	157,800	190,100	227,400	287,200
22		46,200	74,100	96,200	128,800	156,900	188,900	226,000	285,500
22.5		46,000	73,700	95,700	128,000	155,900	187,700	224,500	283,700
23		45,800	73,300	95,200	127,300	155,000	186,500	223,100	281,900
23.5		45,500	73,000	94,700	126,500	154,000	185,300	221,700	280,200
24		45,300	72,600	94,200	125,800	153,100	184,200	220,200	278,400
24.5		45,100	72,200	93,600	125,000	152,100	183,000	218,800	276,600
25		44,800	71,800	93,100	124,300	151,200	181,800	217,300	274,900
25.2	Salt Creek Confluence	44,700	71,700	92,900	124,000	150,800	181,300	216,700	274,200
25.5		44,600	71,400	92,600	123,500	150,200	180,600	215,900	273,100
26		44,400	71,100	92,100	122,800	149,300	179,400	214,400	271,300
26.5		44,100	70,700	91,500	122,000	148,300	178,200	213,000	269,600
27		43,900	70,300	91,000	121,300	147,400	177,000	211,600	267,800
27.4	Platte River near Ashland, NE	43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
27.5		43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
28		43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
28.5		43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
29		43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
29.5		43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
30		43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
30.5		43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
31		43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
31.5		43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
32		43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400
32.3	Elkhorn River Confluence (DS)	43,700	70,000	90,600	120,700	146,600	176,100	210,400	266,400

River Mile	Station/ Location	Flow Frequency (cfs)							
		2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
32.3	Elkhorn River Confluence (US)	30,500	47,600	61,400	82,300	101,700	128,500	162,600	228,100
32.5		30,500	47,500	61,400	82,300	101,600	128,400	162,600	228,000
33		30,500	47,500	61,300	82,100	101,500	128,200	162,300	227,700
33.5		30,400	47,400	61,200	82,000	101,300	128,000	162,100	227,400
34		30,400	47,300	61,100	81,900	101,200	127,900	161,900	227,100
34.5		30,300	47,300	61,000	81,800	101,100	127,700	161,700	226,800
35		30,300	47,200	60,900	81,700	100,900	127,500	161,400	226,500
35.5		30,300	47,100	60,800	81,600	100,800	127,300	161,200	226,200
36		30,200	47,100	60,800	81,500	100,700	127,100	161,000	225,900
36.5		30,200	47,000	60,700	81,400	100,500	127,000	160,800	225,600
37		30,100	46,900	60,600	81,200	100,400	126,800	160,500	225,300
37.5		30,100	46,900	60,500	81,100	100,300	126,600	160,300	225,000
38		30,100	46,800	60,400	81,000	100,100	126,400	160,100	224,700
38.5		30,000	46,800	60,300	80,900	100,000	126,200	159,900	224,300
39		30,000	46,700	60,200	80,800	99,900	126,000	159,700	224,000
39.5		29,900	46,600	60,100	80,700	99,700	125,900	159,400	223,700
40		29,900	46,600	60,100	80,600	99,600	125,700	159,200	223,400
40.5		29,800	46,500	60,000	80,500	99,500	125,500	159,000	223,100
41		29,800	46,400	59,900	80,300	99,300	125,300	158,800	222,800
41.5		29,800	46,400	59,800	80,200	99,200	125,100	158,500	222,500
42		29,700	46,300	59,700	80,100	99,100	124,900	158,300	222,200
42.5		29,700	46,200	59,600	80,000	98,900	124,800	158,100	221,900
43		29,600	46,200	59,500	79,900	98,800	124,600	157,900	221,600
43.5		29,600	46,100	59,500	79,800	98,700	124,400	157,600	221,300
44		29,600	46,000	59,400	79,700	98,500	124,200	157,400	221,000
44.5		29,500	46,000	59,300	79,600	98,400	124,000	157,200	220,700
45		29,500	45,900	59,200	79,400	98,300	123,800	157,000	220,400
45.5		29,400	45,800	59,100	79,300	98,100	123,700	156,700	220,100
46		29,400	45,800	59,000	79,200	98,000	123,500	156,500	219,800
46.5		29,400	45,700	58,900	79,100	97,900	123,300	156,300	219,500
47		29,300	45,700	58,900	79,000	97,700	123,100	156,100	219,200
47.5		29,300	45,600	58,800	78,900	97,600	122,900	155,800	218,900
48		29,200	45,500	58,700	78,800	97,500	122,700	155,600	218,600
48.5		29,200	45,500	58,600	78,600	97,300	122,600	155,400	218,300
49		29,200	45,400	58,500	78,500	97,200	122,400	155,200	218,000
49.5		29,100	45,300	58,400	78,400	97,100	122,200	155,000	217,700
50		29,100	45,300	58,300	78,300	96,900	122,000	154,700	217,400
50.5		29,000	45,200	58,200	78,200	96,800	121,800	154,500	217,100
51		29,000	45,100	58,200	78,100	96,700	121,700	154,300	216,800
51.5		29,000	45,100	58,100	78,000	96,500	121,500	154,100	216,500

River Mile	Station/ Location	Flow Frequency (cfs)							
		2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
52		28,900	45,000	58,000	77,900	96,400	121,300	153,800	216,200
52.5		28,900	44,900	57,900	77,700	96,300	121,100	153,600	215,900
53		28,800	44,900	57,800	77,600	96,100	120,900	153,400	215,600
53.5		28,800	44,800	57,700	77,500	96,000	120,700	153,200	215,200
54		28,800	44,800	57,600	77,400	95,900	120,600	152,900	214,900
54.5		28,700	44,700	57,600	77,300	95,700	120,400	152,700	214,600
55		28,700	44,600	57,500	77,200	95,600	120,200	152,500	214,300
55.5		28,600	44,600	57,400	77,100	95,500	120,000	152,300	214,000
56		28,600	44,500	57,300	77,000	95,300	119,800	152,000	213,700
56.5		28,600	44,400	57,200	76,800	95,200	119,600	151,800	213,400
57		28,500	44,400	57,100	76,700	95,100	119,500	151,600	213,100
57.5		28,500	44,300	57,000	76,600	94,900	119,300	151,400	212,800
58		28,400	44,200	57,000	76,500	94,800	119,100	151,200	212,500
58.5		28,400	44,200	56,900	76,400	94,700	118,900	150,900	212,200
59		28,400	44,100	56,800	76,300	94,500	118,700	150,700	211,900
59.5		28,300	44,000	56,700	76,200	94,400	118,500	150,500	211,600
60		28,300	44,000	56,600	76,100	94,300	118,400	150,300	211,300
60.5		28,200	43,900	56,500	75,900	94,100	118,200	150,000	211,000
61		28,200	43,800	56,400	75,800	94,000	118,000	149,800	210,700
61.5		28,200	43,800	56,300	75,700	93,900	117,800	149,600	210,400
62		28,100	43,700	56,300	75,600	93,700	117,600	149,400	210,100
62.5		28,100	43,700	56,200	75,500	93,600	117,400	149,100	209,800
63		28,000	43,600	56,100	75,400	93,500	117,300	148,900	209,500
63.5		28,000	43,500	56,000	75,300	93,300	117,100	148,700	209,200
64		28,000	43,500	55,900	75,200	93,200	116,900	148,500	208,900
64.5		27,900	43,400	55,800	75,000	93,100	116,700	148,200	208,600
65		27,900	43,300	55,700	74,900	92,900	116,500	148,000	208,300
65.5		27,800	43,300	55,700	74,800	92,800	116,300	147,800	208,000
66		27,800	43,200	55,600	74,700	92,700	116,200	147,600	207,700
66.5		27,800	43,100	55,500	74,600	92,500	116,000	147,300	207,400
67		27,700	43,100	55,400	74,500	92,400	115,800	147,100	207,100
67.5		27,700	43,000	55,300	74,400	92,300	115,600	146,900	206,800
68		27,600	42,900	55,200	74,200	92,100	115,400	146,700	206,400
68.5		27,600	42,900	55,100	74,100	92,000	115,300	146,500	206,100
69		27,600	42,800	55,100	74,000	91,900	115,100	146,200	205,800
69.5		27,500	42,700	55,000	73,900	91,700	114,900	146,000	205,500
70		27,500	42,700	54,900	73,800	91,600	114,700	145,800	205,200
70.5		27,400	42,600	54,800	73,700	91,500	114,500	145,600	204,900
71		27,400	42,600	54,700	73,600	91,300	114,300	145,300	204,600
71.5		27,400	42,500	54,600	73,500	91,200	114,200	145,100	204,300

River Mile	Station/ Location	Flow Frequency (cfs)							
		2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
72		27,300	42,400	54,500	73,300	91,100	114,000	144,900	204,000
72.2	Platte River at North Bend, NE	27,300	42,400	54,500	73,300	91,000	113,900	144,800	203,900
72.5		27,200	42,300	54,400	73,200	91,000	113,900	144,800	203,900
73		27,000	42,100	54,200	73,200	91,000	113,900	144,800	203,900
73.5		26,800	41,900	54,100	73,100	91,000	113,900	144,800	203,900
74		26,700	41,700	53,900	73,000	90,900	113,900	144,800	203,900
74.5		26,500	41,500	53,800	72,900	90,900	113,900	144,800	203,900
75		26,300	41,300	53,600	72,800	90,900	113,900	144,800	203,900
75.5		26,100	41,200	53,400	72,700	90,900	113,900	144,800	203,900
76		25,900	41,000	53,300	72,600	90,900	113,900	144,800	203,900
76.5		25,800	40,800	53,100	72,500	90,900	113,900	144,800	203,900
77		25,600	40,600	52,900	72,400	90,800	113,900	144,800	203,900
77.5		25,400	40,400	52,800	72,300	90,800	113,900	144,800	203,900
78		25,200	40,200	52,600	72,200	90,800	113,900	144,800	203,900
78.5		25,000	40,000	52,500	72,200	90,800	113,900	144,800	203,900
79		24,900	39,800	52,300	72,100	90,800	113,900	144,800	203,900
79.5		24,700	39,700	52,100	72,000	90,800	113,900	144,800	203,900
80		24,500	39,500	52,000	71,900	90,700	113,900	144,800	203,900
80.5		24,300	39,300	51,800	71,800	90,700	113,900	144,800	203,900
81		24,100	39,100	51,700	71,700	90,700	113,900	144,800	203,900
81.5		24,000	38,900	51,500	71,600	90,700	113,900	144,800	203,900
82		23,800	38,700	51,300	71,500	90,700	113,900	144,800	203,900
82.5		23,600	38,500	51,200	71,400	90,700	113,900	144,800	203,900
83		23,400	38,300	51,000	71,300	90,600	113,900	144,800	203,900
83.5		23,200	38,100	50,800	71,200	90,600	113,900	144,800	203,900
84		23,100	38,000	50,700	71,200	90,600	113,900	144,800	203,900
84.5		22,900	37,800	50,500	71,100	90,600	113,900	144,800	203,900
85		22,700	37,600	50,400	71,000	90,600	113,900	144,800	203,900
85.5		22,500	37,400	50,200	70,900	90,600	113,900	144,800	203,900
86		22,300	37,200	50,000	70,800	90,500	113,900	144,800	203,900
86.5		22,200	37,000	49,900	70,700	90,500	113,900	144,800	203,900
87		22,000	36,800	49,700	70,600	90,500	113,900	144,800	203,900
87.5		21,800	36,600	49,600	70,500	90,500	113,900	144,800	203,900
88		21,600	36,500	49,400	70,400	90,500	113,900	144,800	203,900
88.5		21,400	36,300	49,200	70,300	90,500	113,900	144,800	203,900
89		21,300	36,100	49,100	70,300	90,400	113,900	144,800	203,900
89.5		21,100	35,900	48,900	70,200	90,400	113,900	144,800	203,900
90		20,900	35,700	48,700	70,100	90,400	113,900	144,800	203,900
90.5		20,700	35,500	48,600	70,000	90,400	113,900	144,800	203,900
91		20,500	35,300	48,400	69,900	90,400	113,900	144,800	203,900

River Mile	Station/ Location	Flow Frequency (cfs)							
		2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
91.5		20,400	35,100	48,300	69,800	90,400	113,900	144,800	203,900
92		20,200	35,000	48,100	69,700	90,300	113,900	144,800	203,900
92.5		20,000	34,800	47,900	69,600	90,300	113,900	144,800	203,900
93		19,800	34,600	47,800	69,500	90,300	113,900	144,800	203,900
93.5		19,600	34,400	47,600	69,400	90,300	113,900	144,800	203,900
94		19,500	34,200	47,400	69,300	90,300	113,900	144,800	203,900
94.5		19,300	34,000	47,300	69,300	90,300	113,900	144,800	203,900
95		19,100	33,800	47,100	69,200	90,200	113,900	144,800	203,900
95.5		18,900	33,600	47,000	69,100	90,200	113,900	144,800	203,900
96		18,700	33,400	46,800	69,000	90,200	113,900	144,800	203,900
96.5		18,600	33,300	46,600	68,900	90,200	113,900	144,800	203,900
97		18,400	33,100	46,500	68,800	90,200	113,900	144,800	203,900
97.5		18,200	32,900	46,300	68,700	90,200	113,900	144,800	203,900
98		18,000	32,700	46,200	68,600	90,100	113,900	144,800	203,900
98.5		17,800	32,500	46,000	68,500	90,100	113,900	144,800	203,900
99		17,700	32,300	45,800	68,400	90,100	113,900	144,800	203,900
99.5		17,500	32,100	45,700	68,300	90,100	113,900	144,800	203,900
100		17,300	31,900	45,500	68,300	90,100	113,900	144,800	203,900
100.5		17,100	31,800	45,300	68,200	90,100	113,900	144,800	203,900
101		16,900	31,600	45,200	68,100	90,000	113,900	144,800	203,900
101.5		16,800	31,400	45,000	68,000	90,000	113,900	144,800	203,900
102		16,600	31,200	44,900	67,900	90,000	113,900	144,800	203,900
102.5	Loup River Confluence (DS)	16,400	31,000	44,700	67,800	90,000	113,900	144,800	203,900
102.5	Loup River Confluence (US)	8,900	13,900	17,900	23,500	28,100	33,300	38,000	45,400
103		8,900	13,900	17,900	23,500	28,000	33,200	37,900	45,300
103.5		8,900	13,900	17,900	23,500	28,000	33,100	37,900	45,200
104		8,900	13,900	17,900	23,400	27,900	33,000	37,800	45,200
104.5		8,800	13,800	17,800	23,400	27,900	32,900	37,700	45,100
105		8,800	13,800	17,800	23,400	27,800	32,900	37,600	45,000
105.5		8,800	13,800	17,800	23,300	27,800	32,800	37,500	44,900
106		8,800	13,800	17,800	23,300	27,700	32,700	37,500	44,800
106.5		8,800	13,800	17,800	23,200	27,700	32,600	37,400	44,700
107		8,800	13,800	17,700	23,200	27,600	32,500	37,300	44,600
107.5		8,800	13,800	17,700	23,200	27,600	32,500	37,200	44,500
108		8,800	13,800	17,700	23,100	27,500	32,400	37,200	44,400
108.5		8,800	13,800	17,700	23,100	27,500	32,300	37,100	44,300
109		8,800	13,800	17,700	23,100	27,400	32,200	37,000	44,200
109.5		8,800	13,800	17,600	23,000	27,400	32,200	36,900	44,100
110		8,800	13,800	17,600	23,000	27,300	32,100	36,900	44,000

River Mile	**Station/ Location**	**Flow Frequency (cfs)**							
		2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
110.5		8,700	13,700	17,600	23,000	27,300	32,000	36,800	43,900
111		8,700	13,700	17,600	22,900	27,200	31,900	36,700	43,800
111.5		8,700	13,700	17,600	22,900	27,200	31,800	36,600	43,700
112		8,700	13,700	17,500	22,900	27,100	31,800	36,600	43,600
112.5		8,700	13,700	17,500	22,800	27,100	31,700	36,500	43,500
113	Platte River near Duncan, NE	8,700	13,700	17,500	22,800	27,000	31,600	36,400	43,400

Appendix E: Climate Change Assessment

Purpose

A qualitative climate change analysis was undertaken in accordance with Phases I and II of the USACE Engineering and Construction Bulletin No. 2016-25 (USACE, 2016). The purpose of the qualitative climate change assessment is to enhance climate preparedness and resilience by incorporating relevant information about observed and expected climate change impacts in hydrologic analyses. Phase I includes a literature review that outlines the broad trends of observed and projected changes to climate that might impact the project purpose. Phase II focuses on projected changes in the study area. Typically, Phase II includes an investigation into the climate hydrology assessment tool to identify historic trends in the peak flows at gages near the study area and the Nonstationarity Detection Tool to assess abrupt or slowly varying changes in the observed peak flow data. Phase II also typically includes use of the Watershed Vulnerability Assessment Tool that provides information on the vulnerability of a watershed to climate change based on flow variables.

One of the primary assumptions in flood frequency analysis is that the time-series data are stationary. A test of nonstationarity of the available time-series peak flows will be used to check if this assumption is reasonable. If any nonstationarities are detected in the time-series, Bulletin 17C recommends employing time-varying parameters or other appropriate techniques to address the nonstationarity (USGS, 2018).

Phase I: Current Climate & Project Need for Climate Investigation

The Lower Platte River basin has a humid continental climate characterized by cold winters and hot summers. The average annual rainfall is approximately 30 inches falling primarily in May through August. Flooding can be caused by intense rainfall in the spring or summer months or springtime snowmelt. The average annual snowfall is across the Lower Platte River basin from the mouth to Grand Island ranges from approximately 25 to 32 inches (U.S. Climate Data, 2018). Average monthly temperatures and rainfall in Grand Island and Ashland, NE are shown in Figure 25 and Figure 26.

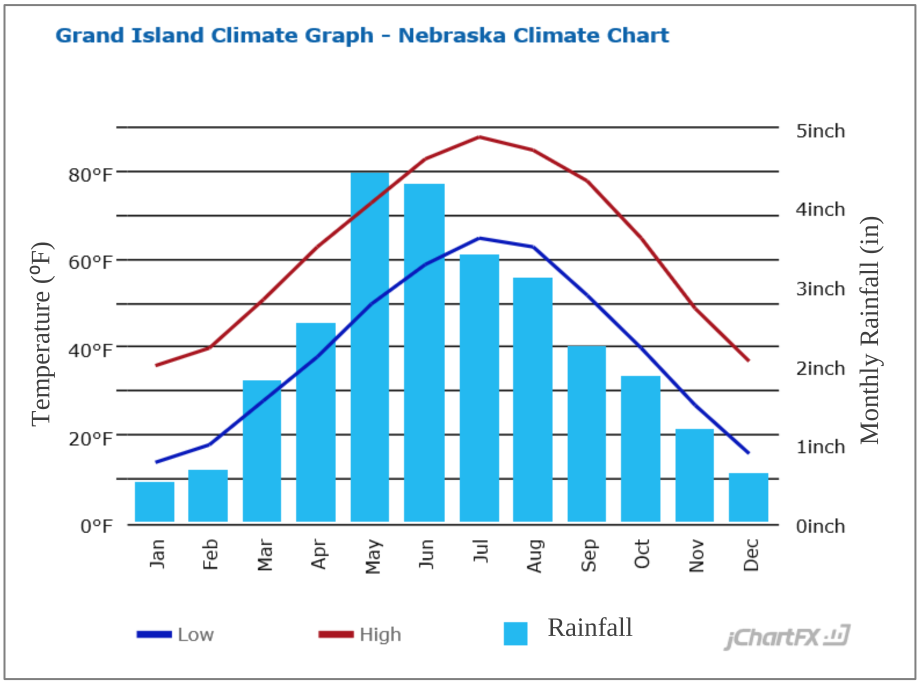


Figure 25. Grand Island climate graph (U.S. Climate Data, 2018).

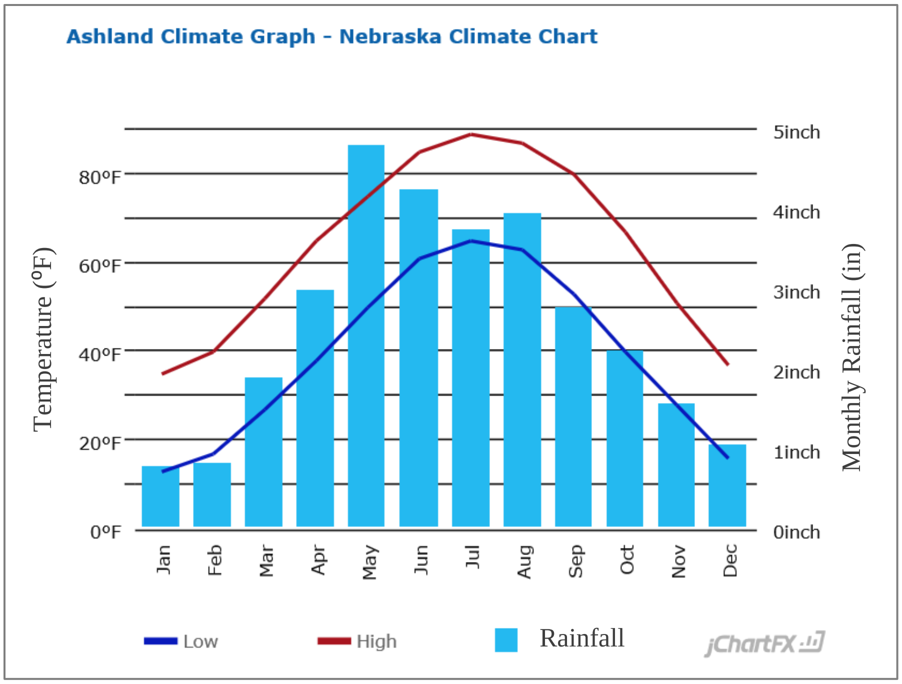


Figure 26. Ashland climate graph (U.S. Climate Data, 2018).

A review of peer-reviewed literature on climate change indicates that the frequency of large floods are increasing over time event though the annual peak stream flows are not (Mallakpour & Villarini, 2015). Therefore, while the largest annual events do not appear to be becoming larger, the frequency of large flood events is increasing.

In addition, several studies forecast that extreme precipitation event intensity will likely increase at rates much larger than that of mean precipitation events. Pall et al. (2007) found that the Clausius-Clapeyron (CC) relationship is a better predictor of change in extreme events for the mid-latitude region of the Earth and that these extreme event intensities are increasing at a much faster rate than the mean event intensities. The Clausius-Clapeyron equation relates saturated water vapor pressure to instantaneous air temperature and it predicts an approximately 7% increase in precipitation intensity of extreme rainfall events per degree Celsius increase in air temperature mass (7%/ºC). The CC relationship implies that atmospheric moisture would increase roughly exponentially with temperature (Pall et al., 2007).

It was determined in Ivancic & Shaw (2016) that the CC rate of increase is applicable to many regions of the United States but that the rate is constrained by the availability of air moisture and influenced by the type of storm (frontal or convective) producing the precipitation. They determined that the CC rate of continental climates as compared to the drier parts of the country (like the southwest) where moisture scaling will occur in typically cooler months meaning that extreme events may increase more quickly in those months than in higher temperature months (Ivancic & Shaw, 2016). Figure 27 from Ivancic & Shaw show that extreme precipitation intensity in the Lower Platte River Basin is forecasted to increase at a rate higher than 7%/ºC and is statistically significant with a p-value less than 0.01. However, the trends are not regionally consistent across the state of Nebraska or the rest of the Platte River watershed.

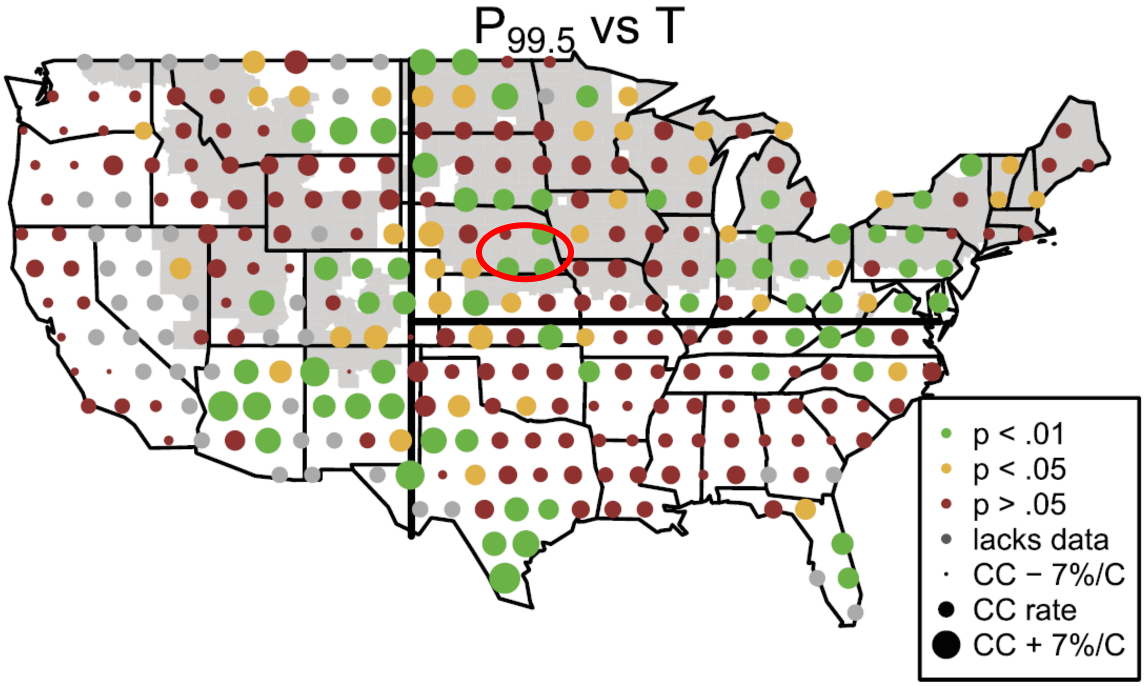


Figure 27. Precipitation intensity vs. temperature. Areas with a continental climate and significant precipitation year round are shaded. (Ivancic & Shaw, 2016).

Literature also indicates that the Great Plains region, which includes the Lower Platte River basin, will experience more intense droughts and increased runoff from rainfall and snow events. The Great Plains are expected to experience increases in winter and spring precipitation, more rapid snowmelts, and more intense rainfall events (Melillo, Richmond & Yohe, 2014). While temperature increases have been observed throughout all seasons, the strongest trends were observed in spring with higher intensity rainfall events as well as more rapid snowmelt events (Mallakpour & Villarini, 2015).

Stationarity is a key assumption in flood frequency analysis. Trends observed over the Lower Platte River region indicate that the existing data and future streamflow may not be stationary. Increases in the frequency of extreme flood events and the likely increase in extreme precipitation intensity at rates consistent with the Clausius-Clapeyron (~7%/degree Celsius) or higher as well as the impact of more rapid snowmelt indicate that the assumption of stationarity might not be valid. Therefore, a climate change assessment is relevant.

Phase II: Projected Changes and Vulnerability Assessment

Three USACE climate tools were used to help assess climate trends and vulnerabilities in the Lower Platte River Basin from 1942-2016. These tools included the Climate Hydrology Assessment Tool, The Nonstationarity Detection (NSD) Tool, and the Watershed Vulnerability Assessment Tool. A tool exists to analyze custom datasets for nonstationarity and will be used in place of the standard USACE NSD tool to analyze the extended records for each site. The other two tools will only analyze observed flows at the sites. The four project streamgage sites were analyzed with the tools: Duncan, North Bend, Ashland, and Louisville, NE.

The Climate Hydrology Assessment Tool (USACE, 2016) was used to develop first-order (linear) trends for annual peak flow at the four study gages for the period after the construction of Kingsley Dam (1942-2016). This tool generates a p-value for the trend that can be used to help interpret if the trend is statistically significant ($p<0.05$). A p-value of 0.05 means there is a 5% chance that the trend is not reflective of the full population trend but is due to randomness in the data selected from the population. Table 40 shows the general results of the four streamgages. Trends in streamflow were generally in the downward direction; however the p-values were very high, ranging from 0.43 to 0.90. In the case of these results, the 0.90 p-value result of the Duncan gage means that there is about a 10 percent chance that the downward trend is representative of the population and a 90% chance that the trend is just due to the randomness of sampling. The statistically strongest trends (lowest p-values) indicate that peak annual flows at the site are decreasing but the p-values are not statistically significant and the record lengths are short which could mean data are not representative of the population of possible flows at the site.

Table 40. First-order trends in annual peak streamflow for 1942-2016.

Streamgage	Site Number	P-Value	General Trend
Duncan	6774000	0.90	Slight Downward
North Bend	6796000	0.43	Slight Downward
Ashland	6801000	0.43	Slight Downward
Louisville	6805500	0.70	Slight Downward

The NSD tool was used to determine if the streamgage records could be treated as stationary, a key assumption in flood frequency analyses. Stationarity assumes that the statistical characteristics of hydrologic time series data are constant through time. However, recent scientific evidence shows that climate change and human modifications to some watersheds are undermining this assumption. Thus, this tool helps to identify if the record of annual peak streamflows are impacted by anthropogenic activities (e.g. urbanization, etc.) or climate change and aids in decision-making for flood frequency analyses.

With assistance from the Cold Regions Research and Engineering Laboratory (CRREL) the complete records (1942-2016) were tested for nonstationarities. Three main types of nonstationarities were considered (mean, variance, and distribution) with a total of 11 tests. The mean-based tests detect a non-stationarity where there has been a significant change in the average value of the data. The variance-based tests detect a nonstationarity where there has been a gradual or abrupt change in variance of the data. The distribution-based tests detect a nonstationarity where there has been a significant change in the underlying distribution of the data which can be caused by a change in the parameters of the same distribution or from one distribution type to another (USACE, 2018). A streamflow gage can hold the assumption of nonstationarity if a detected change point demonstrates consensus among multiple change point detection methods, robustness between changes in statistical properties, and for which an operationally significant change in magnitude is determined. When two or more detected tests target the same statistical property for a change point, detection methods demonstrate consensus while tests targeting changes in two or more different statistical properties indicate robustness between changes in statistical properties (USACE, 2017).

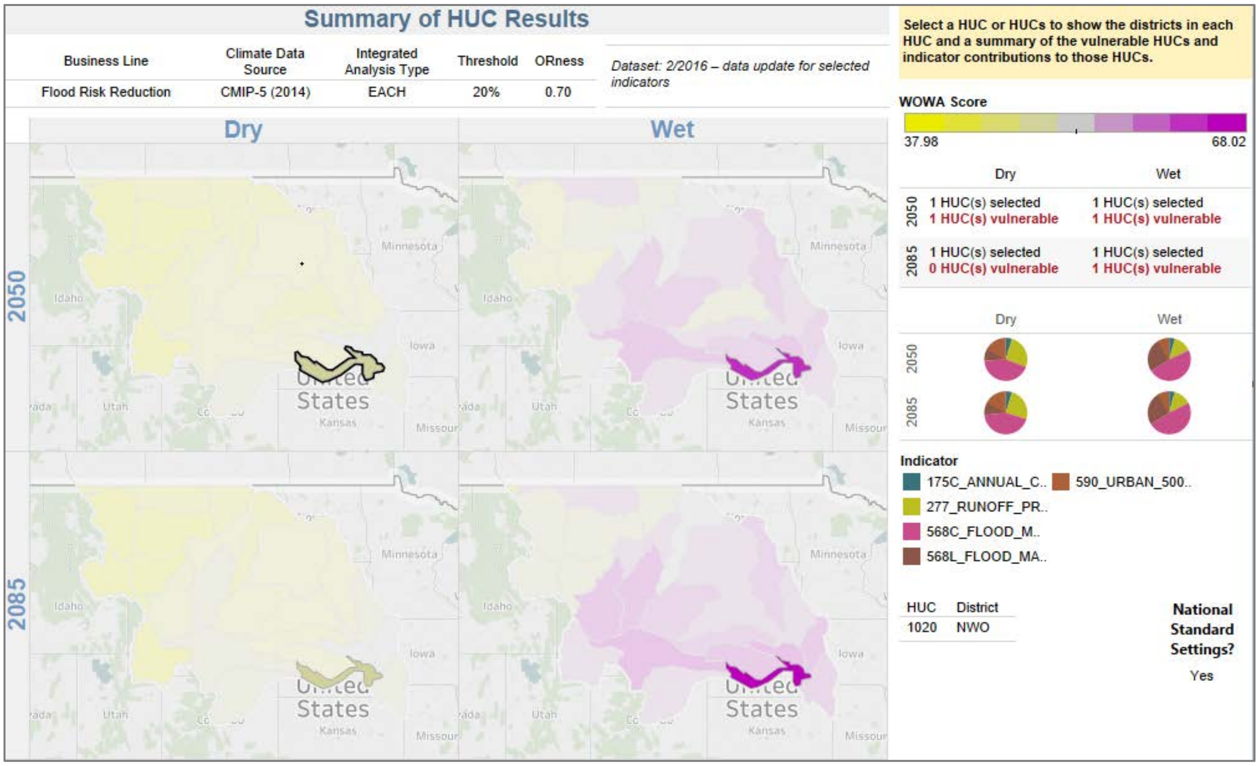
Table 41 summarizes the results for the four streamgages. One mean-based test was triggered at the Duncan gage and one distribution-based test was triggered at the North Bend gage. No nonstationarity tests were triggered at the Ashland and Louisville gages. The test was performed on the annual peak flow datasets as well as the seasonal peak flow datasets, and results were the same regardless. Therefore, all datasets can be considered homogenous and stationary from 1942-2016.

Table 41. NSD results. No consensus nonstationarities were detected in the datasets.

Streamgage	Site Number	Nonstationarity Tests Triggered	Type of Test Triggered	Year of Nonstationarity
Duncan	6774000	1	Distribution-based	2001
North Bend	6796000	1	Mean-based	1998
Ashland	6801000	0	N/A	N/A
Louisville	6805500	0	N/A	N/A

The Screening-Level Climate Change Vulnerability Assessment Tool was used to forecast if the flood risk reduction business line of the USACE will be affected by climate change in the future for the Platte River basin (HUC-4 1020 Platte River basin). This tool currently uses 27 indicators (e.g. flood magnification population in 500-year flood plain, etc.) in its vulnerability assessment at the HUC-4 watershed scale. The tool analyzed 4 epoch scenarios: Dry-2050, Dry-2085, Wet-2050, and Wet-2085. The two epoch represent two 30-year periods centered on the years 2050 (2035-2064) and 2085 (2070-2099). The epochs are sorted by cumulative runoff projections and divided into two equal-sized groups of smaller and larger runoff projections, called dry and wet. Figure 28 shows that the Platte River HUC is vulnerable to flood risk in three of the four epoch-scenario combinations. The main indicator driving this increase in risk is flood magnification of flows exceeding the monthly flow exceeded 10% of the time at the cumulative (flow upstream and within the HUC) levels. This is supported by the Mallakpour and Villarini (2015) study which concluded that while the annual peak flows are not increasing in magnitude with time, the frequency of flood events is increasing in the central United States.

Other indicators driving risk include: an increase in flood magnification of flows exceeding the monthly flow exceeded 10% of the time at the local (within the HUC) level, percent change in runoff divided by percent change in precipitation, annual control volume of unregulated runoff which indicates the reliability of natural water availability, and an increase in urban population within the 500-year floodplain.



Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Threshold	ORness
Flood Risk Reduction	CMIP-5 (2014)	EACH	20%	0.70

Dataset: 2/2016 – data update for selected indicators

Select a HUC or HUCs to show the districts in each HUC and a summary of the vulnerable HUCs and indicator contributions to those HUCs.

WOWA Score

	Dry	Wet
2050	1 HUC(s) selected 1 HUC(s) vulnerable	1 HUC(s) selected 1 HUC(s) vulnerable
2085	1 HUC(s) selected 0 HUC(s) vulnerable	1 HUC(s) selected 1 HUC(s) vulnerable

Indicator
- 175C_ANNUAL_C..
- 590_URBAN_500..
- 277_RUNOFF_PR..
- 568C_FLOOD_M..
- 568L_FLOOD_MA..

HUC	District
1020	NWO

National Standard Settings?

Yes

Figure 28. Platte River basin Vulnerability Assessment results.

Climate Change Conclusions

The purpose of the qualitative climate change assessment is to enhance climate preparedness and resilience by incorporating relevant information about observed and expected climate change impacts in hydrologic analyses. Results from the climate change analysis indicate that the Platte River basin is at an elevated risk of flooding in the future in the way of increased frequency of extreme events. Results of the vulnerability assessment and literature review support this conclusion, while the results of the first-order trend analysis and NSD test do not provide supporting evidence.

The results of the literature review show that extreme precipitation intensity in the lower Platte River basin is forecasted to increase at a rate higher than 7%/ºC and is statistically significant with a p-value less than 0.01 (Ivancic & Shaw, 2016). Trends in increasing temperature have been observed throughout the years, however the strongest trends in increasing temperature have been observed in the spring which could result in higher intensity spring rainfall as well as more rapid snowmelts (Mallakpour & Villarini, 2015). The first-order trend analysis on the peak annual flows indicates annual peaks are slightly decreasing, however, the results were not statistically significant. The trends were detected after the construction of Kingsley Dam and can't be attributed to nonstationarities in the data. The trend is also not strong enough and the datasets are not long enough to attribute the trend to climate change. The vulnerability assessment indicates that the Platte River basin is at an elevated risk of flooding in the future.

A critical assumption of flood frequency analyses is that the data are stationary through time. The results of the NSD test support this assumption.

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