Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Stream Flow Assessment

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
AEA	Alaska Energy Authority
cfs	cubic feet per second
FDC	flow-duration curve
FERC	Federal Energy Regulatory Commission
ILP	Integrated Licensing Process
NAVD	North American Vertical Datum
NEPA	National Environmental Policy Act
NGVD	National Geodetic Vertical Datum
OS	Operation Scenario
Project	Susitna-Watana Hydroelectric Project
PRM	Project River Mile
RM	River Mile
sq. mi.	square mile
USGS	U.S. Geological Survey
WY	Water Year

SUMMARY

The 2012 Stream Flow Assessment involved analysis of pre-Project and post-Project flows in the Susitna River below Watana Dam. The pre-Project condition was based on the extended flow record developed by the USGS. The post-Project condition was based on a hypothetical operational scenario (OS) referred to as Maximum Load Following OS-1.

The purpose of the Stream Flow Assessment was to identify the potential Project related changes in Susitna River flows and stage in the Lower River (the portion of the river downstream of the Susitna, Chulitna and Talkeetna river confluence). The analysis performed was an initial assessment to inform the study planning and early execution phases of the integrated licensing process (ILP). Of primary interest was whether the results of the analysis indicate the need to extend portions of Fluvial Geomorphology Modeling Study and other studies further downstream in the Lower River.

The 2012 work involved four main areas of analysis: Assessment of pre-Project and Maximum Load Following OS-1 stream flows, determination of stage exceedances at the Sunshine and Susitna Station USGS gages, and analysis of the long-term stability of the USGS gages (specific gage analysis) and evaluation of discharge effects on ice elevation an flow characteristics at the USGS gages.

The study results were provided the hydrologic information to perform three other 2012 study efforts, the Reconnaissance Level Assessment of Potential Channel Change in the Lower Susitna River Segment, Development of Sediment-Transport Relationships and an Initial Sediment Balance for the Middle and Lower Susitna River Segments, and Synthesis of the 1980s Lower Susitna River Segment Aquatic Habitat Information. Updated and more detailed analysis of the Susitna River hydrology under Project conditions will be investigated in the 2013 and 2014 studies, including other operating scenarios in addition to Maximum Load Following OS-1.

The most significant finding of the Stream Flow Assessment comes from the results of the annual peak flow frequency analysis. Comparison of results between the existing conditions and the Maximum Load Following Operations Scenario 1 indicates the potential for an appreciable post-Project reduction in flows in the 1.5- to 5-year range of recurrence intervals in the Lower River. Discharges in the range of the 1.5- to 5-year peaks are often representative of the channel forming or effective discharge to which the bankfull channel capacity adjusts in streams such as the Lower River Segment that have mobile bed material and a substantial sediment supply. For the 2-year event, the reduction at Sunshine and Susitna Station were estimated at 24 and 17 percent, respectively. Relationships between channel size and discharge suggest that the level of peak flow reduction could result narrowing of the channel width by in slightly greater than 10 percent in the portion of the Lower River below Sunshine, and less than 10 percent downstream from the Yentna River confluence. These preliminary results have served as part of the decision criteria to extend the Fluvial Geomorphology Modeling Study 50 miles further downstream in the Lower River to the Susitna Station USGS Gage, or approximately 30 miles above the mouth of the river in order to provide more detailed assessment of the potential Project effects in this portion of the river.

1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (Project) using the Integrated Licensing Process (ILP). The Project is located on the Susitna River, an approximately 300-mile-long river in the Southcentral Alaska. The Project's dam site would be located at River Mile (RM) 184. The results of this study provided information to inform the 2013–2014 licensing study program, Exhibit E of the License Application, and FERC's National Environmental Policy Act (NEPA) analysis for the Project license.

This report provides the results of the Streamflow Assessment Task and the River Stage subtask of the Riverine Habitat-Flow Relationship Assessment Task, both conducted as part of the Geomorphology Study's 2012 Reconnaissance Level Geomorphic and Aquatic Habitat Assessment of the Project Effects on the Lower River Channel Study (AEA 2012). The report includes the results of the hydrologic analysis which summarizes pre-Project hydrology and post-Project hydrology under an operations scenario referred to as Maximum Load Following Operation Scenario 1 (OS-1) conditions hydrology.

The pre-Project analysis was performed using 61-year extended hydrologic records developed by the U.S. Geological Survey (USGS 2012) for the period from Water Year (WY) 1950 through WY2010 for 11 streamflow gages located in the Susitna Basin. The Maximum Load Following OS-1 analysis was performed using a simulated record developed with-Project conditions flow routing model (MWH 2012) for the same period. The Maximum Load Following OS-1 is based on the assumption that the entire load fluctuation of the entire Railbelt would be provided by the Susitna-Watana Project, and that all other sources of electrical power in the Railbelt would be running at base load. This assumed condition is not realistic for an entire year, and the results of this condition should be conservative with respect to assessing downstream impacts of load following.

The analysis included monthly flow summaries, flow-duration curves, flood frequencies curves, and associated statistics the gages for which flow records are available. A comparison between the pre-Project conditions and the Maximum Load Following OS-1 conditions was also conducted for the Gold Creek, Sunshine and Susitna Station gages.

The analysis presented in this report is an initial assessment intended to help in the study planning and early execution phases of the ILP. The routing model downstream of the Project utilized the 1980s cross-sections and simplified routing techniques. The open water hydraulic routing (R2 Resource Consultants et al. 2013) model being currently developed will replace 1980s-based routing model applied in this initial assessment. Analysis to be conducted in 2013 and 2014 will replace the initial assessment presented in this report.

2. STUDY OBJECTIVES

The overall objective of this memorandum is to evaluate the relative magnitude of changes to the flow regime of the Susitna River pre- and post-Project and associated change in river stage. More specifically, the objectives are to characterize the existing streamflow regime in the Susitna River and key tributaries, and to perform preliminary quantification of the anticipated changes under Maximum Load Following OS-1 conditions, including assessments of the following, interrelated topics:

- Pre-Project and Maximum Load Following OS-1 streamflows
- Pre-Project and Maximum Load Following OS-1 river stage duration at the Sunshine and Susitna Station USGS gages
- Analysis of specific gages to assess historic changes in the stage-discharge relationships at the mainstem gages
- Using available USGS data identify discharge effects on ice elevation and cross-sectional flow characteristics, if feasible.

Throughout this report, the term "Available Record" refers to the data collected by the USGS at each gage and varies in availability based on the years each gage was in operation. The term "Extended Record" refers to the 61-year (WY1950 and WY2010) record of daily streamflows developed by the USGS through correlation analysis for each of the 11 streamflow gages that was considered in the pre-Project analysis.

3. STUDY AREA

3.1. General

The Susitna River, located in Southcentral Alaska, drains an area of approximately 20,010 square miles and flows about 320 miles from its headwaters at the Susitna, West Fork Susitna, and East Fork Susitna glaciers to the Cook Inlet (USGS 2012). The Susitna River basin is bounded on the west and north by the Alaska Range, on the east by the Talkeetna Mountains and Copper River Lowlands and on the south by Cook Inlet. The highest elevations in the basin are at Mt. McKinley at 20,320 feet while its lowest elevations are at sea level where the river discharges into Cook Inlet. Major tributaries to the Susitna River between the headwaters and Cook Inlet include the Chulitna, Talkeetna and Yentna rivers that are also glacially fed in their respective headwaters. The basin receives, on average, 35 inches of precipitation annually with average annual air temperatures of approximately 29^{o}F.

3.2. Specific Study Area

For the Susitna-Watana Hydro Project licensing effort the Susitna River from Cook Inlet to the Maclaren River confluence at Project River Mile (PRM)261.3, the river has been subdivided into three segments (Tetra Tech 2013) whose general characteristics are governed by the basin geology as described by Wilson et al. (2009). The segments are referred to as the Upper, Middle and Lower Susitna River segments (Figure 3.2-1):

- Upper Susitna River Segment: Maclaren River confluence (PRM 261.3) downstream to the proposed Watana Dam site (PRM 187.1)
- Middle Susitna River Segment: Proposed Watana Dam site (PRM 187.1) downstream to the Three Rivers Confluence (PRM 102.4)

- Lower Susitna River Segment: Three Rivers Confluence (PRM 102.4) downstream to Cook Inlet (PRM 3.3)

In addition to the segment boundaries, Figure 3.2-1 also shows the locations of gaging stations where flow, and in some cases, sediment measurements are available. The upstream-most segment, referred to as the Upper River (UR), extends from PRM 261.3 to PRM 187.1 at the Watana Dam site. The morphologic characteristics of this segment of the river are dominated by the products of Quaternary-age glaciation. The Middle River (MR) segment extends from the Watana Dam site to the Three Rivers Confluence at about PRM 102.4. The general characteristics of the river in this segment are heavily influenced by bedrock outcrop as well as Quaternary-age glaciations. The Lower River (LR) segment extends from the Three Rivers Confluence (PRM 102.4) to the tidal flats at Cook Inlet (PRM 3.3). The morphologic characteristics of the river in this segment are dominated by the sediment loading from the major tributaries and variable resistance to erosion of the Pleistocene-age, glacially-derived materials including tills (moraines), glacio-fluvial sediments in various elevation outwash-surfaces and glacio-lacustrine sediments that control the width of the valley.

The study effort presented in this Technical Memorandum is concentrated on the Lower Susitna River Segment. However, the study area also includes the Middle and Upper Susitna River Segment since USGS gaging stations that helped form the basis for the hydrologic analysis are located throughout the Susitna River Basin.

4. ASSESSMENT OF PRE-PROJECT AND MAXIMUM LOAD FOLLOWING OS-1 STREAM FLOWS

4.1. Objectives

The overall purpose of this task is to develop hydrologic information for both the pre-Project and Maximum Load Following OS-1 (post-Project scenario) conditions and use this information to compare pre-Project and potential post-Project flows. Specific hydrologic indicators to be developed include: monthly and annual flow duration curves, monthly flow statistics (mean, median, maximum and minimum), and annual flood frequency analysis.

4.2. Available Data

There are 14 USGS streamflow gages in the Susitna River Basin plus one on the Little Susitna River that was used as an index station (Table 4.2-1 and Figure 3.2-1). The period of record for these gages ranges from 58 years at the Gold Creek gage to less than 10 years at the Yentna River at Susitna Station and the Susitna River at Sunshine gages. The available data from many of these gages "…might not adequately represent long-term streamflow conditions" in the Susitna River Basin because of the short period of record and the distribution of years during which data were collected (USGS 2012). To provide a consistent long-term record, the USGS extended the record of 11 of these gages to 61 years (WY1950 – WY2010). WY1950 was selected for the start of the record because this was the first full water year of data collection for the primary index station at Gold Creek. The Montana Creek (Mont), Deception Creek (Decep), and the Deshka River (Desh) gages were not included in the extended record analysis because they could not be adequately correlated to any long-term index station for the entire study period (USGS 2012).

4.3. Methods

This section describes the methods used to develop the monthly flows and summary statistics, the flow duration analysis, and the flood frequency analysis for both the pre-Project and Maximum Load Following OS-1 conditions.

4.3.1. Pre-Project

Monthly flow summaries were developed from the USGS (2012) extended records (downloaded from the USGS website at http://pubs.usgs.gov/sir/2012/5210) by calculating the average, maximum, minimum and median flow by month across all 61 years of the extended record, with all results rounded three significant figures. Flow-duration curves (FDCs) that represent the percentage of time each discharge is equaled or exceeded during the period of analysis were then developed using the mean daily data from the extended records. The FDCs were developed for each month and on an annual basis for each gage.

Flood frequency curve were also developed for each of the gages using the U.S. Army Corps of Engineers Hydraulic Engineering Center Statistical Software Package (HEC-SSP) that applies standard methods outlined in Bulletin 17B (IACWD 1982). These methods involve fitting a log-Pearson Type III (LPIII) frequency distribution to the annual peak flow. Recorded annual peak flow data for the available record were downloaded from the USGS water data website (http://waterdata.usgs.gov) for each gage. As noted above, the period of available record at these gages ranges between 10 and 58 years. The records were, therefore, extended to 61 years by developing a correlation relationship between instantaneous peak flow and the corresponding mean daily flow, and applying that relationship to the annual maximum mean daily flow in the extended portion of the record. The LPIII distribution was fit to the extended data using the weighted-skew method with a regional skew coefficient of 0.70 from the map of Generalized Skew Coefficients in IACWD (1982), the station skew that is a function of the measured data, and the recommended value of 0.302 for the mean square error of the generalized skew coefficient. HEC-SSP conducts high and low outlier tests to remove data that departs significantly from the trend of the annual series before fitting the distribution to the data.

To provide a basis for directly comparing modeled flows under Maximum Load Following Operation Scenario 1 (OS-1), MWH (2012) performed HEC-ResSim modeling for the pre-Project condition using the USGS gage records as model input. The HEC-ResSim model used the 1980s cross sections and the Muskingum-Cunge hydrologic routing procedure to route the flows downstream of the Watana Dam site to Sunshine Station. Flood frequency analyses were conducted using the annual hourly maximum flows as a surrogate for the 15-minute "instantaneous" measurements that are typically used for this purpose.

4.3.2. Maximum Load Following Operation Scenario 1

Flow-duration and flood frequency analyses were performed for a post-Project scenario, referred to as Maximum Load Following Operation Scenario 1 (OS-1), were performed for the three mainstem Susitna River gages (Gold Creek PRM 140, Sunshine PRM 88 and Susitna Station

PRM 30) below the Watana Dam site (PRM 187) using the same methods that were described in the previous section for the pre-Project analysis. Data used in the analysis were developed by MWH (2012) using the HEC-ResSim operations model of the Project that uses the USGS 61-year extended record of mean daily flows as a long-term reservoir inflow time series. The model run on which these data are based represents a preliminary operation scenario that was developed by placing the entire variability of the Railbelt electricity load on Susitna-Watana; thus, it represents a maximum (or worst-case) load-following scenario (John Haapala, personal communication, January 24, 2013). The model was used to route the reservoir outflows downstream through the Susitna River to the Sunshine Gage at PRM 88, providing a 61-year period of simulated flows for Maximum Load Following OS-1 at Gold Creek and Sunshine. A 61-year flow record for the Susitna Station gage was estimated by adding the difference between the flows at the Sunshine and Susitna Station gages from the USGS (2012) extended record to the routed flows at Sunshine. Annual hourly maximum hourly flows from the HEC-ResSim routings were used for the peak flood frequency analysis at Gold Creek and Sunshine as a surrogate for the instantaneous (15-minute) gage data that is typically used for this type of analysis, since the maximum temporal resolution of the model output is 1 hour. This approach is not considered to be a significant limitation in the analysis, since Susitna River is relatively large, and the difference between the peak 15-minute and maximum hourly flows is typically quite small. The frequency analysis for Susitna Station was performed based on the annual maximum mean daily flows because sufficient information is not available at this time to reliably estimate maximum flows at a higher temporal resolution. As will be shown in the analysis, this is also not a significant limitation at this location on the river.

4.4. Results

This section details the monthly flows and summary statistics, the flow duration analysis, and the flood frequency analysis for both the pre-Project and Maximum Load Following OS-1 conditions.

4.4.1. Pre-Project

The pre-Project condition is based on the 61-year extended flow record developed by the USGS (2012). It represents flow conditions without the Project in place.

4.4.1.1. Average Annual and Monthly Flow Summary

The average annual discharge from the USGS (2012) extended record at Gold Creek is about 9,700 cfs (average annual volume of ~7M ac-ft), and it is between 8,100 and 11,200 cfs in 80 percent of the years (Tables 4.4-1 and 4.4-2). Due, primarily, to inflows from the Chulitna and Talkeetna rivers that contribute 36 and 17 percent of the total, respectively, the average annual flow increases to about 24,000 cfs (~17.4M ac-ft) at the Sunshine gage, and is between 20,400 and 26,900 cfs in 80 percent of the years. At the Susitna Station gage, the average annual discharge is about 48,600 cfs (~35.2M ac-ft) and is between 42,500 and 55,600 cfs in 80 percent of the years. The Yentna and Skwentna River contribute 40 percent and 14 percent of the total flow at Susitna Station, respectively.

The Susitna River and its tributaries are located at varying elevations and the seasonal variability in flow is, in large part, driven by seasonal snow melt in June and July, and also by the relative timing and magnitude of glacial melt and rainstorm outside this period. Under pre-Project conditions, the highest flows occur in June, the low-flow period occurs between November and April, and flows are typically elevated above baseflow from May through October (Figure 4.4-1 and Table 4.4-2). Monthly flow summaries for each year in the extended record on which these averages are based are provided in Appendix A.

4.4.1.2. Flow-duration Analysis

The annual flow-duration curves indicate the expected increase in discharge from upstream to downstream, consistent with the average annual flows discussed in the previous section (Figures 4.4-2 and 4.4-3, Table 4.4-3). For example, the median annual flow (flow that is equaled or exceeded 50 percent of the time) increases from about 2,050 cfs at Cantwell to about 3,400 cfs at Gold Creek, 8,220 cfs at Sunshine and 19,000 cfs at Susitna Station. Similarly, the 90-percent exceedence flow increases from about 690 cfs at Cantwell, to about 1,200 cfs at Gold Creek, 2,830 cfs at Sunshine and 6,400 cfs at Susitna Station, and the 10-percent exceedence flow increases from 16,500 cfs at Cantwell to about 25,300 cfs at Gold Creek, 64,000 cfs at Sunshine, and 124,000 cfs at Susitna Station. Similar flow-duration curves were developed for each month at each of the stations, including the tributaries (Appendix B), and the values for specific exceedence durations are tabulated in Appendix C. An example of a monthly flow duration curve is provided in Figure 4.4-4.

4.4.1.3. Flood-Frequency Analysis

The pre-Project flood-frequency analysis was performed for each of the gages using a combination of the recorded instantaneous peak flow data and the USGS extended record. This was accomplished by first correlating the recorded peak discharges for the period of record with the mean daily discharges on the day of the peak discharge (Figure 4.4-5). The instantaneous peak discharges for the years in the extended record for which measured data are not available were then estimated by applying the resulting regression relationship to the maximum mean daily discharge. As seen in Figure 4.4-5, the relationship for the Gold Creek gage that is being used here as an example fits the recorded data very well (R2=0.98). This relationship indicates that the instantaneous peak flows at Gold Creek are typically about 4 percent greater than the corresponding mean daily flow at discharges in the 20,000-cfs range, increasing to about 7 percent at flows in the 90,000-cfs range. Similar relationships for the other gages are provided in Appendix D. A potential source of error in this method results from the fact that the instantaneous peak discharge does not always occur on the same day as the maximum mean daily discharge. This is not believed to be a significant limitation, however, because this occurs in less than 20 percent of the years, and the difference between the maximum mean daily flow and the mean daily flow on the day of the peak was not significant during those years.

Flood frequency curves developed using the HEC-SSP program with the resulting extended record of peak discharges indicates that the 2-year recurrence interval peak discharge is about 27,300 cfs at the Cantwell gage and about 43,500 cfs at Gold Creek (Table 4.4-4). The 2-year peak discharges at Sunshine and Susitna Station are substantially higher (106,000 and 170,000 cfs, respectively). The 2-year peak discharges in the Chulitna and Yentna River are 35,200 and 23,200 cfs, respectively (Table 4.4-5). The peak discharges for other events from the 1.25-year through the 100-year recurrence interval flows are also provided in Tables 4.4-4 and 4.4-5, and the plotted flood-frequency curves with the data points from the extended record and upper and lower 90-percent confidence bands and the computed frequency curve at each of the gages being considered in this analysis are provided Appendix E.

4.4.2. Maximum Load Following OS-1

The presence of the Watana Dam at PRM 187 will affect flows in the mainstem of the Susitna River downstream of the project site, but flows in the tributaries and the mainstem upstream from the reservoir will not be affected by the dam. The Maximum Load Following OS-1 analysis, therefore, only considered the three gages along the mainstem downstream from PRM 187 (i.e., Gold Creek, Sunshine, and Susitna Station). As discussed above, the flow records used for the Maximum Load Following Scenarios OS-1 analysis were developed by MWH (2012) using a HEC-ResSIM model that represents a preliminary operation scenario that was developed by placing the entire variability of the Railbelt electricity load on Susitna-Watana; thus, it represents a maximum (or worst-case) load-following scenario (John Haapala, personal communication, January 24, 2013). The HEC-ResSim model only considered flows in the reach between Watana Dam and the Sunshine gage. To estimate the Susitna Station Maximum Load Following OS-1 flows, the pre-Project difference between the mean daily flow at the Sunshine and Susitna Station gages was added to the Maximum Load Following OS-1 Sunshine mean daily flows, under the assumption that flow changes in that part of the reach would be the same under both pre-Project and Maximum Load Following OS-1 conditions. The HEC-ResSim model was also run for pre-Project (i.e., unregulated) conditions. Results from this run were used as the basis for comparing pre- and Maximum Load Following OS-1 conditions since the purpose of the comparison is to assess the differences between the two conditions, and there are minor differences between the measured and simulated flow record that could potentially confound the analysis. This comparison described in Section 6.

4.4.2.1. Monthly and Annual Flow Summary

The Project does not permanently add to or divert flows from the river. As a result, the simulated average annual discharge at the three gages under the Maximum Load Following Scenario OS-1 is essentially the same as under pre-Project conditions, ranging from about 9,700 cfs at Gold Creek to about 24,000 cfs at Sunshine and 48,500 cfs at Susitna Station, and the variability from year to year is also approximately the same (Tables 4.4-6 and 4.4-7). Average monthly flow releases under Maximum Load Following Scenario OS-1 are; however, more uniformly distributed throughout the year than under pre-Project conditions (Figure 4.4-6). Tributary inflows between the dam and the Three Rivers Confluence are relatively small compared to the mainstem flows; thus, the distribution of average monthly flows at the Gold Creek gage is also relatively uniform. Unlike the upstream, smaller tributaries, inflows from the Chulitna and Talkeetna Rivers are significant compared to the upstream mainstem flows, and there is, therefore, significant seasonal variability in the downstream river, even under the Maximum Load Following Scenario OS-1. Monthly flow summaries for the individual gages for each year in the extended record are provided in Appendix F.

4.4.2.2. Flow-duration Analysis

The annual and monthly flow-duration curves also reflect the more uniform distribution of flows throughout the year under Maximum Load Following Scenario OS-1 (Figure 4.4-7 and Tables 4.4-8 through 4.4-10). The median flow at the Gold Creek gage, for example, increases from about 3,400 cfs under pre-Project conditions to about 8,800 cfs under Maximum Load Following Scenario OS-1, and the 10-percent (low) exceedence flow increases from about 1,200 to 7,200 cfs, while the 90-percent (high) exceedence flow decreases from about 25,300 to 12,300 cfs. Similar changes occur at the two downstream gages, but the relative magnitude of the change is smaller because of the influence of the tributary inflows. For example, the median flow at Sunshine for Maximum Load Following Scenario OS-1 (13,200 cfs) is about 60 percent larger than the pre-Project median flow (8,200 cfs) and the Maximum Load Following Scenario OS-1 median flow at Susitna Station (23,100 cfs) is about 20-percent larger than the pre-Project median flow (19,000 cfs). A duration analysis of monthly flows was also conducted, and the resulting duration curves for each of the gages are provided in Appendix G.

4.4.2.3. Flood-frequency Analysis

As noted above, the flood frequency analysis for Maximum Load Following Scenario OS-1 was conducted using the simulated annual maximum hourly flows from the HEC-ResSim model. Based on the analysis, the 2-year peak discharge at Gold Creek will decrease to about 23,900 cfs under Maximum Load Following Scenario OS-1, and the 100-year peak discharge will decrease to about 66,400 cfs, reductions of 45 and 28 percent, respectively (Table 4.4-11, Figure 4.4-8). Consistent with the mean daily flows, the reduction at the two downstream gages is less significant. At Sunshine, for example, the 2-year peak will decrease by about 24 percent to 72,000 cfs and the 100-year peak will decrease by about 23 percent to 137,000 cfs (Figure 4.4-9). The estimated 2- and 100-year peaks at Susitna Station will decrease by only about 18 percent to 142,000 cfs and 5 percent to 261,000 cfs, respectively (Figure 4.4-10).

4.5. Discussion

The pre-Project hydrology analysis was conducted based on the USGS extended record data at the five mainstem gages and six tributary gages for which the data were available. Unregulated flows at the Watana Dam-site were also developed using the HEC-ResSim model to provide a basis for directly comparing pre-Project and Maximum Load Following Scenario OS-1 flows at that location.

The specific effects of the proposed Watana Dam on the downstream flow regime will, of course, depend on the manner in which the reservoir is operated. The HEC-ResSim model on which the Maximum Load Following Scenario OS-1 analysis is based represents a preliminary operation scenario that was developed by placing the entire variability of the Railbelt electricity load on the Susitna-Watana Project; thus, it represents a maximum (or worst-case) load-following scenario (John Haapala, personal communication, January 24, 2013).

Because the Project will not affect mainstem flows upstream from the reservoir or inflows from the downstream tributaries, the Maximum Load Following OS-1 analyses only considered the Gold Creek, Sunshine, and Susitna Station gages. Output from the HEC-ResSim model was used directly for the analysis at Gold Creek and Sunshine. Since the model domain only extends downstream to PRM 88, it was necessary to estimate Maximum Load Following Scenario OS-1 flows at Susitna Station using the simulated Sunshine flows, adjusted for the difference between the Sunshine and Susitna Station flows from the USGS extended record.

4.5.1. Seasonal and Flow-duration Comparison

The Project will change the seasonal flow patterns by increasing flow during the typical low-flow season that occurs in late-fall, winter and early-spring under pre-Project conditions, and decreasing the flows during the pre-Project high-flow period between May and September (Table 4.5-1 and Figure 4.5-1). These changes also affect the annual mean daily flow duration curves by reducing the magnitude of flows in the high-flow range that occur 30 to 40 percent of the time, and increasing flows in the low flow (60 to 70 percent) range (Table 4.5-2 and Figure 4.5-2). In all cases, the relative magnitude of the changes is much greater in the Middle River above the Three Rivers Confluence, and they decrease in the downstream direction because of the influence of the major tributary inflows.

4.5.2. Flood-frequency Comparison

Comparison of the flood frequency curves developed from the 61-year record of flows from the HEC-ResSim model results indicates that the annual peak flows for equivalent recurrence intervals at the Watana Dam site will decrease by about 50 percent for frequent events in the 1.25- to 1.5-year range under Maximum Load Following Operation Scenario OS-1, with the relative change decreasing to approximately 27 percent at the 100-year peak discharge (Table 4.5-4 and Figure 4.5-3). The relative change at Gold Creek is similar, decreasing from 50 percent to 59 percent for frequent events to about 28 percent at the 100-year peak (Figure 4.5-4). At Sunshine, the relative magnitude of the change is somewhat smaller, ranging from about 25 percent for frequent events to about 23 percent at the 100-year peak, due primarily to inflows from the Chulitna and Yentna Rivers (Figure 4.5-5). Tributaries downstream from Sunshine, including the Yentna and Skwentna, cause a further decrease in the relative change at Susitna Station (17 to 18 percent for the frequent event to only about 5 percent at the 100-year peak) (Figure 4.5-6).

These results can also be assessed by comparing the recurrence intervals of equivalent discharges under pre-Project and Maximum Load Following Operation Scenario OS-1 (Table 4.5-5). For example, the 2-year peak discharge of 34,200 cfs at the Watana Dam site under pre-Project conditions would occur only about once in 10 years, on average, and the 20-year flow of 57,600 cfs would occur only about once in 140 years, on average, with Maximum Load Following Operation Scenario OS-1. At Gold Creek, the 2-year peak discharge of 43,700 cfs would occur about once in 12 years on average and the 20-year flow of 72,300 cfs could occur very rarely (once in about 166 years, on average) under Maximum Load Following Operation Scenario OS-1. The 2-year peak discharge at Sunshine of 94,700 cfs would occur about once every 7 to 8 years, and the 20 year flow of 143,600 cfs would occur about once in 150 years, on average. The changes are less significant at Susitna Station, with the pre-Project 2-year flow of 170,300 cfs occurring about once in 5.2 years and the 20-year flow of 233,500 cfs occurring about one in 43 years, on average, with Maximum Load Following Operation Scenario OS-1.

5. STAGE-EXCEEDENCE ANALYSIS

This section documents the analysis that was conducted to evaluate the relative difference in stage associated with the two hydrologic conditions: pre-Project and Maximum Load Following OS-1. This analysis built on the results of the flow duration analysis. The stage exceedence analysis was conducted at two locations along the Lower Susitna River Segment: the Sunshine Gage (USGS 15292780) and the Susitna Station Gage (USGS 15294350).

This stage exceedence analysis was conducted as part of the overall 2012 Lower River Geomorphology Study, specifically as part of the “Riverine Habitat-Flow Relationship Assessment” task.

5.1. Objectives

The objective of this analysis is to quantify the relative change in river stage at two locations in the Lower Susitna River Segment between the pre-Project hydrologic condition and the Maximum Load Following OS-1 hydrologic condition. The results of the analysis provide a preliminary assessment of the change in hydraulic conditions in the Lower Susitna River Segment. The results will also provide a basis for interpreting how hydraulic responses to changes in hydrologic conditions can affect habitats and access to tributaries in the Lower River (described in a separate technical memorandum).

5.2. Methods

The primary sources of information used to conduct the stage exceedence analysis at each gage location were (1) the most recent USGS stage-discharge ratings at each site, and (2) the results of the flow-duration analyses for the pre-Project and the Maximum Load Following OS-1 hydrologic conditions. The mean daily flow record (WY1950 through WY2010) for each hydrologic condition was converted to values of stage, in feet, using the most recent USGS stage-discharge ratings. It is noted that the ratings developed for both gages do not account for the effects of ice on river stage. Each computed stage for the WY1950 through WY2010 period of record therefore represents the stage corresponding to the mean daily flow; it does not necessarily represent the mean daily stage.

5.2.1. Conversion of Mean Daily Flow Records to Stage Records

At the Sunshine Gage, the most recent rating published by the USGS is Rating ID 6.0 (the red line in Figure 5.2-1). Rating ID 6.0 is based on measurements conducted by the USGS through September 2012. According to USGS staff, at this gage there have not been any open water measurements for discharges less than 35,000 cfs, so the rating is not defined for flows less than this threshold (Josh Morse, personal communication, January 31, 2013).

The USGS is not currently maintaining the Susitna Station Gage. Rating ID 4.0 is the most current, with an apparent inflection in the rating at a stage of 10 feet (Figure 5.2-2). This rating and is based on flow measurements conducted through October 2003.

The lowest measured flow used to develop the Sunshine stage-discharge rating is 2,940 cfs and the lowest measured flow used to develop the Susitna Station stage-discharge rating is 28,000 cfs. Since the mean daily flow record at both sites includes flows less than these minima, the published ratings at both gages were extrapolated by fitting trend lines to the published relationships (Figures 5.2-1 and 5.2-2). For the Susitna Station Gage, the extrapolation was based only the stage-discharge relationship for stages less than 10 feet.

In converting the mean daily flow series to corresponding series of stage, the lookup function in Microsoft Excel was used. For flows greater than the minimum value on the published ratings, the published ratings were used to calculated stage; for flows less than these minimum values, stages were estimated using the trend lines extrapolated from the published datasets. This method produced a complete record of stages corresponding to the each value of mean daily flow at each of the two USGS locations for the pre-Project and Maximum Load Following OS-1 conditions.

5.2.2. Stage-Duration Analyses and Stage-Exceedence Analyses

A stage-duration analysis was conducted at each gage location, using the two complete stage records (WY1950 through WY2010) for both the pre-Project and Maximum Load Following OS-1 hydrologic conditions. An annual stage-duration analysis was based on the stage values for the entire period of record, and monthly stage-duration analyses were based on the stage values for each of the twelve months throughout the entire period of record. The results of these analyses were used to identify stage-exceedence relationships on annual and monthly bases. The stage-exceedence relationships corresponding to the pre-Project hydrologic conditions and the Maximum Load Following OS-1 hydrologic conditions were plotted together to compare the relative changes in stage across the range of exceedence values. A statistical analysis was also conducted to quantify the maximum, minimum, average and median stages by month.
To better illustrate how the changes in stage relate to the channel/floodplain morphology at each site, selected stage-exceedence ordinates were converted to water surface elevations and overlaid on plots of cross section geometry. The 10-, 50- and 90-percent exceedence values were selected for this graphical representation. Representative cross section geometry was first developed at each gaging station location using USGS discharge measurement notes for a recent high flow measurement. Table 5.2-1 summarizes the specific USGS flow measurements that were used to develop the representative cross section geometry at each location.

Cross-section geometry was developed by converting each incremental depth measurement (feet) corresponding to the information in Table 5.2-1 to a bed elevation (feet, NAVD88) using Equation 5.2-1.

$$Elev_{bed} = [Gage + Datum + Conversion] - Depth \qquad \textbf{\textit{(5.2-1)}}$$

where

$Elev_{bed}$	=	elevation of bed at each horizontal increment (feet, NAVD88)
Gage	=	gage reading at time of USGS flow measurement (feet), see Table 5.2-1
Datum	=	assumed gage datum relative to NGVD29 (40 feet for Susitna Station; 242 feet for Sunshine)
Conversion	=	conversion from NGVD29 to NAVD88 (6 feet used at both locations)
Depth	=	USGS measured depth at each horizontal increment (feet)

There is no published conversion factor available in the vicinity of the two gaging stations to transform elevations between the NGVD29 geodetic datum and the NAVD88 geodetic datum. However, several National Geodetic Survey control points were found in the vicinity of the Susitna River. A number of these control points reported elevations relative to both NGVD29 and NAVD88. A review of a number of these control points found that the average difference in elevations expressed in NGVD29 and elevations expressed in NAVD88 was approximately 6 feet. This vertical transformation was therefore assumed at both gage locations.

The stages associated with the 10-, 50 and 90-percent exceedences were converted to water surface elevations using Equation 5.2-2.

$$WSEL = Stage + Datum + Conversion \quad \textbf{(5.2-2)}$$

where

WSEL	=	water surface elevation corresponding to specified stage (feet, NAVD88)
Stage	=	stage selected from stage-exceedence relationship (feet)
Datum	=	assumed gage datum relative to NGVD29 (40 feet for Susitna Station; 242 feet for Sunshine)
Conversion	=	conversion from NGVD29 to NAVD88 (6 feet used at both locations)

5.3. Results

This section presents the results of the comparative stage-exceedence analysis for the pre-Project and the Maximum Load Following OS-1 hydrologic conditions at both the Sunshine Gage and the Susitna Station Gage. Specific conclusions drawn from this analysis are presented in Section 5.4. Note that the stage values presented in the graphs and tables in this section are unique to each gage location. In other words, a five-foot stage at the Sunshine Gage is not equivalent to a five-foot stage at the Susitna Station Gage.

Tables 5.3-1 through 5.3-5 present the results of the stage-exceedence analyses of the pre-Project hydrologic condition as compared to those for the Maximum Load Following OS-1 hydrologic condition. Table 5.3-1 includes specific annual stage-exceedence ordinates for both gage locations. Tables 5.3-2 and 5.3-3 include monthly stage-exceedence ordinates for the Sunshine Gage; Tables 5.3-4 and 5.3-5 include monthly stage-exceedence ordinates for the Susitna Station Gage. In each of these tables, the relative change in stage (either positive or negative) for each exceedence percentile is indicated.

Table 5.3-6 (Sunshine Gage) and Table 5.3-7 (Susitna Station Gage) provide results of statistical analyses of monthly stages calculated for both the pre-Project hydrologic conditions and the Maximum Load Following OS-1 hydrologic conditions. In each table, the relative change in stage (either positive or negative) for each statistic is indicated.

At the two gage locations, annual stage-exceedence relationships and monthly stage-exceedence relationships were developed for both the pre-Project and the Maximum Load Following OS-1 conditions. To allow a direct comparison between the results for the two hydrologic conditions, the stage-exceedence relationships were plotted together. Annual stage-exceedence relationships for the Sunshine Gage are provided in Figure 5.3-1; the annual relationships for the Susitna Station Gage are shown in Figure 5.3-2. As seen in these two figures, the line representing the pre-Project conditions is solid whereas the line representing the Maximum Load Following OS-1 conditions is dashed. Figure 5.3-3 (Sunshine Gage) and Figure 5.3-4 (Susitna Station Gage) illustrate the monthly stage-exceedence relationships for the month of May. Appendix J includes plots of the pre-Project and the Maximum Load Following OS-1 annual and monthly stage-exceedence relationships for the two locations.

The results of the stage-exceedence analysis are alternatively presented on representative cross section plots at each gage location, after converting the stages (feet) to water surface elevations (feet, NAVD88). For this presentation, the 90-, 50- and 10-percent pre-Project and Maximum Load Following OS-1 stage-exceedence values were converted to water surface elevations (see Equation 5.2-2) and overlaid on the representative cross section geometry (Figures 5.3-5 and 5.3-6). Appendix K includes identical figures showing the results of the monthly stage-exceedence analyses at both gages. This method of presentation provides a visual assessment of the relative changes in water surface elevation between the pre-Project and the Maximum Load Following OS-1 hydrologic conditions. It also provides a visual assessment of the relationship between the water-surface elevations associated with the range of flows between the 10- and 90-percent stage-exceedences.

5.4. Discussion

The stage-discharge ratings published by the USGS do not include the effect that ice has on river stage. For this reason, the results of the stage-exceedence analyses through the winter months should consider this limitation.

The tables and figures presented in the Section 5.3, Appendices A and B indicate that the magnitude of change in stage (or water-surface elevation) from the pre-Project condition to the Maximum Load Following OS-1 condition varies somewhat between the two gage locations. The results also indicate that the changes in stage vary considerably by season (i.e., month).

Regarding the sensitivity to location, it was found that for a given exceedence percentile and a given month, the magnitude of change in stage from the pre-Project hydrologic condition to the Maximum Load Following OS-1 hydrologic condition was often quite different between the two gage locations (Table 5.4-1). As seen in Table 5.4-1, the relative change in flow from the pre-Project hydrologic condition to the Maximum Load Following OS-1 hydrologic condition for a given exceedence percentile is roughly equivalent between the Sunshine Gage and the Susitna Station Gage. However, the change in stage from the pre-Project hydrologic condition to the Maximum Load Following OS-1 hydrologic condition for this same exceedence percentile varies. For stages less than the 50-percent exceedence, the change is slightly greater at the Susitna Station Gage than at the Sunshine Gage; when the stage is greater than the 50-percent exceedence value; the change at the Sunshine Gage is greater than at the Susitna Station Gage. Since the change in flows is approximately the same for each exceedence probability, the explanation is due to the differences in the slope of the published stage-discharge ratings at the two sites. For higher flow conditions, an equivalent change in flow rate at the two locations is associated with a larger change in stage at the Sunshine Gage than at the Susitna Station Gage (Figure 5.4-1).

Regarding the sensitivity to seasonality, it was found that for a given exceedence percentile and a given month, the magnitude of change in stage from the pre-Project hydrologic condition to the Maximum Load Following OS-1 hydrologic condition was often quite different between the two gage locations. For high-flow conditions (i.e. during the months of May through August, inclusive), the changes in stage at the Sunshine Gage were higher than at the Susitna Station Gage for all exceedence probabilities.

The magnitude of the change in flow in the Susitna River from the pre-Project to the Maximum Load Following OS-1 condition varies by month, as illustrated in the monthly flow-duration curves provided in Appendix G. This monthly variability is a product of the assumptions that were made for Watana Dam operating under the Maximum Load Following OS-1 hydrologic condition. Correspondingly, the magnitude of the change in stage also varies by month. This monthly variability was shown in the tables in the previous section and is further illustrated in monthly bar charts (Figures 5.4-2 through 5.4-7). These bar charts illustrate the change in stage, by month, at a specific location (either the Sunshine Gage or the Susitna Station Gage) for a specific stage-exceedence value. For instance, Figure 5.4-2 is for the Sunshine Gage location, illustrating the change in magnitude for the 90-percent stage exceedence value for each of the twelve months. Similar figures were developed for the 50- and 10-percent exceedence values at both gage locations.

The months that exhibited the least pronounced absolute change in hydrologic conditions were the months of August and September. This same observation was identified for the absolute change in stage at both gage locations. At the Sunshine Gage, the change in stage for the exceedence percentiles summarized in Table 5.3-3 ranged from -1.00 to +0.27 feet. At the Susitna Station Gage, the change in stage for the exceedence percentiles summarized in Table 5.3-5 ranged from -0.45 to +0.22 feet.

During the months of June and July, the entire flow-exceedence relationship for the Maximum Load Following OS-1 hydrologic condition was lower than for the pre-Project condition at both gage locations. Therefore, stage values for the entire range of flows for these months were also reduced. For instance, the median value of stage (50-percent exceedence) at the Sunshine Gage was reduced by 1.43 feet (June) and 1.21 feet (July). At the Susitna Station Gage, the reduction in the median value of stage was 0.87 feet (June) and 0.77 feet (July). The months of June and July exhibited the largest reduction in stage values, using the median value as the measure.

Overall, the largest changes in stage occurred during the winter/spring months of November through April. For each of these months, the median value of stage was increased by more than one foot at both of the gage locations (see Tables 5.3-6 and 5.3-7). This observation is attributed to the lowest magnitude flows during these months of the year, and incremental changes in lower flows producing relatively larger changes in stage due to the steepness of the lower part of the stage-discharge ratings. However, as previously stated, it is noted that the stage-discharge ratings published by the USGS do not include the effect that ice has on river stage. Thus, interpretation of the calculated stages should consider this limitation.

In summary, the months of October through April exhibit increased stages at both gage locations for the entire range of exceedence probabilities that were included in Tables 5.3-2 through 5.3-5. The month of May exhibits increased stages for the lower flow conditions and reduced stages for the higher flow conditions. The months of June and July show reduced stages at both gage locations for all flow conditions. The months of August and September showed increased stages for the lower flow conditions and reduced stages for the higher flow conditions.

6. SPECIFIC GAGE ANALYSIS

This section documents the specific gage analysis that was conducted to characterize the relative vertical stability of the Susitna River channel. The analysis requires comparisons of stage-discharge ratings over time, so analyses were planned for the two USGS gaging stations that are located in the Lower River Segment. The analysis was to be conducted at the Susitna River at Sunshine Gage (USGS Gage 15292780) and the Susitna River at Susitna Station Gage (USGS Gage 15294350); however, as further described in Section 6.2, the analyses were completed only for the Susitna Station Gage.

This specific gage analysis was conducted as part of the overall 2012 Lower River Geomorphology Study, specifically as part of the "Riverine Habitat-Flow Relationship Assessment" task (AEA 2012).

6.1. Objectives

The objective of this analysis is to assess the relative vertical stability of the Susitna River channel in the immediate vicinity of the two USGS gaging stations in the Lower River Segment.

6.2. Methods

A specific gage analysis involves the development of a graph of stage for a specific discharge at a particular location plotted over time. When such an analysis is made for a family of specific discharges, a family of graphs can be plotted. The resulting family of curves illustrates the changes in stage for each specific discharge, so the curves can be used to interpret if the channel in the vicinity of the gaging station is considered to be in equilibrium. If the family of curves neither progressively rise nor fall over time, the channel may be considered to be in a state of dynamic equilibrium. If the family of curves exhibits a progressive pattern of rising (falling), this may be interpreted to indicate bed aggradation (degradation).

Specific gage analyses are ideally conducted using direct measurements of stage and discharge. However, an adequate number of measurements are required for each specific discharge of interest over the period of analysis for meaningful interpretation of the results. In this study, insufficient measurement data were available, so the analyses were conducted using an adaptation of the "specific gage" technique described by Blench (1969) and Klingeman (1973). The adaptation relied on published stage-discharge ratings developed by the USGS for the gaging stations instead of directly measured stages and discharges. There are six such ratings available for the Sunshine Gage and four ratings available for the Susitna Station Gage. Information regarding each of the ratings is summarized in Tables 6.2-1 and 6.2-2, along with relevant station notes from the USGS station description.

The current location of the Susitna River at Sunshine Gage is on the left bank, approximately fifty feet downstream of the George Parks Highway Bridge near PRM 88 (Figure 6.2-1). The flow in the 2012 aerial photo (Figure 6.2-1) is 38,000 cfs, as measured at the Sunshine Gage. The channel is straight for about 2,500 feet downstream of the gage and for about 1,500 feet upstream. Further upstream, the channel is braided. According to the USGS station notes, at low and medium stages, a side channel can form along the right bank upstream of and under the bridge, and at medium to high stages, this channel can flow back into the main channel downstream of the gage. Since its original installation, the gage has been moved twice. Each time the gage was moved, the USGS revised the reference datum. According to the USGS station notes, the datum was "lowered by 5.0 feet on May 28, 1982". However, the stage values in the rating table for Rating No. 1 were subsequently adjusted so that this rating, as currently published, is relative to the lowered datum (Josh Morse, personal communication, January 31, 2013). When the gage was re-established on October 6, 2011 at its new location downstream of the bridge, the USGS station notes indicate that 10 feet was added to the datum to prevent negative gage height values. It is not certain whether this adjustment of 10 feet reflects the actual difference in elevation between the datums at the two locations.

The location of the Susitna River at Susitna Station Gage is on the left bank, approximately 1.5 miles downstream of the confluence with the Yenta River, near Project River Mile (PRM) 30 (Figure 6.2-2). The gage is located at the mid-point of a one-mile long straight section of the river. According to the USGS station notes for this gage, the hydraulic control at the site is the downstream channel for all but extreme stages, when the island 2,000 feet downstream may become the control. The station notes go on to state that while at higher flows there is one channel, at mid- to low-flows, a sand bar is exposed approximately 1,000 feet from the left bank which divides the river into two channels. This sand bar can be seen in Figure 6.2-2. The aerial photo used in this figure was flown on September 30, 2012 when the recorded discharge at the USGS gage at Sunshine was 48,000 cfs. This flow corresponds approximately to a 25 percent pre-Project annual exceedence flow.

The Susitna River at Sunshine Gage was in continuous operation from May 1981 through June 1986 and was subsequently re-established in October 2011. To date, a total of fifty-six flow measurements have been made at the site, with only two measurements made during the 25 year period between June 1986 and October 2011. Figure 6.2-3 graphically illustrates the time of survey and the magnitude of the USGS discharge measurements. Measurements that were rated as "Poor" by the USGS are distinguished since these were generally made during periods of ice cover. Rating No. 6 is the current rating for this station.

The Susitna River at Susitna Station Gage was in continuous operation from May 1975 through September 1993 and is now considered inactive. For the entire period of record, the gage remained in the same location and was never moved. To date, a total of 130 flow measurements have been made at the site, with six of them having been made subsequent to when the gage became inactive. Figure 6.2-4 graphically illustrates the time of survey and the magnitude of the USGS discharge measurements. Measurements that were rated as "Poor" by the USGS are distinguished since these were generally made during periods of ice cover. Rating No. 4 was the last published rating for this station.

The specific gage analysis was not completed for the Sunshine Gage location for several reasons. The gage has been moved on two occasions, with changes made to the recording datum after each move. More importantly, however, the gage was discontinued in 1986 so there is only a short five year period of gage operation and discharge measurement data. There was nearly a twenty-five year gap in time between when the gage was discontinued in 1986 and re-established in 2011 (at the new location downstream of the George Parks Highway Bridge), and although there have been eight flow measurements conducted since the gage was re-established, there is some uncertainty that the gage datum at the new location is correctly tied to the previous datum. Therefore, the specific gage analysis was only conducted for the Susitna Station Gage.

The first step for conducting a specific gage analysis is to confirm that measured stages reference the same datum over the entire period of the analysis. If different datums are referenced, conversions to a consistent reference are required. No adjustments were needed for the Susitna Station Gage because the gage was never moved and the USGS never changed the reporting datum. Figure 6.2-5 shows the four ratings published by the USGS for this gaging station.

The next step was to select specific discharges for analysis. The flow magnitudes that were selected for the Susitna Station Gage analysis were obtained from the pre-Project flow-duration analysis and the pre-Project flood-frequency analysis. The magnitudes that were selected were intended to cover a wide range of flow rates, and to include flows that had geomorphological significance. For instance, the 1.01- and 2-year return period flows were selected because they bracket the return period of bankfull discharge (Leopold et al. 1964). Table 6.2-3 summarizes the flow rates that were selected to develop the family of curves for the Susitna Station specific gage analysis. As indicated in this table, the minimum flow rate common to all of the published ratings is 30,000 cfs, so this selected as the minimum flow of interest. It is noted that 30,000 cfs is approximately equal to the pre-Project 45 percent annual exceedence flow. The maximum flow common to all of the published rating curves was 201,000 cfs. The pre-Project 5-year return period flow of 197,000 cfs was selected as the maximum flow for analysis because it was reasonably close to the maximum value on the published ratings.

The final step was to calculate the stage for each selected flow in Table 6.2-3 from each of the four USGS rating curves representing different periods in time. The results were plotted to develop the specific gage graphs.

6.3. Results

The tabular results of the specific gage analysis conducted at the Susitna Station Gage are summarized in Table 6.3-1. The stages in this table were calculated using the four ratings published by the USGS. The results shown in Table 6.3-1 were plotted to develop a family of nine specific gage curves (Figure 6.3-1). In developing the figure, the stage values for each flow rate were assumed constant throughout the range of effective dates for each rating, thus giving the curves a stair-step appearance. Each curve illustrates the changing conditions in river stage for the indicated flow rate over the period of record for the gaging station.

6.4. Discussion

A specific gage analysis was conducted for the Susitna River at Susitna Station Gage. A similar analysis was not conducted for the Susitna River at Sunshine Gage, in part because the period of time when the gage was in operation and when discharge data was collected was only five years (May 1981 through June 1986). Although the Sunshine Gage was re-established in 2011, and flow measurements have been conducted since this time, there is some uncertainty as to whether the gage datum at the new location is tied to the previous datum.

The analysis of the Susitna River at Susitna Station encompassed four periods (each defined by a published USGS rating) over the course of approximately 18 years, from 1975 through 1993. During this period, the USGS conducted 69 discharge measurements, ranging from 5,380 to 221,000 cfs, rated as either “Good” or “Fair”. The fact that the USGS only developed four ratings for this 18-year period is indicative of a fairly stable channel section over this time.

This observation is substantiated by the graphical results of the specific gage analysis. The family of specific gage curves shows evidence that for the range of flows selected, there has been only minor changes in stage, with no more than 0.5 feet of change for a given flow rate between any two rating periods. If net stage change for a given flow rate is defined as the change in stage between Rating 1 and Rating 4, then the flows associated with the largest net increase in stage are 80,000 and 94,000 cfs, each showing a net increase of 0.3 feet. The flow rate with the largest net decrease in stage (i.e., 0.5 feet) was 197,000 cfs.

Overall, the trend in stage change was for a net decrease of no more than 0.5 feet for flows greater than or equal to 152,000 cfs (1.25-year return period), and a net increase of no more than 0.3 feet for flows between 60,000 and 132,000 cfs. For flows less than 60,000 cfs, the results indicated a net decrease in stage of no more than 0.3 feet.

The flow rates with the least amount of net change in stage were 132,000 cfs (1.01-yr return period) and 152,000 cfs (1.25-year return period), each with a net change of only 0.1 feet.

The small observed net decrease of specific gage for flows greater than 152,000 cfs may indicate a minor change in the downstream channel control during high flows. This might be due to changes in the planform of the downstream island that the USGS indicated may function as a high flow control, or it might be due to widening of the channel downstream of the gage. The variation in specific gage for flows less than 152,000 cfs might simply be a result of the changing influence of the adjacent sandbar over time. However, given the small magnitudes of change in stage as summarized above and as seen in Figure 6.3-1, and the apparent absence of any substantial progressive changes in stage for specific discharges over and 18-year period, the Susitna River channel section in the vicinity of the Susitna Station Gage can be considered to be in equilibrium.

7. DISCHARGE EFFECTS ON ICE ELEVATION AND CROSS-SECTIONAL FLOW CHARACTERISTICS

The available data from the USGS Susitna River at Sunshine and Susitna River at Susitna Station mainstem gages were evaluated to assess potential discharge effects on ice elevation and cross sectional flow characteristics (depth and velocity) at the gage locations, as part of the Riverine Habitat-Flow Relationship Assessment.

Ice cover over a river channel increases resistance to flow in several ways, including the following (Beltaos 1995):

- Increases in the wetted perimeter on which shear stress operates, causing a significant reduction in the hydraulic radius for the same flow depth, compared to open-water conditions,
- Increases in the total channel resistance due to the roughness of the undersurface of the ice cover, and
- Potentially significant reductions in cross-sectional area due to large, undersurface ice protrusions.

Resistance to flow and the conveyance capacity in an ice-covered channel are often difficult to estimate precisely due to the following complicating factors (Beltaos 1995):

- The increase in roughness of the undersurface of the ice cover is difficult to measure directly or estimate indirectly from velocity profiles,
- The unobstructed waterway under the ice cover varies with large deposits of loose slush in a manner that is difficult to estimate,
- With an ice cover, the slope of the energy grade line is assumed to be parallel to that for uniform, steady, open channel flow conditions, an assumption that may be invalid, particularly with heavy frazil loads or rapid flow variation,
- The bed roughness can be significantly different under ice cover than for open channel conditions

7.1. Objectives

The objective of this analysis was to determine whether discharge effects on ice elevation and flow characteristics could be detected from the available data at the USGS gages, and if so, to approximate the magnitude of these effects.

7.2. Methods

Winter gage data are available from 13 measurements taken between 1981 and 1986 at the Sunshine gage and 23 measurements taken between 1982 and 1993 at the Susitna Station gage. These measurements were recorded by hand, and the hand-written notes were entered into an Excel spreadsheet to analyze the relationships between discharge, ice thickness, and cross sectional flow characteristics (Tables 7.2-1 and 7.2-2).

The data were reviewed to determine discharge effects on ice elevation and flow characteristics. Unfortunately, neither the stage nor the water-surface elevation were surveyed during the field discharge measurements, thus comparisons to ice elevation were not possible. In addition, the hydraulic condition of the flow and the interface of the ice cover were not noted. It is, therefore, not possible to evaluate whether the flow was under pressure, and if so, by how much. As a result, the effects of the pressure head on the hydraulic properties cannot be assessed with the available data.

Further analysis could not be performed for the Susitna Station gage site, because the hydraulic (i.e., area, width and velocity) data from the open-water field measurements were not reported.

The USGS NWIS site contains field measurement data for the Sunshine gage for 48 measurements from 1981 through 2012, including 15 ice measurements. The 13 measurements for which hand written notes were obtained, and additional measurements taken on January 31, 2012, and March 19, 2012, are included (Table 7.2-1). There are 35 measurements reported for open water conditions.

Reported data for the field measurements include channel discharge, channel width, channel area and channel velocity (hydraulic depth was calculated by dividing the channel area by the channel width). The data for the 48 measurements were used to compare trends of velocity, hydraulic depth and flow area with discharge between ice covered and open channel flow conditions.

The available data at the Susitna Station gage site does not include the hydraulic (i.e., area, width and velocity) data from the field measurements.

7.3. Results

Independent regression lines through the velocity versus discharge data at the Sunshine gage indicates that there may be difference in the relationship for ice-covered conditions compared to open-water conditions (Figure 7.3-1). The ice cover line is steeper and appears to be shifted to somewhat higher velocities than the open-water line, which is reasonable based on the expected relationships for pressure flow and open-water flow at equivalent discharges. However, since the range of discharges for the ice-cover data is relatively small and all of the points were collected at discharges less than the range of discharges from the open-water data, drawing this conclusion from the data, alone, is tenuous. In fact, a regression line through the combined data set appears to fit reasonably well, with the exception of a few points at the lower end of each data set that had unusually low velocities compared to the remainder of the data sets. The hydraulic (i.e., average) depth and cross sectional relationships (Figures 7.3-2 and 7.3-3) lead to the same conclusions.

7.4. Discussions

The available data at the Sunshine and Susitna Station gages, that represent pre-Project conditions, do not provide sufficient information with which to draw defensible conclusions about the differences in hydraulic conditions between ice-covered and open-water conditions, particularly those that will occur under Project conditions. Future discharge measurements under ice-cover conditions should include the elevation of the top of the ice and the static water-level to provide a basis for assessing the degree of pressure flow.

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9. TABLES

Table 4.2-1. List of streamflow gages.

Gage Number	Gage Name	Drainage Area (sq. mi.)	Gage Datum (NGVD 29,ft)	Latitude	Longitude	Available Record	Extended Record	Main Stem River Mile
15290000	Little Susitna River near Palmer	63	917	61° 42' 37"	149° 13' 47"	1948 - 2011		-
15291000	Susitna River near Denali	950	2,440	63° 06' 14"	147° 30' 57"	1957 - 1966; 1968 - 1986	Yes	291
15291200	Maclaren River near Paxson	280	2,866	63° 07' 10"	146° 31' 45"	1958 - 1986	Yes	-
15291500	Susitna River near Cantwell	4,140	1,900	62° 41' 55"	147° 32' 42"	1961 - 1972; 1980 - 1986	Yes	223
15292000	Susitna River at Gold Creek	6,160	677	62° 46' 04"	149° 41' 28"	1949 - 1996; 2001 - 2011	Yes	136
15292400	Chulitna River near Talkeetna	2,570	520	62° 33' 31"	150° 14' 02"	1958 - 1972; 1980 - 1986	Yes	-
15292700	Talkeetna River near Talkeetna	1,996	400	62° 20' 49"	150° 01' 01"	1964 - 2011	Yes	-
15292780	Susitna River at Sunshine	11,100	270	62° 10' 31.3"	150° 10' 13.5"	1981 - 1986	Yes	84
15292800	Montana Creek near Montana	164	250	62° 06' 19"	150° 03' 27"	2005 - 2006; 2008 - 2011		-
15294005	Willow Creek near Willow	166	350	61° 46' 51"	149° 53' 04"	1978 - 1993; 2001 - 2011	Yes	-
15294010	Deception Creek near Willow	48	250	61° 44' 52"	149° 56' 14"	1978 - 1985		-
15294100	Deshka River near Willow	591	80	61° 46' 05"	150 20' 13"	1978 - 1986; 1998 - 2001		-
15294300	Skwentna River near Skwentna	2,250	200	61° 52' 23"	151 22' 01"	1959 - 1982	Yes	-
15294345	Yentna River near Susitna Station	6,180	80	61° 41' 55"	150 39' 02	1980 - 1986	Yes	-
15294350	Susitna River at Susitna Station	19,400	40	61° 32' 41"	150 30' 45	1974 - 1993	Yes	28

Table 4.4-1. Average annual flows (cfs) for pre-Project conditions based on the USGS extended record.

Water Year	Average Annual Flow, Q (cfs), for Pre-Project Conditions										
	Susitna River near Denali	Maclaren River near Paxson	Susitna River near Cantwell	Susitna River at Gold Creek	Chulitna River near Talkeetna	Talkeetna River near Talkeetna	Susitna River at Sunshine	Willow Creek near Willow	Skwentna River near Skwentna	Yentna River near Susitna Station	Susitna River at Susitna Station
1950	2,200	816	5,080	8,030	7,410	3,390	19,600	277	5,520	16,300	42,400
1951	2,620	978	5,790	9,110	8,470	3,860	22,300	394	6,190	18,500	47,300
1952	2,570	962	6,060	9,530	8,190	4,030	22,900	423	6,280	18,300	46,800
1953	2,830	1,070	6,410	10,100	9,240	4,260	24,700	351	6,830	20,400	52,200
1954	2,810	1,040	6,150	9,680	8,890	4,090	23,700	308	6,560	19,600	49,700
1955	2,730	1,030	6,520	10,300	8,730	4,320	24,600	391	6,730	19,700	50,300
1956	3,180	1,190	7,310	11,400	9,790	4,880	27,600	343	7,420	21,800	55,200
1957	3,650	1,100	6,610	10,400	9,240	4,360	25,300	361	6,950	20,600	52,300
1958	2,510	1,110	5,990	9,480	8,770	3,970	23,000	271	6,420	18,900	48,700
1959	2,610	843	6,710	10,600	8,380	4,070	25,500	404	6,910	20,400	51,700
1960	2,900	1,180	6,140	9,690	8,360	3,920	23,600	340	6,390	17,900	47,700
1961	2,660	1,110	6,460	10,800	9,450	4,350	26,300	381	7,250	20,300	52,200
1962	3,190	1,010	7,990	11,600	8,820	4,370	27,500	431	5,700	16,000	47,900
1963	3,150	1,290	7,370	11,100	8,270	4,150	26,700	500	5,850	16,400	47,100
1964	2,600	960	6,610	9,770	9,310	3,950	22,600	351	6,270	17,500	42,700
1965	2,510	985	6,630	10,200	9,360	4,750	25,800	385	6,630	18,600	49,300
1966	2,410	816	5,190	9,430	8,650	4,220	23,600	327	6,430	18,000	46,300
1967	2,970	1,150	6,840	11,200	11,100	4,470	26,900	423	5,610	15,700	45,200
1968	3,430	896	6,130	9,790	9,170	4,470	24,600	379	6,440	18,000	46,800
1969	2,290	697	4,190	5,600	6,110	2,250	14,000	204	5,200	14,600	33,400

Water Year	Average Annual Flow, Q (cfs), for Pre-Project Conditions										
	Susitna River near Denali	Maclaren River near Paxson	Susitna River near Cantwell	Susitna River at Gold Creek	Chulitna River near Talkeetna	Talkeetna River near Talkeetna	Susitna River at Sunshine	Willow Creek near Willow	Skwentna River near Skwentna	Yentna River near Susitna Station	Susitna River at Susitna Station
1970	2,240	735	4,550	7,590	8,740	3,500	19,700	308	7,240	20,300	46,600
1971	2,900	1,090	6,820	10,300	8,410	5,300	25,400	399	6,940	19,400	47,800
1972	2,940	1,060	6,910	10,900	8,340	4,480	26,500	402	6,000	16,800	46,700
1973	2,240	890	5,110	8,090	7,590	3,850	20,800	350	5,240	14,700	41,400
1974	2,960	846	4,820	7,630	7,910	3,320	19,500	337	5,160	14,500	40,000
1975	3,000	1,030	6,550	10,300	8,970	4,340	25,400	410	6,490	18,900	46,100
1976	2,580	920	5,170	8,170	7,590	3,400	20,500	311	5,820	17,200	43,000
1977	3,050	1,160	6,410	10,100	8,740	4,360	24,700	434	10,100	26,300	56,000
1978	2,680	925	5,150	8,190	7,660	3,300	20,400	256	6,370	17,800	42,000
1979	3,040	886	6,030	9,490	8,940	4,450	24,000	433	6,630	20,700	53,700
1980	2,910	1,020	6,770	10,700	9,650	4,350	26,100	511	9,050	26,000	61,900
1981	3,400	1,170	7,890	12,000	10,400	4,420	28,400	367	9,050	24,900	55,700
1982	2,620	806	6,020	9,670	8,450	4,200	24,100	427	6,130	18,600	47,100
1983	2,830	994	6,510	9,920	8,220	3,640	23,600	349	6,390	18,300	43,800
1984	2,930	938	6,650	9,580	8,460	3,640	23,500	331	6,950	20,000	45,400
1985	3,000	1,070	5,930	9,880	8,460	4,260	24,300	468	6,840	19,700	47,300
1986	2,970	1,060	5,770	8,530	7,470	3,350	20,600	320	6,480	19,700	46,300
1987	3,060	1,070	6,710	10,600	9,860	4,810	26,700	416	7,750	23,600	54,900
1988	3,050	983	6,500	10,200	8,080	3,740	24,800	349	7,520	22,900	53,600
1989	3,210	1,030	6,500	10,300	8,960	4,240	25,500	413	7,980	24,400	56,500
1990	3,700	1,290	8,310	13,000	10,900	5,390	31,800	536	8,610	26,400	61,200

Water Year	Average Annual Flow, Q (cfs), for Pre-Project Conditions										
	Susitna River near Denali	Maclaren River near Paxson	Susitna River near Cantwell	Susitna River at Gold Creek	Chulitna River near Talkeetna	Talkeetna River near Talkeetna	Susitna River at Sunshine	Willow Creek near Willow	Skwentna River near Skwentna	Yentna River near Susitna Station	Susitna River at Susitna Station
1991	2,600	855	5,390	8,530	7,940	3,780	21,600	383	6,740	20,600	48,200
1992	2,430	863	5,510	8,720	7,510	3,530	21,600	335	6,080	18,400	43,900
1993	3,040	1,090	6,410	10,100	10,000	4,840	26,000	383	6,830	20,400	53,100
1994	2,770	990	6,300	9,960	9,170	4,340	25,100	413	6,710	19,800	51,800
1995	2,850	1,020	6,540	10,300	8,680	4,040	25,400	360	6,970	20,600	51,300
1996	1,860	648	4,260	6,800	6,790	3,120	17,700	245	4,750	13,800	38,300
1997	2,440	827	5,510	8,800	7,670	3,580	23,100	317	6,050	18,400	44,600
1998	2,670	907	5,890	9,380	8,230	3,850	24,600	336	6,380	19,500	47,100
1999	2,520	864	5,810	9,290	8,080	3,850	24,400	326	6,360	19,500	46,600
2000	2,750	963	6,400	10,200	8,900	4,450	26,600	429	6,910	21,100	50,300
2001	2,510	901	6,030	9,540	7,850	3,700	23,800	355	6,380	19,200	46,900
2002	2,420	865	5,360	8,480	8,090	3,800	21,700	315	5,800	17,100	45,100
2003	2,820	1,000	6,510	10,300	9,080	4,250	25,600	338	6,930	20,300	52,400
2004	2,570	912	5,960	9,400	7,900	3,610	23,300	268	6,400	18,900	47,700
2005	3,660	1,330	7,820	12,200	11,700	5,860	30,900	607	7,970	23,600	61,400
2006	2,710	983	6,550	10,300	8,290	4,010	24,900	434	6,800	20,000	49,500
2007	2,550	917	6,100	9,650	7,840	3,590	23,700	313	6,640	19,800	48,500
2008	2,360	844	5,630	8,900	7,460	3,420	22,000	314	6,120	18,000	45,300
2009	2,530	903	6,020	9,500	7,730	3,560	23,400	289	6,470	19,200	47,700
2010	2,720	983	6,440	10,100	8,180	3,760	24,800	293	6,870	20,500	50,300

Water Year	Average Annual Flow, Q (cfs), for Pre-Project Conditions										
	Susitna River near Denali	Maclaren River near Paxson	Susitna River near Cantwell	Susitna River at Gold Creek	Chulitna River near Talkeetna	Talkeetna River near Talkeetna	Susitna River at Sunshine	Willow Creek near Willow	Skwentna River near Skwentna	Yentna River near Susitna Station	Susitna River at Susitna Station
Average	2,790	980	6,190	9,730	8,600	4,060	24,050	370	6,660	19,460	48,560
Median	2,750	980	6,300	9,790	8,460	4,040	24,400	360	6,490	19,500	47,700
90% Exceed-ence	2,370	820	5,120	8,110	7,530	3,390	20,420	280	5,630	16,060	42,460
10% Exceed-ence	3,210	1,170	7,230	11,180	9,850	4,800	26,860	430	7,930	23,600	55,600
Annual Volume (af)	2,018,000	711,000	4,486,000	7,047,000	6,230,000	2,938,000	17,426,000	266,000	4,828,000	14,101,000	35,180,000

Table 4.4-2. Average monthly flows (cfs) at USGS gages in the Susitna River watershed for pre-Project conditions based on the USGS extended record.

Period	Susitna River near Denali	Maclaren River near Paxson	Susitna River near Cantwell	Susitna River at Gold Creek	Chulitna River near Talkeetna	Talkeetna River near Talkeetna	Susitna River at Sunshine	Willow Creek Near Willow	Skwentna River near Skwentna	Yentna River near Susitna Station	Susitna River at Susitna Station
Drainage Area (sq. mi.)	950	280	4,140	6,160	2,570	1,996	11,100	166	2,250	6,180	19,400
OCT	1,330	465	3,800	6,320	5,750	2,840	15,900	332	4,780	13,400	36,000
NOV	503	182	1,600	2,670	2,260	1,160	6,490	153	2,020	5,350	14,400
DEC	326	125	1,130	1,890	1,550	801	4,490	105	1,400	3,640	9,510
JAN	263	102	938	1,590	1,300	655	3,720	84	1,160	3,020	7,910
FEB	229	88	820	1,420	1,140	553	3,260	71	1,020	2,650	7,080
MAR	212	81	755	1,300	1,060	502	2,960	60	916	2,400	6,510
APR	293	106	1,030	1,740	1,370	670	4,030	79	1,330	3,480	8,990
MAY	3,120	1,140	8,630	13,800	10,400	5,120	33,200	487	9,280	26,900	66,100
JUN	7,400	2,800	16,900	26,300	21,500	10,700	63,700	1,040	17,400	50,600	120,000
JUL	8,580	2,920	15,800	24,000	23,200	10,300	60,500	745	16,700	49,900	122,000
AUG	7,300	2,420	13,900	21,400	20,600	9,210	54,200	666	14,200	43,100	109,000
SEP	3,640	1,290	8,620	13,700	12,600	5,940	34,900	573	9,320	27,900	72,800
Annual	2,780	982	6,190	9,720	8,600	4,060	24,100	368	6,660	19,500	48,600

Table 4.4-3. Annual flow exceedence ordinates (cfs) for pre-Project conditions based on the USGS Extended Record.

Annual Flow Exceedence Ordinates											
Percentile	Susitna River near Denali	Maclaren River near Paxson	Susitna River near Cantwell	Susitna River at Gold Creek	Chulitna River near Talkeetna	Talkeetna River near Talkeetna	Susitna River at Sunshine	Willow Creek near Willow	Skwentna River near Skwentna	Yentna River near Susitna Station	Susitna River at Susitna Station
99%	110	47	440	750	820	380	1,740	38	600	1,460	5,210
95%	181	60	560	960	965	450	2,310	51	750	1,910	5,840
90%	200	76	694	1,200	1,040	500	2,830	60	850	2,280	6,400
75%	263	100	940	1,600	1,230	621	3,750	80	1,140	2,970	7,710
50%	650	220	2,050	3,400	2,840	1,430	8,220	171	2,660	6,950	19,000
25%	5,070	1,820	11,400	17,800	16,100	7,240	45,000	526	12,000	36,500	94,000
10%	8,500	2,950	16,500	25,300	23,400	10,500	64,000	930	17,200	51,300	124,000
5%	9,570	3,400	19,400	29,800	26,200	12,800	72,800	1,240	19,900	58,700	138,000
1%	12,700	4,400	25,700	39,300	33,700	18,100	91,200	1,870	26,400	73,700	164,000

Table 4.4-4. Mainstem Susitna River estimated return period peak flows (cfs) for pre-Project conditions based on the USGS extended record.

Return Period (years)	Flow (cfs)				
	Denali	Cantwell	Gold Creek	Sunshine	Susitna Station
1.25	11,300	23,100	35,100	90,200	152,000
2	13,500	27,300	43,500	106,000	170,000
5	17,200	33,400	56,200	129,000	197,000
20	23,100	41,900	74,600	160,000	233,000
50	27,500	47,600	87,500	181,000	258,000
100	31,200	52,100	98,000	197,000	276,000

Table 4.4-5. Susitna River Tributary estimated return period peak flows (cfs) for pre-Project conditions based on the USGS extended record.

Return Period (years)	Flow (cfs)					
	Maclaren	Chulitna	Talkeetna	Willow	Skwentna	Yentna
1.25	4,220	30,200	17,700	1,970	25,000	74,100
2	4,900	35,200	23,200	2,700	29,100	83,600
5	5,950	43,000	32,700	3,990	35,300	97,400
20	7,510	54,800	49,100	6,240	44,400	116,000
50	8,620	63,200	62,300	8,080	50,800	129,000
100	9,510	70,100	73,900	9,700	55,900	139,000

Table 4.4-6. Average monthly flows (cfs) at three USGS gages in the Susitna River watershed for Maximum Load Following Scenario OS-1, based on the HEC-ResSim model.

Period	Susitna River at Gold Creek	Susitna River at Sunshine	Susitna River at Susitna Station
Drainage Area (sq. mi.)	6,160	11,100	19,400
OCT	8,240	18,000	38,100
NOV	7,990	11,900	19,800
DEC	8,750	11,300	16,300
JAN	9,140	11,300	15,500
FEB	9,750	11,600	15,400
MAR	7,460	9,190	12,700
APR	6,950	9,160	14,100
MAY	8,490	27,400	60,200
JUN	10,200	47,500	104,000
JUL	10,800	47,200	108,000
AUG	15,400	48,400	103,000
SEP	12,700	34,100	72,000
Annual	9,660	24,000	48,500

Table 4.4-7. Average annual flows (cfs) for Maximum Load Following OS-1 conditions based on the HEC-ResSim model.

Water Year	Average Annual Flow, Q (cfs), for Maximum Load Following OS-1 Conditions		
	Susitna River at Gold Creek	Susitna River at Sunshine	Susitna River at Susitna Station
1950	8,470	20,100	42,900
1951	9,110	22,300	47,300
1952	9,000	22,400	46,300
1953	9,890	24,500	52,000
1954	9,640	23,700	49,700
1955	10,100	24,400	50,100
1956	11,400	27,500	55,100
1957	10,300	25,200	52,200
1958	9,440	23,000	48,700
1959	10,300	25,200	51,400
1960	9,630	23,500	47,600
1961	10,800	26,300	52,200
1962	11,500	27,500	47,900
1963	11,000	26,600	47,100
1964	9,740	22,600	42,600
1965	10,100	25,700	49,100
1966	9,410	23,700	46,300
1967	10,900	26,600	44,900
1968	9,770	24,600	46,800
1969	8,180	16,500	36,000
1970	6,880	19,000	45,900
1971	8,230	23,400	45,800
1972	10,800	26,400	46,700
1973	8,480	21,300	41,800
1974	8,860	20,700	41,200
1975	8,490	23,600	44,300
1976	8,550	20,900	43,400
1977	9,640	24,200	55,500
1978	8,420	20,700	42,300
1979	9,180	23,700	53,400
1980	10,600	25,900	61,800
1981	11,600	28,000	55,400

Water Year	Average Annual Flow, Q (cfs), for Maximum Load Following OS-1 Conditions, cont.		
	Susitna River at Gold Creek	Susitna River at Sunshine	Susitna River at Susitna Station
1982	9,610	24,000	47,000
1983	9,880	23,500	43,800
1984	9,550	23,500	45,400
1985	9,820	24,200	47,200
1986	8,550	20,600	46,400
1987	10,400	26,600	54,700
1988	10,200	24,800	53,500
1989	10,200	25,500	56,400
1990	12,900	31,600	61,100
1991	8,570	21,700	48,300
1992	8,620	21,500	43,800
1993	10,000	25,900	53,000
1994	9,960	25,100	51,800
1995	10,200	25,300	51,200
1996	8,450	19,400	40,000
1997	8,270	22,600	44,000
1998	8,680	23,800	46,400
1999	8,800	23,900	46,100
2000	10,100	26,400	50,100
2001	9,530	23,800	47,000
2002	8,530	21,700	45,100
2003	10,100	25,500	52,300
2004	9,440	23,400	47,800
2005	12,000	30,700	61,200
2006	10,100	24,800	49,300
2007	9,570	23,700	48,500
2008	8,860	22,000	45,200
2009	9,460	23,400	47,600
2010	10,100	24,800	50,300

Table 4.4-8. Annual and monthly flow exceedence ordinates (cfs) for Maximum Load Following OS-1 conditions at Susitna River at Gold Creek based on the HEC-ResSim model.

Susitna River at Gold Creek													
Percentile	**Annual**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
99%	1,400	6,440	7,140	6,880	7,070	795	800	952	2,240	7,980	7,880	7,900	6,200
95%	6,870	6,710	7,250	7,210	7,880	8,160	1,400	1,420	6,200	8,480	8,380	8,420	6,730
90%	7,210	6,920	7,330	7,660	8,220	8,500	6,900	6,250	6,620	8,700	8,600	8,730	7,170
75%	7,840	7,300	7,690	8,240	8,720	8,850	7,250	6,970	7,460	9,200	9,000	9,260	8,150
50%	8,750	7,730	8,010	8,740	9,190	9,800	7,850	7,390	8,300	9,890	9,480	12,600	11,000
25%	9,920	8,390	8,230	9,230	9,560	10,700	8,210	7,750	9,560	10,800	10,300	20,300	15,500
10%	12,300	10,100	8,450	9,760	10,300	11,400	8,620	7,990	10,800	11,900	12,000	25,600	21,100
5%	17,800	12,000	8,760	10,200	10,600	11,700	9,040	8,210	11,600	12,800	22,400	29,500	24,200
1%	26,900	15,900	9,610	11,300	11,700	13,200	9,650	8,730	13,300	16,500	29,700	39,600	32,200

Table 4.4-9. Annual and monthly flow exceedence ordinates (cfs) for Maximum Load Following OS-1 conditions at Susitna River at Sunshine based on the HEC-ResSim model.

Susitna River at Sunshine													
Percentile	**Annual**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
99%	3,240	11,000	9,300	8,880	8,840	2,110	2,080	2,360	5,400	26,400	32,000	21,900	13,800
95%	8,840	11,800	9,920	9,590	9,810	9,760	3,270	3,360	9,710	31,100	35,000	31,400	15,900
90%	9,470	12,400	10,300	10,000	10,200	10,100	8,290	7,850	10,700	33,400	37,400	34,900	18,300
75%	10,800	13,500	10,900	10,600	10,700	10,700	8,920	8,700	14,600	39,800	41,100	39,500	23,300
50%	13,200	15,800	11,600	11,300	11,400	11,700	9,510	9,320	25,900	48,000	45,800	46,000	31,300
25%	38,400	20,200	12,500	11,900	11,900	12,700	10,000	9,890	36,900	54,100	51,800	55,100	41,400
10%	51,000	26,800	13,800	12,500	12,600	13,500	10,600	10,700	48,500	60,400	58,200	64,800	54,300
5%	57,100	31,700	14,700	13,000	13,100	14,000	11,100	11,600	54,900	65,000	63,900	73,300	62,000
1%	71,300	42,900	16,500	14,000	13,900	15,100	11,700	17,000	60,400	77,200	77,000	97,800	80,300

Table 4.4-10. Annual and monthly flow exceedence ordinates (cfs) for Maximum Load Following OS-1 conditions at Susitna River at Susitna Station based on the HEC-ResSim model.

Susitna River at Susitna Station													
Percentile	**Annual**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
99%	6,810	16,500	13,200	12,500	11,900	6,020	5,450	5,760	10,100	58,200	73,700	45,200	22,900
95%	12,300	19,600	14,000	13,300	13,400	13,200	7,000	6,880	14,000	69,500	81,700	68,900	34,200
90%	13,000	21,900	14,800	13,800	13,900	13,600	11,500	11,300	17,400	77,400	88,100	76,600	39,400
75%	15,100	26,700	16,500	14,800	14,500	14,400	12,300	12,100	32,700	90,400	97,600	88,400	50,900
50%	23,100	33,600	18,500	16,000	15,400	15,500	12,900	12,900	57,700	106,000	107,000	102,000	68,000
25%	87,400	43,800	21,800	17,600	16,400	16,600	13,700	14,700	85,800	117,000	118,000	116,000	88,800
10%	112,000	60,200	25,800	18,800	17,500	17,600	14,600	18,100	106,000	128,000	129,000	129,000	112,000
5%	122,000	70,600	29,200	19,700	18,100	18,400	15,300	23,000	116,000	134,000	139,000	144,000	123,000
1%	145,000	97,000	40,900	25,400	19,000	19,700	16,300	39,000	128,000	149,000	162,000	188,000	152,000

Table 4.4-11. Susitna River estimated return period peak flows (cfs) for Maximum Load Following OS-1 conditions based on the HEC-ResSim model.

Return Period (years)	Flow (cfs)		
	Gold Creek	Sunshine	Susitna Station
1.25	16,900	60,500	125,000
2	23,900	72,000	142,000
5	34,300	88,200	169,000
20	48,800	110,000	209,000
50	58,600	125,000	238,000
100	66,400	137,000	261,000

Table 4.5-1. Average monthly flow (cfs) comparison for pre-Project and Maximum Load Following OS-1 conditions.

Period	Watana Dam			Susitna River at Gold Creek			Susitna River at Sunshine			Susitna River at Susitna Station		
	Pre-Project	Max LF OS-1	Δ	Pre-Project	Max LF OS-1	Δ	Pre-Project	Max LF OS-1	Δ	Pre-Project	Max LF OS-1	Δ
OCT	5,100	7,020	1,920	6,320	8,240	1,920	15,900	18,000	2,100	36,000	38,100	2,100
NOV	2,150	7,520	5,370	2,670	7,990	5,320	6,490	11,900	5,410	14,400	19,800	5,400
DEC	1,520	8,540	7,020	1,890	8,750	6,860	4,490	11,300	6,810	9,510	16,300	6,790
JAN	1,280	8,840	7,560	1,590	9,140	7,550	3,720	11,300	7,580	7,910	15,500	7,590
FEB	1,130	9,450	8,320	1,420	9,750	8,330	3,260	11,600	8,340	7,080	15,400	8,320
MAR	1,040	7,170	6,130	1,300	7,460	6,160	2,960	9,190	6,230	6,510	12,700	6,190
APR	1,400	6,650	5,250	1,740	6,950	5,210	4,030	9,160	5,130	8,990	14,100	5,110
MAY	11,300	6,090	-5,210	13,800	8,490	-5,310	33,200	27,400	-5,800	66,100	60,200	-5,900
JUN	21,700	5,680	-16,020	26,300	10,200	-16,100	63,700	47,500	-16,200	120,000	104,000	-16,000
JUL	20,000	6,980	-13,020	24,000	10,800	-13,200	60,500	47,200	-13,300	122,000	108,000	-14,000
AUG	17,800	11,900	-5,900	21,400	15,400	-6,000	54,200	48,400	-5,800	109,000	103,000	-6,000
SEP	11,300	10,100	-1,200	13,700	12,700	-1,000	34,900	34,100	-800	72,800	72,000	-800
Annual	8,010	7,990	-20	9,720	9,660	-60	24,100	24,000	-100	48,600	48,500	-100

Table 4.5-2. Average annual flow (cfs) comparison for pre-Project versus Maximum Load Following OS-1 conditions.

Water Year	Average Annual Flow, Q (cfs), Comparison							
	Watana Dam		Susitna River at Gold Creek		Susitna River at Sunshine		Susitna River at Susitna Station	
	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1
1950	6600	7100	8,030	8,470	19,600	20,100	42,400	42,900
1951	7500	7500	9,110	9,110	22,300	22,300	47,300	47,300
1952	7800	7400	9,530	9,000	22,900	22,400	46,800	46,300
1953	8300	8100	10,100	9,890	24,700	24,500	52,200	52,000
1954	8000	8000	9,680	9,640	23,700	23,700	49,700	49,700
1955	8400	8300	10,300	10,100	24,600	24,400	50,300	50,100
1956	9400	9400	11,400	11,400	27,600	27,500	55,200	55,100
1957	8600	8500	10,400	10,300	25,300	25,200	52,300	52,200
1958	7800	7800	9,480	9,440	23,000	23,000	48,700	48,700
1959	8700	8500	10,600	10,300	25,500	25,200	51,700	51,400
1960	8000	8000	9,690	9,630	23,600	23,500	47,700	47,600
1961	8700	8700	10,800	10,800	26,300	26,300	52,200	52,200
1962	9800	9800	11,600	11,500	27,500	27,500	47,900	47,900
1963	9300	9300	11,100	11,000	26,700	26,600	47,100	47,100
1964	8200	8200	9,770	9,740	22,600	22,600	42,700	42,600
1965	8500	8400	10,200	10,100	25,800	25,700	49,300	49,100
1966	7400	7400	9,430	9,410	23,600	23,700	46,300	46,300
1967	9100	8900	11,200	10,900	26,900	26,600	45,200	44,900
1968	8000	8000	9,790	9,770	24,600	24,600	46,800	46,800
1969	4900	7500	5,600	8,180	14,000	16,500	33,400	36,000

Water Year	Average Annual Flow, Q (cfs), Comparison							
	Watana Dam		Susitna River at Gold Creek		Susitna River at Sunshine		Susitna River at Susitna Station	
	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1
1970	6100	5400	7,590	6,880	19,700	19,000	46,600	45,900
1971	8600	6600	10,300	8,230	25,400	23,400	47,800	45,800
1972	8900	9000	10,900	10,800	26,500	26,400	46,700	46,700
1973	6600	7100	8,090	8,480	20,800	21,300	41,400	41,800
1974	6300	7500	7,630	8,860	19,500	20,700	40,000	41,200
1975	8500	6700	10,300	8,490	25,400	23,600	46,100	44,300
1976	6700	7100	8,170	8,550	20,500	20,900	43,000	43,400
1977	8300	7900	10,100	9,640	24,700	24,200	56,000	55,500
1978	6700	7000	8,190	8,420	20,400	20,700	42,000	42,300
1979	7800	7600	9,490	9,180	24,000	23,700	53,700	53,400
1980	8800	8700	10,700	10,600	26,100	25,900	61,900	61,800
1981	10000	9700	12,000	11,600	28,400	28,000	55,700	55,400
1982	7900	7900	9,670	9,610	24,100	24,000	47,100	47,000
1983	8300	8300	9,920	9,880	23,600	23,500	43,800	43,800
1984	8200	8200	9,580	9,550	23,500	23,500	45,400	45,400
1985	8000	8000	9,880	9,820	24,300	24,200	47,300	47,200
1986	7200	7200	8,530	8,550	20,600	20,600	46,300	46,400
1987	8700	8500	10,600	10,400	26,700	26,600	54,900	54,700
1988	8400	8400	10,200	10,200	24,800	24,800	53,600	53,500
1989	8400	8400	10,300	10,200	25,500	25,500	56,500	56,400
1990	10700	10600	13,000	12,900	31,800	31,600	61,200	61,100

Water Year	Average Annual Flow, Q (cfs), Comparison							
	Watana Dam		Susitna River at Gold Creek		Susitna River at Sunshine		Susitna River at Susitna Station	
	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1
1991	7000	7100	8,530	8,570	21,600	21,700	48,200	48,300
1992	7200	7100	8,720	8,620	21,600	21,500	43,900	43,800
1993	8300	8300	10,100	10,000	26,000	25,900	53,100	53,000
1994	8200	8200	9,960	9,960	25,100	25,100	51,800	51,800
1995	8500	8500	10,300	10,200	25,400	25,300	51,300	51,200
1996	5600	7300	6,800	8,450	17,700	19,400	38,300	40,000
1997	7200	6700	8,800	8,270	23,100	22,600	44,600	44,000
1998	7700	7000	9,380	8,680	24,600	23,800	47,100	46,400
1999	7600	7200	9,290	8,800	24,400	23,900	46,600	46,100
2000	8400	8300	10,200	10,100	26,600	26,400	50,300	50,100
2001	7800	7800	9,540	9,530	23,800	23,800	46,900	47,000
2002	7000	7100	8,480	8,530	21,700	21,700	45,100	45,100
2003	8500	8300	10,300	10,100	25,600	25,500	52,400	52,300
2004	7700	7800	9,400	9,440	23,300	23,400	47,700	47,800
2005	10100	10000	12,200	12,000	30,900	30,700	61,400	61,200
2006	8500	8300	10,300	10,100	24,900	24,800	49,500	49,300
2007	7900	7900	9,650	9,570	23,700	23,700	48,500	48,500
2008	7300	7300	8,900	8,860	22,000	22,000	45,300	45,200
2009	7800	7800	9,500	9,460	23,400	23,400	47,700	47,600
2010	8300	8300	10,100	10,100	24,800	24,800	50,300	50,300

Table 4.5-3. Annual flow exceedence ordinate (cfs) comparison for Pre-Project and Maximum Load Following Scenario OS-1.

Annual Flow Duration Comparison (cfs)								
Percentile	Watana Dam		Susitna River at Gold Creek		Susitna River at Sunshine		Susitna River at Susitna Station	
	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1
99%	603	1,120	750	1,400	1,740	3,240	5,210	6,810
95%	777	4,960	960	6,870	2,310	8,840	5,840	12,300
90%	956	5,400	1,200	7,210	2,830	9,470	6,400	13,000
75%	1,280	6,140	1,600	7,840	3,750	10,800	7,710	15,100
50%	2,730	7,370	3,400	8,750	8,220	13,200	19,000	23,100
25%	14,700	8,670	17,800	9,920	45,000	38,400	94,000	87,400
10%	20,900	10,800	25,300	12,300	64,000	51,000	124,000	112,000
5%	24,600	14,700	29,800	17,800	72,800	57,100	138,000	122,000
1%	32,500	22,900	39,300	26,900	91,200	71,300	164,000	145,000

Table 4.5-4. Susitna River estimated return period peak flow (cfs) comparison for pre-Project and Maximum Load Following Scenario OS-1.

Return Period (Years)	Watana Dam Site				Gold Creek				Sunshine				Susitna Station			
	Pre-Project Flow (cfs)	Max LF OS-1 (cfs)	Difference (cfs)	Difference (%)	Pre-Project Flow (cfs)	Max LF OS-1 (cfs)	Difference (cfs)	Difference (%)	Pre-Project Flow (cfs)	Max LF OS-1 (cfs)	Difference (cfs)	Difference (%)	Pre-Project Flow (cfs)	Max LF OS-1 (cfs)	Difference (cfs)	Difference (%)
1.01	21,100	12,800	-8,300	-39%	25,400	12,600	-12,800	-50%	64,000	47,600	-16,400	-26%	131,700	109,500	-22,200	-17%
1.25	27,800	14,100	-13,700	-49%	35,100	14,400	-20,700	-59%	80,200	60,500	-19,700	-25%	151,600	124,900	-26,700	-18%
1.5	30,700	15,800	-14,900	-49%	39,000	19,100	-19,900	-51%	87,000	65,800	-21,200	-24%	160,400	132,900	-27,500	-17%
2	34,200	20,700	-13,500	-39%	43,700	23,900	-19,800	-45%	94,700	72,000	-22,700	-24%	170,300	141,900	-28,400	-17%
5	43,700	28,700	-15,000	-34%	55,800	34,300	-21,500	-39%	115,400	88,200	-27,200	-24%	197,000	168,900	-28,100	-14%
20	57,600	40,200	-17,400	-30%	72,300	48,800	-23,500	-33%	143,600	110,400	-33,200	-23%	233,500	209,400	-24,100	-10%
50	67,300	48,200	-19,100	-28%	83,400	58,600	-24,800	-30%	162,500	125,100	-37,400	-23%	257,600	238,200	-19,400	-8%
100	75,100	54,600	-20,500	-27%	92,100	66,400	-25,700	-28%	177,300	136,700	-40,600	-23%	276,300	261,400	-14,900	-5%

Table 4.5-5. Recurrence interval of annual peak flows for pre-Project and Maximum Load Following Scenario OS-1.

Watana Dam Site			Gold Creek			Sunshine			Susitna Station		
Discharge (cfs)	Pre-Project Return Period (yrs)	Max Load Following OS-1 Return Period (yrs)	Discharge (cfs)	Pre-Project Return Period (yrs)	Max Load Following OS-1 Return Period (yrs)	Discharge (cfs)	Pre-Project Return Period (yrs)	Max Load Following OS-1 Return Period (yrs)	Discharge (cfs)	Pre-Project Return Period (yrs)	Max Load Following OS-1 Return Period (yrs)
21,100	1.01	2.1	25,400	1.01	2.2	64,000	1.01	1.4	131,700	1.01	1.5
27,800	1.25	4.5	35,100	1.25	5.4	80,200	1.25	3.1	151,600	1.25	2.7
30,700	1.5	6.4	39,000	1.5	7.8	87,000	1.5	4.6	160,426	1.5	3.6
34,200	2	9.8	43,700	2	12	94,700	2	7.4	170,300	2	5.2
43,700	5	30	55,800	5	39	115,400	5	27	197,000	5	13
57,600	20	136	72,300	20	166	143,600	20	149	233,500	20	43

Table 5.2-1. USGS Measurements Used to Develop Representative Cross Section Geometry.

Gage	USGS Measurement No.	Date of Measurement	Flow Rate Measured (cfs)	Stage (ft)
Sunshine	55 [a]	9/22/2012	155,000	25.17
Susitna Station	127	7/18/2003	234,000	19.54

Notes:

a. Specifically, Transect 2 from Measurement 55 was used

Table 5.3-1. Annual Stage-exceedence Ordinate (feet) Comparison for pre-Project and Maximum Load Following OS-1 Hydrologic Conditions at Sunshine Gage and Susitna Station Gage.

Percentile	Sunshine Gage (USGS 15292780)			Susitna Station Gage (USGS 15292780)		
	Annual Stage-exceedence Value			Annual Stage-exceedence Value		
	Pre-Project	Max LF OS-1	Delta [a]	Pre-Project	Max LF OS-1	Delta [a]
99%	10.93	11.08	0.15	2.59	3.03	0.44
95%	10.97	12.28	1.31	2.77	4.28	1.51
90%	10.99	12.40	1.41	2.93	4.43	1.50
75%	11.21	12.62	1.41	3.26	4.83	1.57
50%	12.17	13.02	0.85	5.53	6.21	0.68
25%	16.85	16.17	-0.68	13.00	12.57	-0.43
10%	18.60	17.42	-1.18	14.77	14.04	-0.73
5%	19.35	17.98	-1.37	15.51	14.66	-0.85
1%	20.81	19.22	-1.59	16.77	15.85	-0.92

Notes:

a. Delta calculated as Max LF OS-1 value minus pre-Project value, with negative values indicated in red text.

Table 5.3-2. Monthly (October through March) Stage-exceedence Ordinate (feet) Comparison for pre-Project and Maximum Load Following OS-1 Hydrologic Conditions at Sunshine Gage.

Sunshine Gage (USGS 15292780)									
Percentile	October			November			December		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
99%	11.57	12.65	1.08	10.99	12.36	1.37	10.97	12.29	1.32
95%	11.91	12.78	0.87	11.17	12.47	1.30	10.98	12.42	1.44
90%	12.15	12.88	0.73	11.30	12.53	1.23	10.99	12.50	1.51
75%	12.57	13.07	0.50	11.54	12.65	1.11	11.21	12.59	1.38
50%	13.09	13.42	0.33	11.75	12.75	1.00	11.40	12.70	1.30
25%	13.94	14.02	0.08	12.02	12.91	0.89	11.55	12.82	1.27
10%	14.81	14.86	0.05	12.34	13.10	0.76	11.69	12.91	1.22
5%	15.40	15.44	0.04	12.57	13.26	0.69	11.81	12.98	1.18
1%	16.85	16.64	-0.21	13.00	13.52	0.52	12.22	13.13	0.91
Percentile	January			February			March		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
99%	10.95	12.28	1.33	10.91	10.95	0.04	10.90	10.95	0.05
95%	10.95	12.46	1.50	10.94	12.45	1.51	10.92	11.09	0.16
90%	10.97	12.51	1.54	10.95	12.51	1.56	10.94	12.18	1.24
75%	11.08	12.62	1.54	10.99	12.62	1.63	10.97	12.29	1.32
50%	11.20	12.72	1.52	11.09	12.77	1.68	11.00	12.40	1.40
25%	11.36	12.80	1.44	11.21	12.93	1.72	11.14	12.50	1.36
10%	11.46	12.91	1.45	11.35	13.06	1.71	11.25	12.60	1.35
5%	11.49	12.99	1.50	11.39	13.13	1.74	11.37	12.67	1.30
1%	11.64	13.12	1.48	11.51	13.32	1.81	11.46	12.78	1.32

Notes:

a. Delta calculated as Max LF OS-1 value minus pre-Project value, with negative values indicated in red text.

Table 5.3-3. Monthly (April through September) Stage-exceedence Ordinate (feet) Comparison for pre-Project and Maximum Load Following OS-1 Hydrologic Conditions at Sunshine Gage.

Sunshine Gage (USGS 15292780)									
Percentile	April			May			June		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
99%	10.91	10.97	0.05	11.03	11.60	0.57	15.22	14.81	-0.41
95%	10.94	11.10	0.17	11.58	12.44	0.86	16.03	15.36	-0.67
90%	10.95	12.09	1.14	11.93	12.62	0.69	16.42	15.62	-0.80
75%	10.98	12.26	1.28	13.01	13.24	0.23	17.39	16.32	-1.07
50%	11.15	12.37	1.22	15.37	14.76	-0.61	18.56	17.13	-1.43
25%	11.35	12.47	1.12	17.12	16.00	-1.12	19.44	17.71	-1.73
10%	11.70	12.62	0.92	18.76	17.18	-1.58	20.34	18.29	-2.05
5%	12.08	12.77	0.69	19.54	17.78	-1.76	20.98	18.69	-2.29
1%	13.41	13.58	0.17	20.34	18.28	-2.06	22.88	19.71	-3.17
Percentile	July			August			September		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
99%	16.13	15.48	-0.65	14.14	14.26	0.12	12.83	13.10	0.27
95%	16.65	15.81	-0.84	15.69	15.41	-0.28	13.35	13.43	0.08
90%	16.98	16.07	-0.91	16.13	15.79	-0.34	13.73	13.78	0.05
75%	17.52	16.44	-1.08	16.80	16.29	-0.51	14.50	14.44	-0.06
50%	18.13	16.92	-1.21	17.61	16.94	-0.67	15.48	15.39	-0.09
25%	18.91	17.49	-1.42	18.36	17.80	-0.56	16.61	16.48	-0.13
10%	19.68	18.08	-1.60	19.23	18.67	-0.56	17.91	17.73	-0.18
5%	20.14	18.60	-1.54	19.94	19.39	-0.55	18.62	18.43	-0.20
1%	21.29	19.69	-1.60	22.30	21.30	-1.00	19.96	19.95	-0.01

Notes:

a. Delta calculated as Max LF OS-1 value minus pre-Project value, with negative values indicated in red text.

Table 5.3-4. Monthly (October through March) Stage-exceedence Ordinate (feet) Comparison for pre-Project and Maximum Load Following OS-1 Hydrologic Conditions at Susitna Station Gage.

Susitna Station Gage (USGS 15294350)									
Percentile	October			November			December		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
99%	4.02	5.09	1.07	3.00	4.47	1.47	2.82	4.32	1.5
95%	4.82	5.63	0.81	3.27	4.62	1.35	2.89	4.50	1.61
90%	5.36	6.02	0.66	3.51	4.78	1.27	3.04	4.59	1.55
75%	6.26	6.75	0.49	3.95	5.08	1.13	3.29	4.77	1.48
50%	7.45	7.74	0.29	4.43	5.44	1.01	3.57	5.01	1.44
25%	8.90	9.01	0.11	5.13	5.99	0.86	3.95	5.29	1.34
10%	10.57	10.58	0.01	5.91	6.62	0.71	4.23	5.49	1.26
5%	11.31	11.36	0.05	6.50	7.07	0.57	4.49	5.65	1.16
1%	13.21	13.18	-0.03	8.13	8.66	0.53	5.68	6.55	0.87
Percentile	January			February			March		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
99%	2.73	4.21	1.48	2.51	2.82	0.31	2.44	2.66	0.22
95%	2.76	4.52	1.76	2.63	4.47	1.84	2.55	3.08	0.53
90%	2.87	4.60	1.73	2.76	4.55	1.79	2.61	4.12	1.51
75%	3.08	4.73	1.65	2.92	4.70	1.78	2.76	4.28	1.52
50%	3.30	4.90	1.60	3.08	4.90	1.82	2.94	4.42	1.48
25%	3.47	5.08	1.61	3.22	5.10	1.88	3.08	4.56	1.48
10%	3.74	5.27	1.53	3.45	5.29	1.84	3.22	4.75	1.53
5%	3.87	5.37	1.50	3.62	5.42	1.80	3.57	4.87	1.30
1%	4.02	5.53	1.51	3.80	5.64	1.84	3.69	5.05	1.36

Notes:

a. Delta calculated as Max LF OS-1 value minus pre-Project value, with negative values indicated in red text.

Table 5.3-5. Monthly (April through September) Stage-exceedence Ordinate (feet) Comparison for pre-Project and Maximum Load Following OS-1 Hydrologic Conditions at Susitna Station Gage.

Susitna Station Gage (USGS 15294350)									
Percentile	April			May			June		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
99%	2.53	2.75	0.22	3.12	3.82	0.70	10.96	10.43	-0.53
95%	2.65	3.05	0.40	3.89	4.63	0.74	11.85	11.27	-0.58
90%	2.69	4.07	1.38	4.76	5.26	0.50	12.49	11.88	-0.61
75%	2.85	4.26	1.41	7.62	7.60	-0.02	13.48	12.76	-0.72
50%	3.08	4.41	1.33	10.86	10.39	-0.47	14.56	13.69	-0.87
25%	3.62	4.75	1.13	13.07	12.46	-0.61	15.41	14.33	-1.08
10%	4.53	5.37	0.84	14.65	13.71	-0.94	16.21	14.99	-1.22
5%	5.53	6.19	0.66	15.36	14.29	-1.07	16.63	15.32	-1.31
1%	8.20	8.44	0.24	16.11	14.99	-1.12	17.59	16.07	-1.52
Percentile	July			August			September		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
99%	12.08	11.60	-0.48	9.03	9.17	0.14	5.96	6.18	0.22
95%	12.79	12.18	-0.61	11.38	11.23	-0.15	7.66	7.81	0.15
90%	13.26	12.62	-0.64	12.04	11.82	-0.22	8.41	8.49	0.08
75%	13.83	13.21	-0.62	12.89	12.63	-0.26	9.77	9.78	0.01
50%	14.53	13.76	-0.77	13.77	13.45	-0.32	11.20	11.16	-0.04
25%	15.26	14.40	-0.86	14.71	14.30	-0.41	12.76	12.66	-0.10
10%	15.96	15.06	-0.90	15.51	15.06	-0.45	14.18	14.04	-0.14
5%	16.44	15.57	-0.87	16.23	15.79	-0.44	14.82	14.72	-0.10
1%	17.78	16.66	-1.12	18.18	17.85	-0.33	16.29	16.18	-0.11

Notes:

a. Delta calculated as Max LF OS-1 value minus pre-Project value, with negative values indicated in red text.

Table 5.3-6. Monthly Stage Statistics for pre-Project and Max Load Following OS-1 Hydrologic Conditions at Sunshine Gage.

Sunshine Gage (USGS 15292780)									
Statistic	Oct			Nov			Dec		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
Maximum	22.15	20.39	-1.76	14.25	14.23	-0.02	12.53	13.32	0.79
Median	13.09	13.42	0.33	11.75	12.75	1.00	11.40	12.70	1.30
Average	13.33	13.68	0.34	11.80	12.80	0.99	11.39	12.70	1.32
Minimum	11.09	12.33	1.24	10.98	12.29	1.31	10.96	12.13	1.17
Statistic	Jan			Feb			Mar		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
Maximum	11.89	13.29	1.40	12.01	13.43	1.42	11.52	13.16	1.64
Median	11.20	12.72	1.52	11.09	12.77	1.68	11.00	12.40	1.40
Average	11.22	12.70	1.48	11.12	12.75	1.63	11.06	12.33	1.27
Minimum	10.94	10.96	0.01	10.89	10.95	0.06	10.90	10.95	0.05
Statistic	Apr			May			June		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
Maximum	17.25	15.85	-1.40	22.01	19.13	-2.88	25.51	21.19	-4.32
Median	11.15	12.37	1.22	15.37	14.76	-0.61	18.56	17.13	-1.43
Average	11.28	12.32	1.04	15.28	14.77	-0.51	18.49	17.05	-1.45
Minimum	10.91	10.95	0.04	10.94	11.08	0.14	14.64	14.31	-0.33
Statistic	July			Aug			Sept		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
Maximum	24.89	21.86	-3.03	25.57	23.26	-2.31	21.65	21.02	-0.63
Median	18.13	16.92	-1.21	17.61	16.94	-0.67	15.48	15.39	-0.09
Average	18.25	17.02	-1.23	17.65	17.11	-0.54	15.67	15.59	-0.08
Minimum	15.40	15.01	-0.39	12.98	13.42	0.44	12.36	12.83	0.47

Notes:

a. Delta calculated as Max LF OS-1 value minus pre-Project value, with negative values indicated in red text.

Table 5.3-7. Monthly Stage Statistics for pre-Project and Max Load Following OS-1 Hydrologic Conditions at Susitna Station Gage.

Susitna Station Gage (USGS 15294350)									
Statistic	Oct			Nov			Dec		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
Maximum	21.93	21.98	0.05	9.49	9.64	0.15	6.65	7.31	0.66
Median	7.45	7.74	0.29	4.43	5.44	1.01	3.57	5.01	1.44
Average	7.72	8.04	0.32	4.62	5.62	1.00	3.66	5.05	1.39
Minimum	3.14	4.45	1.31	2.93	4.31	1.38	2.82	4.14	1.32
Statistic	Jan			Feb			Mar		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
Maximum	4.43	5.78	1.35	4.98	6.17	1.19	3.80	5.39	1.59
Median	3.30	4.90	1.60	3.08	4.90	1.82	2.94	4.42	1.48
Average	3.30	4.90	1.60	3.09	4.89	1.80	2.95	4.36	1.41
Minimum	2.72	2.89	0.17	2.35	2.70	0.35	2.42	2.66	0.24
Statistic	Apr			May			June		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
Maximum	13.71	12.89	-0.82	17.28	16.46	-0.82	18.18	16.89	-1.29
Median	3.08	4.41	1.33	10.86	10.39	-0.47	14.56	13.69	-0.87
Average	3.45	4.58	1.13	10.27	9.95	-0.32	14.45	13.53	-0.92
Minimum	2.23	2.69	0.46	2.85	3.03	0.18	9.97	9.06	-0.91
Statistic	July			Aug			Sept		
	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta	Pre-Project	Max LF OS-1	Delta
Maximum	19.47	19.05	-0.42	19.55	19.14	-0.41	18.74	18.74	0.00
Median	14.53	13.76	-0.77	13.77	13.45	-0.32	11.20	11.16	-0.04
Average	14.57	13.81	-0.76	13.79	13.45	-0.34	11.26	11.22	-0.04
Minimum	10.65	10.40	-0.25	6.87	7.18	0.31	4.85	5.43	0.58

Notes:

a. Delta calculated as Max LF OS-1 value minus pre-Project value, with negative values indicated in red text.

Table 5.4-1. Annual Flow-exceedence and Stage-exceedence Comparison for the pre-Project and Maximum Load Following OS-1 Hydrologic Conditions at Sunshine Gage and Susitna Station Gage.

Percentile	Sunshine Gage (USGS 15292780)			Susitna Station Gage (USGS 15292780)			Sunshine Gage (USGS 15292780)			Susitna Station Gage (USGS 15292780)		
	Annual Flow Exceedence Value			Annual Flow Exceedence Value			Annual Stage Exceedence Value			Annual Stage Exceedence Value		
	Pre-Project (cfs)	Max LF OS-1 (cfs)	Delta [a] (cfs)	Pre-Project (cfs)	Max LF OS-1 (cfs)	Delta [a] (cfs)	Pre-Project (ft)	Max LF OS-1 (cfs)	Delta [a] (ft)	Pre-Project (ft)	Max LF OS-1 (cfs)	Delta [a] (ft)
99%	1,740	3,240	1,500	5,210	6,810	1,600	10.93	11.08	0.15	2.59	3.03	0.44
95%	2,310	8,840	6,530	5,840	12,300	6,460	10.97	12.28	1.31	2.77	4.28	1.51
90%	2,830	9,470	6,640	6,400	13,000	6,600	10.99	12.40	1.41	2.93	4.43	1.50
75%	3,750	10,800	7,050	7,710	15,100	7,390	11.21	12.62	1.41	3.26	4.83	1.57
50%	8,220	13,200	4,980	19,000	23,100	4,100	12.17	13.02	0.85	5.53	6.21	0.68
25%	45,000	38,400	-6,600	94,000	87,400	-6,600	16.85	16.17	-0.68	13.00	12.57	-0.43
10%	64,000	51,000	-13,000	124,000	112,000	-12,000	18.60	17.42	-1.18	14.77	14.04	-0.73
5%	72,800	57,100	-15,700	138,000	122,000	-16,000	19.35	17.98	-1.37	15.51	14.66	-0.85
1%	91,200	71,300	-19,000	164,000	145,000	-19,000	20.81	19.22	-1.59	16.77	15.85	-0.92

Notes:

a. Delta calculated as Max LF OS-1 value minus pre-Project value, with negative values indicated in red text

Table 6.2-1. USGS Ratings and Effective Dates at Sunshine Gage.

Rating ID	Effective Dates of Rating	USGS Notes within Effective Period of Rating [a]
1	5/8/81 – 5/1/82	• Gage established on 5/8/81 • Gage datum established on 5/7/81 • Gage located on right bank, 300 feet upstream of road • Stage values in this rating were adjusted by the USGS subsequent to the 5/28/82 lowering of the datum so that Rating 1 is relative to the same datum as Rating 2
2	5/1/82 – 10/1/83	• Datum was lowered by 5.0 feet on 5/28/82 • Gage moved on 7/13/82 to left bank, 100 feet upstream of bridge
3	10/1/83 – 5/1/84	
4	5/1/84 – 10/1/86	• Gage discontinued on 6/30/86
5	10/1/86 – 10/6/11	
6	10/6/11 - present	• Gage re-established on 10/6/11, using the lowered datum • Gage located on left bank, 50 feet downstream of bridge • Datum was lowered by an additional 10.0 feet to prevent negative gage height values

Note:
a. USGS notes were obtained from the USGS station description and from personal communication with USGS staff (Josh Morse, personal communication, January 31, 2013)

Table 6.2-2. USGS Ratings and Effective Dates at Susitna Station Gage.

Rating ID	Effective Dates of Rating	USGS Notes within Effective Period of Rating [a]
1	5/1/75 – 9/30/78	• Gage installed on 5/23/75 • Located on left bank approximately 1.5 miles downstream from Yentna River
2	10/1/78 – 5/23/85	
3	5/24/85 – 9/30/85	
4	10/1/85 – 9/30/93	• Gage discontinued on 9/30/93

Note:
a. USGS notes were obtained from the USGS station description

Table 6.2-3. Flows Selected for Specific Gage Analysis, Susitna Station Gage.

Flow Magnitude [a] (cfs)	Flow Statistic [a]
30,000	Minimum flow common to all rating curves
43,000	40% annual exceedence flow
60,000	35% annual exceedence flow
80,000	30% annual exceedence flow
94,000	25% annual exceedence flow
132,000	1.01-year return period flow
152,000	1.25-year return period flow
170,000	2-year return period flow
197,000	5-year return period flow

Note:
a. Based on pre-Project flow duration and flood frequency analysis

Table 6.3-1. Stages at Selected Specific Discharges Calculated from USGS Published Ratings for the Susitna Station Gage.

Rating ID	Effective Dates of Rating	Stage (feet) at Specified Discharge [a]								
		30,000	43,000	60,000	80,000	94,000	132,000	152,000	170,000	197,000
1	5/1/75 – 9/30/78	7.4	9.2	10.4	11.8	12.7	15.1	16.3	17.3	18.8
2	10/1/78 – 5/23/85	7.3	8.7	10.3	11.9	12.9	15.3	16.5	17.5	18.8
3	5/24/85 – 9/30/85	7.3	8.7	10.3	11.9	12.9	15.1	16.1	17.1	18.3
4	10/1/85 – 12/31/02	7.2	8.9	10.6	12.1	13.0	15.2	16.2	17.0	18.3

Note:
a. All stages are relative to the gage datum established at the time the gage was installed

Table 7.2.1. Ice Covered Discharge Measurement at USGS Susitna at Sunshine Gage.

Date of Measurement	Total Discharge (cfs)	Flow Depth to Ice Thickness Ratio	Total Depth (ft)	Average Ice Thickness (ft)	Average Flow Depth (ft)	Total Ice Area (ft^2)	Total Flow Area (ft^2)	Average Velocity (ft/s)
March 25, 1981	3,796	1.65	8.15	3.07	5.08	2,031	1,937	1.81
January 20, 1982	3,504	3.54	11.98	2.64	9.35	403	1,348	2.61
March 2, 1982	2,656	1.36	11.53	4.88	6.65	1,124	1,141	2.36
April 9, 1982	3,347	1.54	10.89	4.29	6.59	879	1,185	2.63
December 22, 1982	5,495	0.94	12.78	6.57	6.21	2,194	1,739	2.82
December 30, 1982	6,800	0.95	13.85	7.12	6.74	2,898	2,337	3.01
January 20, 1983	4,719	20.4	10.99	3.61	7.38	796	1,619	2.28
March 17, 1983	3,321	1.98	8.87	2.98	5.90	744	1,419	2.02
January 10, 1985	4,644	0.69	7.36	4.37	3.00	2,831	1,353	1.91
January 14, 1985	3,657	0.83	6.55	3.58	2.97	2,049	1,235	1.71
March 19, 1985	3,976	0.87	8.01	4.27	3.73	2,317	1,381	2.07
November 22, 1985	5,395	0.61	10.28	6.37	3.91	2,868	1,730	1.90
March 18, 1986	2,862	1.29	7.92	3.47	4.46	1,218	1,598	1.49

Table 7.2.2. Ice Covered Discharge Measurement at USGS Susitna at Susitna Gage.

Date of Measurement	Total Discharge (cfs)	Flow Depth to Ice Thickness Ratio	Total Depth (ft)	Average Ice Thickness (ft)	Average Flow Depth (ft)	Total Ice Area (ft^2)	Total Flow Area (ft^2)	Average Velocity (ft/s)
March 22, 1993	6,952	2.13	9.97	3.19	6.78	1,627	3,172	2.10
January 8, 1993	10,305	1.79	9.42	3.38	6.04	3,416	4,209	2.22
April 2, 1992	9,726	1.11	10.49	4.98	5.51	3,735	4,130	1.96
February 7, 1992	9,410	1.57	9.88	3.84	6.04	3,674	4,926	1.75
April 5, 1991	6,135	1.02	11.48	5.68	5.80	5,145	3,953	1.58
February 27, 1991	7,280	1.24	12.75	5.70	7.06	4,304	5,371	1.74
April 5, 1990	9,993	1.29	11.34	4.95	6.39	5,292	4,247	2.10
March 22, 1989	6,884	1.06	8.82	4.29	4.53	6,965	3,909	1.72
February 6, 1989	6,052	0.96	10.07	5.14	4.94	9,857	3,547	1.54
March 8, 1988	9,370	1.06	10.68	5.19	5.49	4,888	4,941	1.60
January 7, 1988	11,285	1.40	10.80	4.49	6.31	6,596	6,973	1.46
March 31, 1987	7,211	1.59	10.47	4.04	6.43	2,635	3,969	1.59
February 4, 1987	7,442	1.28	10.35	4.55	5.81	3,397	3,985	1.69
April 1, 1986	5,399	1.80	7.88	2.82	5.06	2,468	3,606	1.51
December 4, 1985	12,319	2.32	9.80	2.95	6.85	3,312	6,079	1.97
March 27, 1985	6,015	2.36	12.69	3.78	8.91	1,655	3,406	1.66
February 23, 1985	6,606	1.10	12.31	5.88	6.44	4,614	4,619	1.50
February 11, 1985	6,333	2.53	11.83	3.35	8.48	1,702	3,816	1.89
April 6, 1984	9,276	1.17	12.77	5.90	6.87	7,378	4,932	1.63
April 4, 1983	6,520	1.39	10.93	4.57	6.36	3,921	4,356	1.43
January 20, 1983	7,947	1.35	11.48	4.88	6.60	4,334	5,464	1.36
April 4, 1982	4,004	0.82	11.82	6.49	5.33	5,630	4,861	0.83
January 12, 1982	8,960	1.33	10.03	4.30	5.73	3,597	5,074	1.58

10. FIGURES

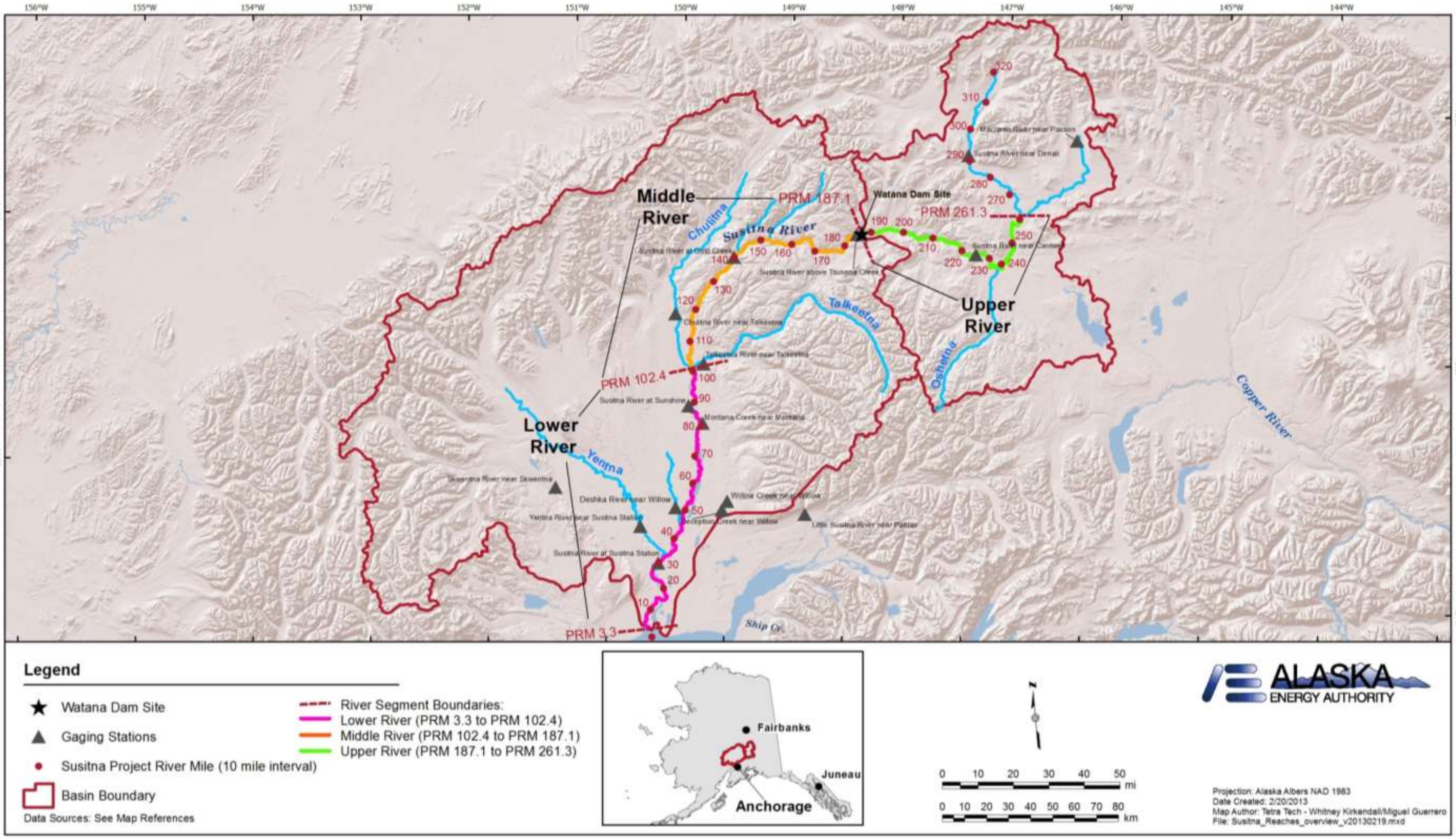

Figure 3.2-1. Susitna River study area and large-scale river segments.

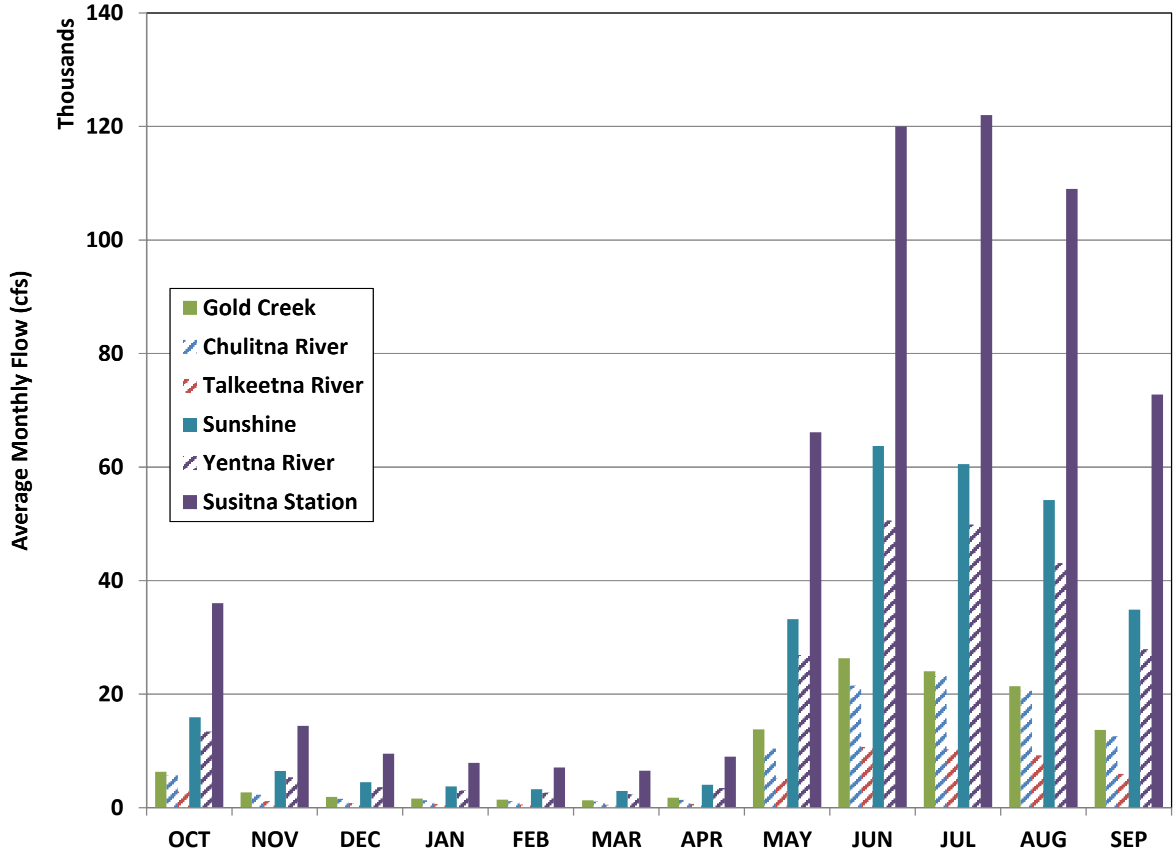

Figure 4.4-1. Average monthly flows (cfs) in the Susitna River and major tributaries downstream from the Watana Dam site under pre-Project conditions based on the USGS (2012) 61-year extended record. Solid bars are mainstem gages; cross-hatched bars are tributaries.

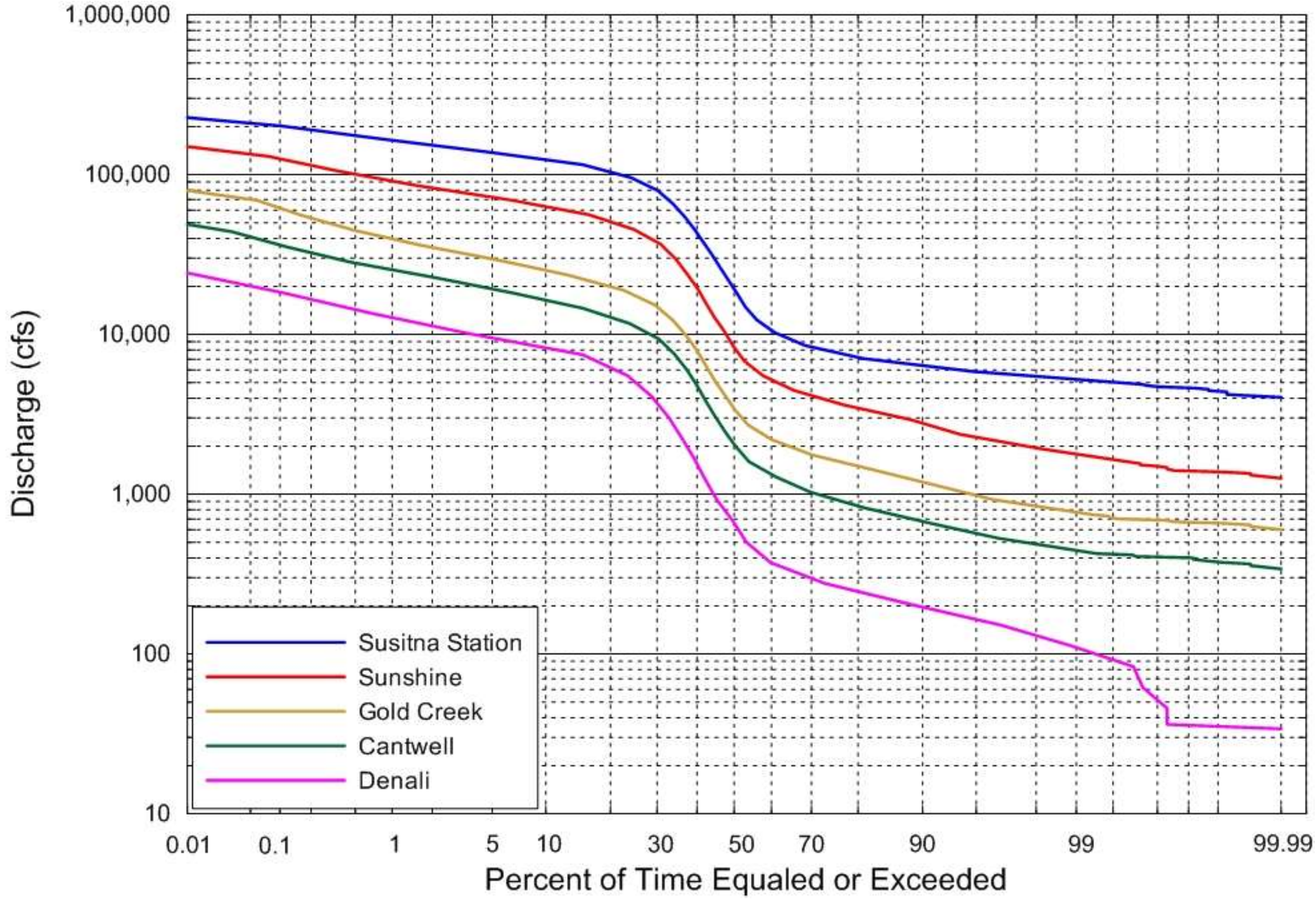

Figure 4.4-2. Annual flow-duration curves mainstem gages for pre-Project conditions based on the USGS extended record.

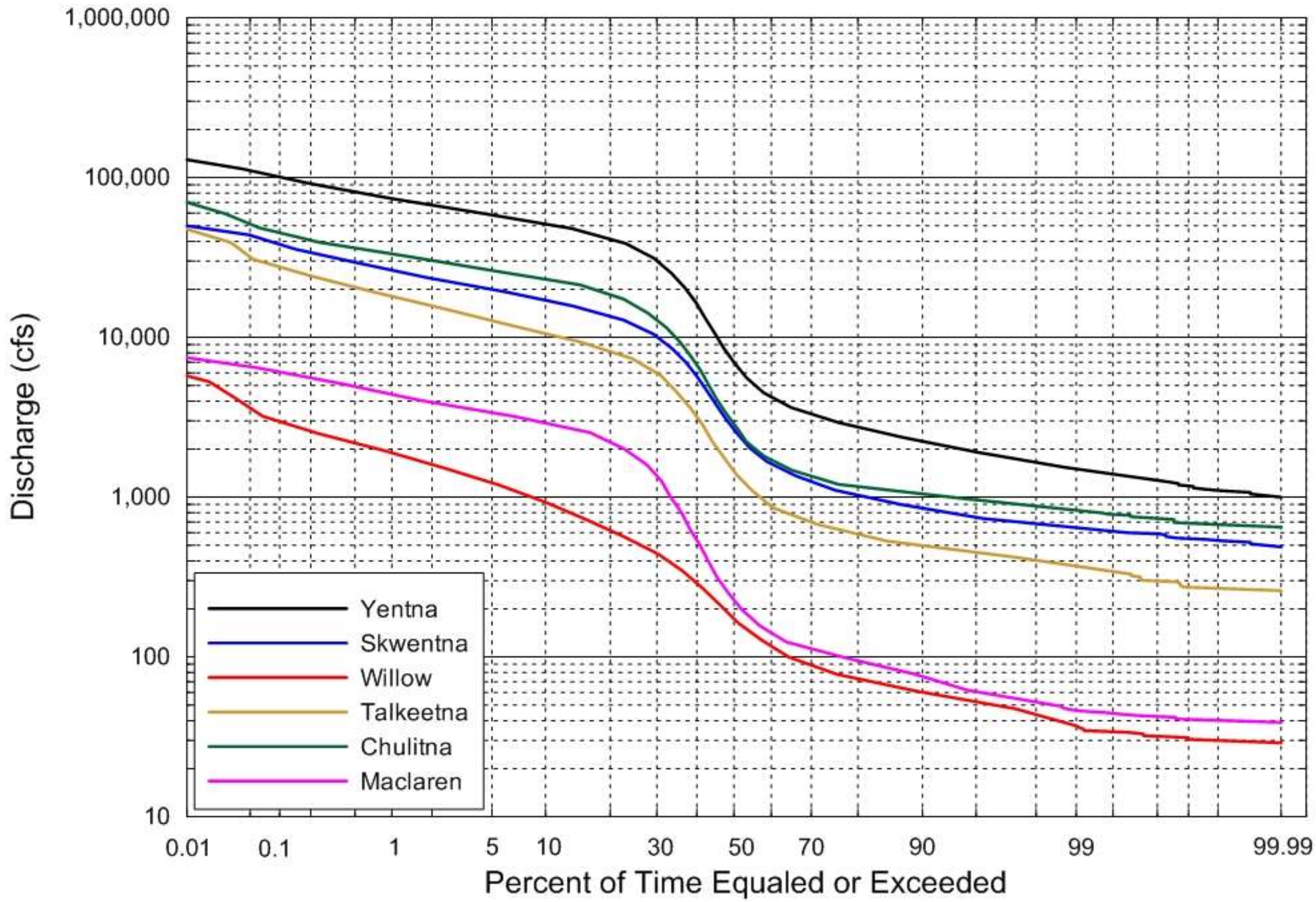

Figure 4.4-3. Annual flow-duration curves tributary gages for pre-Project conditions based on the USGS extended record.

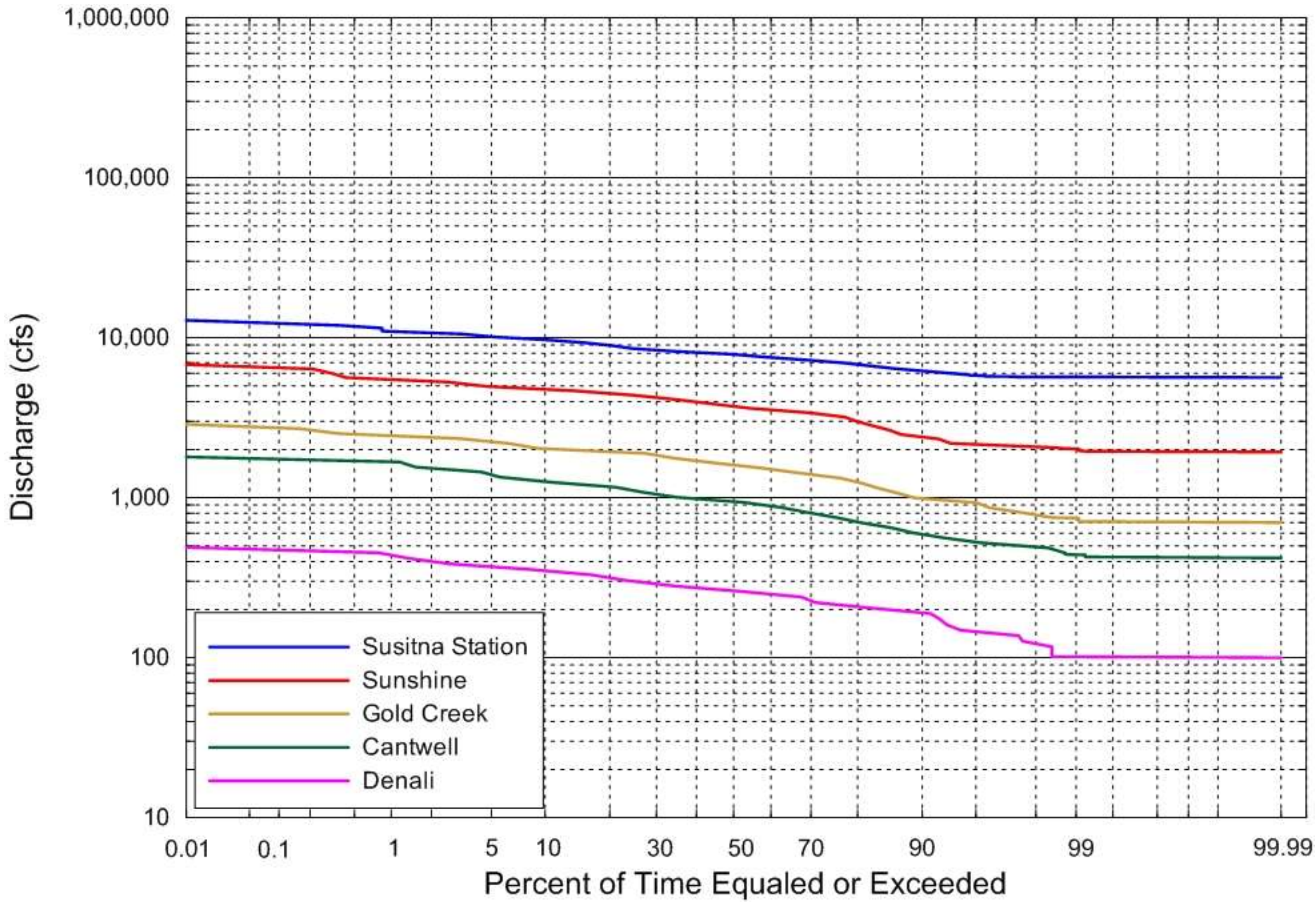

Figure 4.4-4. Monthly Flow-duration curves for January for mainstem gages for pre-Project conditions based on the USGS extended record.

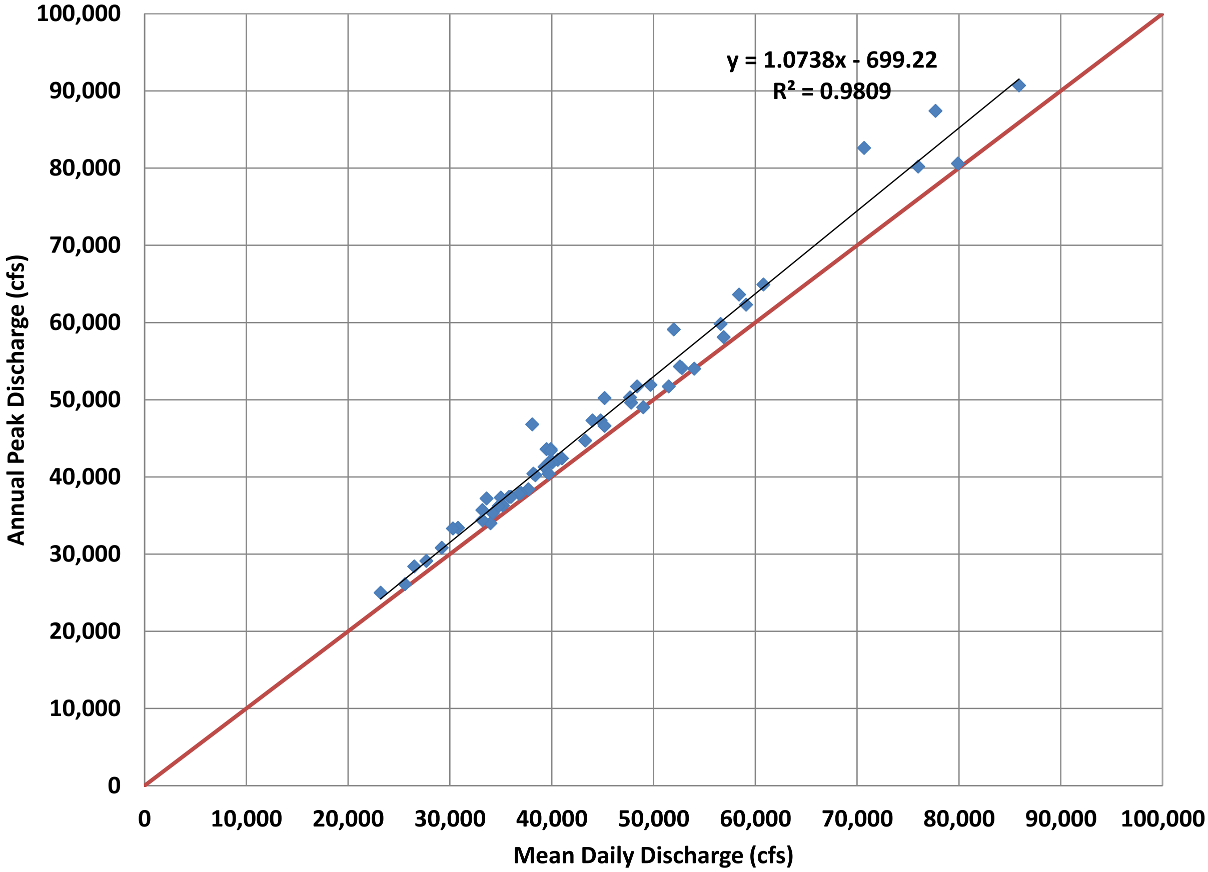

Figure 4.4-5. Relationship between recorded annual instantaneous peak discharge and the corresponding mean daily discharge at Gold Creek. Similar plots for other gages are provided in Appendix D.

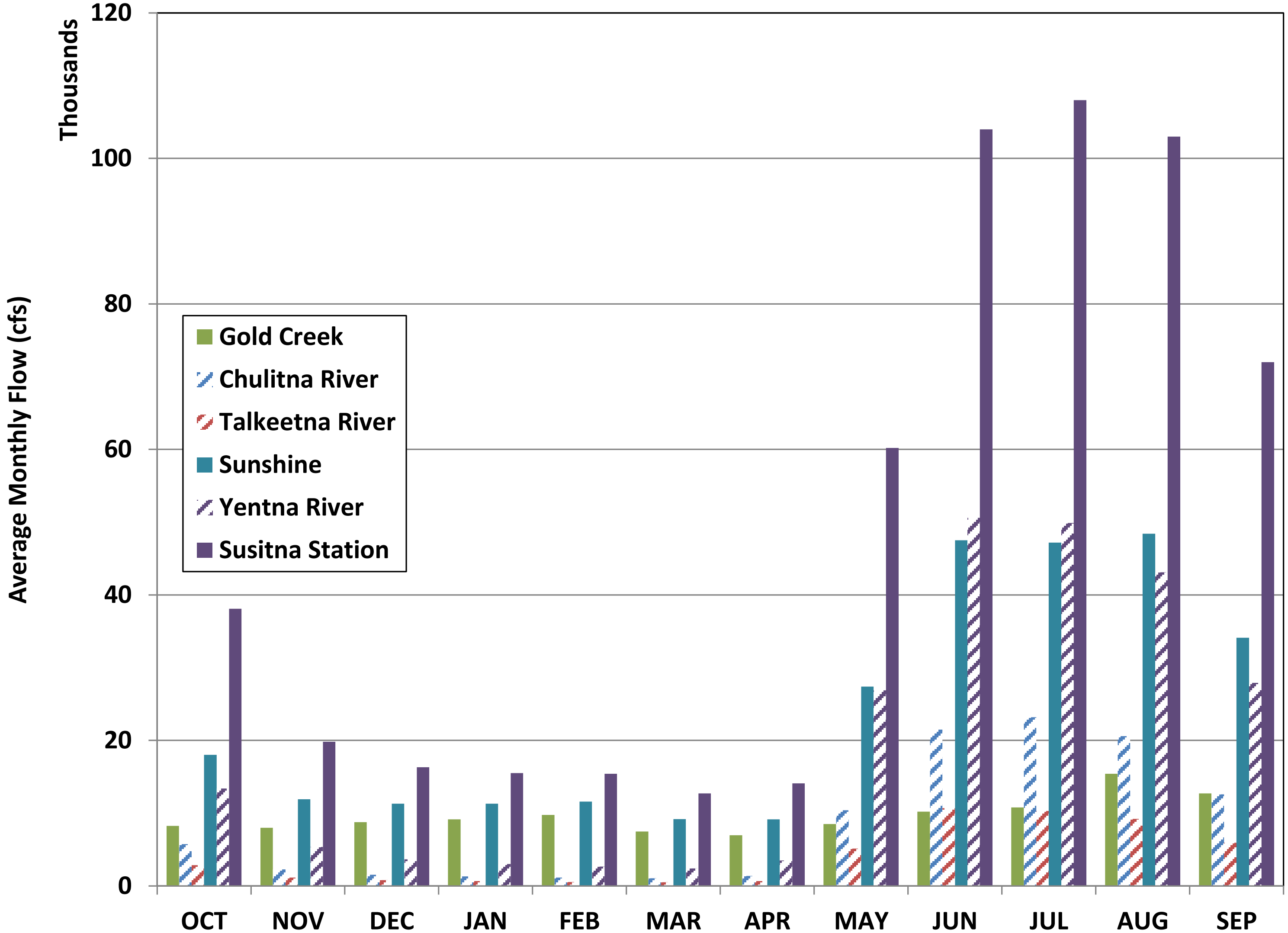

Figure 4.4-6. Average monthly flows (cfs) in the Susitna River under Maximum Load Following Scenario OS-1, based on the HEC-ResSim model results. Also shown are major tributary inflows.

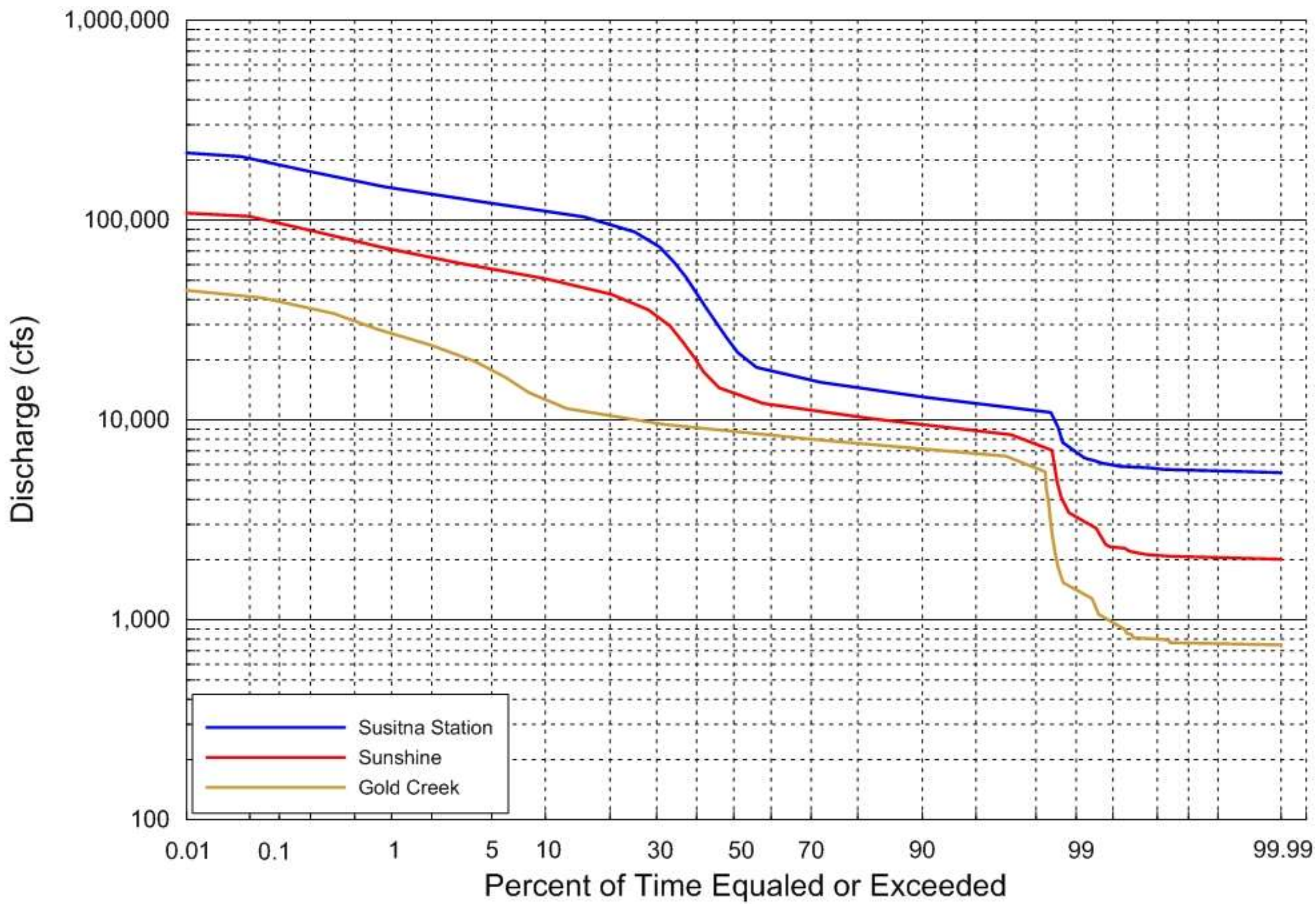

Figure 4.4-7. Annual flow-duration curves for three mainstem gages for Maximum Load Following OS-1 Conditions based on HEC-ResSim model.

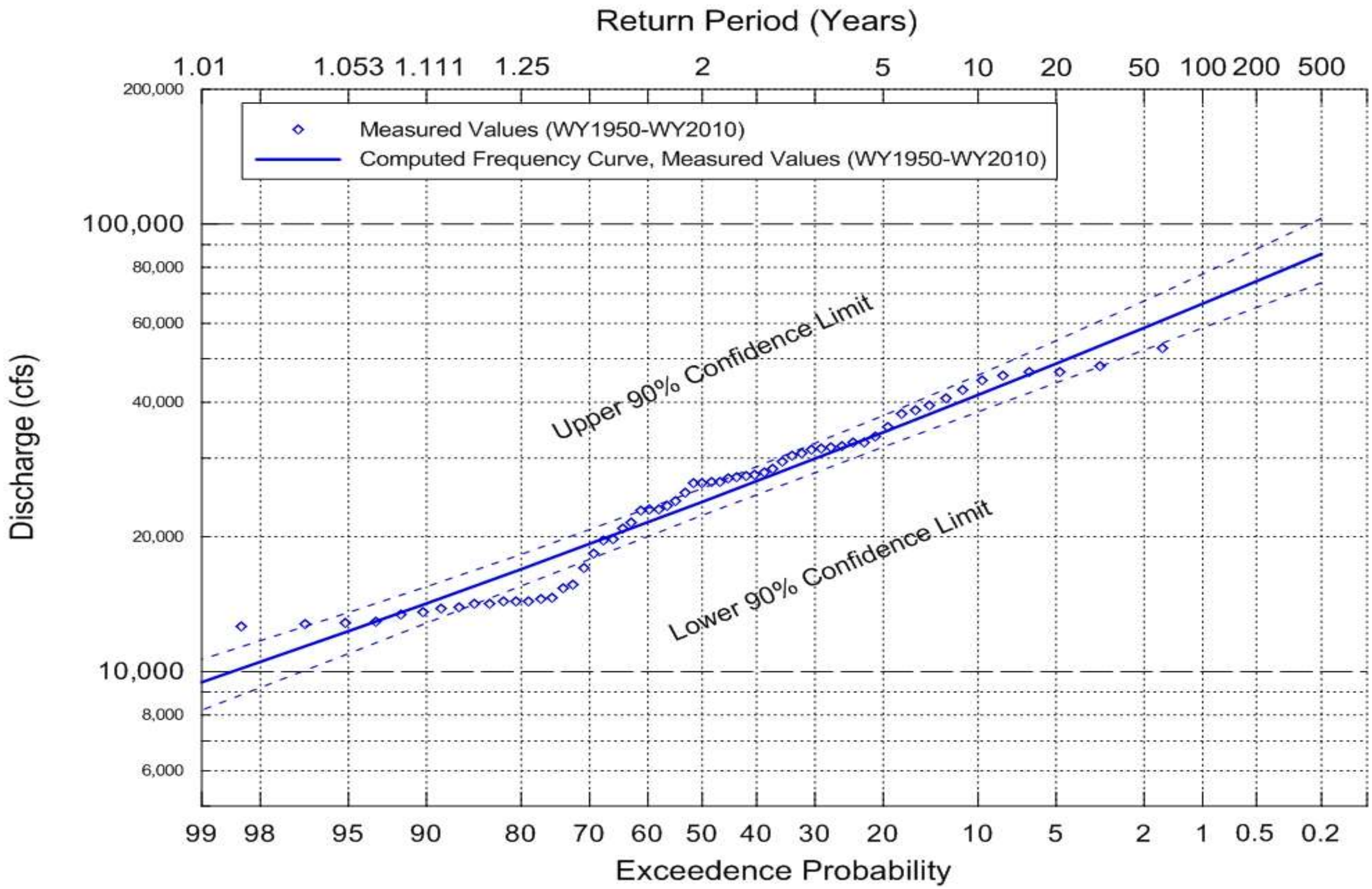

Figure 4.4-8. Flood-frequency curve for Susitna River at Gold Creek for Maximum Load Following OS-1 conditions based on the HEC-ResSim model.

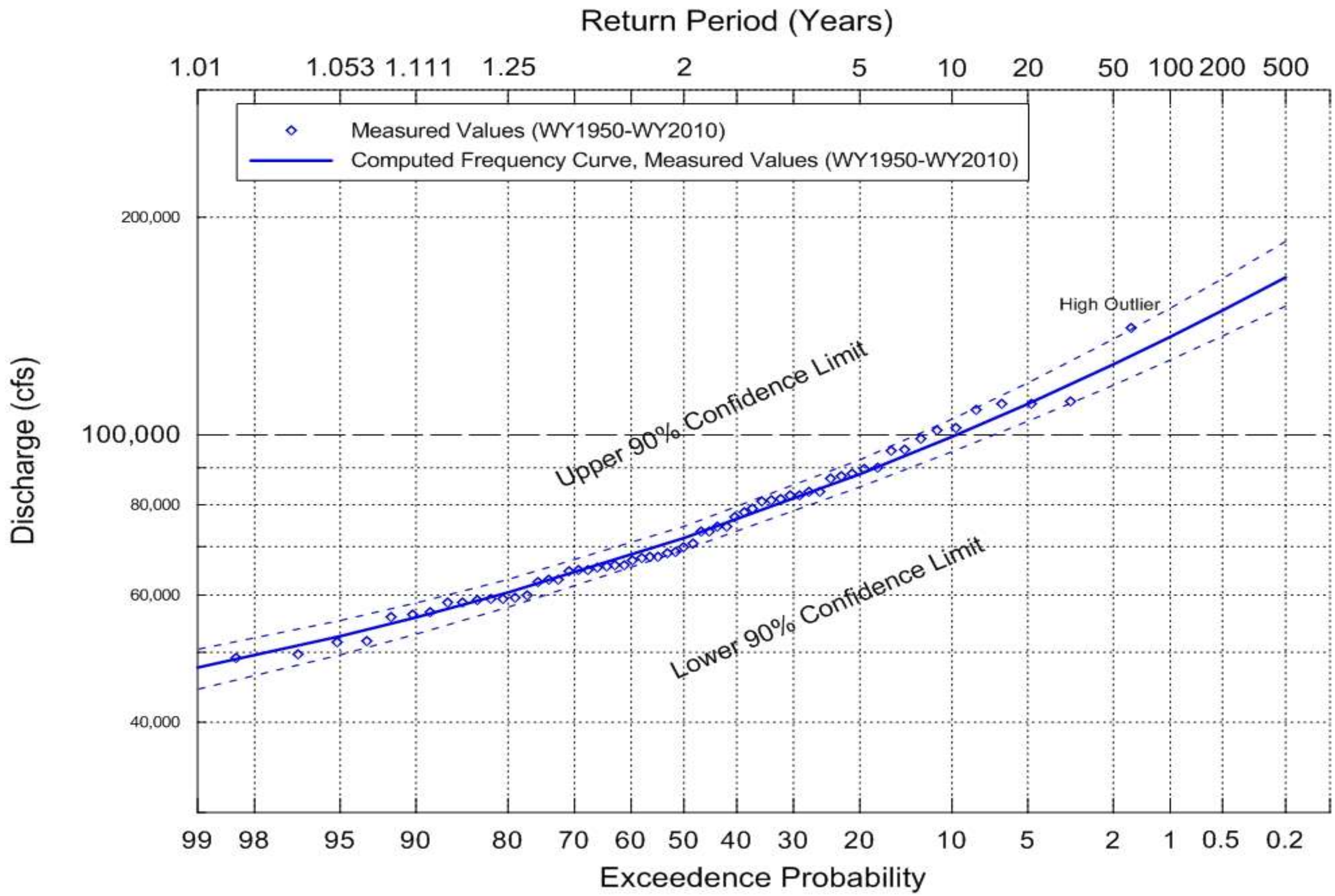

Figure 4.4-9. Flood-frequency curve for Susitna River at Sunshine for Maximum Load Following OS-1 conditions based on the HEC-ResSim model.

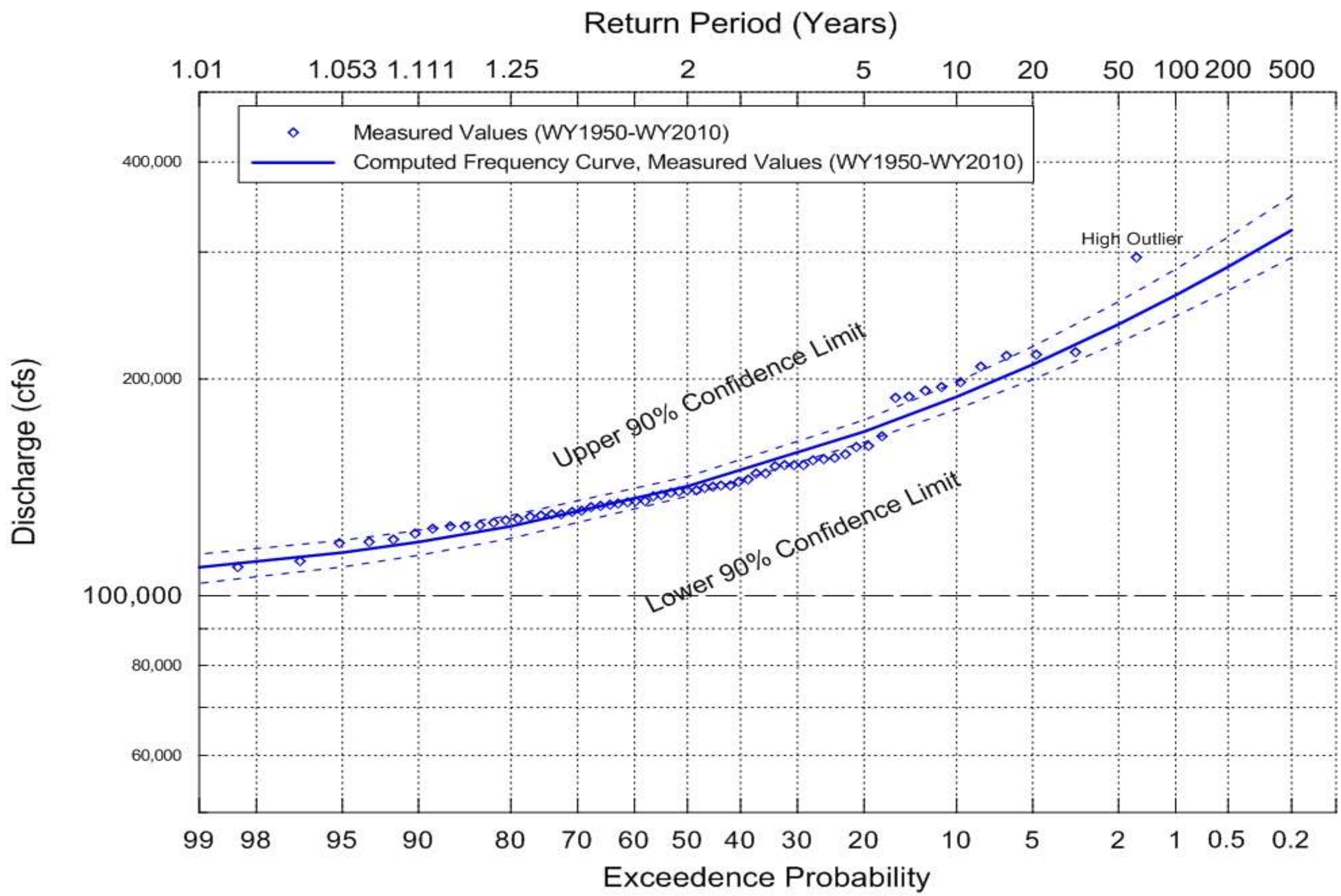

Figure 4.4-10. Flood-frequency curve for Susitna River at Susitna Station for Maximum Load Following OS-1 conditions based on estimated HEC-ResSim model output.

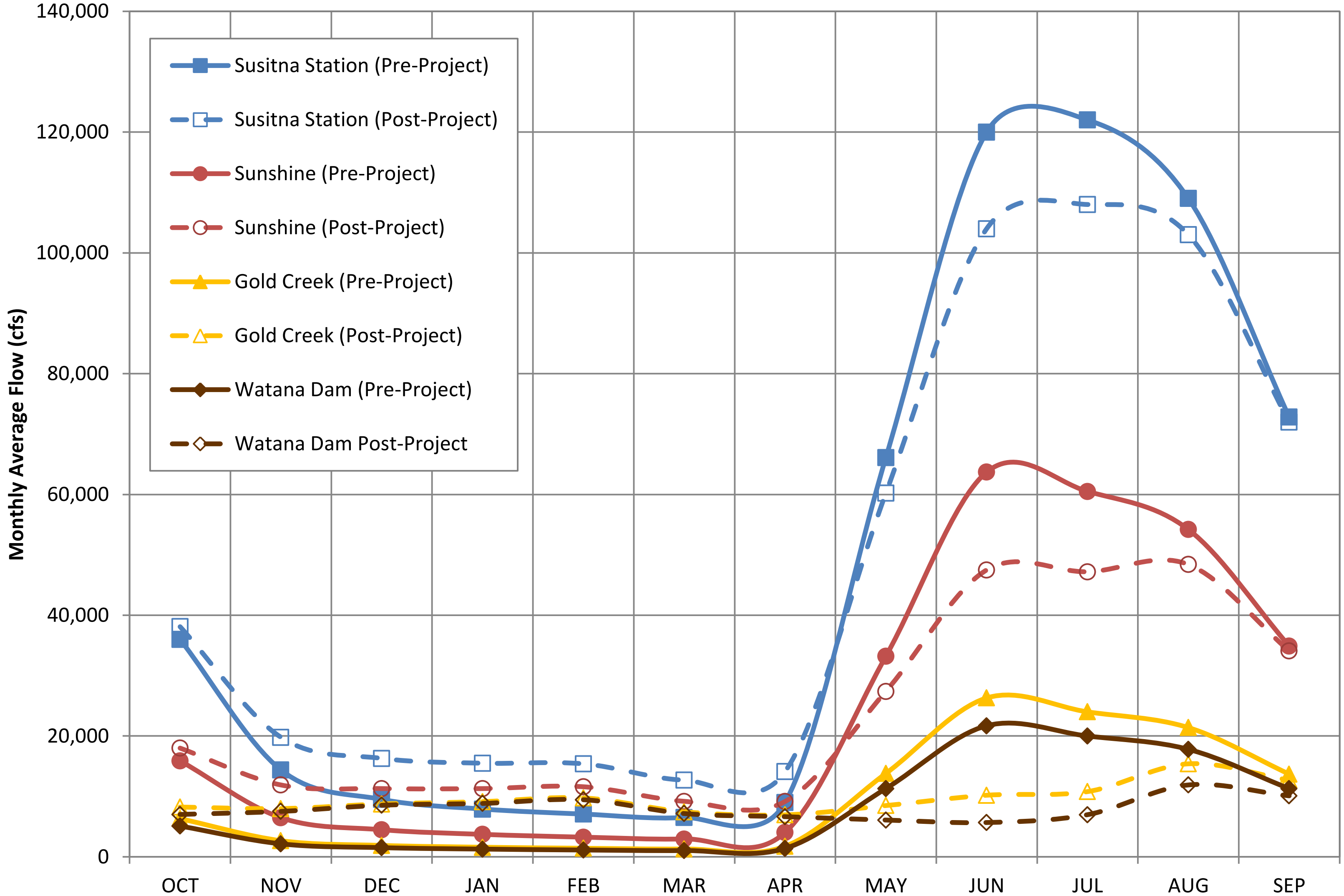

Figure 4.5-1. Average monthly flows (cfs) in the Susitna River watershed for pre-Project and Maximum Load Following OS-1 conditions.

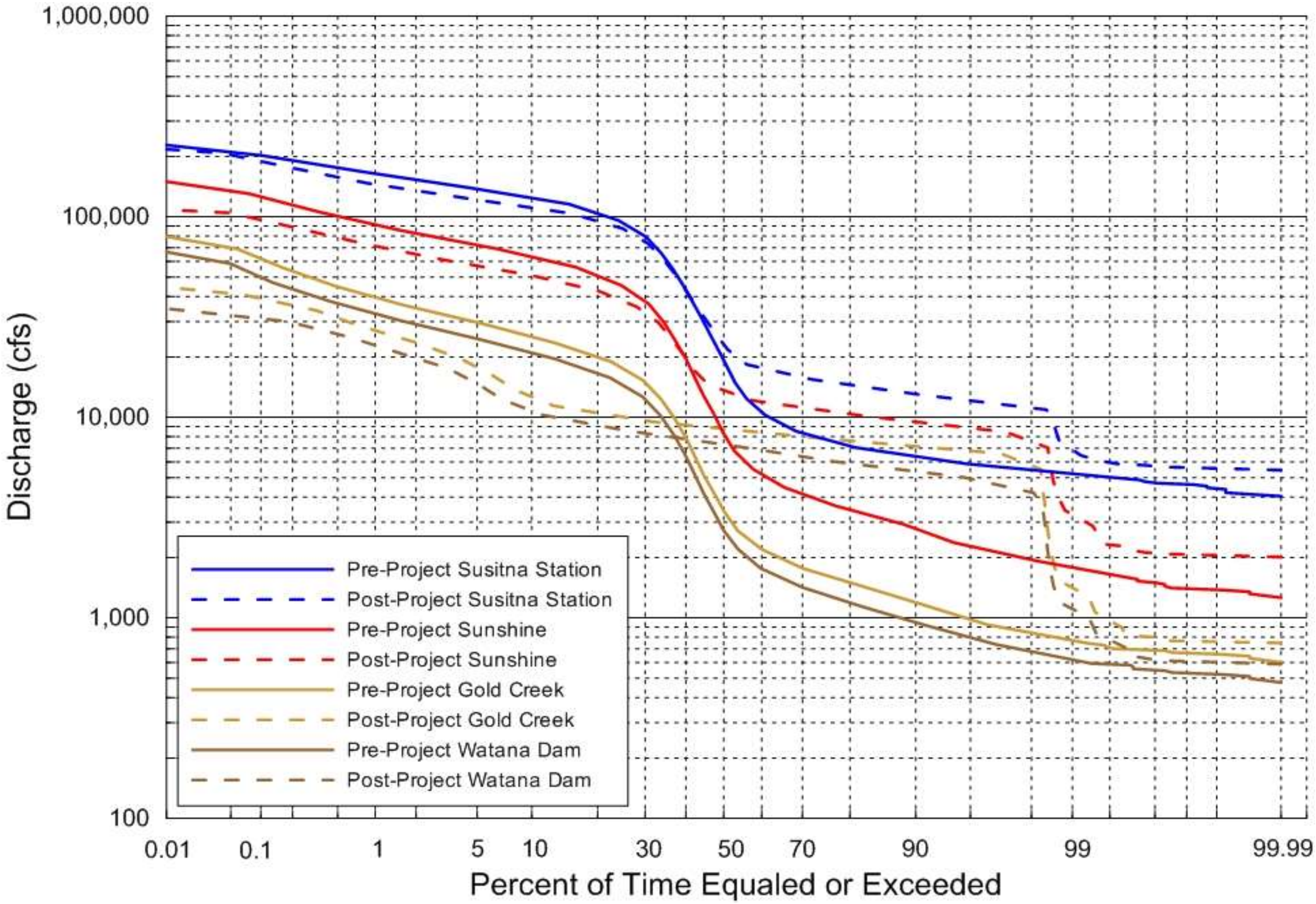

Figure 4.5-2. Annual flow-duration curve comparison for Pre-Project and Maximum Load Following OS-1 conditions.

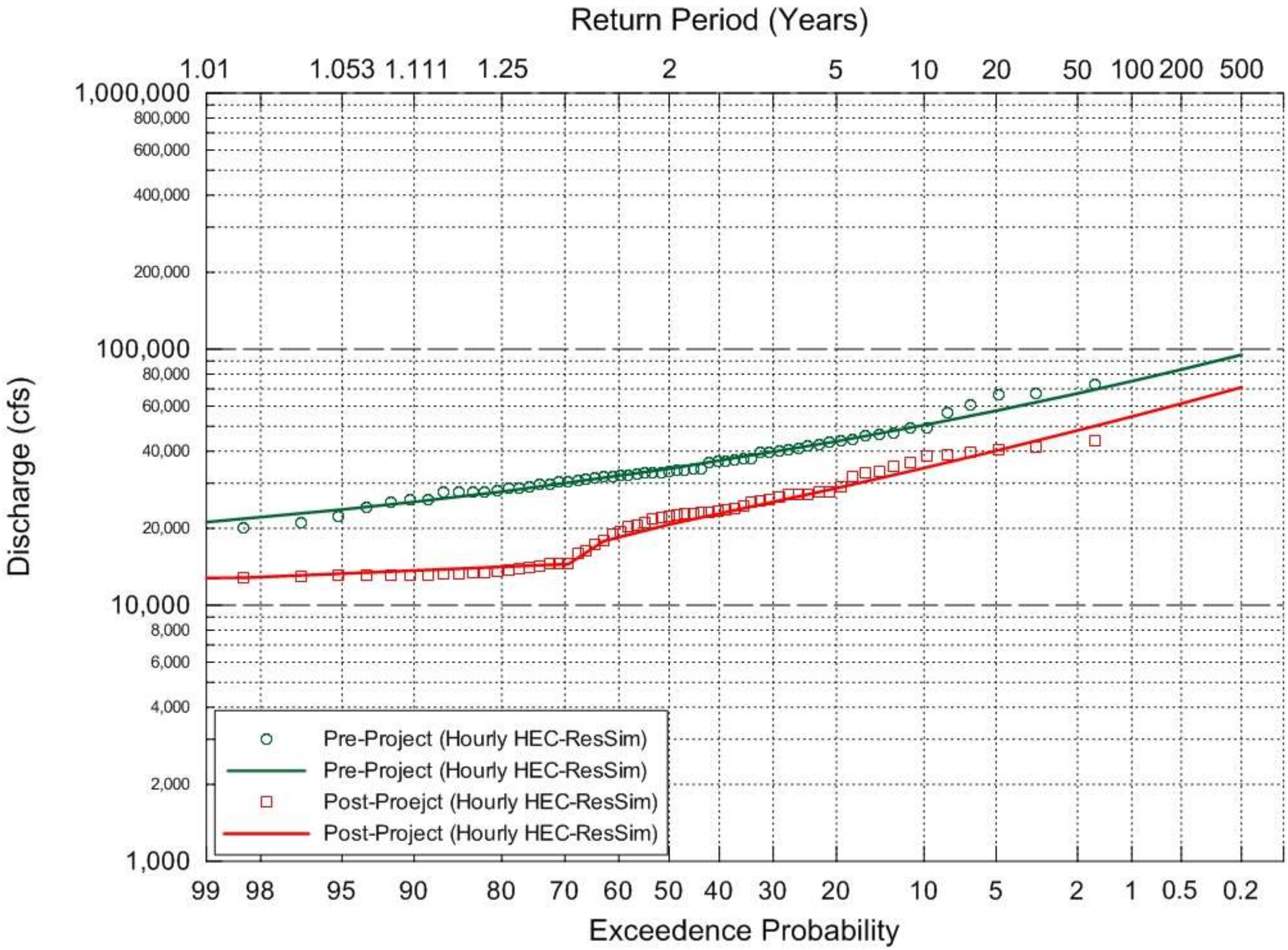

Figure 4.5-3. Flood-frequency curve for Susitna River at the Watana Dam for Maximum Load Following OS-1 conditions based on estimated HEC-ResSim model output.

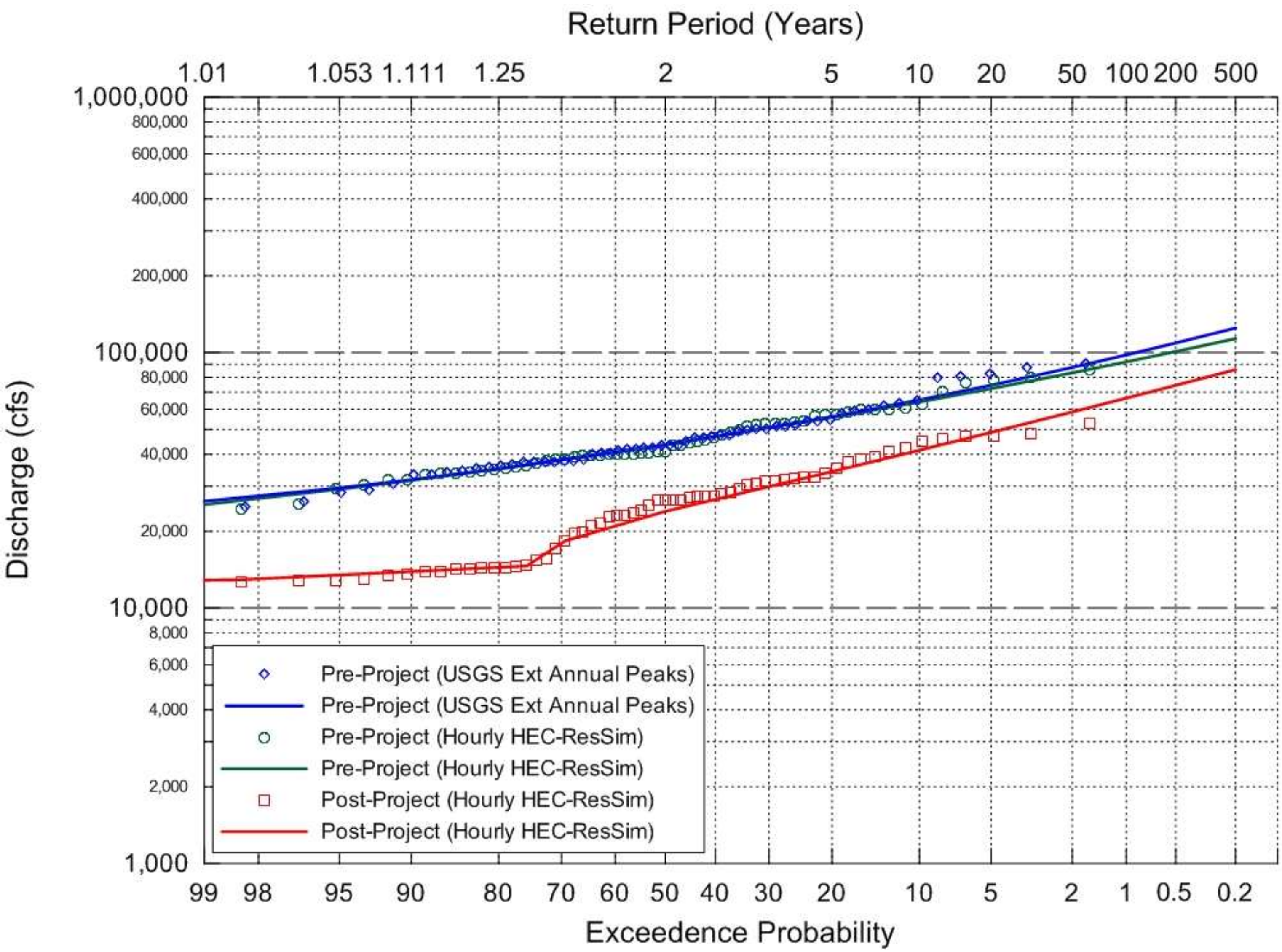

Figure 4.5-4. Flood-frequency curve for Susitna River at Gold Creek (USGS Gage No. 1529200) for Maximum Load Following OS-1 conditions based on estimated HEC-ResSim model output.

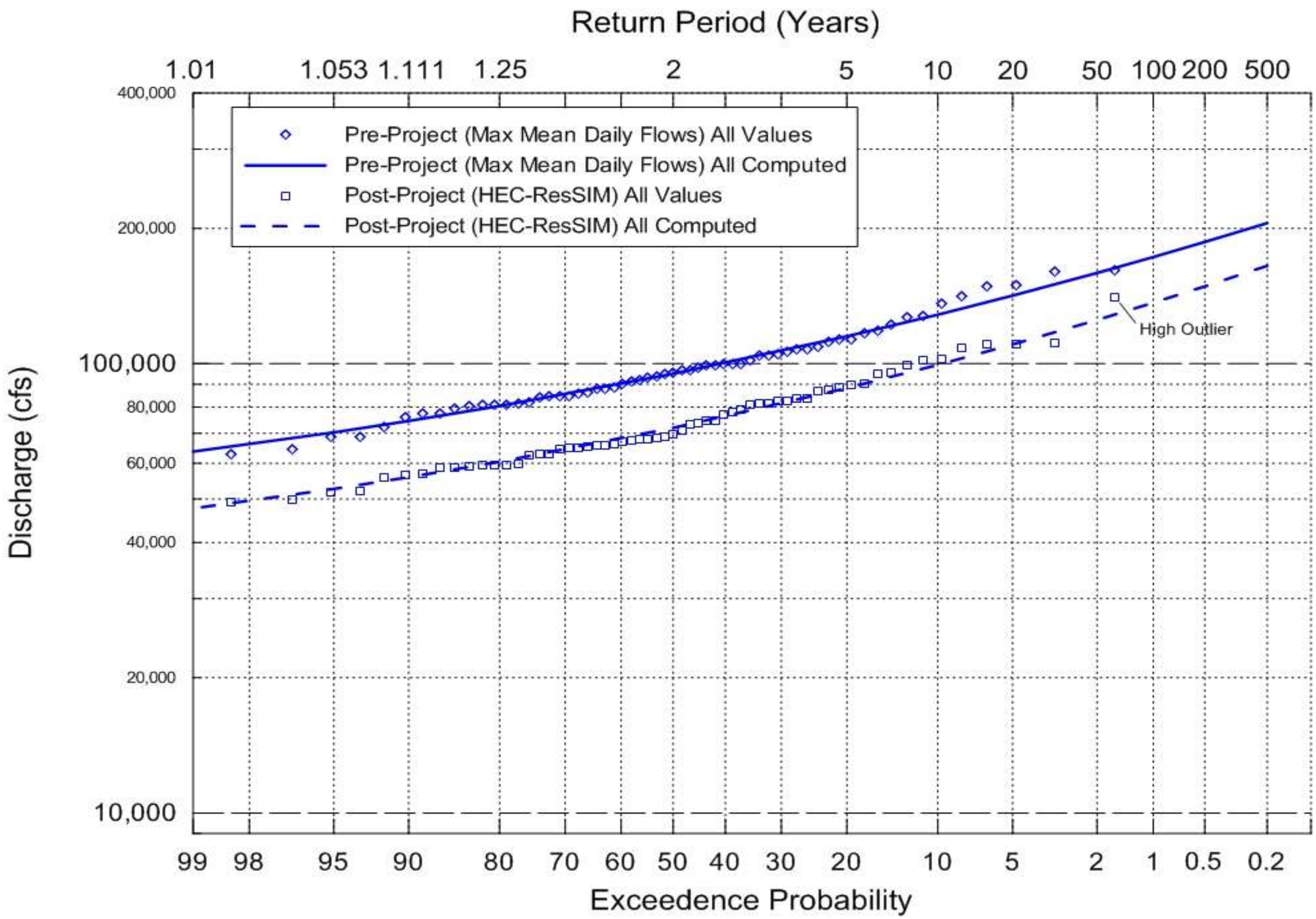

Figure 4.5-5. Flood-frequency curve for Susitna River at Sunshine (USGSG Gage No. 15292780) for Maximum Load Following OS-1 conditions **based on estimated HEC-ResSim model output.**

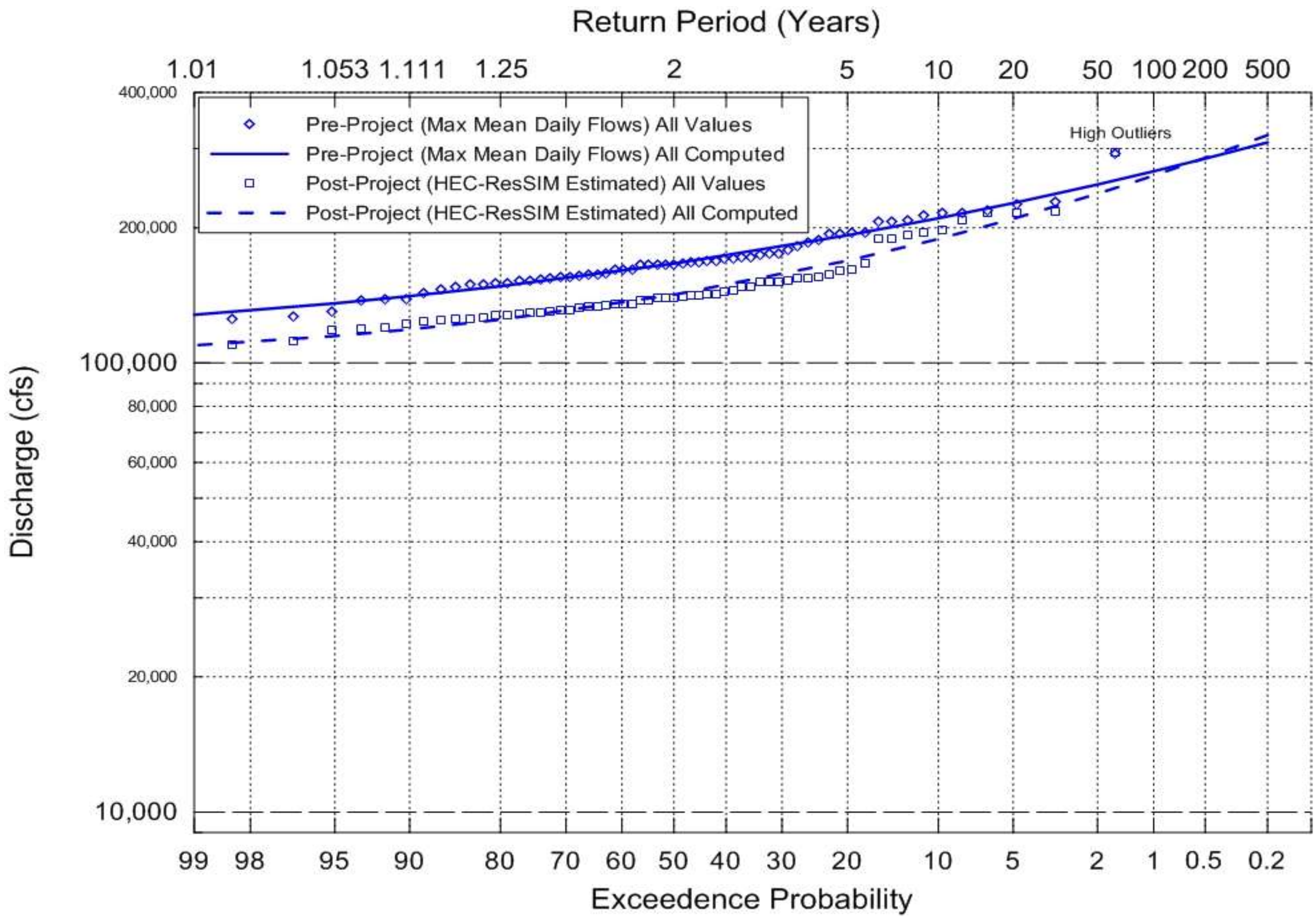

Figure 4.5-6. Flood-frequency curve for Susitna River at Susitna Station (USGS Gage No. 1524350) for Maximum Load Following OS-1 conditions based on estimated HEC-ResSim model output.

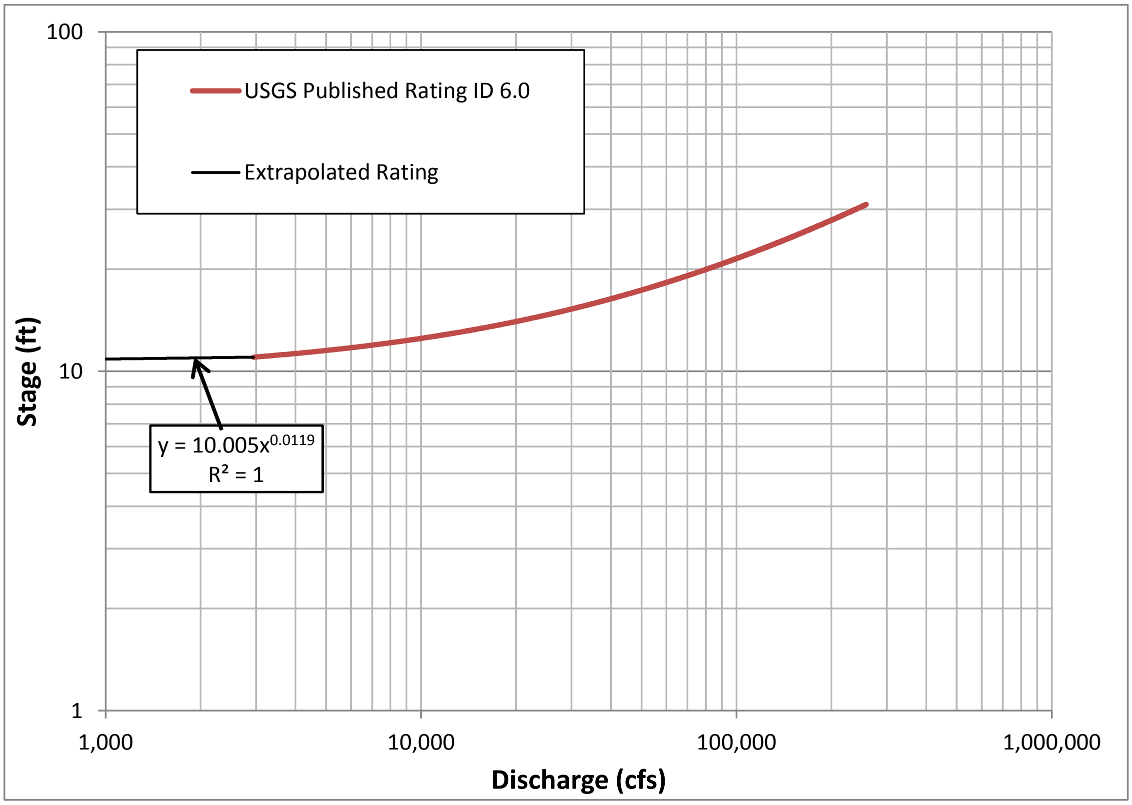

Figure 5.2-1. USGS Published and Extrapolated Stage-Discharge Rating for Susitna River USGS Gage at Sunshine.

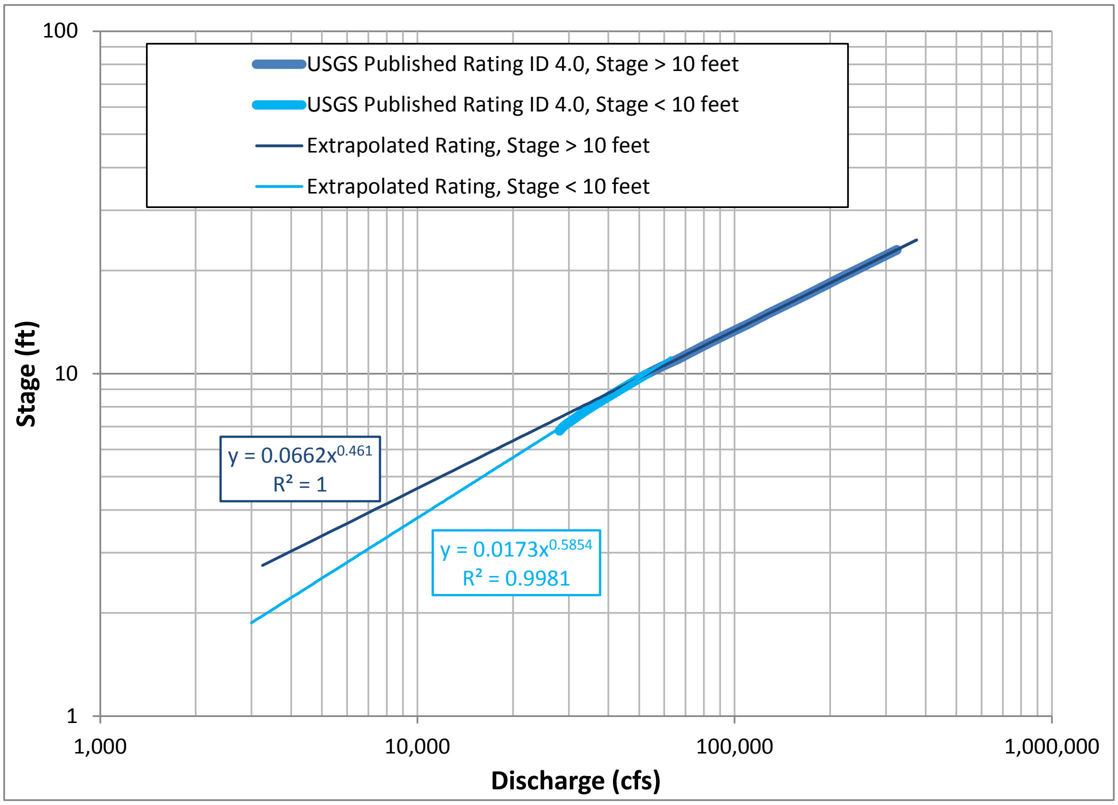

Figure 5.2-2. USGS Published and Extrapolated Stage-Discharge Ratings for Susitna River USGS Gage at Susitna Station.

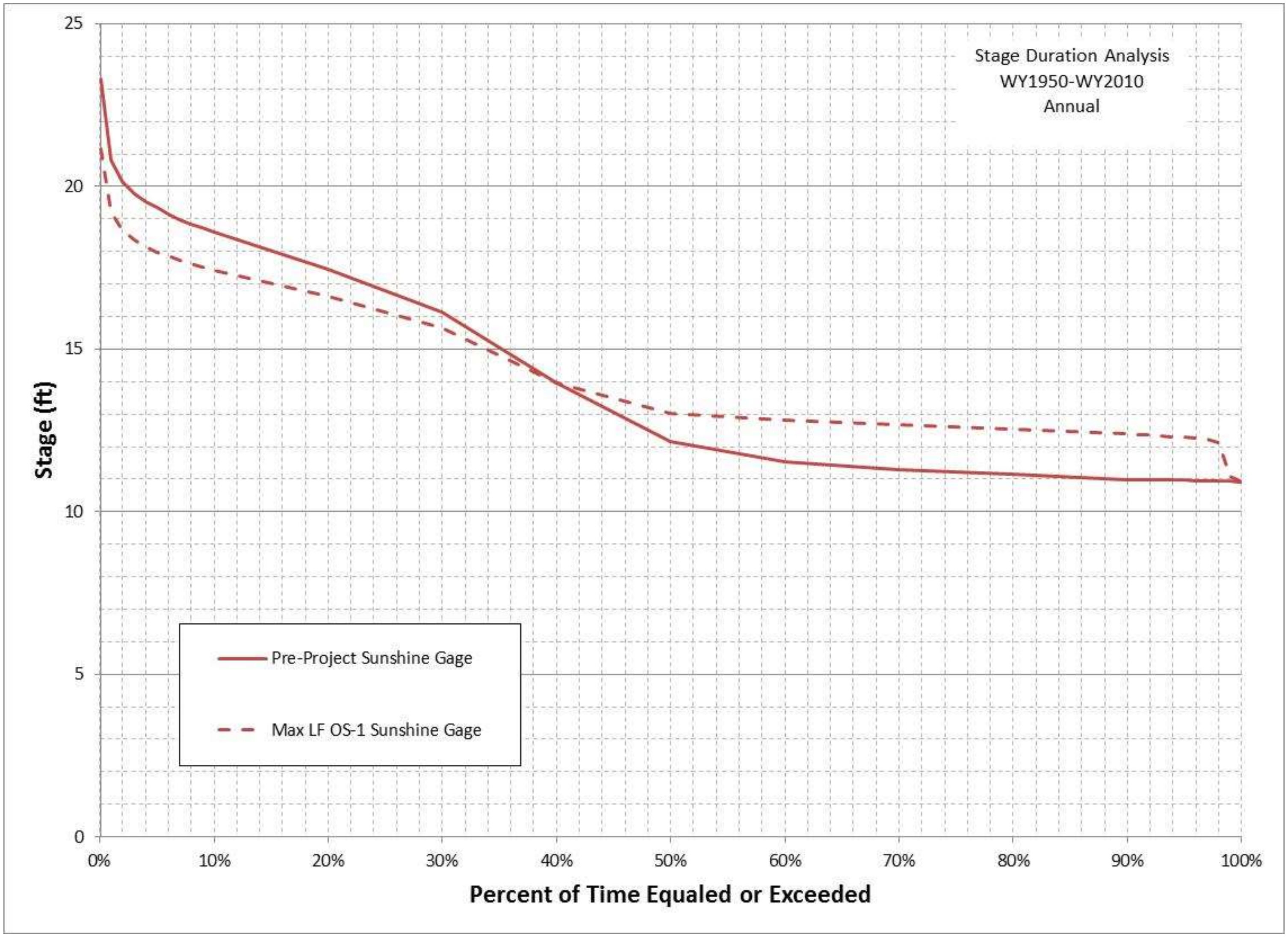

Figure 5.3-1. Annual Stage-exceedence Relationships for pre-Project and Max LF OS-1 Conditions, Sunshine Gage.

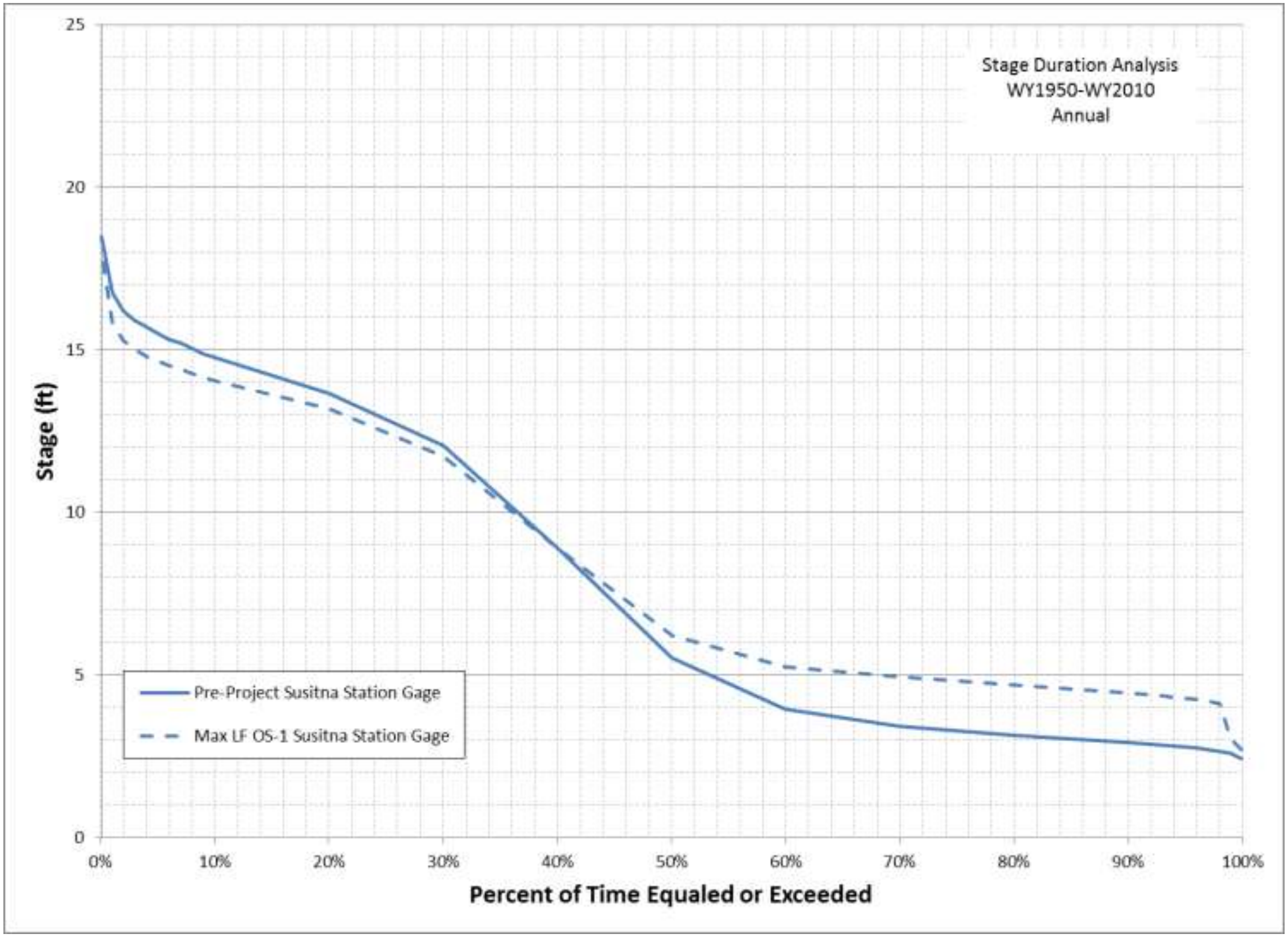

Figure 5.3-2. Annual Stage-exceedence Relationships for pre-Project and Max LF OS-1 Conditions, Susitna Station Gage.

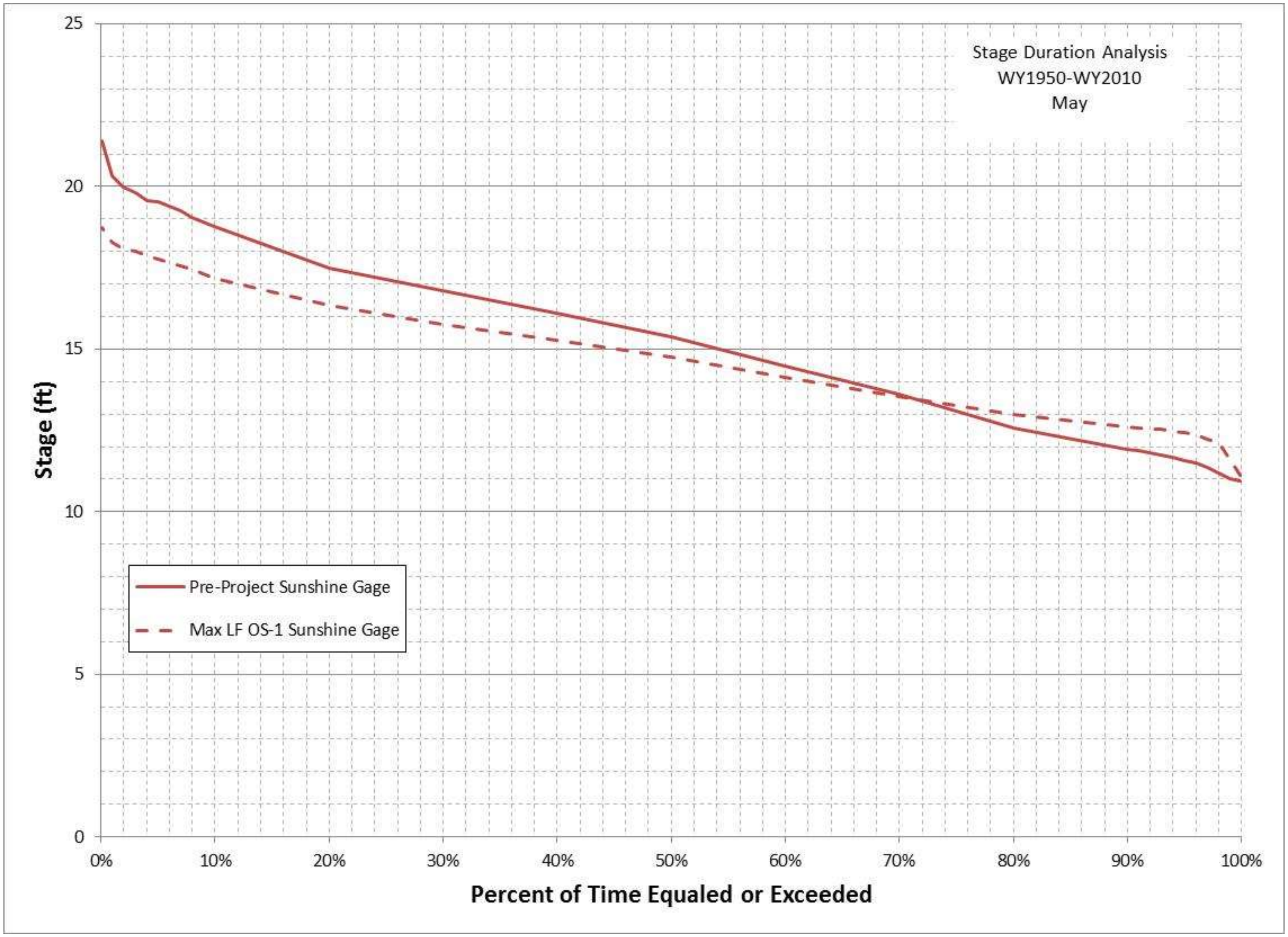

Figure 5.3-3. Monthly Stage-exceedence Relationships for May for pre-Project and Max LF OS-1 Conditions, Sunshine Gage.

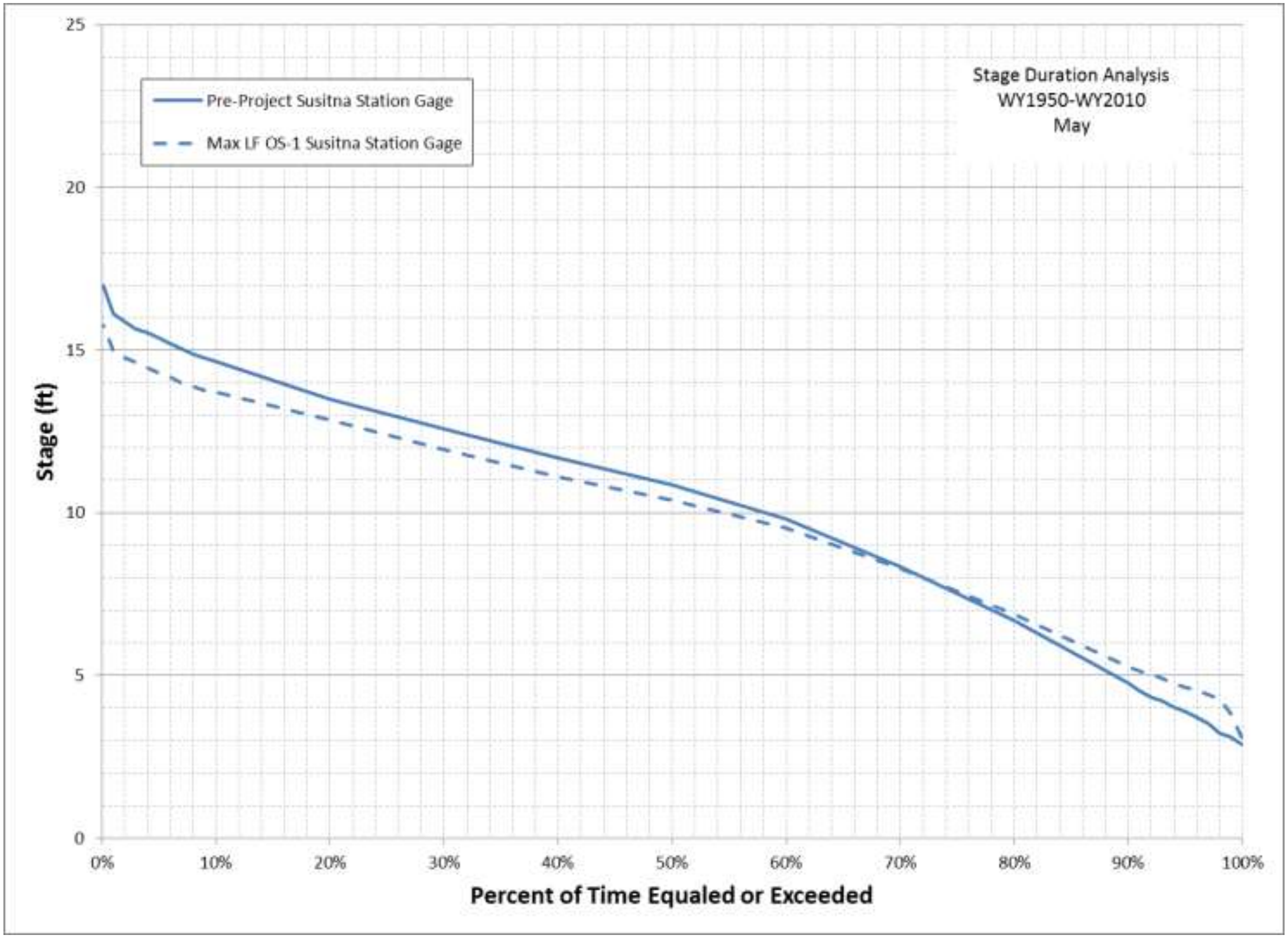

Figure 5.3-4. Monthly Stage-exceedence Relationships for May for pre-Project and Max LF OS-1 Conditions, Susitna Station Gage.

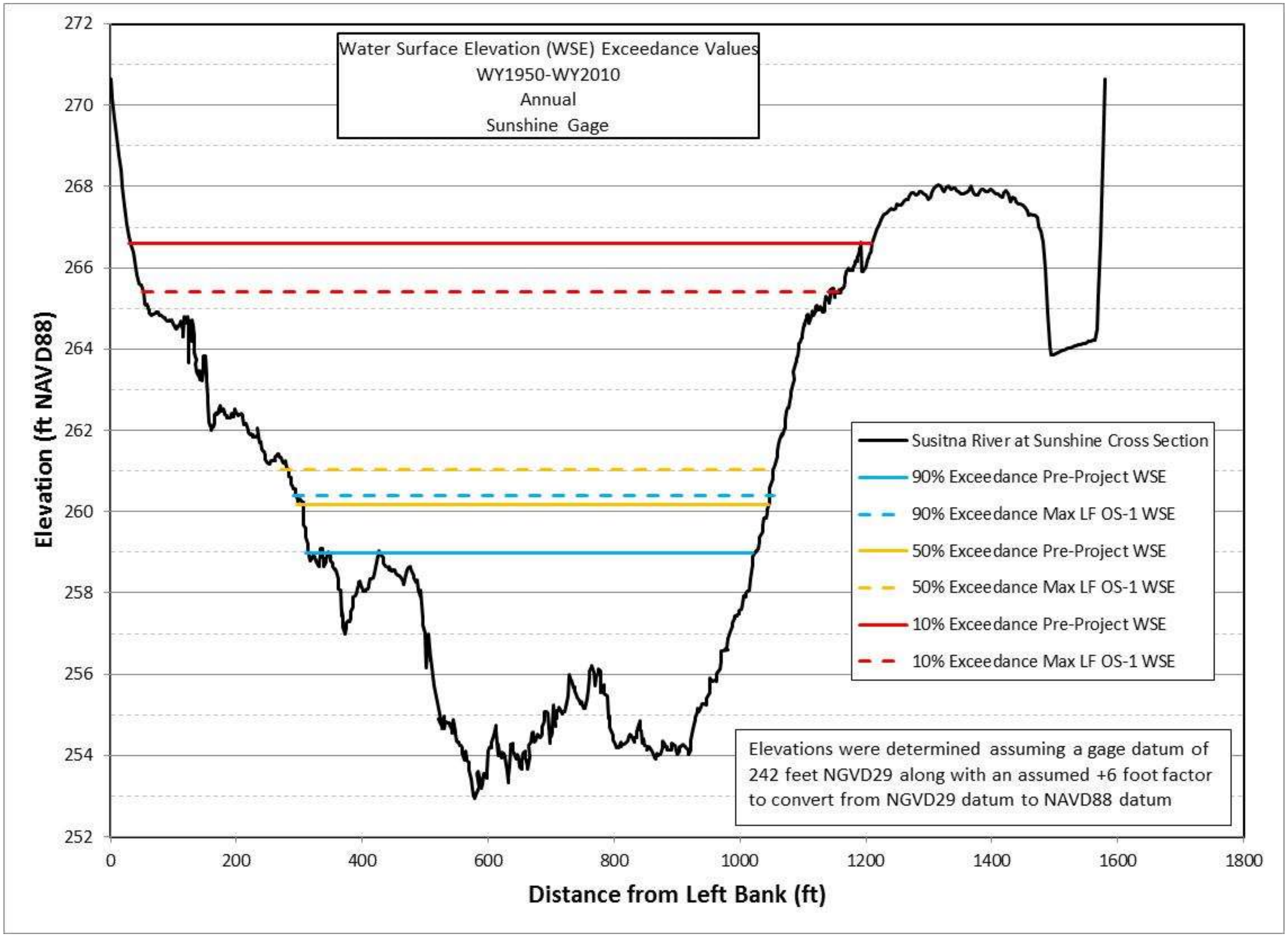

Figure 5.3-5. Select Annual Water-surface Elevation exceedence Values for pre-Project and Max LF OS-1 Conditions, Sunshine Gage.

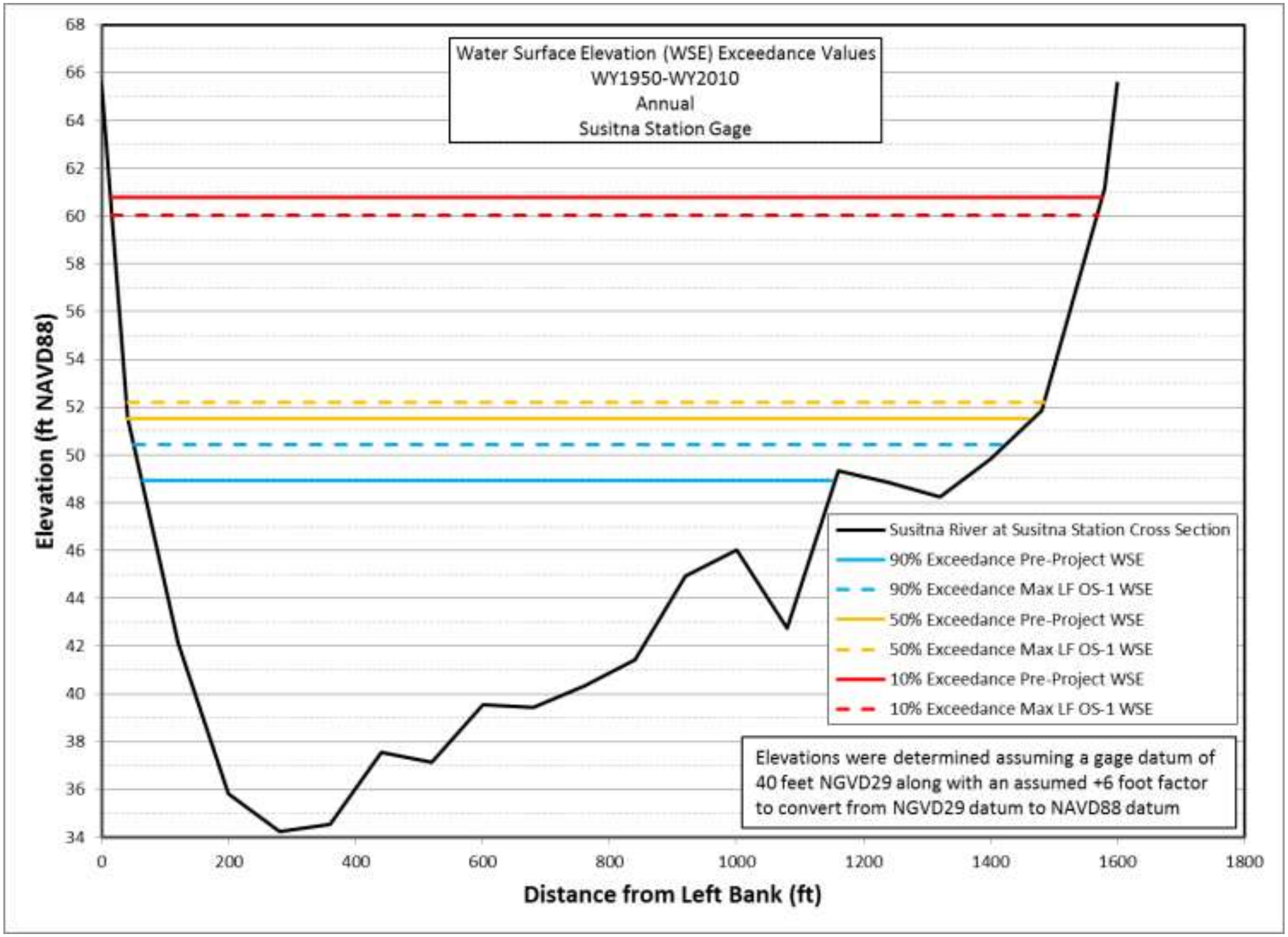

Figure 5.3-6. Select Annual Water-surface Elevation exceedence Values for pre-Project and Max LF OS-1 Conditions, Susitna Station Gage.

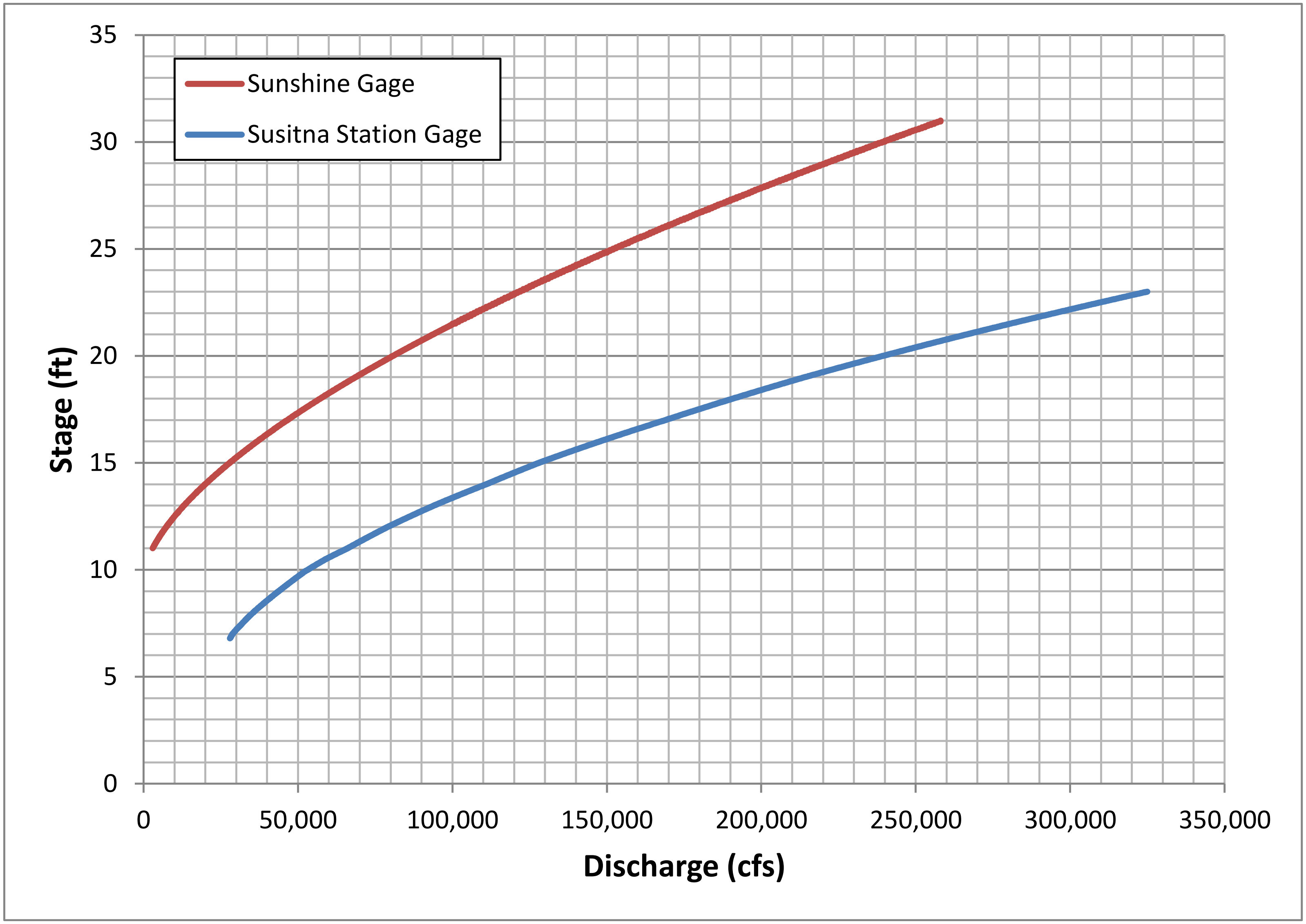

Figure 5.4-1. Comparison of Stage-Discharge Ratings for Susitna Station and Sunshine Gages.

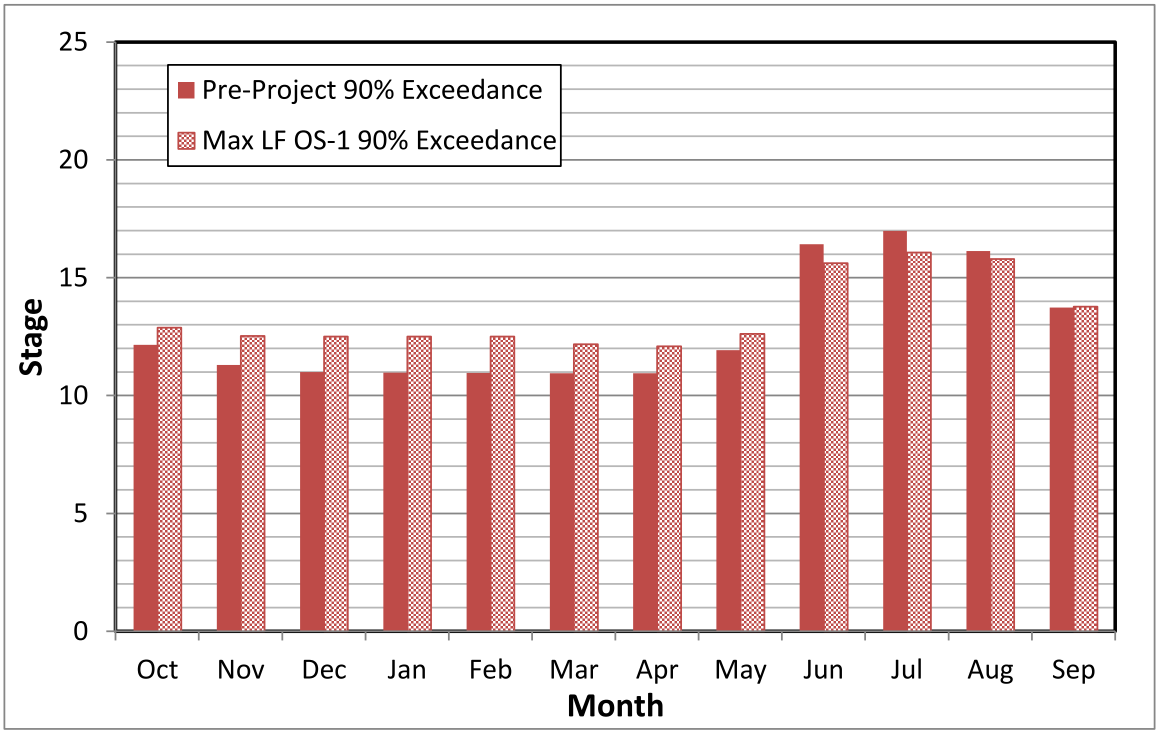

Figure 5.4-2. Monthly 90 percent pre-Project and Max LF OS-1 Stage-exceedence Values, Sunshine Gage.

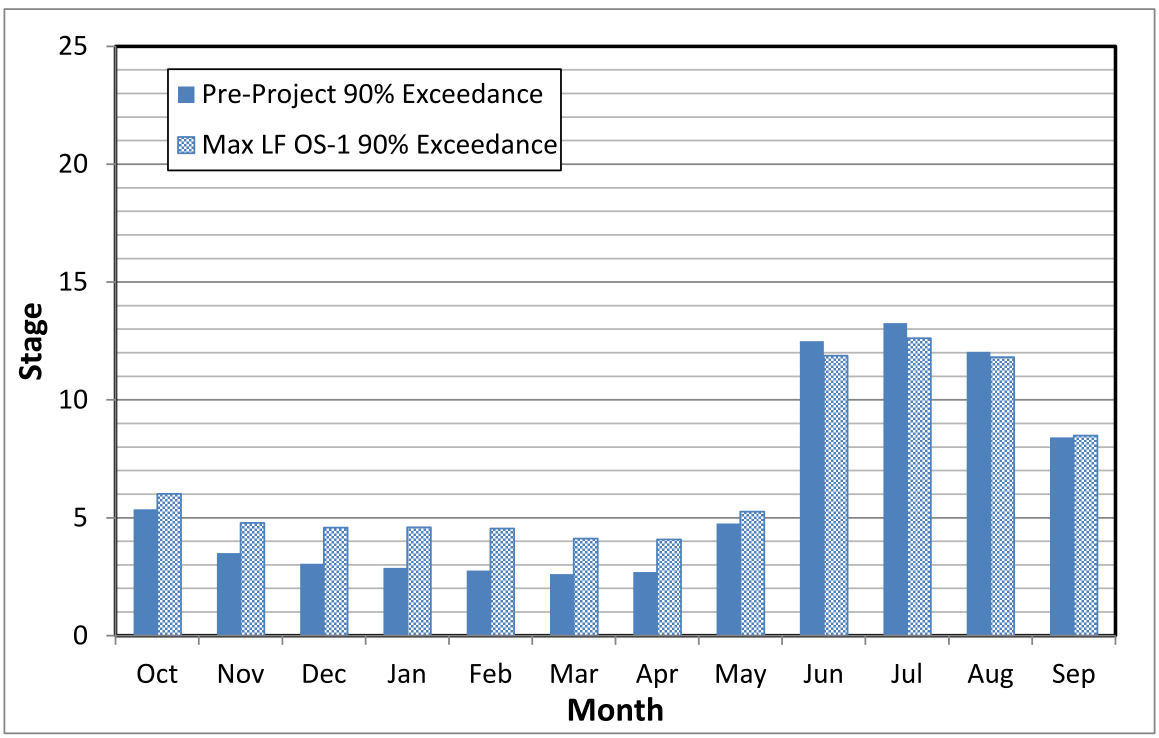

Figure 5.4-3. Monthly 90 percent pre-Project and Max LF OS-1 Stage-exceedence Values, Susitna Station Gage.

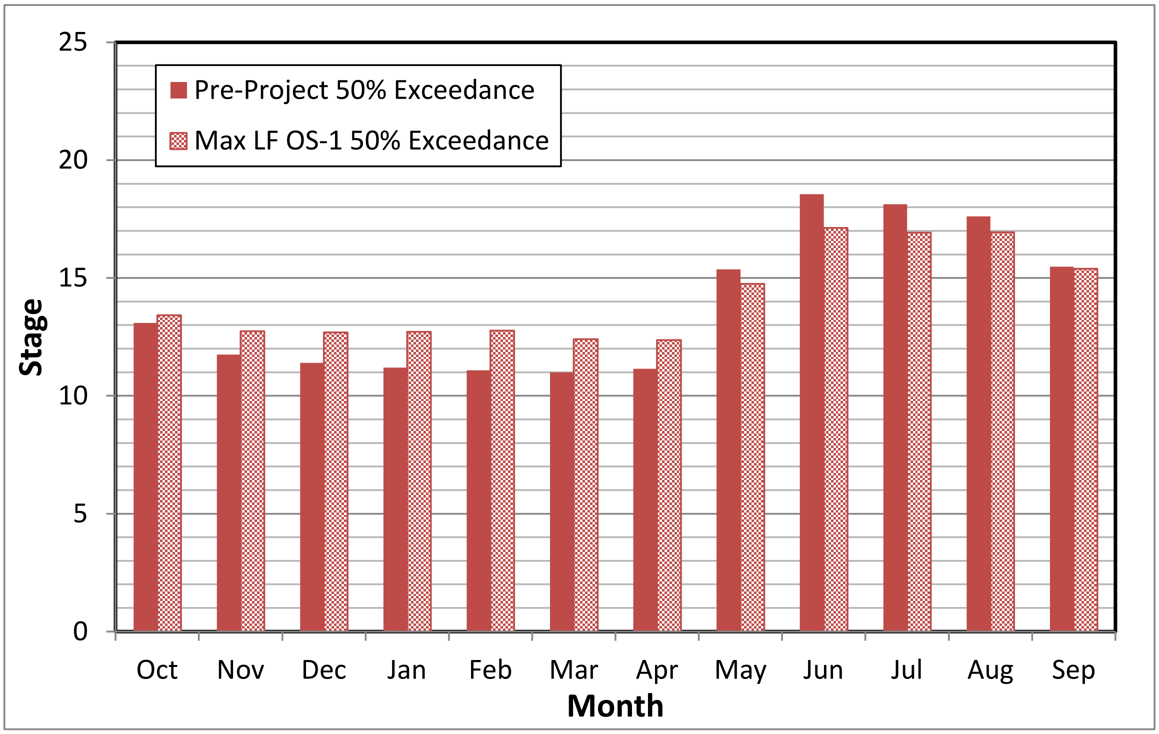

Figure 5.4-4. Monthly 50 percent pre-Project and Max LF OS-1 Stage-Exceedence Values, Sunshine Gage.

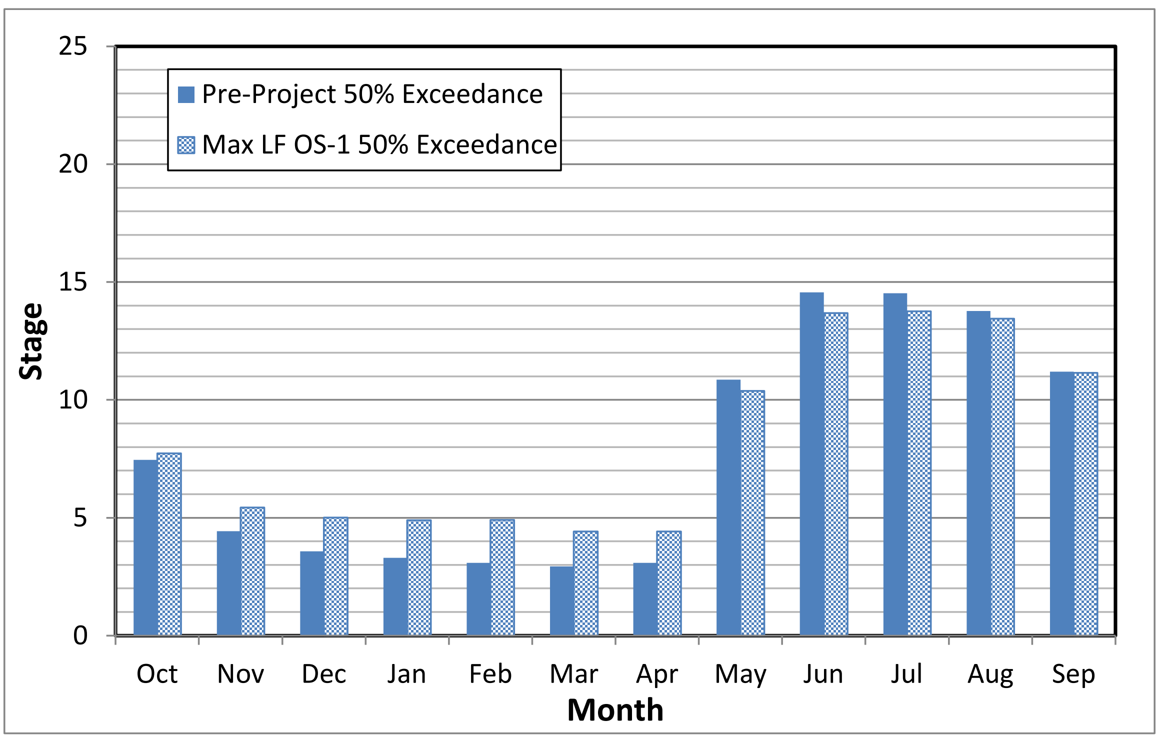

Figure 5.4-5. Monthly 50 percent pre-Project and Max LF OS-1 Stage-exceedence Values, Susitna Station Gage.

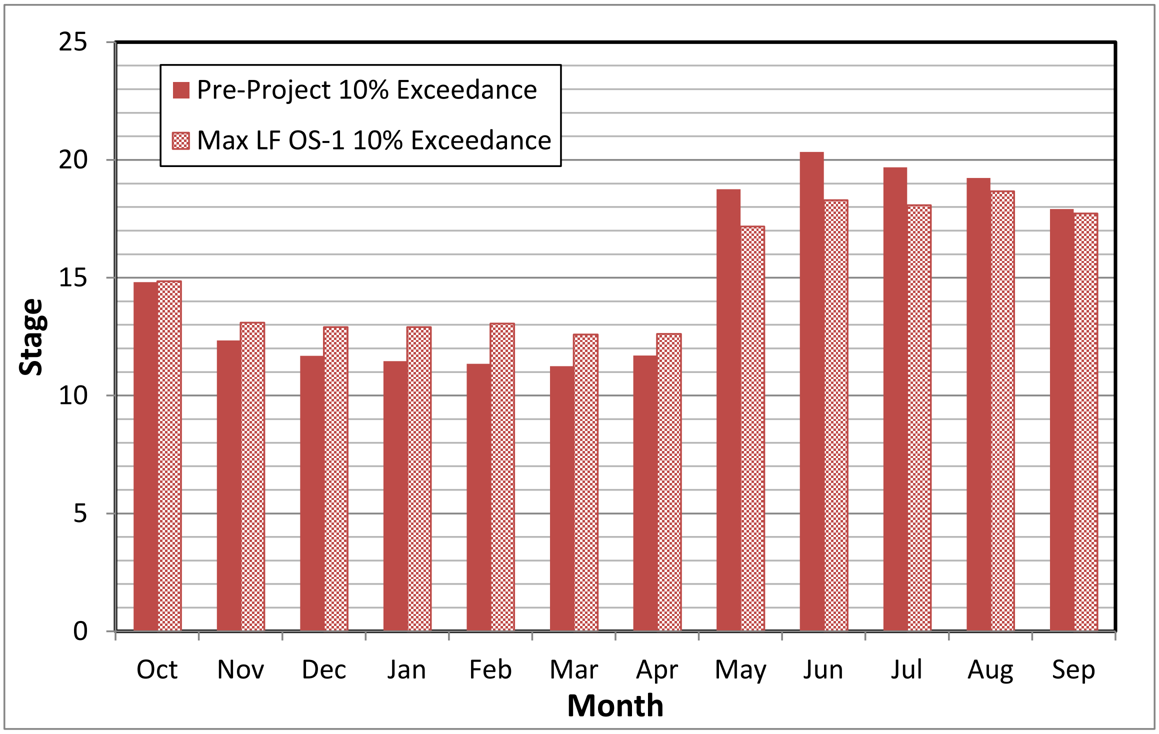

Figure 5.4-6. Monthly 10 percent pre-Project and Max LF OS-1 Stage-exceedence Values, Sunshine Gage.

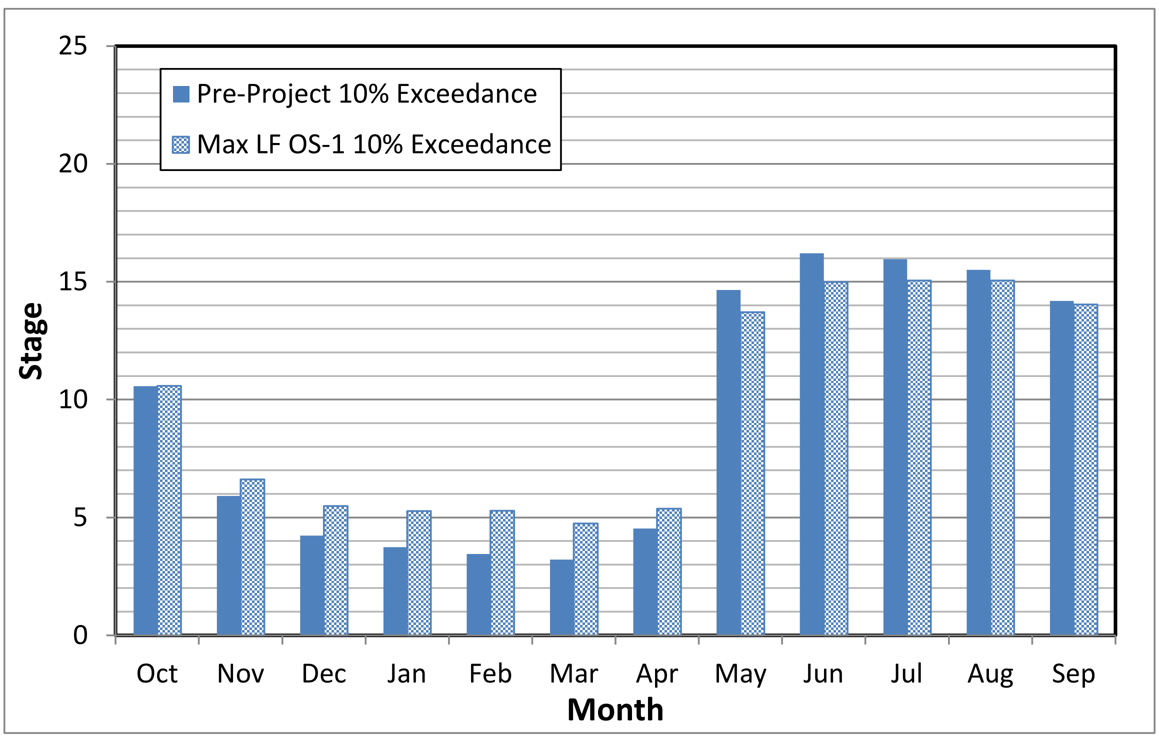

Figure 5.4-7. Monthly 10 percent pre-Project and Max LF OS-1 exceedence Values, Susitna Station Gage.

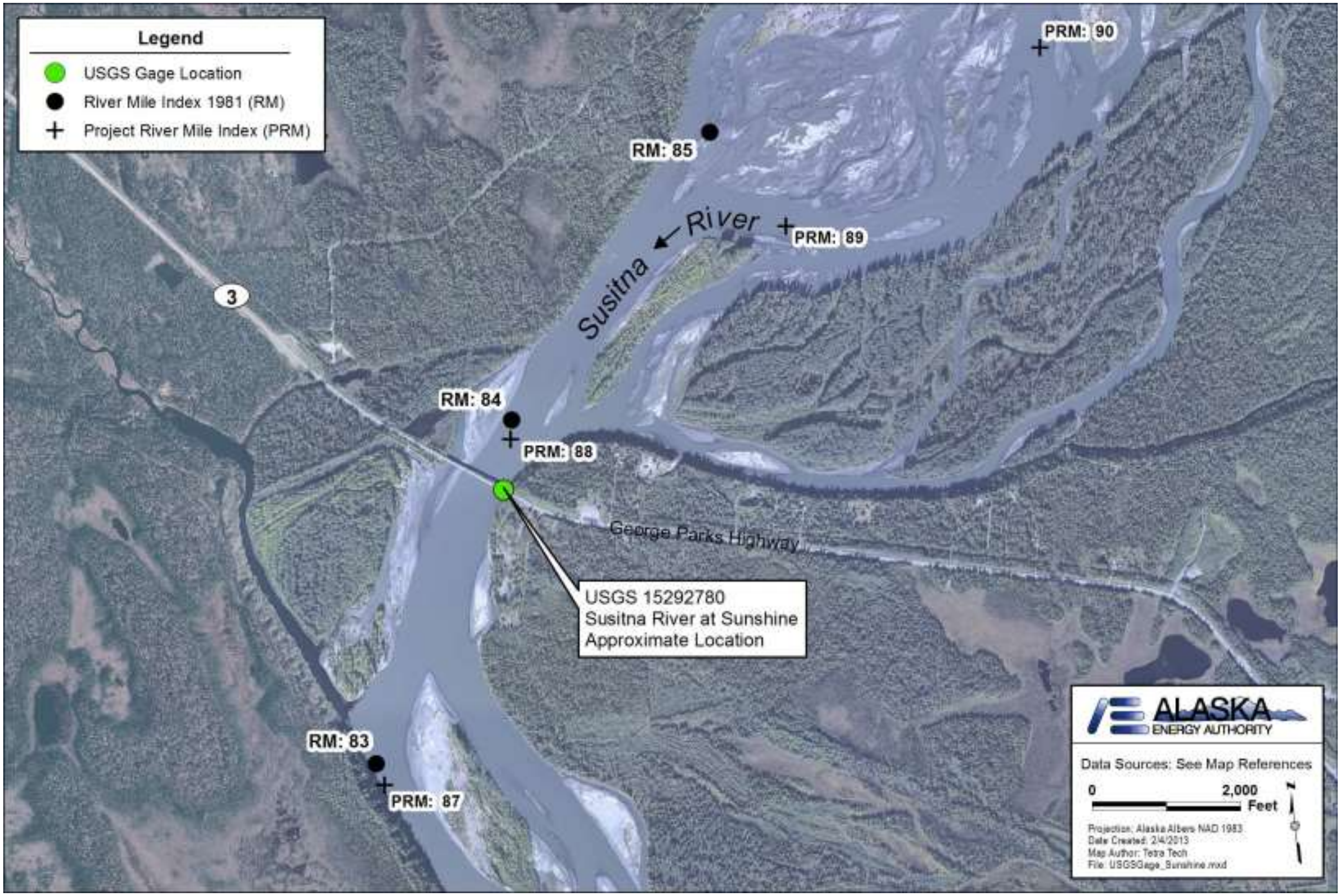

Figure 6.2-1. Vicinity Map for Susitna River at Sunshine Gage.

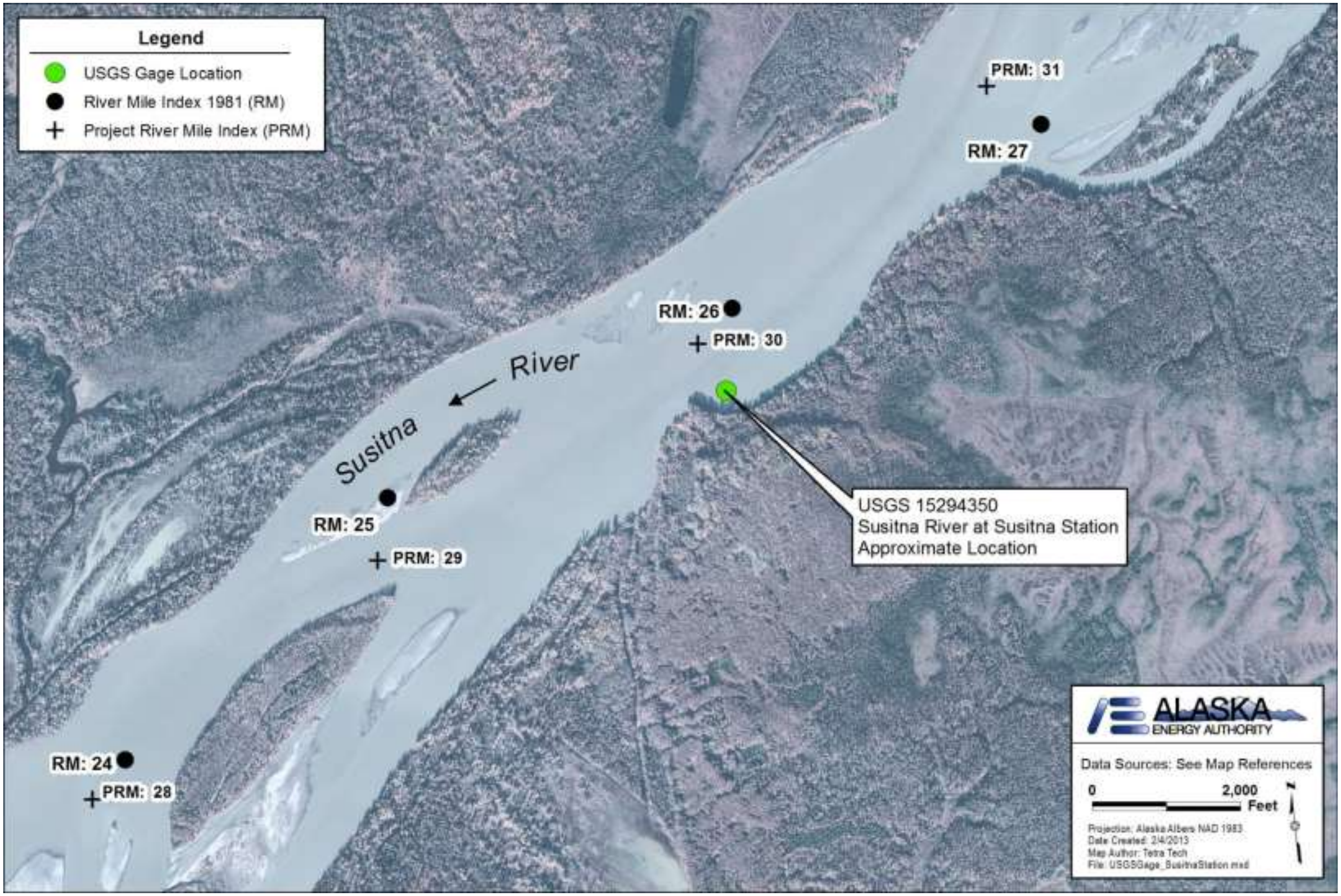

Figure 6.2-2. Vicinity Map for Susitna River at Susitna Station Gage.

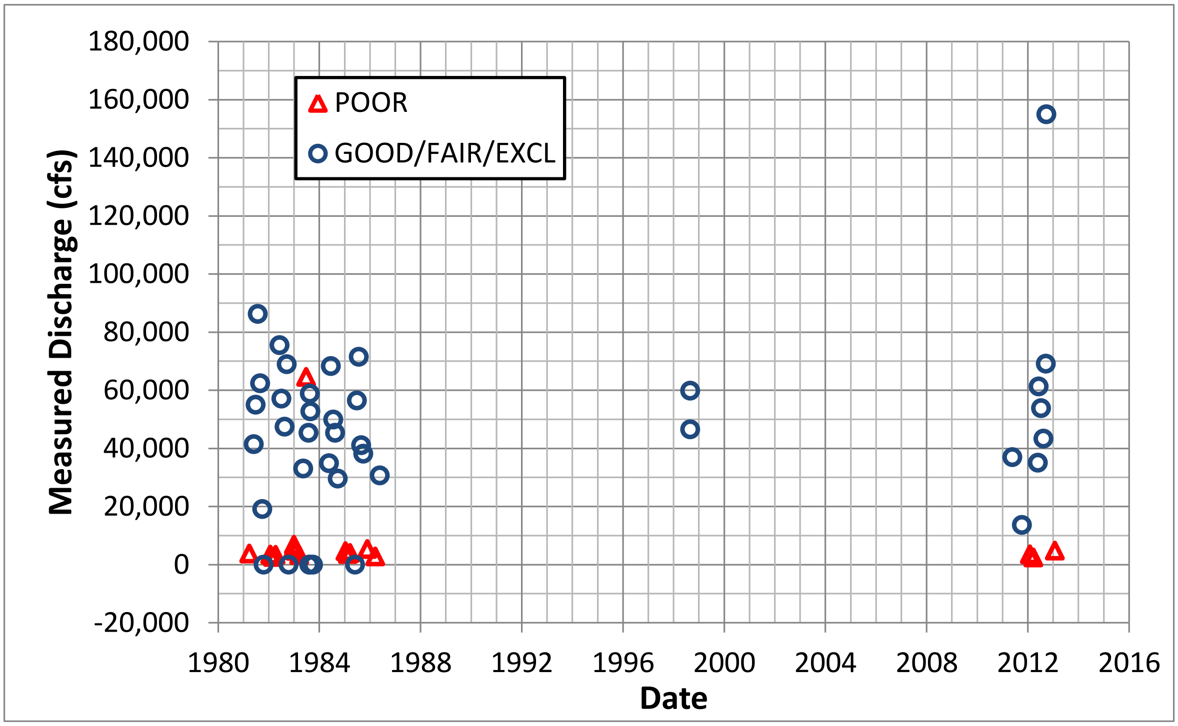

Figure 6.2-3. USGS Stage and Discharge Measurements at Susitna River at Sunshine Gage (USGS 15292780).

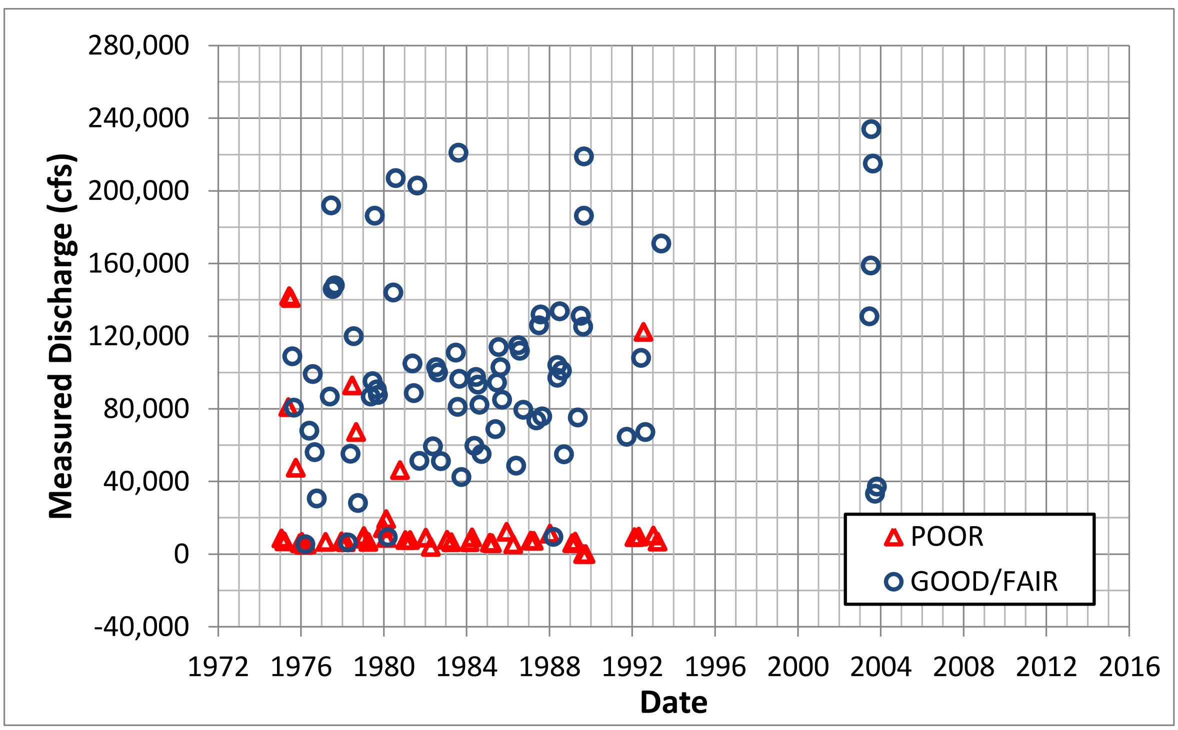

Figure 6.2-4. USGS Stage and Discharge Measurements at Susitna River at Susitna Station Gage (USGS 15294350).

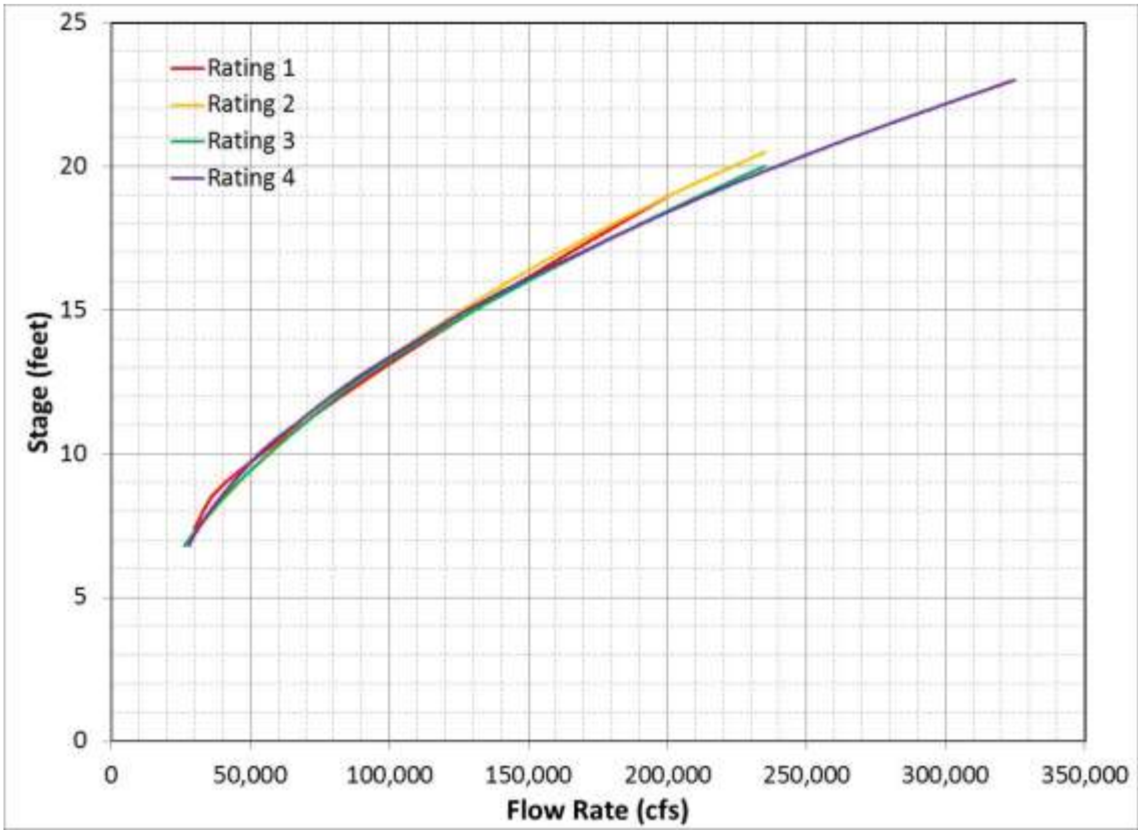

Figure 6.2-5. Historical Stage-Discharge Ratings for Susitna River at Susitna Station Gage.

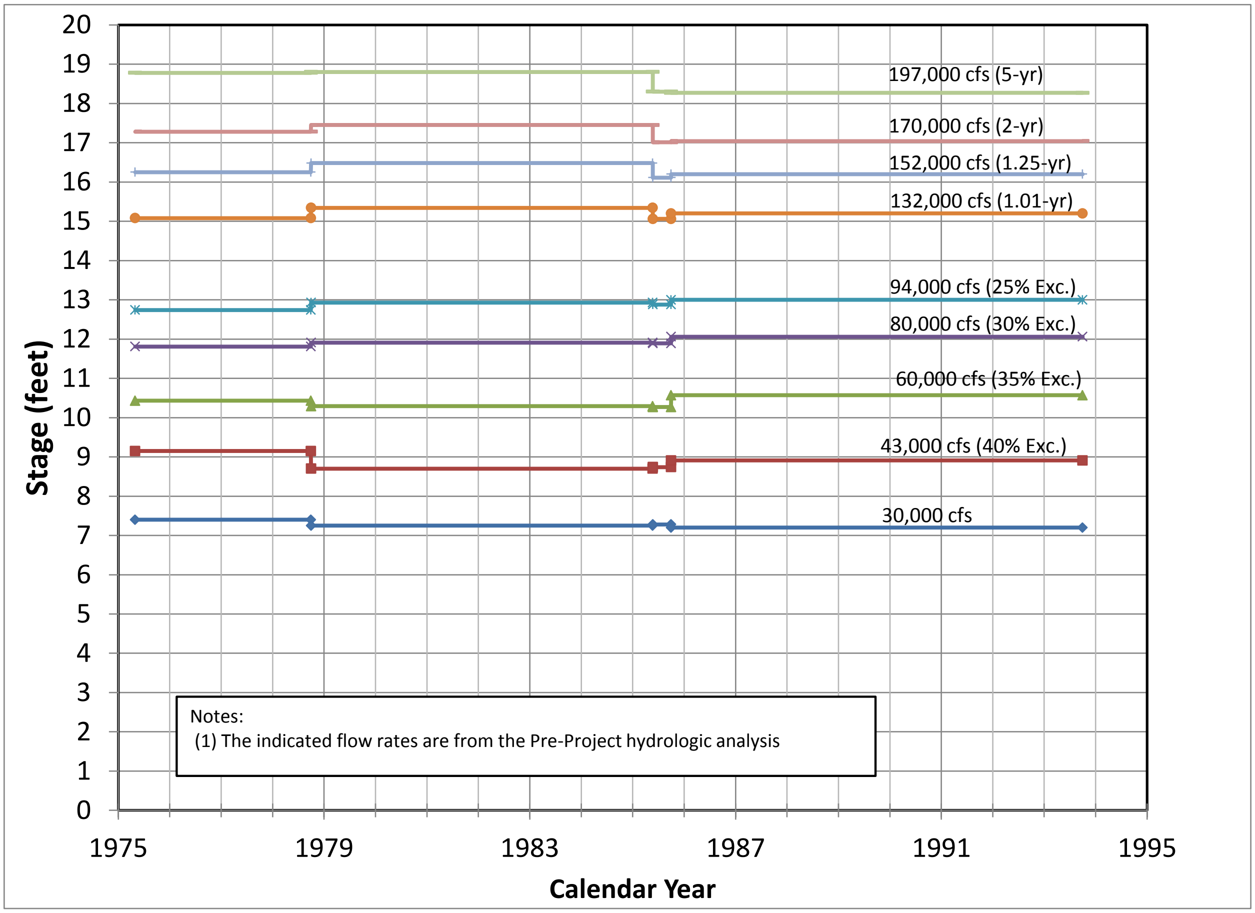

Figure 6.3-1. Specific Gage Curves for Susitna River at Susitna Station Gage.

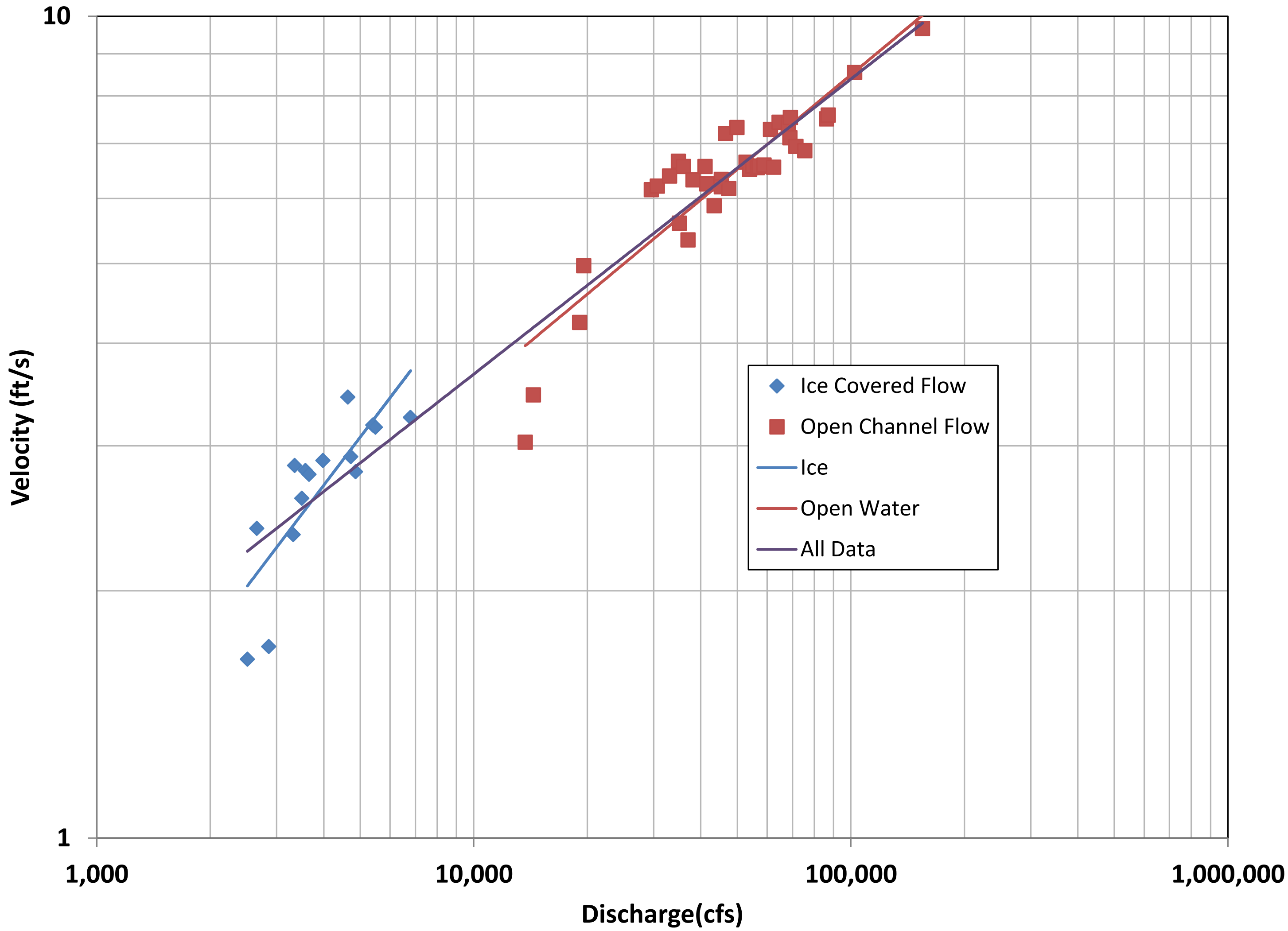

Figure 7.3.1. Velocity versus discharge for ice-covered and open-water conditions based on USGS measurements at the Susitna River at Sunshine gage.

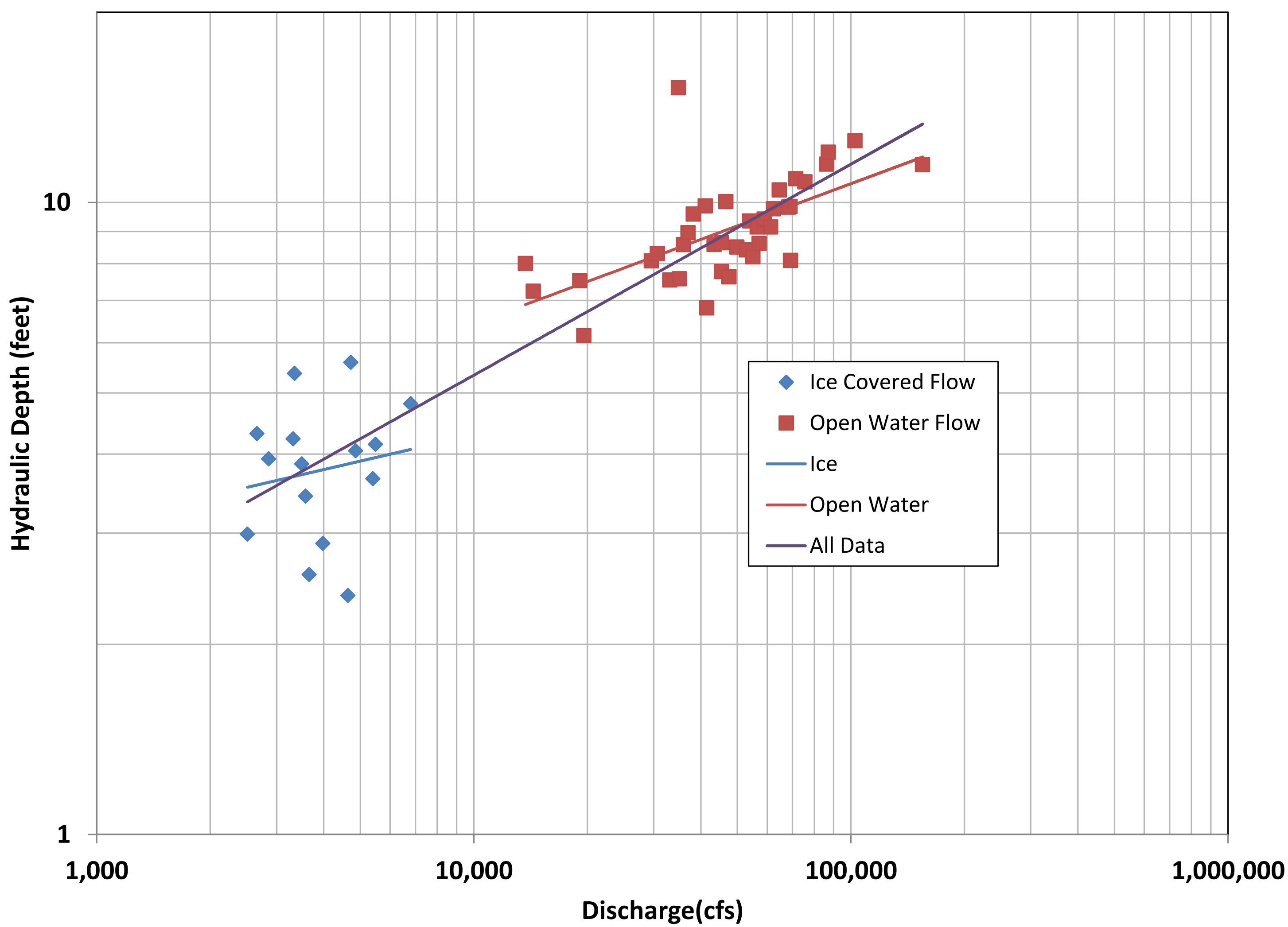

Figure 7.3.2. Hydraulic (i.e., average) depth versus discharge for ice-covered and open-water conditions based on USGS measurements at the Susitna River at Sunshine gage.

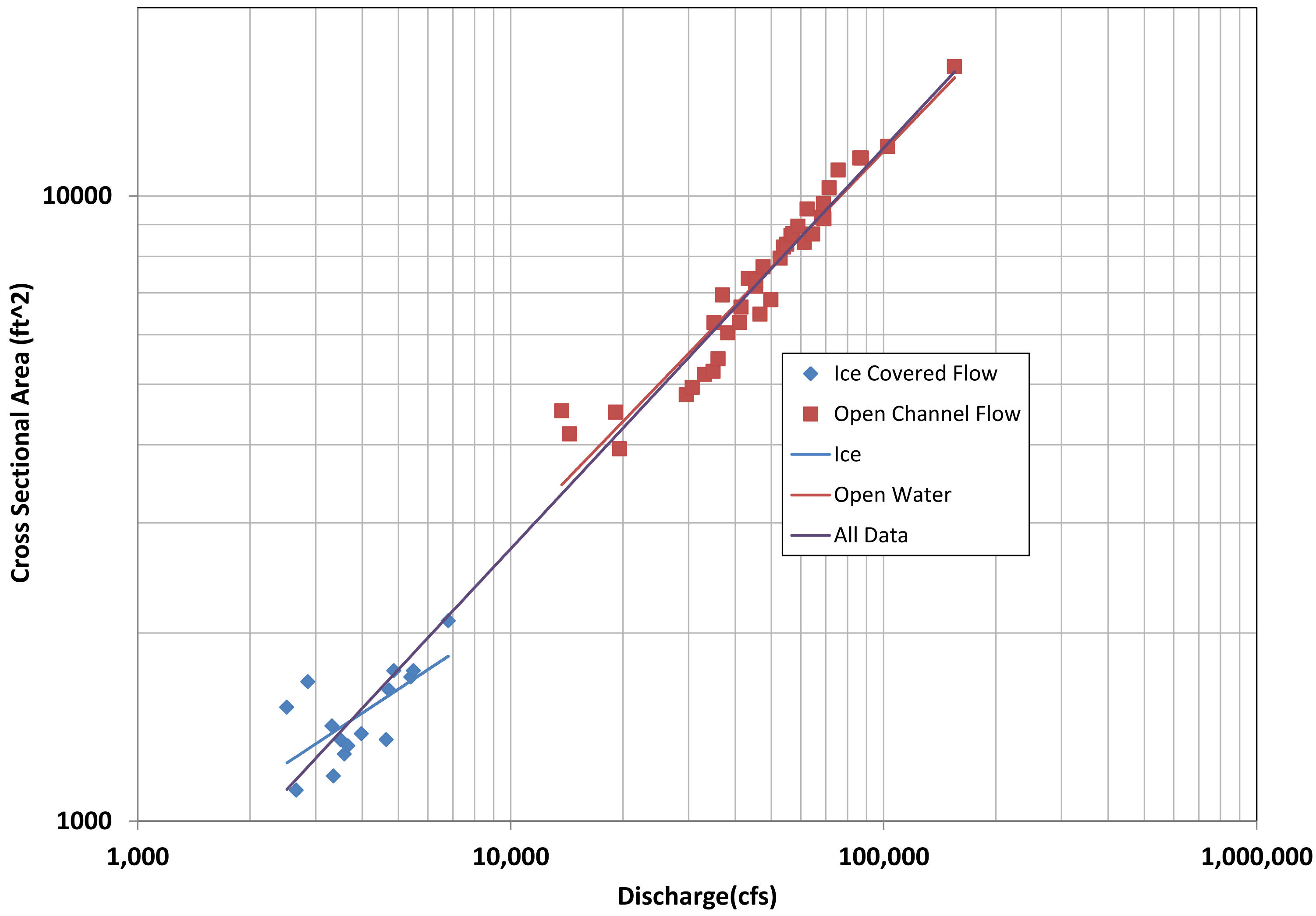

Figure 7.3.3. Cross-sectional area versus discharge for ice-covered and open-water conditions based on USGS measurements at the Susitna River at Sunshine gage.